SECTION 3

MANAGEMENT OF SAFETY ENGINEERING WORK

APPLIED SCIENCE AND ENGINEERING: MANAGING AN ENGINEERING PROJECT

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LEARNING OBJECTIVES

- Recognize and understand the relevant concepts of managing project work.
- Be able to analyze project status to ascertain budget.
- Establish a schedule for the overall performance elements of project work.
- Understand the relevant concepts of leadership, team building and interaction, and managing conflict.
- Be able to analyze one's own leadership abilities.
- Be able to analyze the interpersonal and managerial skills of others.

TO PROPERLY TREAT the subject of managing safety engineering work, some discussion should be provided about what safety engineering is. It is difficult to define since it is one specialty in the larger and more broadly defined safety and health discipline, and, as such, it is often loosely defined and discussed.

Paul Wright in his book *Introduction to Engineering* (1989) states that the Accreditation Board of Engineering Technology (ABET) defines *engineering* as "A profession in which a knowledge of mathematical and natural sciences gained by study, experience and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind."

ABET defines an *engineer* as a person, who by reason of their special knowledge and use of mathematical, physical and engineering sciences and the principles and methods of engineering analysis and design, acquired by education and experience, is qualified to practice engineering (Duderstadt, Knoll, and Springer 1982). Wright (1989) adds to this definition: "The engineer's knowledge must be tempered with judgment. Solutions to engineering problems must often satisfy conflicting objectives and the preferred optimum solution does not always result from a clean-cut application of principles or formulas." He also states that "Engineers are concerned with the creation of structures, devices and systems for human use."

In the foreword of James CoVan's book *Safety Engineering* (1995), Rodney D. Stewart writes: "Safety Engineering is an increasingly important and growing 'horizontal' dimension of engineering that cuts across all the traditional vertical dimensions (civil, mechanical, electrical, chemical and software)." CoVan writes: "Safety is a broad, multidisciplinary topic and this book addresses the engineering aspects of the subject." This indicates that there are engineering aspects of safety that must be managed.

Safety engineering is a diverse and often poorly understood subject. Many critics doubt that engineering is involved. "A weakness of the discipline that developed to serve the underlying need is that many of its practitioners were untrained and undisciplined in its application" (CoVan 1995). Roger Brauer writes in his book *Safety and Health for Engineers* (1990): "Safety engineering is devoted to application of scientific and engineering principles and methods to the elimination of hazards. Safety engineers need to know a lot about many different engineering fields." Gloss and Wardle (1984) write in their book *Introduction to Safety Engineering*: "Safety engineering is slowly maturing as a recognized profession. Safety engineering is a relatively new profession and reflects our mounting concerns for the environment, the consumer and the rights of workers." This lends importance to the need to apply established management practices to this new field.

Many aspects of the safety engineer's job fit the ABET definition for engineering. While safety engineers do not often create "structures" or "devices" as noted by Wright (1989), it can be strongly argued that the safety engineer does create "systems" for the benefit of humankind.

This chapter does not attempt to formally define safety engineering work, but proposes a working definition for the purposes of discussing specific management concepts, principles, and activities associated with projects and work in which safety engineering is inherent. These management concepts, principles, and activities include scheduling, manpower and other resource allocation, budgeting, effectiveness measurement systems, purchasing, work definition, and so on, associated with projects involving the design, construction, installation, operation, maintenance, and dismantling and/or disposal of equipment, systems, processes, or facilities in which safety engineering is an integral component. These types of projects may include excavation protection systems, fall protection systems, energy isolation systems, confined space entry systems, general construction, and general maintenance turnaround activities.

It is important to recognize that safety is no different than any other aspect of a project, or of work in general. It is often presented and discussed as a separate entity that must be accomplished and that must be treated individually. However, for the purposes of this chapter, *safety* is not a noun describing a specific activity; in most cases, throughout the chapter, it will be used as an adjective describing the way in which all work gets done. Even though it is not a separate entity, the safety-related aspects of the job have to be managed just like all other aspects of any project. For example, budgeting, developing specifications, ordering adequate quantities, and dispersing respiratory protective equipment must be done for a confined space entry job just as these must be done for the structural support members for a bridge.

This chapter provides discussion on what a project is, as well as what a managed system is. It discusses where safety engineering fits into a project or system. It covers general management principles such as organizing, defining the work, scoping, scheduling, budgeting, and staffing. Workforce issues such as training and learning, motivating, team building, conflict, and leadership are covered, and the chapter also addresses work and workforce analysis concepts such as performance ratings, work sampling, allowances, time study, and resource allocation. Final products and deliverables are discussed and many of the concepts are further illustrated in the form of examples and open-ended problems to work out.

Introduction to Managing Engineering Work

A *system* is defined throughout the literature in many ways, but for the purposes of this book, consider a system to be any process involving the interaction between humans and equipment in which raw materials (input) are converted to final products (output) (Eisner 2002). Managing the safety engineering aspects of work requires that one focus on the interaction between humans and equipment as well as on the conversion process of raw materials to final products. This interaction involves such issues as workers responding, in the form of physical action, to signals from equipment in the process of its operation. The interaction could also involve workers being exposed to hazards associated with the raw materials or intermediate products or to hazards inherent in the equipment itself. The conversion process will likely involve moving parts, conveyor-belt operations, changing chemical states, heating or cooling, changing structural conditions, changing pressures, and so on. The manufacture of paper, pharmaceuticals, beer, or televisions, the refining of oil, the production of electricity, all involve work done by systems. The safety engineering aspects of these systems must be managed.

A *project* can be described as a formal gathering of people and equipment in an industrial setting, working toward satisfying a set of goals, objectives, and requirements. A project usually has a defined time period, a limited scope, and an established budget, and is managed by a project manager. In many cases, a project deals only with one aspect of a system's life cycle, such design, construction, installation, or maintenance. Projects have a safety engineering aspect just as a system does, and many times this aspect is related to exposure to hazards, time pressure to complete the work, or implementation with people who may be less trained or experienced (Eisner 2002). The safety engineering aspects of a project must therefore be managed.

What does it mean to manage safety engineering work associated with projects or systems? To answer this question, one must go back to the traditional key elements of managing any type of work. The classic definition of management usually includes a discussion of planning, organizing, leading, and controlling the operation for the purpose of productivity (Schermerhorn 1993).

Managers rely on a number of different management approaches to control their operations. A *classical approach* to management includes scientific management, administrative principles, and bureaucratic organizations. It assumes all people are rational. The *scientific approach* to management is one which Fredrick Taylor helped to develop in 1911. His principles involve developing a "science" for every job that would include the rules of motion, standardized work tools and proper working conditions, carefully selecting the right person for each job, properly training each worker for the job, giving them the right incentives, and supporting the workers by planning their work. The *behavioral approach* to management assumes that people are social and self-actualizing. It assumes people act on the basis of desires for satisfying social relationships, responsiveness to group pressures, and the search for professional fulfillment. In the *quantitative approach* to management, managers focus on the use of mathematical techniques for managing the problem solving of the operation. *Modern approaches* to management focus on the total system and look at the business as one interrelated big picture, utilizing contingency thinking and an awareness of a more global picture. Each approach has its own merits, advantages, and disadvantages, and one should understand the system under which he or she is operating to allow for a smooth integration.

Project Plan

Objectives

Objectives are usually statements that express the desires and expectations of the organization managing an overall operation. Objectives for the safety engineering aspects of the project often are developed as a result of a safety, health, fire, or compliance problem and are identified through the various analytical and evaluation methods used in the safety engineering community. Once a safety-related problem is identified, objectives for its resolution must be developed. These objectives describe expected accomplishments that will help to resolve or correct the safety-related problem and ensure the success of the organization. Usually, when safety engineering work results from a problem, the scope is bigger than just managing the implementation of corrective actions. Correcting the problem may require implementing a large-scale, resource-demanding effort. Such an effort must be cost effectively and efficiently managed. Examples of project-level objectives might include: ensure all operations personnel learn to operate the waste water plant to ensure human-error-induced catastrophic incidents do not occur, reduce exposure to noise in the compressor operation area to a level that does not exceed 50% allowable daily dose, or reduce the risk of a catastrophic release of chlorine from the five one-ton storage cylinders in the cooling water operation to a value of lower risk. To achieve these objectives will likely require the implementation of a large-scale, project-driven course of action.

Project Requirements

Once the objectives are defined, it is the project coordinator who must determine the next course of action. This cannot take place without first identifying all of the *requirements* that must be met to safely and efficiently achieve the stated objectives. This will have a large bearing on nearly all aspects of the project, namely, schedule, cost, satisfaction of objectives, satisfaction of regulatory demands, resource allocation, and so on. While each project will have its own specific requirements, objectives, audience and scope, there are some standard areas that must be addressed by the project safety engineer that can be generalized across all projects. Considering project requirements from a generalized approach will help analysts be sure they have addressed every necessary requirement and worked them into the project plan.

Customer Objectives: Technical and Functional

One must start with the requirements of the customer. What objective must be achieved to satisfy the person or organization requesting the accomplishment? In the field of safety engineering, the customer is often an operation's management team, and, to a large extent, the workforce. The customer's objective is likely to be a safer operation, a product made with less risk of incident, fewer injuries, fewer failures, less damage, and so on. These objectives are general in nature, so the safety engineer in charge of managing the project must be sure that agreement is reached or approval given for the means by which the objective will be achieved. For example, if the objective is to reduce benzene exposures plant-wide, a project team must assemble to determine and agree on what achieving the objective will entail. Will it be achieved through the use of personal protective equipment and training? Or will engineering controls and hardware installation be required, such as zero leak valves, enclosed and ventilated sample stations, and activated-carbon filtration systems on building air intakes?

The customer's requirements will usually be technical and have functional requirements such as fire resistance, structural integrity, spacing and layout, level of system automation and control system logic, warmth, adequate illumination, vessels that meet appropriate pressure ratings (see the Pressure Vessel chapter in the Risk Assessment and Hazard Control section of this handbook), accessibility (foot, reach, and traffic), ease of maintenance, or personal protective equipment (PPE) comfort and aesthetics.

An additional factor that must be considered by the project manager and discussed among the project team is the potential for future expansion and growth. This must be considered from a spacing and real estate point of view as well as from the standpoint of interface and integration of old and new systems. In other words, it is important to leave a system owner with the ability to tie old and new together without having to worry about complete replacement due to obsolescence of interfaces, fittings, power requirements, control system logic, and so on.

Regulatory Objectives

Once the customer's requirements are determined, the project manager (or, in the case of a safety-related project, the safety engineer) must determine the requirements of government agencies, local municipalities, and consensus organizations. Regulatory requirements that must be considered include those involving proximity to local businesses and residences, process and storm water runoff (during construction and normal operations), odors, airborne concentrations, noise levels (during construction and normal operations), local building and fire codes, evacuation and emergency vehicle access/egress, rail or trucking access, pressure vessel or boiler codes, and Americans with Disabilities Act (ADA) access requirements. A project manager will meet and work with agency representatives to identify all of the applicable regulatory requirements that must be satisfied and then estimate the time needed to satisfy the demands of all of the agencies so that the project schedule includes this time. Sometimes project managers consider only the technical and functional requirements of the project and then become frustrated when agency needs hold up the schedule. They must realize that it takes time to perform all the necessary analysis and design reviews and get the necessary permits processed and that this time must be incorporated into the schedule.

Human Resource and Expertise Objectives

Technical, functional, and regulatory requirements are critical to any project's success but no more important than the human requirements for the project. The expertise of the personnel who will help develop, design, and install the project is likely to be varied and wide ranging. The existing expertise and experience of the project team is one requirement, but the project manager may also need to consider the availability of outside expertise. He or she may also need to consider on-site training requirements necessary to bring a fully functioning project team up on site. Once the necessary expertise categories are defined, they must be quantified—how many crews or individuals are needed for the project? For example, if three welding crews are needed and only one is available at a given time, the schedule will be affected, and the effect may not necessarily be linear, because other types of crews will also be held up waiting for the welding to be completed.

The project manager must consider the types of engineers (e.g., industrial, chemical, mechanical, electrical) and analysts that are needed for their expertise during the design phase of the project's life cycle. He or she needs to obtain the input of regulatory experts, industrial hygienists, operations and maintenance experts, instrumentation experts, human factors experts, or ergonomists, among others. One expert in each discipline is usually considered adequate; however, this is dependent upon the size and complexity of the project. It is critical to avoid delays in project implementation due to the lack of input from any of the team's members. Regular project meetings must include the presence and input of each discipline on the team, and it is the project manager's responsibility to ensure that all team members attend project meetings. It is not the objective of this chapter to provide a formula for determining the correct number of personnel for each discipline; the objective is to provide information to consider in determining the makeup of the project team.

Statements of Work, Task Statements, and Work Breakdown Structure

When objectives, goals, and project requirements are defined and agreed upon, descriptions of the work to be done can then be developed. This is started through the development of a statement of work, task statements, and a work-breakdown structure. The *statement of work*, although often used interchangeably with a task statement, could be viewed more as a description of the overall work to be completed. It can also contain a complete list of task statements (or individual tasks within the overall project). Statements of work may include

1. Excavation and earthwork
2. Driving piles
3. Laying concrete foundations
4. Running electricity to the site
5. Running water and steam to the site
6. Installing structural steel
7. Setting the vessels
8. Installing the pumps, exchangers, valves, etc.
9. Installing the piping, valves, etc.
10. Installing control system wiring and computers

Each of these statements of work will include a description of any work that requires the input and coordination of the safety engineer/project manager.

Task statements are more defined, specific task descriptions within each statement of work, and they lend themselves to integration into a work breakdown structure (which will be discussed in upcoming paragraphs). Task statements associated with the excavation work of a project might be: perform a soil analysis, complete a nearby exposure and structures analysis, perform a water-content analysis, perform water influx and drainage analysis, complete a shoring or side-wall angling design, implement a spoil pile management plan, and design a confined space entry plan. Task statements for a "Complete Pile Driving" statement of work may require the safety engineer to evaluate the vibration impact on nearby structures and perform an evaluation of noise exposure for crews working in the area. Setting vessels, installing piping, and bringing utilities to the site may require the safety engineering project manager to evaluate layout and placement as well as accessibility and adherence to material specification and welding requirements. These are a few examples of possible task statements that may be developed in a project that has a particularly significant amount of safety engineering issues associated with it. Each task statement list is specific to the type of project being undertaken.

A *work breakdown structure* is a formal categorization of the work to be performed as part of a project. Task statements are developed under each work categorization. Organizing the project work into categories can help in establishing the project schedule and in allocating human resources—in terms of both crafts and expertise and pure worker numbers (Eisner 2002). In a safety engineering project, a work breakdown structure and associated task statements may look like the following example, which could describe the elevated-work aspects associated with the "installing the piping and valves" statement of work noted in the list above.

Work Breakdown Structure Example

1. Pre-project analyses
   - 1.1. Support structure analysis of integrity of members intended for use in fall-protection systems
   - 1.2. Determination of attachment points and weight limitations
   - 1.3. Determination of scaffold vs. harness and lanyard
   - 1.4. Support structure analysis of scaffold base if scaffolding is required
   - 1.5. Analysis of fall-protection equipment status and condition
2. Fall-protection system design (based on pre-project analyses)
   - 2.1. Scaffold design (and approval if large enough to require design oversight by a professional engineer)
   - 2.2. Lanyard and harness system design (allowing for adequate mobility and fall-distance limitation)
   - 2.3. Access system design
   - 2.4. Specification development for harnesses, lanyards and connections
3. Fall-protection system construction and installation
   - 3.1. Oversight of contractors or employee construction crews
   - 3.2. Inspection and testing of system upon installation completion
   - 3.3. Approval of necessary scaffolding permits
4. Site inspections during elevated work to determine continued compliance and condition integrity
5. Updating of fall-protection permits as needed throughout project

Most safety engineers would not be assigned as a project manager for a construction project. However, a safety engineer might be assigned to manage the safety-related aspects of an overall construction project, and all the same principles apply to the tasks and organization of the safety-engineering-related work (such as for the fall protection example noted above). It is also important for a safety engineer to understand how a construction project is described, organized, arranged, and managed so that he or she will be able to participate in, integrate with, and contribute to its development and implementation.

Scheduling

PERT Charting

PERT is an acronym for *Program Evaluation and Review Technique*. This technique is often used to create the project network layout and is also referred to as a network diagram. PERT is described as a critical path analysis tool since it can help an engineer to determine which pathway through a network is critical to the project's on-schedule completion.

A safety engineer can use a PERT chart as a planning tool to lay out the steps of a project and determine a sequential relationship between activities. It allows the project safety engineer to find the optimum route through the project to achieve its objective. It can be used in assessing the risk of not completing a project on time (or to the project team's satisfaction) through a time-estimating process that assigns three levels of estimated implementation time to each activity—an optimistic time, a pessimistic time, and a most likely time. From these estimates, it is possible for the safety engineer to develop probability distributions around the completion time for each activity. From that, a risk value can be assigned to the completion of the project. From a practical standpoint, most practicing engineers use only two time-estimate levels (earliest and latest) for completion and often do not carry out probability distribution determinations. This type of time estimating is most often used to determine a project's critical path or to identify possible bottlenecks.

On a PERT chart, activity milestones are represented by *nodes* (see Figure 1) that are generally shown as positions in time using either the beginning or the end of an operation. The nodes are connected by lines called *arcs*. Each arc represents the time needed to complete the activity within the project's scope. Activities that are needed to ensure a correct sequence in a project but have zero time or no cost are referred to as *dummy activities*.

A PERT network is devised and analyzed using its principles and methods as follows (as shown in Figure 1 and Table 1):

1. Determine and define known end events and milestones and ask what needs to be accomplished to achieve each objective (or milestone).
2. Work backward from each milestone (node) until reaching the project start. This will help to define the steps in the project.
3. While determining the steps in the project, this backward approach will help to define the sequential relationship of each node to each other (i.e., node A must be done before node B, node C can be done concurrently with node D). This sequence can be serial and/or parallel. Each node should be labeled—in this case, they are given letters.
4. These first three steps allow the analyst to draw a network, as shown in Figure 1. At this point he or she must estimate the amount of time, given available resources, that it will take to achieve each milestone and assign that number of hours, days, or weeks to the arc between the starting milestone node and its related end node. For example, in the Figure 1 network, start at node A (day 0). Achieving node B (arc AB—Analyze excavation accidents, Table 1)—is expected to take 8 days with available resources.

TABLE 1

PERT Chart Analysis Data

Activity	Description	Task Duration	Early Start (Day)	Late Start (Day)	Slack Time
AB	Analyze excavation incidents	8 days	0	10 − 8 = 2	2 days
AD	Analyze lockout/tagout incidents	11 days	0	11 − 11 = 0	0 days
AF	Analyze confined-space incidents	3 days	0	13 − 3 = 10	10 days
BC	Create soil analysis survey and map	7 days	8	17 − 7 = 10	2 days
BD	Include excavation findings in LO	1 day	8	11 − 1 = 10	2 days
BE	Develop excavation procedures	7 days	8	18 − 7 = 11	3 days
DC	Identify and diagram energy sources	6 days	11	17 − 6 = 11	0 days
DE	Develop LO/TO procedures	7 days	11	18 − 7 = 11	0 days

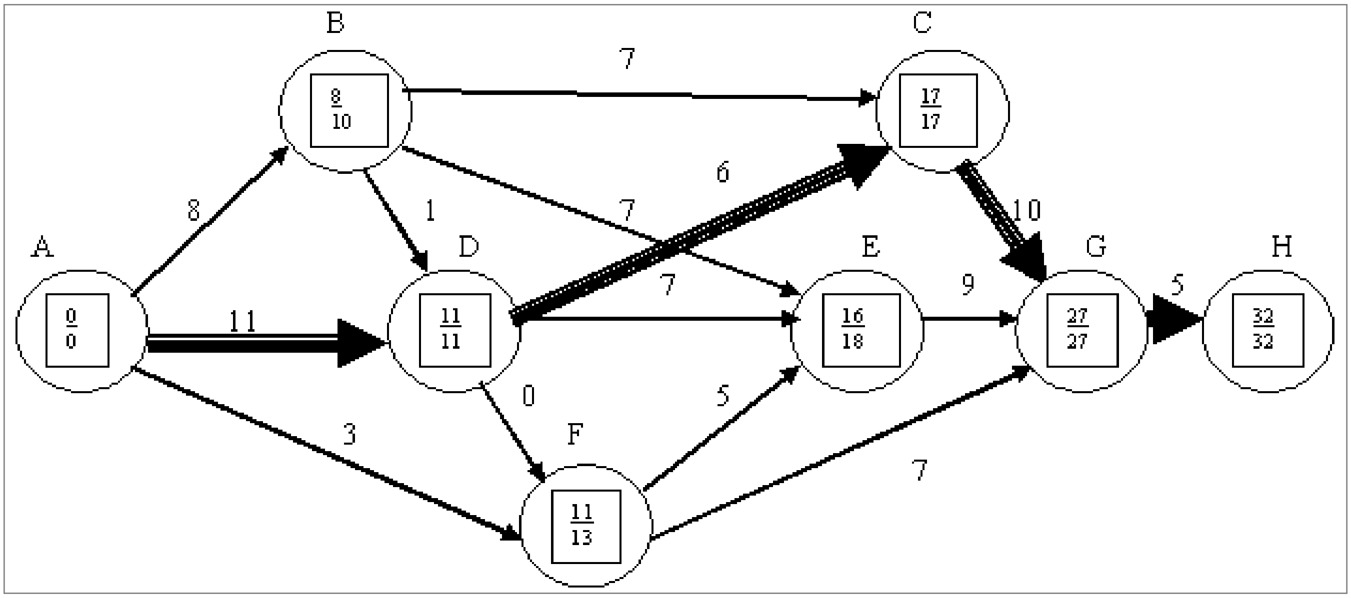

FIGURE 1. PERT Chart Representing a Project to Develop a Training Program Based on Injury-Type History (critical path is highlighted with bolder arrows)

5. Once all the time estimates are assigned, begin at node A, and using the 8-day estimate for arc AB, the 11-day estimate for arc AD, and the 3-day estimate to achieve node F, determine the earliest possible time to achieve each milestone. This will define the earliest possible time in which of the each following nodes can be achieved. Input that number (day) inside the node above the line. Work your way through the network, being sure to respect the sequential relationship you built for the project. [Suppose you have only one welding crew and they have two steps in the project (arc-node combinations). One crew can work on only one step at time, so one step must be completed before the next can be started.]
6. When you reach the node indicating project completion, you will have defined the earliest completion time (the smallest number of days to complete) for the project. In the Figure 1 example, it will take 32 days to complete the project.
7. From the final node, work backward through the network, again using the completion-time estimates to determine the latest possible completion time for each node. This number is recorded below the line inside the circle of each node. In the example, the project completion (node H) is at day 32 and with only one node immediately preceding it (node G), the analyst must address only the 5 days needed to accomplish task GH and record 32 – 5 = day 27 below the line at node G. From node G, the analyst travels backward, subtracting the 10 days it will take to complete task CG from day 27 and determines that the latest completion of node C is achieved at day 17. This number is recorded below the line inside the node C circle. At this point, care must be exercised when a node has more than one arc coming from it. The analyst must record the value defined by the arc yielding the lowest value. For example, from node G, the analyst travels backward, subtracting the 7 days needed to complete task FG from day 27 and records the latest completion of node F. This is 20; however, the lowest value is achieved for node F when subtracting the 5 days it takes to complete task FE from node

E's latest value of 18, so the latest start for node F is at day 13. This number is recorded below the line inside the circle of node F. The analyst works back through the entire network in this manner until reaching day zero at the project's first task.

8. Once the earliest and latest start times are determined, the analyst can set up a table such as Table 1 and determine slack time for each task where it applies, and most importantly, can determine the project's critical path. This is the path through the network along which the project can afford no slack time; a delay in the tasks along it will result in a delay in the project.
9. Complete the first three columns of the table (Table 1) from the information already developed as shown on the network. The earliest start day for each node is the number above the line inside the node circle—enter that in the fourth column of the table.
10. For the fifth column, labeled "Late start (day)," some additional considerations must be integrated into the entries. First, use the day value below the line in the final node and subtract the task duration leading to it. Then subtract the earliest start value for that task (the number below the line inside the project's final milestone or node). This result is the slack time or the amount of delay time the project can stand without suffering a delay in the overall project. For example, if slack time is established at 2 days and a task requires an order of materials to be received on day 22, the project will not be delayed as long as the material arrives and the task can be completed by day 24.
11. As the analyst looks down the last column, it is easy to determine the critical path from the arcs or tasks that have zero (0) slack time. In this example, the critical path shows that the tasks AD (Analyze the lockout/tagout incidents), DC (Identify and diagram energy sources), CG (Develop excavation training program) and GH (Present complete training program to workers) cannot experience any delays or the whole project will take longer than the 32 days expected.

For projects of critical time or financial demand, the most resources or most attention should be focused on the critical path tasks to ensure that they are not delayed. In giving information to the operation's decision makers, the analyst can provide these same data at three levels: optimistic estimate, expected estimate, and pessimistic estimate. The analyst can also draw confidence bands around each duration estimate. The PERT chart provides much information for decision makers to use in determining time estimates, human resource allocation, costs, and so on for achieving a project's objective (Eisner 2002 and Niebel and Freivalds 1999).

Gantt Charting

A Gantt chart is a valuable tool that is used extensively throughout industry today even though it was developed in the 1940s. It is often used in safety engineering applications as well as in many other types of project-based applications. It is a project planning and control technique that is designed to show the expected completion times for each step in a project. It makes use of a horizontal timeline. Bars are plotted against this timeline to represent first the expected and then the actual completion times for each project activity. The benefits of its use are many. First, it forces a safety engineer to plan and lay out a project before starting the work. Second, the engineer can tell from the layout whether there is activity overlap, and where this is the case, determine whether resources are available to support the overlap. Third, from this graphical representation of project status, the engineer can easily tell whether the project is ahead of or behind schedule.

Gantt charts have some disadvantages in that they don't always give the project engineer the ability to see the interactions between two or more activities—if the same group of workers for a specific craft is scheduled to do three things at once, the Gantt chart alone would not show this. For example, suppose that the same group of pipe fitters is expected to install energy-isolating blinds or blanks in three separate toxic liquid lines in three separate locations in the plant during a maintenance turnaround all at the same time. The Gantt chart would not show this. It does not point out specific manpower allocation problems, but it does at least help to provide the impetus for a project engineer to think about the problem when an overlap occurs. See Figure 2 for an example of a Gantt chart.

Bars are used to show the expected time to complete each activity in terms of start and finish dates as well as expected duration. The bars are also darkened to indicate activity completion status. In the case of the Figure 2 project, the darkened bars indicate completion; the bar colored on the left and uncolored on the right indicates an activity that is in progress. One can see that everything is completed through September. The activities corresponding to the uncolored bars have not yet been started. From this Gantt chart, one can tell that the first five activities were completed as scheduled, as were the seventh and eighth. Completing the PHAs is in progress and still on schedule, but training, writing, and implementing the contractor safety program are not started yet. If the current date is 30 September, all is on schedule, but if it is 20 November, these four activities would be behind schedule.

One powerful benefit of a Gantt chart is that it allows a project safety engineer to determine whether there are enough resources (human, computers, and so on) to work on overlapping activities. This is illustrated in the following example:

The safety engineer may ask whether there are enough hourly employee time resources available in February to "implement employee participation" at the same time as they provide input to "writing the process safety information (PSI) document." If so, the project schedule is acceptable as is, but if a maximum-production test happens to be scheduled, which demands people time, and enough people are no longer available at the same time, the schedule will have to be adjusted. The PSI activity may have to be moved to March, but then that will impact the rest of the schedule.

This short example illustrates one of the benefits of Gantt charting a project, but there are many. This type of schedule/chart is regularly used as a reference whenever project schedule and resource estimates are discussed.

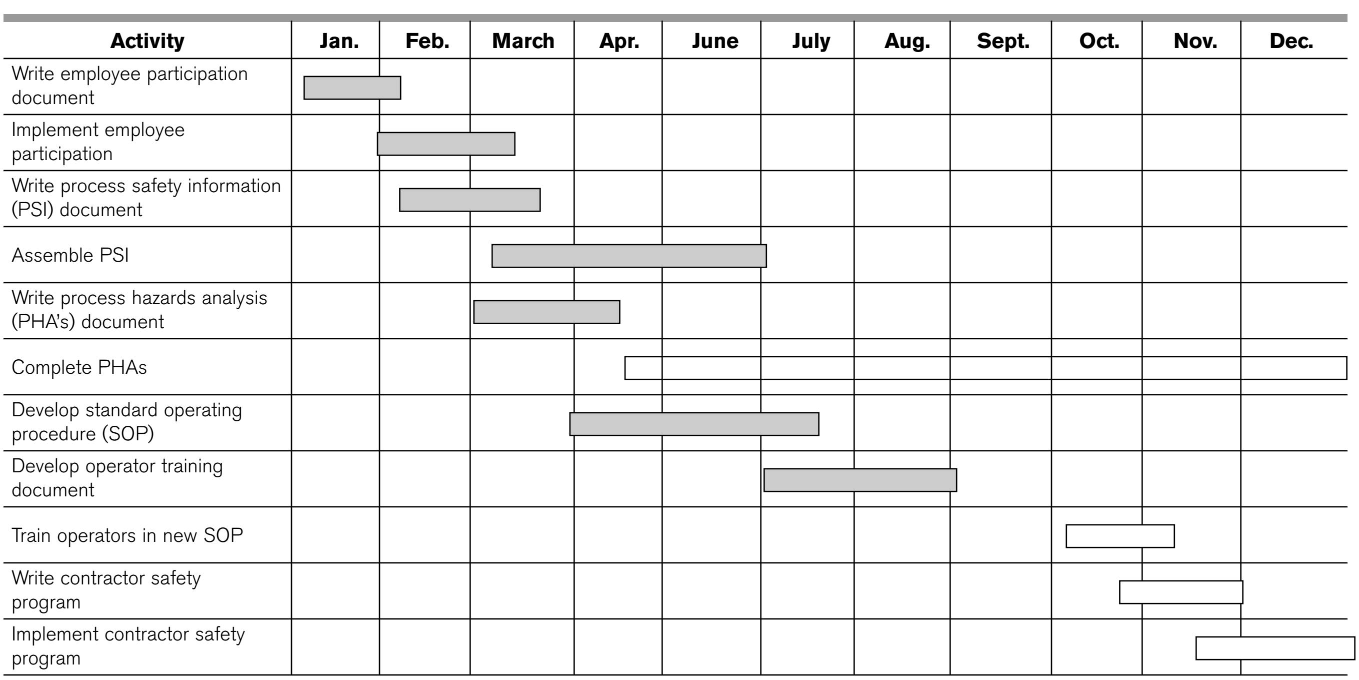

FIGURE 2. **Gantt Chart for Developing a Written Process Safety Management Program (not a complete program)**

TABLE 2

Task Responsibility Matrix: Vessel and Piping Installation Tasks

	Welders		Pipe Fitters		Inspectors		Instrument Engineers		
	No. people in crew	Person-weeks	No. people in crew	Person-weeks	No. people in crew	Person-weeks	No. people in crew	Person-weeks	Total Person-Weeks
Task A	4	4	5	5	2	2	2	2	13
Task B							1	1	1
Task C	4	4	5	5	2	2			11
Task D	4	2	7	3.5	2	1			6.5
Task E	4	8	7	14	2	4	2	2	28
Task F							2	1	1
Task G							2	1	1
Task H	4	4	7	7	2	2	2	2	15
Totals		22		34.5		11		9	76.5

(Adapted from Eisner 2001)

Financial Considerations and Cost Monitoring

Project Budget

Once the project manager has a solid project plan in place and the work is defined, he or she must determine a budget for the project and a means to determine the financial performance and budget status throughout the life of the project. This process includes developing a task responsibility matrix, developing a direct labor and materials budget from the matrix, and then determining a cost budget per week. An example is the best way to illustrate the process. The sour gas processing plant project described above will be used to show the budget development steps. The example will not provide specific costs for each budget element, as this responsibility will reside with individual project managers and their staff analysts. The cost (in dollar amounts) used in this example are for illustration purposes only.

From Table 2 we determine that the project will require 22 person-weeks of work for the welding crew, 34.5 for the pipe fitters, 11 for the inspectors, and 9 for the instrument engineers. The total human resource demand for the project is 76.5 person-weeks. The chart shows the person-weeks by task as well.

The process of establishing a project budget and analyzing the project's financial performance on a weekly basis (or other appropriate frequency), allows the project manager to maintain fiscal control early enough in the project so that available funds do not run out before the project is complete. There are several means for assessing budget performance; however, this tabular method is a relatively straightforward means that does not require extensive financial training (see Tables 3 and 4). It should be noted that the examples used in this chapter propose cost percentages that are only for example purposes. Anyone using these types of tables should use only their company's internal cost data.

TABLE 3

Project Budget: Vessel and Piping Installation Tasks

Direct Labor	Rate/Week (in $)	Person-Weeks Required	Cost (in $)
Welders	1400	22	30,800
Pipe fitters	1120	34.5	38,640
Inspectors	1200	11	13,200
Instrumentation engineers	1500	9	13,500
Subtotal 1			96,140
Fringe rate @ 30%			28,842
Subtotal 2			124,982
Overhead rate @ 68%			84,988
Direct costs (materials, supplies, delivery, etc.)	vessels, piping, welding supplies		526,700
Subtotal 3			736,670
General and administrative @ 12%			88,400
Total cost			825,070

(Adapted from Eisner 2001)