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NOTE ON INTRODUCTION TO PROJECT MANAGEMENT

Fraser Johnson and Professor Robert Klassen prepared this note solely to provide material for class discussion. The authors do not intend to provide legal, tax, accounting or other professional advice. Such advice should be obtained from a qualified professional.

Project management techniques are goal-directed, and are commonly used by managers to help them plan, control, direct and re-plan resources for large, complex projects. These techniques allow managers to focus on specific objectives, such as a required completion date, and to manage resources accordingly. Situations where project management can be used include: process re-engineering; design of tooling and machinery; software development; and construction.

Ultimately, the objective is to establish a plan that outlines the sequence of individual activities or tasks. This usually involves making trade-offs with respect to the dedication of resources and their sequence. Quite often, when anticipated completion schedules or costs must be adjusted, project managers are forced to re-schedule activities. Project management techniques assist managers with their planning activities by identifying the trade-off between increased use of resources and faster project completion.

PERT (program evaluation and review technique) and CPM (critical path method) are the two most common project management techniques. CPM was developed by J.E. Kelly, of Remington-Rand, and M.R. Walker, of DuPont, as a tool to assist with scheduling maintenance shut-downs of chemical plants. PERT was developed the following year for the U.S. Navy, to help manage the Polaris missile project. Originally, PERT was more flexible in dealing with variations in lead times, while CPM assumed that project activities could be estimated accurately. Today, however, differences between PERT and CPM techniques are relatively minor, and the two terms are often used interchangeably. The term PERT/CPM will be used here.

PERT/CPM techniques display project activities in a network diagram to help managers focus their attention on the sequence of events most crucial for project completion. In order to create a network diagram, the project must include activities that not only are clearly defined, but also must be carried out in a specific order (precedence relationships). In most situations, opportunities exist to re-order, compress or extend the activities with the objectives of revising the program budget or completion date.

Due to the large number of activities involved with many projects, computers are commonly used to simplify the analysis and provide answers to "what if" questions. A variety of relatively inexpensive software packages are available. These packages organize your project in a standard format based on the duration time of each activity and the sequence of activities.

THE PROJECT MANAGEMENT PROCESS

Project management using a network model can be separated in the following four steps:

- define the project
- identify activities, precedence relationships and time elements
- establish critical path
- make adjustments

1. Define the Project

Each project should have clearly defined beginning and ending points. It is up to the project manager to describe the project activities in terms that team members will easily comprehend. Consequently, a clear statement should be created, identifying the scope of the project, its major activities and their relationships, and the time unit in which the project will be monitored.

2. Identify Activities, Precedence Relationships and Time Elements

The project should then be broken down into "activities," which represent the individual tasks that the project team expects to coordinate. The activities will have precedence relationships; that is, the sequence of activities is constrained because certain activities must be completed before others can begin.

A difficult part of this step is establishing time estimates for each activity. In particular, at the beginning of the project, time estimates may be difficult to establish. Experienced project managers, however, rely on a variety of sources to determine their initial time estimates, ranging from personal experience to formal engineering studies.

One easy method of organizing this data is to create a three column list which includes the following: Activity, Activity Description, and Immediate Predecessor(s). Once organized, the activities can then be translated into diagrams that can take on any of several formats.

The Gantt chart, similar to a bar chart, shows individual activities and the length of time required for each activity, with each activity depicted with a bar. The Gantt chart often organizes the sequence of activities by listing at the top with those that must be completed first. While Gantt charts can be used to display relationships among activities for small projects, it becomes difficult to visualize activity relationships for large, complex projects when relying on Gantt charts alone. Furthermore, it is also difficult to establish the critical path and other important information for managing the project solely by relying on a Gantt chart.

To overcome these weaknesses, the PERT/CPM diagram shows the activities as a series of nodes on a network. An activity, shown as a node, is directly linked by an arrow to activities that immediately follow it and depend on its completion. This format makes the inter-relationships between activities immediately apparent. Both PERT/CPM and Gantt charts are widely used by managers to track projects.

3. Determine Critical Path

The critical path is defined as the sequence of activities which takes the longest time to complete. The critical path represents the completion time of the project. A project can have more than one critical path; however, the completion time of each of these paths must be equal.

4. Make Adjustments

Most projects are constrained by two factors: time and cost. Since improvements in project completion times often require additional resources at a premium cost, balancing the trade-offs between activity cost and project completion time is an important component of the project management process. Additional activity cost can take many forms, including additional personnel, equipment, expedited delivery, etc.

Calculation of the critical path sequence permits the project manager to identify both the activities that influence total project completion time and other activities that can be extended without delaying the completion of the project. Adding time to any critical path activity extends the total time needed to complete the project, while reducing these activity times (termed "crashing") may shorten the total time. If more than one path is critical, the activity times for several activities might need to be simultaneously crashed to reduce the total project completion time.

As activities on the critical path are crashed, new critical paths may be added. Consequently, managers might be forced to deal with several different critical paths before finalizing their project plan.

AN EXAMPLE

The following example illustrates the application of PERT/CPM techniques to a project.

Bart is a first-year student, who plans to go skiing over Winter break. He intends to leave the business school immediately following the mid-term exam in his operations course, which is expected to conclude at 12:00 noon on February 16, 1996. The trip from the business school to his apartment usually takes 30 minutes.

Unfortunately, Bart has spent the last few days studying for the exam, and as a result has not prepared for his vacation. After arriving home, Bart knows that he must wash his clothes. Ideally, he will do three loads of laundry, which he expects to take four hours. He knows that packing, which he anticipates will take 30 minutes, must wait until he has finished doing his laundry.

Bart also needs to go to the bank to withdraw some money and obtain travellers' cheques for the trip. He expects this activity to take one hour, and this can take place at the same time his laundry is being done. Finally, Bart must pack the car and drive to the meeting place to catch the bus; he expects both of these activities to take 30 minutes each. The bus was scheduled to leave at 5:00 p.m., and Bart knows that he cannot be late.

The list of activities that Bart must complete is provided in Table 1. Note that this table also identifies predecessor activities and estimated completion times.

Table 1

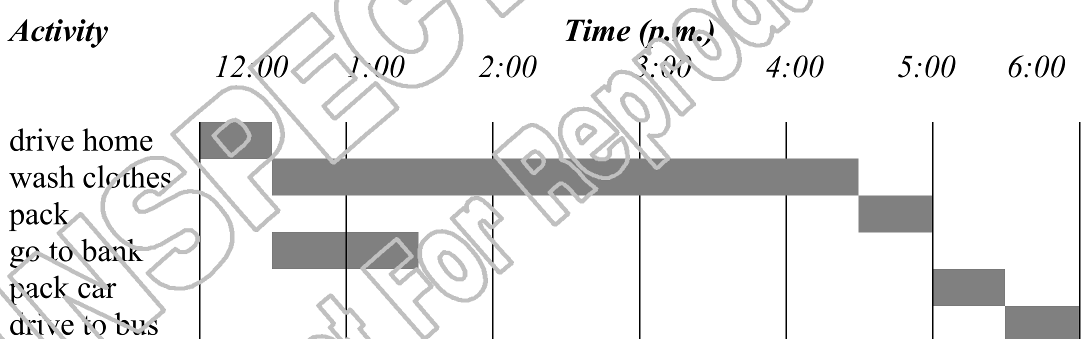
BART'S SKI TRIP

Activity	Activity name	Immediate predecessor	Estimated time (hours)
A	drive home	—	0.5
B	wash clothes	A	4.0
C	pack	B	0.5
D	go to bank	A	1.0
E	pack car	C, D	0.5
F	drive to bus	E	0.5

A Gantt chart, outlining the activities together with their duration, start and finish times, is presented in Figure 1. The difficulty in using this data to manage Bart's activities is that it fails to show the relationships among the activities, the sequence of events constraining completion of the project (the critical path), and the slack times. In short, we know when the project starts and when it needs to be completed, but we cannot see how the activities are interrelated.

Figure 1

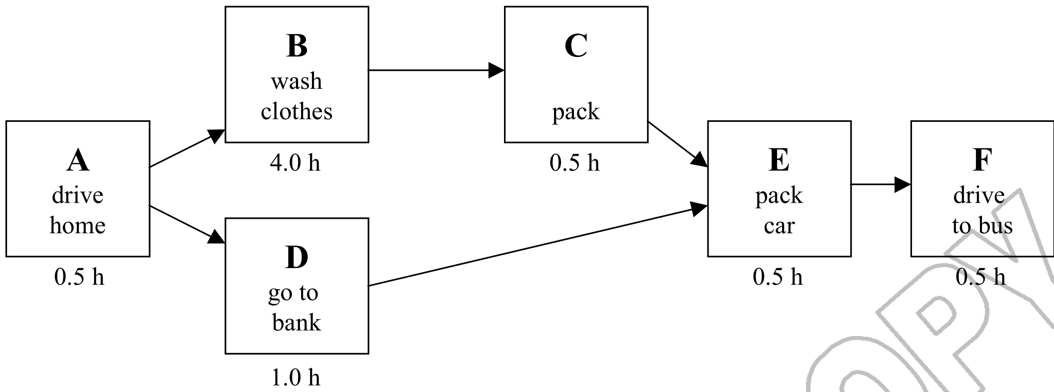
GANTT CHART FOR BART'S SKI TRIP



As an aid in analyzing the above information, it is useful to represent it schematically as an activity-on-node diagram. To do this, we adopt the convention of using the nodes (small squares) to represent activities and the arrows to represent the sequence in which they are performed. An activity is a specific task which takes time and resources. Bart's ski trip preparation is presented in Figure 2.

Figure 2

SKI TRIP PERT DIAGRAM



The network diagram shows the activities which must be performed before Bart leaves, their duration, as well as the sequence in which they must be performed. Specifically, note that both activities C and D must be completed before E can begin. The diagram typically includes the letter representing the activity inside each node, along with its activity time (duration).

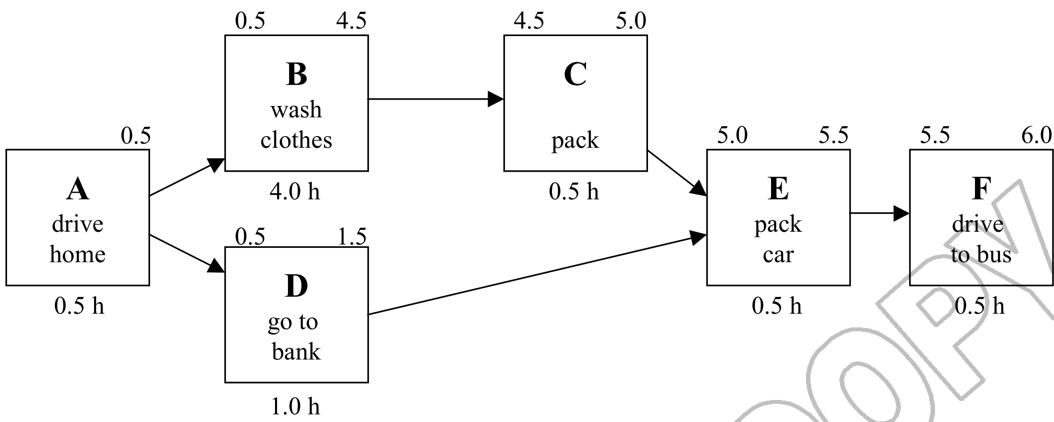
Now we can begin our analysis. The first thing we do is establish for each activity the earliest possible time that the activity can begin and finish, termed the Earliest Start time (ES) and Earliest Finish time (EF), respectively. By convention, for the first activity, here A, we define its ES as zero, and record this above and to the left of the node. The EF time is equal to the ES plus the activity duration time. This time is noted above and to the right of the activity. For activity A, the EF is 0.5 hours.

Earliest Finish time (EF) = Earliest Start time (ES) + activity duration (d)

Then, for each of the activities that follow this activity, their ES is equal to the EF of the preceding activity. Thus, the ES and EF for activity B are 0.5 and 4.5 hours; for activity D is 0.5 and 1.5 hours. When two or more activities immediately precede an activity, such as E, the ES for that activity is the largest of all preceding EF times. For example, at activity E, the EF for activity C is 5.0 hours, while for activity D is 1.5 hours. Consequently, we take the greater of the two, and use 5.0 hours. We continue this way until we have calculated an ES and EF for each activity, as illustrated in Figure 3. The EF for the last activity, F, is 6.0 hours. This last figure is the total time to complete this project.

Figure 3

SKI TRIP WITH EARLY START AND EARLY FINISH TIMES



We now work backward through the diagram to establish the latest times that we can start and finish an activity, without delaying the whole project. These are termed the Latest Start (LS) time and Latest Finish (LF) time for each activity. The LF for the last activity, here F, is equal to the EF, and is recorded beside the EF, separated by a slash. The LS for F equals the LF minus the duration, here 5.5 hours. We record this figure beside the ES, separated by a slash. In general, the LS time is given by:

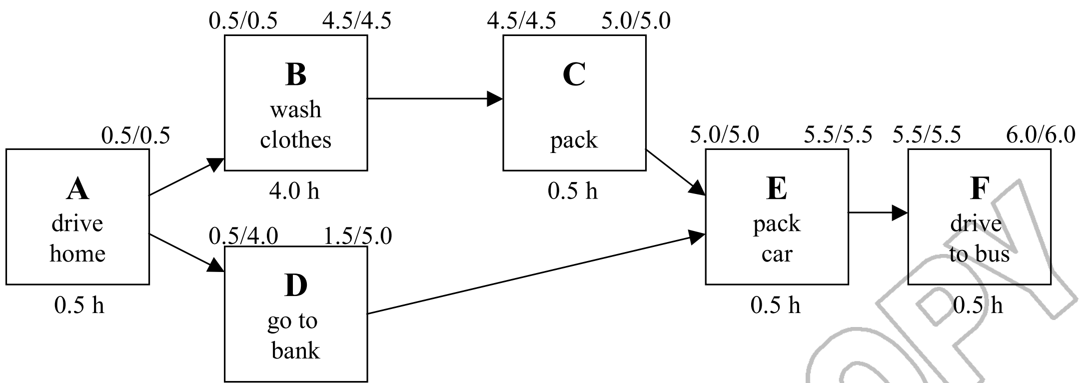
Latest Start time (LS) = Latest Finish time (LF) – activity duration (d)

For each preceding activity, the LF is equal to the LS of the next activity. Thus, for activity E, the LF is 5.5 hours and the LS is 5.0 hours.

If two or more activities follow an activity, such as activity A, we used the smallest LS time of those activities as the LF time of A. Thus, because the LS of event B is 0.5 hours and the LS of D is 4.0 hours, therefore, we use 0.5 hours as the LF for activity A. Figure 4 updates the network diagram with LS and LF data.

Figure 4

SKI TRIP WITH LATE START AND LATE FINISH TIMES



The final calculation is to identify the "slack" or "float" for each activity. Total slack is the maximum amount of time that an activity can begin late or be extended by, without delaying completion of the entire project. Notice that the slack time for an activity is <u>not</u> independent of the slack for other activities. Thus, it is <u>not</u> meaningful to add together the slack times of two or more activities.

$$\text{Slack} = LS - ES = LF - EF$$

Here the only activity with any slack is activity D, where the time is (4.0 – 0.5) = 3.5 h.

Now, we find the *critical path*. It is the chain or chains of activities which have zero slack. For the Ski Trip, this chain is A-B-C-E-F. Any lateness in these critical activities will delay the completion of the entire project. In addition, any effort to reduce the total project time must be directed first at the activities on the critical path.

USING MICROSOFT PROJECT

1. What Microsoft Project can do

Microsoft Project (MS Project) is a powerful software package that allows you to plan, organize and control projects consisting of multiple activities that may be interrelated. MS Project uses information about the project, such as activity durations, start dates, available working time and completion dates/deadlines to build a model of the project that you are managing.

Using a software package, such as MS Project, provides the user with several advantages. First, MS Project automatically organizes your activities based on the duration times and sequences identified in the data. The data will be organized into standard format, making it easy to share information. MS Project allows you to view your project in a variety of different ways: Gantt charts, PERT/CPM diagrams and calendar view. Second, the flexibility of the system allows you to easily ask "what if" questions and perform sensitivity analysis. Third, as a project is undertaken, management can use MS Project to monitor the overall project schedule and completion of activities, thus permitting the replanning of activities based on their early or late completion.

2. General Concepts

a. Creating and organizing a project

MS Project refers to all activities as tasks. Creating a project requires the user to input the following information:

- task names/descriptions;
- duration;
- start and finish date restrictions, if appropriate;
- precedence relationships; and
- available working time.

When entering the data, time units must be consistent (e.g., days or hours).

MS Project will use this information to organize the project, indicating expected completion dates, critical paths and project sequencing.

b. Scheduling activities

Activity scheduling should begin by identifying the start date of the project. Although certain activities may be pre-scheduled to begin at a specific date, most will start following completion of their predecessor activities. Consequently, those activities not on the critical path may have "slack" among them if the start dates are flexible or otherwise delayed.

Understanding the precedence relationships is important. MS Project organizes the project, however, this requires the user to provide accurate information with respect to the sequencing of the activities.

c. Gantt Chart view

MS Project has three views: Gantt Chart, PERT Chart and calendar. These represent standardized views for project managers, each displaying the same general information in slightly different formats. Typically, the default format on MS Project is the Gantt Chart view. Toggling between views is done using the View menu.

The Gantt Chart displays data in both text and graph form. The position of the various activities allow the user to identify the sequencing of the activities and the expected completion date. To overcome one of the weaknesses of Gantt charts, MS Project identifies predecessor relationships between activities using arrows.

d. PERT Chart view

The PERT Chart view displays activities as a network diagram. Each activity is represented by a node (or box). Predecessor relationships are identified by connecting lines. As the project progresses, the PERT Chart will display a single diagonal line through an activity in-progress and crossed diagonal lines through completed activities. The nodes display information about the status of the activities, including duration, start date and completion dates.

e. Calendar view

The calendar view displays data which allow the user to quickly identify when particular events are scheduled, during which days, weeks and months. This method makes it easy to schedule resource activities, such as labor, based on forecasted needs.

The calendar format can be changed to highlight particular activities. For example, personnel requirements can be highlighted to simplify staff scheduling.

f. Critical path

Virtually every project manager must worry about the critical path. MS Project analyzes available "slack" time and calculates the critical path(s). The critical path can be highlighted in all three views.

g. Evaluating and adjusting the project

After your project data have been entered, it is often necessary to evaluate the project plan in terms of meeting specific objectives, such as completion dates. MS Project allows managers to easily ask "what if" questions in order to evaluate the impact of particular changes in terms of the amount of resources required and their costs. For example, management might re-examine the original specification of precedence relationships, and identify and evaluate alternatives. In addition, the benefits, if any, of "crashing" activity times also can be quantified.

TUTORIAL

The following tutorial, Bart's Ski Trip, will introduce you to project management using Microsoft Project (MS Project). The model can be found in the Operations Management directory on the network. The model follows the activities described earlier. Please feel free to access the Microsoft Help, under the Help menu, at any time.

1. Define the Project

Bart has six activities to manage before starting his vacation: drive home, wash clothes, pack, go to the bank, pack car and drive to the bus. Each of these have been listed in the Task name column in the file. Note that the calendar has been set to February 16, 1996, which is consistent with the timing of the tutorial.

2. Identify activities, precedence relationships and activity times

We need to establish the precedence relationships between activities and the duration time for each activity. First, set the time scale. From the Format menu, select the "Timescale…" command and define hours for the major scale. Under minor scale select minutes, and set the count at 30. This allows us to track the project based on 30-minute intervals.

Next, click the "drive home" cell in row 1. Using the arrow key on your keyboard, move the cursor one cell to the right, under the Duration column. Enter the duration of the activity, in this case 0.5 h. Repeat this step for each activity.

Next, we must enter the required sequence for the activities. In the Predecessor events column, enter the immediate predecessor activity, if any. Click the "wash clothes" cell and move the cursor with the keyboard arrow key two columns to the right, under the Predecessor events column. Predecessor events must be identified by row number. For, example, before Bart can start his laundry, he must first drive home. Therefore, in the Predecessor column in row 2, enter "1". Table 1 provides a summary of Bart's activities.

Alternatively, the activities, their durations, and their precedence relationships can be entered directly in the PERT Chart window. Switch to the PERT Chart window under the View menu, and select Task under the Insert menu or press the Insert key. A task box can be "dragged" with the mouse when the cursor changes to a four-way arrow over the edge of the task box.

Activity data, including the name and duration, can be entered by double clicking on the center of any task box, or by using the "Task Information…" command under the Insert menu when the task box is highlighted. The fields that should be completed are "Name" and "Duration." The time units are denoted with "d" for days, "h" for hours and "m" for minutes, and these must be entered, or days are assumed. Click "OK" when finished. Precedence relationships are easily entered by dragging from the center of a task box to the center of its successor task boxes. Tasks can be deleted by clicking on the task box and pressing the "Delete" key; precedence relationships can be deleted by double-clicking on the arrow and pressing the "Delete" button in the "Task Information" dialog window.

In addition, you can customize the information displayed in the task boxes in the PERT window using the "Box Styles…" command on the Format menu.

3. Establish critical path

From the Gantt Chart we see that the expected completion time is 6:00 p.m. Recall that Bart must be ready to go by 5:00 p.m. Under the View menu, you can select a PERT diagram. The PERT diagram depicts the sequence of activities and the critical path.

In order to address this problem facing Bart, we must first establish the critical path, which represents the longest sequence of activities in the project, and therefore, has zero slack time. MS Project can highlight a project's critical path.

In the Gantt Chart view, the names of the activities on the critical path are then highlighted. From the Format menu, select "Text Styles…" in the item to change box, select Critical activities. In the Color box select a color (e.g. red) for the names of the critical activities.

In the PERT view, the critical task boxes are automatically highlighted. The color can be changed by using the "Boxes Styles…" command under the Format menu. Either the Gantt or PERT view allows us to see that the sequence of drive home, wash clothes, pack car and drive to bus represents the critical path.

4. Make Adjustments

From Bart's project schedule, it is obvious that he cannot get everything done, at least as planned, and still get to the bus on-time. The current project plan indicates he will be one hour late. However, recognizing this is a problem, Bart can identify alternatives.

First, he might call his bank and have them prepare the travellers' cheques in advance. This new activity might require five additional minutes; he would still have to go to the bank, but the time spent going to the bank would be reduced to 0.5 hours. Second, Bart might also reduce the amount of laundry from three loads to two loads. Bart estimated that he would need only two-thirds the time, two hours and 40 minutes, to complete two loads of wash. Which activity should be changed and what is the impact?

As established earlier, the sequence of activities that is the critical path is drive home, wash clothes, pack car, and drive to bus. Since Bart can go to the bank while doing his wash, this activity is not critical.

We can confirm that changing this activity will not help us complete the project more quickly by changing the time of the "go to bank" activity to 0.5 hours, and adding a new activity of five minutes for phoning the bank. (Go to the PERT view. First, delete the precedence arrow between "drive home" and "go to bank" by double-clicking on it and pressing the "Delete" button in the "Task Dependency" dialog window. Then, press the "Insert" key to add a new task, double click on the center of the task box to access the "Task Information" dialog box, and enter the "phone bank" as the task name and "5m" for the duration. Press "OK." Finally, connect this task to other tasks in the network by dragging from "drive home" to "phone bank" and from "phone bank" to "go to bank.")

The completion time of the project does not change. Consequently, Bart does not reduce the overall time for completing the project by calling the bank and ordering the travellers' cheques in advance.

The other option is to do only two loads of wash, thus reducing the time of this activity by one-third. The cost of crashing this activity is not financial, rather only the amount of clean clothes. By changing the duration time on this activity, we see that this compromise will allow Bart to get to the bus on time. (Go to the PERT view. Double-click on the task box and change the duration to "2.67h." Click the "OK" button.) The project completion time is now 4:40 p.m.