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NOTE ON PROJECT MANAGEMENT FUNDAMENTALS

Professors Fraser Johnson and 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.

What do the following have in common: launch of a new car model, development of a new computer software package, and construction of an office tower? Each of these are examples of a project. Shorter product life cycles, the proliferation of product lines and the need to react quickly to dynamic market forces are but a few of the reasons why projects have become commonplace. For example, many organizations have turned to project management as a means of coordinating cross-functional activities.

This Note is designed to review the fundamental aspects of project management. In doing so, it covers the rudimentary project planning techniques and critical path analysis, and summarizes other basic issues that need attention when managing a complex project.

WHAT IS A PROJECT?

Projects are defined as a set of interrelated activities that are directed at achieving a particular goal or objective. In all cases, projects have a definitive starting and ending point. The output of a project is not necessarily a physical product, such as the launch of a new consumer product, but also can be service-related, such as a Broadway play. Although each project is unique, the reality is that the steps planned for one project usually can be transferred to similar projects in the future.
The activities that make up a project may involve company personnel, subcontractors, customers, suppliers, or a variety of other possible sources. In

general, some of the activities that collectively make up a project can occur in parallel, while others must occur in a definite sequence. Each activity is characterized by a completion time.

Project management is then defined as the process of planning and controlling the resources that make up a project, with the objective of completing the project within specified time, cost and other performance parameters, like quality. Ultimately, a project manager must establish a plan that identifies the sequence of individual activities and the assignment of resources. Quite often, as the project develops, the manager is forced to re-schedule activities or adjust cost estimates. Project management techniques assist by providing a quantitative tool to assess the impact of using more or fewer resources for particular activities or adjusting the sequence of activity on overall project completion time.

PROJECT MANAGEMENT TECHNIQUES

In general, project management techniques are used by managers to help them plan, control, direct and re-plan resources for their projects. These techniques are also extremely helpful to communicate the overall project plan to the many people involved in undertaking a typical project.

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 for analysis and provide answers to “what if” questions. A variety of relatively inexpensive software packages is available. These packages organize the project using 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 into 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 specify accurately. 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 these 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, depicts individual activities and the length of time required to complete each activity with a bar. The Gantt chart often organizes the sequence of activities by listing at the top those that must be completed first. Gantt charts allow a manager to quickly identify, in a visual way, the relative start and finish times of individual activities in a project plan.

However, while Gantt charts also can display relationships between activities for small projects, it becomes increasingly difficult to visualize these relationships as the number of activities in a project increases. Furthermore, it is also difficult to identify the critical path 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 interrelationships between activities immediately apparent visually. However, because each activity is only represented by a node, the relative start and end dates for each are difficult to portray visually. In practice, both PERT/CPM and Gantt charts are widely used to plan and 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 minimum 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. Once the critical path is calculated, all activities can be divided into two general types:

- *critical* activities; and
- *non-critical* activities.

Critical activities directly impact the total project completion time; their delay immediately impacts the overall completion time of the entire project. In contrast, if non-critical activities are delayed or extended, the entire project may still be completed on schedule, depending on the degree of *slack* available with that activity. Total slack is defined as the maximum amount of time that an activity can begin late or be extended by, without delaying completion of the entire project. In general, the slack for any individual non-critical activity is <u>not</u> independent of the slack for other activities.

4. Make Adjustments

Most projects are constrained primarily 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 overall project completion time is an important issue in the project management process. Additional activity cost can take many forms, including more personnel, expedited delivery, additional equipment, etc. Identification of critical and non-critical activities is central to managing these trade-offs.

Because critical activities directly impact the total project completion time, management decisions to delay or speed the completion of these activities are very important. If the overall project completion time is initially assessed to be too long or delays develop as the project proceeds, additional resources can be allocated to the critical activities to reduce their completion time, and ultimately, shorten the project completion time. Other options include expedited delivery and activity redesign.

All these actions to shorten an activity time are termed *crashing.* Activity crashing should only be directed at critical activities. However, it is very important to assess the overall project as individual activities are crashed. *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. 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.

Another option to reduce project completion time is to re-sequence or *reorder the precedence relationships.* Obviously in a project such as a product launch, the ordering of some activities is constrained, e.g., with equipment installation preceding initial production. However, rather than necessarily having employee training also follow equipment installation, training might occur in parallel if a simulation could be used or similar facility is available elsewhere.

In contrast, non-critical activities provide an opportunity for cost savings. Because these activity completion times do not directly impact overall project completion time, they can be extended if cost savings result. Slower modes of shipping, eliminating overtime, reducing peak usage of resources, etc. are possible cost-saving options. The maximum that any non-critical activity can be extended is given by its total slack. Like crashing, careful monitoring is necessary as each non-critical activity is extended, or non-critical activities will quickly become critical and potentially delay the entire project.

AN EXAMPLE

The following example illustrates the use of PERT/CPM techniques in a project. Bart plans to go skiing for his week-long holiday. He intends to leave the office immediately after completing a major presentation for senior management, which is expected to conclude at 12:00 noon on Friday. The trip from his office to his apartment usually takes 30 minutes.

Unfortunately, Bart has spent the last few days preparing for the presentation, 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 airport; he expects both of these activities to take 30 minutes each. The check-in time for his flight is 5:00 p.m., and Bart knows that he cannot be late.

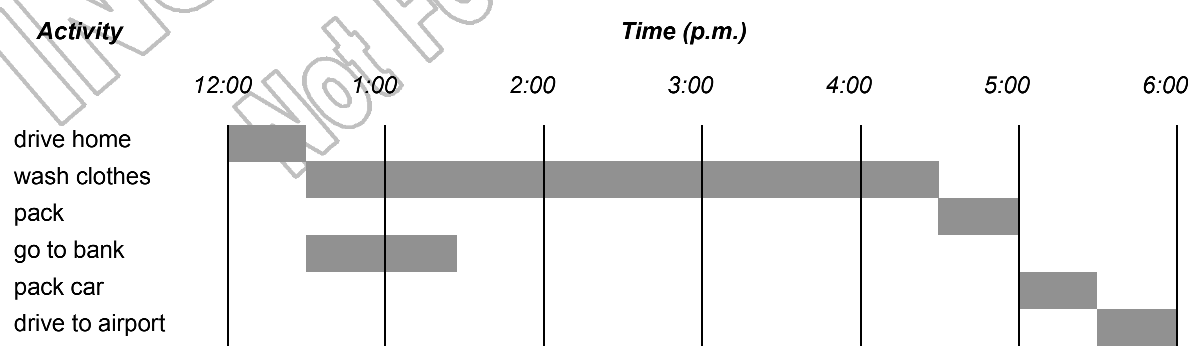
The list of activities that Bart must complete is provided in Table 1. Note that this table also identifies predecessor activities and estimated completion times.

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 airport	E	0.5

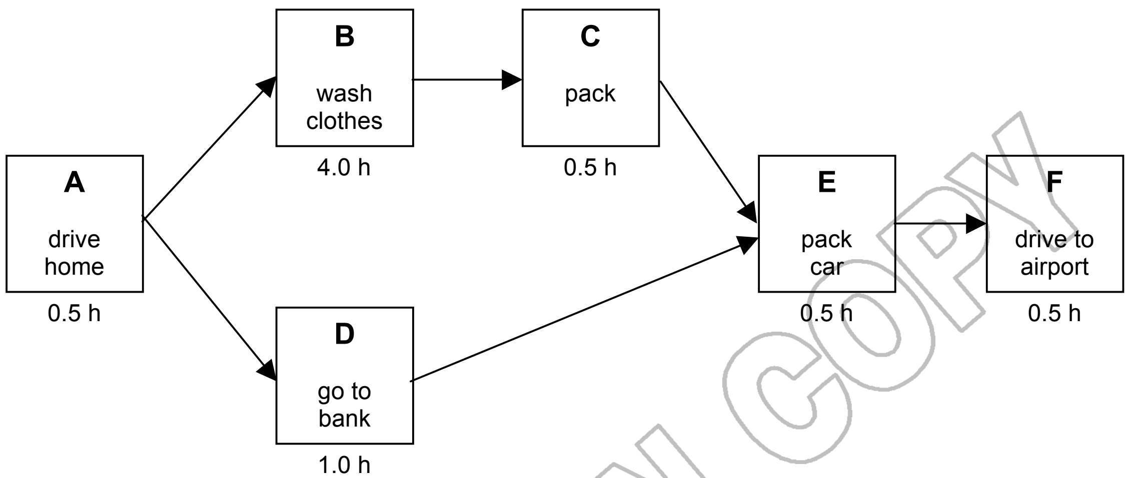
A Gantt chart, outlining the activities together with their duration, start and finish times, is presented in Figure 1. Recall that an activity is a specific task which takes time and resources. This diagram immediately communicates the planned start and completion times for each activity and the overall project. The difficulty in using these data to manage Bart's activities is that they fail 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 arrows to represent the necessary sequence in which they are performed. The PERT diagram for 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). This format helps us to quickly calculate critical path, along with the planned activity start and finish times.

Now we can begin our analysis. First, we must establish the earliest possible time that each activity can begin and finish, termed the <u>Earliest Start</u> time (ES) and <u>Earliest Finish</u> 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.

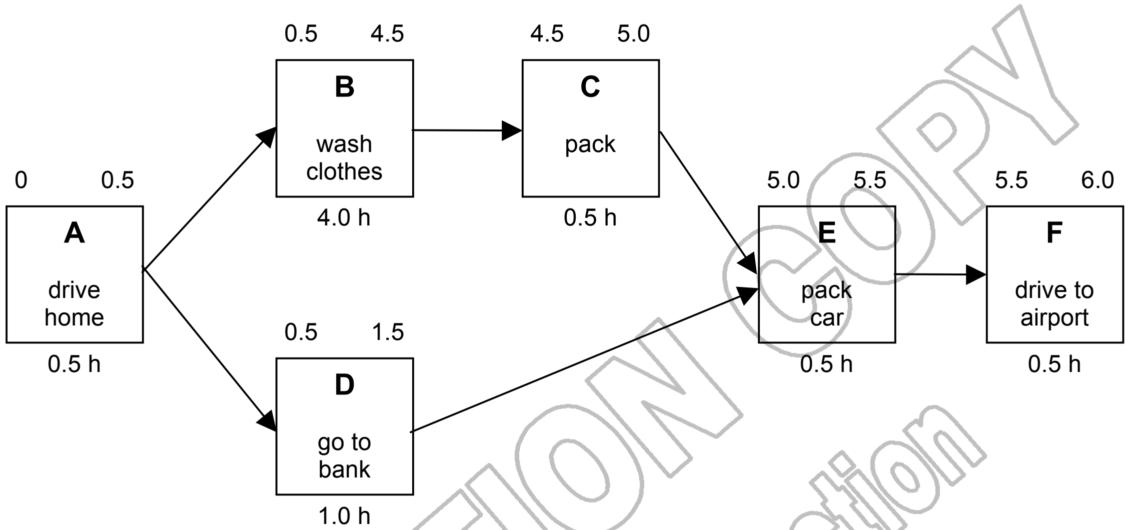
Earliest Finish time (EF) = Earliest Start time (ES) + activity duration (d)

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, respectively; for activity D is 0.5 and 1.5 hours, respectively.

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. The rationale is that we cannot begin the next activity until *all* of the preceding activities are complete.

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)

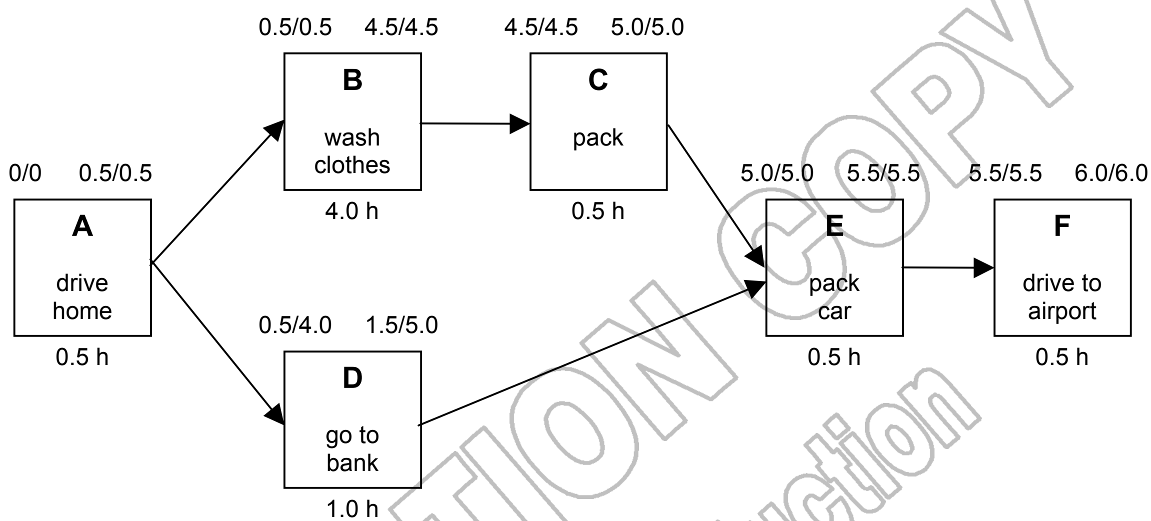
For each preceding activity, the LF is equal to the LS of the next activity. Thus, for activity E, the LF is 5.5 hours and the LS is 5.0 hours.

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. The rationale now is that we must finish the preceding activity by this time in order to avoid delaying all subsequent activities. 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.

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. As stated before, 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.

Slack = LS – ES = LF – EF

Figure 4: Ski Trip with Late Start and Late Finish Times



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

Now, we find the *critical path*. It is the chain or chains of activities that have zero slack, which for the Ski Trip is A-B-C-E-F. If any of the critical activities are late, the completion of the entire project is delayed. Moreover, efforts to reduce the total project time first must be directed at the activities on the critical path.

THE BENEFITS OF PROJECT MANAGEMENT SOFTWARE

There are many different project management software packages available, the most popular being Microsoft Project (MS Project). Project management software simplifies the process of planning, organizing and controlling complex projects. It 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 is being managed.

Using project management software offers several advantages. First, the software automatically organizes the 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. Generally, the project can be viewed in many different ways, e.g., Gantt charts, PERT/CPM diagrams, calendar-based views, task summary sheets, resource graphs and resource usage views. Each view gives the a particular user a different way to examine the data, dependent largely on the type of analysis needed.

The flexibility of project management software systems allows the manager to ask "what if" questions easily and perform sensitivity analyses. Allocating resources at the planning stage can be a complicated process, characterized by vast amounts of data, leading to a seemingly endless number of possible alternatives. Project management software assists with the comparison and evaluation of proposed alternatives. For example, assumptions can be adjusted in order to assess trade-offs with respect to timing and cost. Different options also are available for levelling the demand placed on costly resources or for constraining the availability of other resources over the course of a project.

Finally, as a project is undertaken, project management software can be used to monitor the overall project schedule, note the achievement of key milestones, track the use of resources and generate progress reports. These capabilities allow managers to anticipate and respond to problems before they impact the schedule by replanning activities.