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For the Project Management Professional[®]

Your Key to PMP Certification and Understanding the PMBOK® Fourth Edition

J. Alex Sherrer, PMP www.PMRoadTrip.com *Project Management Road Trip for the Project Management Professional: Your Key to PMP Certification and Understanding the PMBOK Fourth Edition*

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6.0 Project time management Hard The Project Time Management relationships schedule knowledge area is concerned with FS SS scheduling project activities and milestone list FF SF network diagrams activity list the completion of the project. In leads the previous Scope Management dependencies **PROJECT** knowledge area, we established schedule work packages from deliverables. compression TIME FNET SNET lags The work we perform in the Time FNLT SNLT MANAGEMENT Management processes will effort further decompose the work RBS duration packages into explicit activities resource calendar that we'll use to establish the three-point estimate project schedule. 6.6 Control Schedule **PROJECT TIME** scope MANAGEMENT 6.5 Develop Schedule WBS schedule activities diagrams 6.1 Define Activities 6.2 Sequence Activities 6.4 Estimate Activity 6.3 Estimate Activity Durations Resources resources duration

Keywords

- □ Activity attributes
- □ Activity list
- □ Activity sequencing process
- \Box Analogous estimating
- \Box Apportioned effort
- □ Arrow Diagramming Method (ADM/AOA)
- □ Bottom-up estimating
- □ Budget estimate
- □ Buffers
- \Box Composite resource calendar
- \Box Contingency reserve
- \Box Control schedule process
- \Box Crashing
- □ Critical activity
- □ Critical chain
- \Box Critical chain method
- \Box Critical path
- □ Critical path method
- \Box Definitive estimate
- \Box Define activities process
- \Box Develop schedule process
- \Box Discrete effort
- □ Discretionary dependencies
- □ Duration
- \Box Early finish (EF)
- □ Early start (ES)
- □ Effort
- □ Estimate activity durations process
- □ Estimate activity resources process
- □ External dependencies
- □ Fast-tracking
- □ Finish-no-earlier-than (FNET) constraint
- □ Finish-no-later-than (FNLT) constraint
- □ Finish-to-finish (FF) relationship
- □ Finish-to-start (FS) relationship
- □ Float/slack
- □ Free float/free slack

- □ Hammock activities
- □ Hard logic
- 🗆 Lag
- \Box Late finish (LF)
- $\Box \quad \text{Late start (LS)}$
- □ Lead
- $\Box \quad \text{Level of effort (LOE)}$
- □ Mandatory dependencies
- □ Milestone list
- □ Monte Carlo analysis
- □ Parametric estimating
- Parkinson's Law
- □ PERT
- □ Precedence Diagramming Method (PDM/AON)
- □ Project calendar
- □ Project float/project slack
- □ Project schedule
- □ Project schedule network diagram (PND)
- □ Resource breakdown structure (RBS)
- \Box Resource calendar
- \Box Resource intensity
- \Box Resource leveling
- \Box Resource smoothing
- \Box Rough order of magnitude estimate
- \Box Schedule baseline
- \Box Schedule change control system
- \Box Schedule data
- □ Schedule management plan
- \Box Schedule model
- □ Schedule network analysis
- □ Standard deviation
- □ Start-no-earlier-than (SNET) constraint
- □ Start-no-later-than (SNLT) constraint
- □ Start-to-finish (SF) relationship
- □ Start-to-start (SS) relationship
- □ Three-point estimate
- \Box Top-down estimating
- □ Total float/total slack

CHAPTER 6: TIME MANAGEMENT



The **project schedule** provides the starting and ending dates for all project activities. The schedule is what the project team refers to for what needs done and when it needs done.

In order to develop a project schedule, the work packages have to be further decomposed into activities. These activities must then be sequenced, and the resources needed for each activity determined, and this is followed by figuring out how long each activity will take. Once all the component pieces are known, a project schedule can be created. Time management processes occur at least once on every project, but since the project tasks are closely tied to scope, cost, and quality, it's very likely that these processes will reoccur often during the project and that the project schedule will under revisions. Software engineers are eternal optimists. When planning software projects, we usually assume that everything will go exactly as planned. Or, we take the other extreme position: the creative nature of software development means we can never predict what's going to happen, so what's the point in making detailed plans? Both of these perspectives can lead to software surprises, when unexpected things happen that throw the project off track. In my experience, software surprises are never good news.¹

Know Your Enemy: Introduction to Risk Management, Software Development magazine.

Though in practice the Time Management processes may be performed concurrently, there is an inherent order as illustrated on the following page to the scheduling processes. The processes in Time Management are:

- Define Activities: Decomposing the work packages into activities.
- Sequence Activities: Determining the order the activities need performed in.
- Estimate Activity Resources: Finding out the quantities and types of resources needed for the activities.
- Estimate Activity Durations: Determining how long the activities will take.
- **Develop Schedule:** Creating the project schedule.
- **Control Schedule:** Monitoring the schedule and influencing the factors that can lead to schedule changes.



Schedule management plan

Each knowledge area has at least one subsidiary plan focusing on a specific subject as part of the overall project management plan. Preplanning is the purpose of these components, and these plans map out the specific requirements for the deliverables and project management processes that will take place in that knowledge area. This preplanning may sound like a lot of work, but we can think of these subsidiary plans as being the scope statements for the knowledge area because they describe the who, what, where, why, and how of the project management work that will be performed for that section's subject matter.

The schedule management plan is a subsidiary component of the project management plan, created in the Develop Project Management Plan process (4.2), and it should be established before work begins in the time management processes because it describes:

- What activities, methodologies, tools, and processes will be used for creating the project schedule.
- How the schedule will be approved by the stakeholders and project team.
- How likely schedule changes are to occur on the project and what kind of special approvals are necessary for schedule changes.

As with other subsidiary plans, templates can help provide the basis for the schedule management plan. The complexity of the project and how likely schedule changes are to occur will be factors in deciding how detailed the schedule management plan needs to be.

activity attributes

activity list

6.1 Define activities

The goal of the first Project Time Management Process, Define Activities. is to create the complete list of project activities, called the activity list, which itemizes all the tasks required to produce the work packages.

ACTIVITIES work packages

DEFINE

planning package

decomposition

rolling wave planning

milestone list



Defining activities is an iterative process performed together by the project manager and the project team member by further decomposing the WBS work packages. Since the activity list and WBS can be looked upon as companion documents, each activity should have a unique identifier that correlates it to the WBS work package. Though presented here as a discrete process, some level of activity definition will usually occur while the work breakdown structure is being created, and other planning processes are very likely to uncover additional activities which may require change requests to the project scope if the scope baseline is already in existence.

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To identify activities, work packages are evaluated for how they can be broken down into manageable activities. An adequate level of activity decomposition is generally reached when the activities:

- Are assignable to one person
- Can have a level of effort determined for them
- Can have their resource needs estimated
- Can have their expected costs reasonably established
- Can have their progress determined and tracked.

A companion to the activity list is the activity attributes document. The **activity attributes** document contains sufficient detail to fully describe the activity. It includes supplemental information about the activities, such as explanations of any special dependencies or relationships that exist, assumptions that were made, person responsible for the activity, special equipment or materials needed, or information specific to the activity that will vary depending upon the project's application area and the type of activity. Activity attributes are to the activity list as what the WBS dictionary is to the WBS --the two documents go hand in hand.

The activity attributes document will also identify the **activity type**. Activity types categorize how measurable the activity is and how it's related to the project's objectives. Activity types are discrete effort, level of effort (LOE), and apportioned effort (AE).

• A **discrete effort** activity is one whose work directly relates to a work package or deliverable on the work breakdown structure. These types of activities need to be measurable since they tie directly to the project's core objectives. If the activity ties to the project's objectives, and it can be measured then it's a discrete effort. For instance, an activity consisting of binding a training

manual for a software project would be considered a discrete effort since the effort to produce the manual could be measured and the training manual would be an identified deliverable in the WBS.

- A level of effort (or LOE) is usually an activity performed by a supporting role that is difficult to measure, but is still related to the project's core objectives. For example, a salesperson acting as a liaison between the customer and the project team would usually be performing LOE activities.
- An **apportioned effort** (or AE) activity is one which is usually related to project management it's necessary for the efficient functioning of the project, but it isn't directly related to the project's final product, service, or result.

Another important output of activity definition is the **milestone list**, which provides all significant events and dates on the project. Milestones can be points at which major deliverables are completed, phases are reached, or other important dates. On large projects, milestones can help keep everyone motivated, so the team may want to add its own milestones to the list. Milestones also provide a very

A frequent misuse of milestones is simply not using them enough. Milestones can be an efficient scheduling tool, taking the place of tasks which take less than a day to complete.²

Paul Brough, Vice President of Warner Construction Consultants, Inc. Scheduling Group

effective method for communicating the schedule progress to stakeholders. The milestone list is a component of the project management plan.

<u>Inputs</u>

□ Scope baseline

The scope baseline is the approved project scope statement, WBS, and WBS dictionary. These define the deliverables and work packages, which are used to create the activity list.

Enterprise environmental factors

Any of the many enterprise environmental factors and systems, such as the PMIS, that influence the project should be considered while defining the activities.

□ Organizational process assets

Organizational process assets are the source of existing policies, processes, organizational data and knowledge. These assets include the entire collection of formal and informal methodologies, policies, procedures, plans, and guidelines, as well as the organization's "knowledge base," which includes lessons learned from prior projects.

Tools and Techniques

□ Decomposition

Decomposition breaks down larger items into manageable components. Work packages from the WBS are decomposed into the activities needed.

□ Rolling wave planning

An iterative approach in which items not required immediately by the project are planned for later as the need for them draws closer. This means that future activities may only be decomposed at a relatively high level, but as the need for them draws near, further planning will take place.

□ Templates

Activities and milestones from similar projects may be useful as a starting point for defining activities and milestones on a new project.

□ Expert judgment

Expert judgment is based upon the experience and knowledge of subject matter experts. Subject matter expertise in scheduling, scope statements, and WBS decomposition is needed for time management.

Outputs

□ Activity list

The activity list is the complete list of project activities that are needed to produce the work packages. Activities are decomposed from the WBS work packages. The activity list is a component of the project management plan.

□ Activity attributes

The activity attributes document is a companion to the activity list. It provides sufficient detail to fully describe the activity, and any supplementary information about activity, such as its relationships, constraints, assumptions, dependencies, and responsible people.

□ Milestone list

The milestone lists contains all project milestones regardless of whether they originated from the customer, enterprise, stakeholders, or the project team. The list also identifies whether each milestone is optional or mandatory. The milestone list is a component of the project management plan.

6.2 Sequence activities

Properly sequencing activities involves determining the dependencies and relationships between activities and applying leads and lags. Activity sequences are shown through project schedule network diagrams, which are schematics showing the order and relationships of project activities.

- Mandatory: A required, hard logic, or inherent order to the activities. For example, a book can't be bound until it has been printed. Mandatory dependencies can also be caused by regulatory requirements or organizational procedures. Mandatory dependencies cannot be altered --they are what they are and the project has to adhere to those dependencies.
- **Discretionary:** A logical or preferred order to the activities. For example, in a remodeling project the team would prefer that carpeting not be installed until all painting has been completed. Discretionary dependencies can be reordered if necessary but doing so may result in additional risk factors.

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• External: The dependency is outside of the project and usually beyond its direct control. For example, a technician can't begin installing the equipment until the vendor delivers it. Though sometimes external dependencies can be influenced or made contractual (such as with a vendor or consultant), they can't usually be altered. External dependencies can also lead to scheduling problems when no hard date is available. For example, some modes of transportation can provide only a date range of when materials can be expected to arrive.

Activity relationships

that affect the order of activities by establishing the start and finish relationships between successor and predecessor activities. If there is any unusual logic to the relationships, it should be documented on the activity attributes document as well as through narratives on the project schedule network diagram or on a supplementary document to the diagram. There are four types of activity precedence relationships.

Activity relationships are another restriction

Finish-to-Start (FS): The successor activity can begin only after the predecessor activity is completed (Activity B can't start until Activity A is completed). This is the most common type of relationship. For example, a house's concrete foundation can't be poured until the excavation activity is fully completed.

Finish-to-Finish (FF): The completion of the successor activity depends upon the completion of the predecessor activity (Activity B can't finish until Activity A is finished). This relationship is necessary when both activities need to finish at the same time (or very close) to each other, but there's not any relationship between the activity start dates. For example, in order to be ready for binding, the cover of a book needs completed around the same time as the printing of the book's pages are done.

Start-to-Start (SS): The successor activity can't start until the predecessor activity starts (Activity B can't start until Activity A has started). This relationship is needed when the starting dates of the activities are dependent upon each other, but the ending dates are not. For example, survey responses can start being tabulated as soon as the survey results begin coming in since there's no real need to wait until all survey results have been returned before entering them into a database.

Start-to-Finish (SF): The completion of the successor activity depends upon the predecessor activity starting (Activity B can't complete until Activity A has started). For example, in a project in which equipment is being replaced, before the old equipment can be fully decommissioned (Activity B), the initial testing of the new equipment should have been successfully started (Activity A). The testing doesn't need to be fully completed but just far enough along that the team can be assured the new equipment is functioning before the old equipment is dismantled.

Leads and lags

Leads and lags are artificial effects on the timing of activities and are used in conjunction with activity relationships and dependencies. Leads and lags and the reasoning behind their use should be well documented because it may not be obvious to the casual observer why they were established.

Lags are delays or waiting time between activities. For example, if a parking lot is being resurfaced and there's a 24-hour curing period for asphalt before striping can begin, there would be a one day lag between these activities used in conjunction with a finish-to-start relationship: Activity B (striping) can't begin until one day after Activity A (asphalting) is completed. We can think of lag as positive time added to an activity's duration. If the asphalting task takes two days and there's a one day lag while waiting for it

to cure, the duration of the asphalt activity is three days.

Leads speed up activities without changing the relationships between the activities. We can think of leads as "negative" time because they allow activities to occur in parallel that would

normally be done sequentially. For example, after the parking lot has been resurfaced with asphalt and the painting of parking spaces begun, inserting the signs for handicapped spaces could start even though striping of the spaces isn't done. Activity C (posting handicapped parking spaces) will begin one day before Activity B (striping) is scheduled to be completed. Leads can lead to rework and usually pose other risk factors as well, so they should be used carefully.

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Project schedule network diagrams

Project schedule network diagrams, sometimes referred to by the acronym **PND**, graphically show the relationships, sequences, and durations of all activities from the start to the end of the project. These diagrams are an integral part of the scheduling process and are necessary for determining the critical path

of the project. Most project management software applications will produce project schedule network diagrams, but we should know how to read them and create them by hand for the PMP examination. Though time consuming, producing them by hand, even if only at a summary level, has the added benefit of often uncovering missed activities, incorrectly sequenced, or erroneous relationships between activities.

Project schedule network diagrams for complex projects can become very large documents and become difficult to view. If only a portion of the diagram is shown, these snippets are called a **subnetwork** or **fragment**. It's also common for PNDs to sometimes show only summary activities, called **hammock**

...computers have made it easy to slap together something that looks right, but there is a thought process that must be involved, and it is hard to tell in many contemporary schedules if the thinking happened or not. ³

Critics Can't FInd the Logic in Many of Today's CPM Schedules

activities. These summary activities, cancer minimized several component activities and are aggregated from the detailed activities. For example, a software development project might involve many activities related to a particular user-interface form; however, for simplicity, one hammock activity, such as *Develop Form XYZ*, is used to represent all associated activities.

All project schedule network diagrams must have one starting and ending point, and they can't have any circular references. A circular reference is an erroneous relationship between activities that results in an endless loop in the network path. For example, setting a relationship so that activity D can't start until activity C is completed, and also having activity C dependent upon activity D being completed results in a circular reference.

There are two types of network diagrams: the Arrow Diagramming Method (known as ADM) and the Precedence Diagramming Method (PDM). For now we're only concerned with properly sequencing the activities and don't need to worry too much about the diagrams. Later on during the Develop Schedule process (section 6.5), we'll spend more time with these diagrams as we add activity durations, calculate float, and use them to determine the project's critical path.

The Arrow Diagramming Method (ADM) creates diagrams known as activity-on-arrow (AOA). This is because ADM diagrams use activities shown on arrows and connected by nodes, usually shown as circles. ADM is the oldest diagramming method, and is now infrequently used. It's drawback is that it can only show finish-to-start (FS) relationships. In order to show relationships between tasks on different node branches, ADM diagrams use dummy activities. These are fictional activities shown as dotted lines with a duration of zero that join nodes.

In the example diagram to the right, a dummy activity between E and C indicates that there's a finish-to-start relationship --activity C can't begin until activity E has been completed.

The **Precedence Diagramming Method (PDM)** creates diagrams known as **activity-on-node** (AON). It uses nodes, usually shown as squares, to hold the activities which are connected by arrows to show the

relationships. The PDM diagram is the one most commonly used because it's more flexible and can show any activity relationship.

6.2 Process decomposition

<u>Inputs</u>

□ Activity list

The activity list is the complete list of project activities that are needed to produce the work packages. It's decomposed from the WBS work packages. It's the source document this process needs to identify what the activities are that need sequenced.

□ Activity attributes

The activity attributes document is a companion to the activity list. It provides sufficient detail to fully describe the activity, and any supplementary information about activity, such as its relationships, constraints, assumptions, dependencies, and responsible people.

□ Milestone list

The milestone lists contains all project milestones regardless of where they originated and whether the milestone is optional or mandatory. Milestones can originate from the customer, performing organization, project manager, or project team. Milestones can generate dependencies and relationships between activities and might necessitate the need for leads and lags.

□ Project scope statement

The product scope describes the characteristics and functionality of the product, service, or result. Compared to the project scope, it is more focused on explaining what the product will be and how it will be used. The scope statement may identify constraints that will generate dependencies and relationships between activities and might necessitate the need for leads and lags.

□ Organizational process assets

Organizational process assets are the source of existing policies, processes, organizational data and knowledge. These assets include the entire collection of formal and informal methodologies, policies, procedures, plans, and guidelines, as well as the organization's "knowledge base," which includes historical performance data. Of use to sequencing activities could be data from prior projects.

Tools and Techniques

□ Precedence diagramming method (PDM)

A method for producing project schedule network diagrams, PDM produces activity-on-node (AON) diagrams. These are schematics that show activity sequencing and relationships and are used in the Critical Path Methodology (CPM).

□ Dependency determination

When they exist, dependencies between activities can be mandatory, discretionary, or external. Mandatory dependencies are dictated by contract or the nature of the work; discretionary dependencies are a preferred sequence; and external dependencies are those controlled by factors outside the project.

□ Applying leads and lags

Leads and lags are needed in the schedule for a variety of reason, such as dependencies between activities. Leads cause two activities to occur (for some period of time) in parallel when they'd normally have been sequential. Lags cause a delay between the finish of one activity and the start of the successor activity.

□ Schedule network template

Templates can be helpful to decrease the time needed to create a project network diagram.

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Outputs

□ Project schedule network diagram

Project schedule network diagrams (PND) are schematics that show the sequencing of activities and activity interrelationships. The two types of diagrams are activity-on-arrow (AOA) and activity-onnode (AON).

□ Project document updates

Sequencing of activities will usually result in updates to one or more other project documents.

anything having a monetary cost and include materials. equipment. licenses, fees, and personnel needed for the project's activities. Estimating resource needs is usually performed concurrently with cost estimating (section 7.1).

ttom-up	calendars
ESTI	MATE
ΑΟΤ	IVITY
BS RESO	URCES
resouce	accuracy
breakdown	rough order of magnitude
structure	budget estimate definitive estimate

The project team may need to consult subject matter experts in order to determine what types and quantities of resources will be required. For some activities there may be commercially published estimating data that will be useful, and another excellent source is similar activities from past projects, though care must be taken to factor into the estimates the unique situation of the current project.

The quantity designations will depend upon the type of resource --resource quantities for personnel may be expressed in hours, work days, or work weeks while the quantity designations for materials to be consumed will be expressed in whatever unit is applicable (cases, boxes, pounds, tons, kilograms, and so on), and quantity designations for equipment or facilities would likely be expressed as a unit of time (hours, weeks, or months).

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For human resources we're not trying to identify specific named individuals but rather only the types of personnel needed and the effort required, such as programmers, engineers, architects, electricians, foremen, specialists, and so on. Regulations, industry requirements, laws, and regional codes may restrict the types of personnel that can perform some activities.

Other enterprise and organizational factors may limit what personnel types are available, and we'll need to keep in mind the general availability of resources and whether availability Many (perhaps most) of the problems that you have with estimating result from not being really sure what the work entails. You should avoid estimating work that you don't understand. If you're getting ready to start a project, you should know enough so that you can estimate the work to within plus or minus 10%. If you can't estimate the work to this level of confidence, you should spend more time investigating and understanding the work. If the work is just too large to be able to estimate at that level of confidence, consider breaking the project into smaller pieces so that you can estimate each smaller project to within 10%.⁴

Tom Mochal, PMP and President, TenStep, Inc.

is restricted by geography, experience, cost, or any other factor. Known limitations will force us to look for alternatives. For instance, we might need to use a junior-level staff member to perform some activities rather than a senior-level staff member, but in finding alternative approaches, we should keep in mind any performance or quality trade-offs the alternative approach will have.

Estimating methods

There are two general approaches to estimating. Which approach we take is largely dependent upon how much information we have, so estimating during early phases is likely to be prone to inaccuracies, and the two different approaches can end up with different results.

Top-down estimating is a form of expert judgment through which an item is looked at broadly and a generalized estimate created. Top-down estimating is required when the details are not yet known, usually during the initiating and early planning processes. While estimating resource needs for activities, we're usually performing top-down estimating against summary (a.k.a. hammock) activities that haven't been fully decomposed.

Top-down estimating

Bottom-up estimating provides estimates for each component activity, and then aggregates these into an overall estimate. For example, if we were to develop a bottom-up estimate for cleaning out the garage, we'd start by estimating how long it'd take to remove the accumulated boxes, sort the items into keep, dispose, and donate piles, and then estimate how long to put everything back into the garage. The aggregate of each of these estimates would become our estimate for the summary activity *clean out garage*. Bottom-up estimating takes much more time than top-down, but it will generally produce the most accurate results as long as the component items are known and properly estimated. Bottom-up estimating also requires a thorough level of decomposition of the item being estimated, which may not be possible when details are not yet fully known.

Estimating accuracy

Estimates are at the core of many project management processes, and inaccurate estimates can lead to later perceptions that the project is off track. Estimates are generally looser during the initiating phases, get clearer during the planning processes, and continue to be fine-tuned as further planning and executing processes get underway. So that other people don't reach the wrong conclusions, whenever estimates are provided we need to clearly identify and document how the estimates were derived, how probable they are, and what their accuracy range is.

There are three general classifications for the accuracy of estimates:

- **Rough order of magnitude estimate**: These are usually top-down estimates made by expert judgment. The variance range for this type of
- estimate is expected to be -25% to +75% of the final actual figure. During early initiating or planning phases, this may be the only estimate available.
- Budget estimate: These have less variance than rough order of magnitude, but they are still broad estimates. The variance range for this type of estimate is expected to be -10% to 25% of the final

actual figure. Budget estimates should be used once planning processes are underway, and previous rough order of magnitude estimates should be re-estimated.

Definitive estimate: This type is the most accurate estimate. The variance range for this type of estimate is expected to be -5% to 10%. Budget estimates of this type should be expected once substantial planning has occurred or project execution has been underway.

Resource breakdown structure

The **resource breakdown structure (RBS)** provides a categorized, hierarchical representation of the project's resource requirements. The purpose of the resource breakdown structure is to present the different resource types needed by a project, and a good RBS will also assist in cost estimating. The resource breakdown structure is not intended to show us *when* resources are needed, only *what types* are needed.

The resource breakdown structure provides many of the same benefits that the WBS does. It improves estimating, communication, and overall project integration. The first level of the RBS is usually grouped by categories such as:

 Labor: A categorization for the different types of people needed for the project, whether internal or external (consultants, services). To develop the RBS, it is necessary to begin by dividing the pool of resources into entities specific enough so that this structure can serve as a shopping catalog for resources that are necessary to accomplish project activities...⁵

Parviz Rad & Dennis Cioffi, Work and Resource Breakdown Structures for Formalized Bottom-Up Estimating

- **Tools, Machinery**: Any items needed for the project but which are already available within the organization.
- Materials, Equipment, Hardware, Software: Items needed for the project which must be specially purchased, rented, or leased for the project.
- Fees, Taxes, Licenses: Non-material Items needed.

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For the subsequent levels in the RBS, it can be helpful for later cost estimating if the RBS matches the deliverables-oriented categorization of the work breakdown structure because it can be used to determine cost by deliverable. This approach can take significant work and may require re-classifications to both the RBS and WBS to make them companion documents, but the extra up-front work will save time in the long run by providing the project manager with better cost management tools.

6.3 Process decomposition

<u>Inputs</u>

□ Activity list

The activity list is the complete list of project activities that are needed to produce the work packages. It's decomposed from the WBS work packages. It's the source document this process needs to identify what resources are required.

□ Activity attributes

The activity attributes document is a companion to the activity list. It provides sufficient detail to fully describe the activity, and any supplementary information about activity, such as its relationships, constraints, assumptions, dependencies, and responsible people.

□ Resource calendars

This may be one or more calendars that identify when people, equipment, and material are available and for what lengths of time. For example, a resource calendar would indicate when supplies were expected to arrive and in what quantity. There is also a composite resource calendar that shows the availability of named human resources on the project as well as their skills. These calendars are useful during resource estimating because alternative resources may need identified if there's a shortage of a desired resource.

Enterprise environmental factors

Any of the many enterprise environmental factors and systems that influence the project should be considered. These factors can include its personnel, its organizational culture, its tolerance of risk, and its formal and informal hierarchy. Organizations may also have custom or commercial analytical databases that can include cost estimating, risk, or demographic data.

□ Organizational process assets

Organizational process assets are the source of existing policies, processes, organizational data and knowledge. The organization may have policies relating to staffing, rental, leasing, and purchasing of material.

Tools and Techniques

□ Expert judgment

Expert judgment is based upon the experience and knowledge of subject matter experts. Estimating is always based on expert judgment.

□ Alternatives analysis

Finding alternatives looks for different approaches in performing the work required by the project or in the methods for achieving the project's objectives. Identifying resource needs will require evaluation of different resource types, financial comparisons between staffing or outsourcing, renting versus leasing, and building versus buying.

D Published estimating data

A variety of commercially available publications and databases provide standardized rates, resources, labor, material, and other related categories which might be useful for estimating resource needs of the project's activities.

□ Bottom-up estimating

Bottom-up estimating looks at all the components of an activity in order to provide estimates. These component estimates are then aggregated to derive an estimate for the activity. This is in comparison to top-down estimating, which relies heavily on expert judgment and looks only at the activity at high, overall level.

□ Project management software

Project management software will offer tools to plan, calendar, estimate, evaluate, organize, and manage resource needs.

Outputs

□ Activity resource requirements

The activity resource requirements document describes the resource needs at the activity level, which can be aggregated up to the work package level. It focuses on the resource types and quantities needed.

□ Resource breakdown structure

The Resource Breakdown Structure is a graphical, hierarchical presentation of resources by type. There is no hard and fast rule for its categorization, but it's generally better to have the RBS's categorization be in a manner similar to the work breakdown structure.

□ Project document updates

Resource estimating and alternatives analysis may result in updates to the activity list, activity attributes, and resource calendars.

The Estimate Activity Durations process results in an expected duration for each project activity. This process is performed by the project manager, the project team, and often subject matter experts. This process will occur at least once on every project, but will likely reoccur several times and may also occur concurrently with other processes, such as activity resource estimating.

three-point	estimates	analogous estimating
Standard		
deviation	ESTIMATE	Parkinson's
reserves	ACTIVITY	Law
I	DURACTION	S
parameti	buffers	
estimatir	ng	

Several of the outputs from other processes are needed for us to establish how long each activity is going to take. These are the activity list and activity attributes, resource requirements, resource calendars, and the risks.

Effort and duration

Effort is the amount of labor required for an activity while **duration** is how long the activity will take expressed in a work period. The *effort* needed for activities was estimated through the activity resource estimating process and is shown on the activity resource requirements document. Duration is not just the effort converted into a different working time period. Though directly linked to effort, duration is usually longer because of non-project time that is part of most people's working day. Since activity durations are the basis for the schedule, inaccuracies will result in an unrealistic schedule, so below are some generalizations affecting duration estimates that will help us establish better durations.

- Number of resources: Activities with a large number of human resources will take somewhat longer because of the "overhead" involved in coordination and communication.
- Work periods: The normal or acceptable work periods may be different between companies, offices, regions, personnel classifications or professions. Regulations may also be applicable which limit the wor

may also be applicable which limit the work periods for some resource types.

- Multiple shifts: Productivity levels are usually different between shifts for the same resource type.
- **Resource allocation:** Most resources will not be able to devote their entire working day to project work. This is true in any organization structure, but more of a factor in functional and matrix organizations.

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- **Resource types:** Though experienced resources may be more efficient than those with less experience, resource availability or cost factors will influence what resource types can be used on which activities. Sometime it's necessary to opt for less-experienced personnel because of availability or scarcity, meaning it'll usually take them longer to perform the same tasks.
- **Risk factors:** Risky activities need undertaken with more attention to detail, which likely means longer efforts and durations.
- **Multi-tasking:** Multi-tasking is a productivity loser, but it can't always be avoided. Any resource who is juggling other job duties or performing multiple project activities simultaneously is multi-tasking. When we cannot rearrange the person's tasks to eliminate multitasking, we need to allow longer durations for those resource's activities.
- **Funding limits:** Calendar-based funding limits, either established by the customer or performing organization, may restrict when work can be performed and can affect durations. For example, if the budget limit for November is \$25,000, but there is \$30,000 of scheduled activities planned, \$5,000 of those scheduled activities is going to have to be adjusted, either by rescheduling the start date or limiting the number of resources performing those activities, which will increase duration.

Parkinson's Law

Another contributor to inaccurate duration estimates is a situation known as Parkinson's Law. Though the intent of his paper was not directly related to its subsequent interpretation, Cyril Parkinson first introduced this topic in a 1955 paper⁶. **Parkinson's Law** states that *work expands to fill the time available*. This means that if it we estimated an activity will take two weeks, it'll end up taking two weeks even if it could have been finished it in one.

This isn't due to deliberate misinformation on anyone's part. For example, our two week estimate might have included padding because we know some other things are also due during that two weeks, or we might have allowed extra time for risks that we knew

Overcoming Parkinson's Law⁷

- Determine priorities.
- Give more time to top priorities.
- Use reliable estimating techniques.
- Take frequent measurements on performance.
- Maintain visibility of those measurements.

Ralph Kliem and Irwin Ludain, Tools and Tips for Today's Project Manager

might be involved in the activity. We might also have just wanted to be absolutely sure we would meet that deadline, so we gave ourselves several extra days. But the problem that arises from Parkinson's Law is that even when this "padding" is done with the best of intentions, it results in additional time that is invisible and unaccountable.

As project managers, we have no real idea whether the activity indeed took two weeks or only seven days, and this not only makes the activity durations on

our project inaccurate, but could lead to inaccuracies in other projects which rely on our project for historical data.

Estimating techniques

There are three estimating approaches that can help make duration estimates more accurate. These are analogous estimating, parametric estimating, and three-point estimates.

Analogous estimating is a form of expert judgment that relies on the duration from a similar past activity to predict how long another activity will take. Care must be taken when using historical information from other projects because an activity can sometimes appear similar in project documentation but have actually been much different or have been performed under much different circumstances. For example, the experience level of the other project team may have been lower or there could have been hidden padding in the activity's duration. Still, analogous estimating is more accurate than estimates from the project team or expert judgment alone.

Parametric estimating uses mathematical formulas as the source for duration estimates. It isn't applicable to all activities, but it can be used when the quantity of work and productivity rate are known. For example, if brochures can be produced at the rate of 1000 per hour, it will take 10 hours to print 10,000 brochures. As long as other activity factors and attributes are also taken into consideration, parametric estimates can be very accurate.

We have to account for uncertainty in our estimates, and so it's common to use pessimistic, optimistic,

Importance of correct estimating is obvious. Under-estimating may result in the client getting an unpleasant shock when tenders are opened and drastically modifying or abandoning the work at that stage. Overestimating may lose the engineer or estimator his client or his job, or in any case his confidence.⁸

Construction Estimating Techniques, Construction Information Services

and most likely values. **Pessimistic** is the worst-case scenario, **optimistic** is the best-case scenario, and the **most likely** estimate is the one based on a reasonable situation. Standard deviation and three-point estimates can be used when the estimates that are coming from team members for the same activity are varying widely. **Standard deviation** identifies how diverse the data population is. A high standard deviation indicates a lot of uncertainty in the estimates.

The formula for standard deviation used by the PMBOK is:

For example, the most pessimistic estimate received from the project team is 12 weeks, and the most optimistic estimate is 4 weeks. The standard deviation for this activity is 1.33. (12 - 4) / 6 = 1.33

Some of the uncertainty in estimates can be factored out by using three-point estimates. A **three-point estimate**, sometimes referred to as PERT, uses the three estimates and applies a mathematical formula. The result is a duration estimate that is a weighted average.

The formula for a three-point estimate is:

(Pessimistic Estimate + (4 x Most Likely Estimate) + Optimistic Estimate)

If the pessimistic estimate for an activity is 12 weeks, the optimistic estimate is 4 weeks, and the most likely is 7 weeks, then the three-point estimate is 7.33.

(12 + (4 x 7) + 4) / 6 (12 + 28 + 4)/6 44 / 6 = 7.33

Reserve analysis

Another scheduling tool that can be used is reserve analysis. **Reserve analysis** looks at various factors in the project, such as risks and overall uncertainty, and sets aside separate **contingency reserves**, time **reserves**, or **buffers** that can be drawn from if activities exceed their duration. Buffers can also achieve more accurate estimates by moving the padding out of the activity and into a separate bucket where it can be better managed.

Any buffers and the reasoning behind those buffers needs to be fully documented. Whether this reserve time is added to the schedule as a whole, to individual activities, or to crucial points within the schedule depends upon the project manager and his

or her scheduling approach. But wherever they appear in the schedule, the best reserve amounts are ones that give just the right amount of breathing room because reserves needs constant monitoring as unexpected items may draw down the contingency reserve too much or an excessive reserve may never be needed.

6

6.4 Process decomposition

<u>Inputs</u>

□ Activity list

The activity list is the complete list of project activities that are needed to produce the work packages. It's decomposed from the WBS work packages. It's the source document this process needs to identify what resources are required.

□ Activity attributes

The activity attributes document is a companion to the activity list. It provides sufficient detail to fully describe the activity, and any supplementary information about activity, such as its relationships, constraints, assumptions, dependencies, and responsible people.

□ Activity resource requirements

The activity resource requirements document describes the resource needs at the activity level, which can be aggregated up to the work package level. It focuses on the resource types and quantities needed.

□ Resource calendars

This may be one or more calendars that identify when people, equipment, and material are available and for what lengths of time. For example, a resource calendar would indicate when supplies were expected to arrive and in what quantity. There is also a composite resource calendar that shows the availability of named human resources on the project as well as their skills. These calendars are useful during duration estimating because scarcity or unavailability of resources may increase the duration of activities.

□ **Project scope statement**

Assumptions and constraints are factors in activity durations. The project scope statement details the measurable goals, objectives, deliverables, and requirements of the project, and what the acceptance criteria of deliverables will be. It also describes the work required to meet all objectives and deliverables of the project, and it also contains milestones, assumptions, risks, and costs.

□ Enterprise environmental factors

Any of the many enterprise environmental factors and systems that influence the project should be considered when estimating activity durations. These factors can include its personnel, its organizational culture, its tolerance of risk, and its formal and informal hierarchy. Organizations may also have custom or commercial analytical databases that can include cost estimating, risk, or demographic data.

□ Organizational process assets

Organizational process assets are the source of existing policies, processes, organizational data and knowledge. These assets include the entire collection of formal and informal methodologies, policies, procedures, plans, and guidelines, as well as the organization's "knowledge base," which includes historical performance data, labor information, service and maintenance history, issue and defect history, project files, and financial data.

Tools and Techniques

□ Expert judgment

Expert judgment is based upon the experience and knowledge of subject matter experts. It's used to assess and evaluate the inputs and the information they contain.

\Box Analogous estimating

Analogous estimating is a form of expert judgment that uses similar activities from past projects to provide duration or cost estimates.

□ Parametric estimating

Parametric estimating uses mathematical formulas, usually involving quantity and productivity rates, to determine estimates.

□ Three-point estimates

Three-point estimates provide a weighted average that helps level out some of the uncertainty in estimates. Three point estimates use the optimistic, pessimistic, and most likely estimates.

□ Reserve analysis

Reserves are time or cost buffers in the project schedule or budget that help the project respond to uncertainties. Reserve analysis monitors these buffers and will use, reduce, or eliminate them based on the current situation.

Outputs

□ Activity duration estimates

Activity duration estimates are the work periods required to complete a scheduled activity. There are many factors that influence duration, including resource availability, multi-tasking, and risks.

□ Project document updates

Estimating activity durations may result in updates to project documents, including constraints, assumptions, and activity attributes.

CHAPTER 6: TIME MANAGEMENT

The Develop Schedule process results in the **project schedule**, which is the planned start and finish dates for all project activities. Scheduling involves the project manager and the project team, but it's not very likely that the schedule will be completed and approved in one sitting. In fact creating a schedule is usually the most difficult of the project management processes because it's one of the more iterative and integrative processes, both in its initial development and because most changes that occur in the project will in the end impact the schedule.

The schedule provides a form of contract between every person on a team...There is psychological power in a schedule that externalizes and amplifies the commitment that is being made...It is not as easy to forget or ignore something when it's posted on a whiteboard.⁹

Scott Berkum The Art of Project Managment

Creating the schedule relies on outputs from other processes, including the activity list, project schedule network diagrams, activity resource requirements, resource calendars, duration estimates, and the project scope.

Schedule development doesn't on the just rely resource requirements and durations of the activities. It must also consider the activity attributes, milestones, constraints. assumptions, and risks. This entire collection of documents supporting the schedule logic is called the schedule data. At a minimum. the schedule data includes the milestones. activities. activity attributes. assumptions, and constraints.

Schedule network analysis is the various techniques used to analyze and apply scenarios to the schedule. Schedule network analysis includes the critical path method, critical chain method, resource leveling and smoothing, what-if analysis, and schedule compression, as well as any other analysis methods employed by the project manager.

The project schedule will undergo some manner of approval or sign-off. Once approved, the schedule baseline comes into existence. The **schedule baseline** is not a document that is specifically created. It just comes into existence when the schedule is approved, and it's the project schedule with approved changes incorporated into it. Another way of thinking about the schedule baseline is that it's the latest approved version of the project schedule.

Schedules may change as a direct or indirect result of variance analysis, corrective actions, preventative actions, or approved changes to any project component. Once the schedule baseline is established any requested changes affecting the schedule should be directed through Integrated Change Control. Complex projects may require a **schedule change control system**. Like other change control systems, this one is

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part of the project change control system, and it ensures that the review, approval, and documentation processes for schedule changes are followed.

Some people also mistakenly refer to the project plan and project schedule interchangeably, but the two are not the same. We know from the chapter four that the project plan is a comprehensive document that drives the entire execution, management, and control of the project, of which the project schedule is just one component.

There is no single best way for the schedule to be represented. There can also be alternative views of the

schedule for different audiences though they are derived from the detailed project schedule. Milestone charts, bar charts, and project schedule network diagrams are commonly used. At a minimum, the project schedule must clearly show the planned start and finish dates for all project activities.

Task Name	Duration	Start	Finish
Activity A	27 days	Mon 6/14/10	Tue 7/20/10
Actvity A1	5 days	Mon 6/14/10	Fri 6/18/10
Activity A2	13 days	Fri 6/18/10	Tue 7/6/10
Activity A3	7 days	Mon 7/12/10	Tue 7/20/10
Activity B	29 days	Mon 8/2/10	Thu 9/9/10
Activity C	10 days	Thu 7/15/10	Wed 7/28/10

Activity constraints

We usually face limitations on when activities can start and end. Those constraints can be imposed by the customer, sponsor, regulations, vendors, industry guidelines, market conditions, environmental or weather conditions, and even the project team. Milestones, whether established by the sponsor, customer, or the project team, may also result in activity constraints.

Constraints can also be applied to the project as a whole, such as the project must be started or completed by a predetermined date. When constraints are applied to activities, they serve to restrict when the activities can begin or end. Use of constraints may also force mandatory leads and lags in the schedule.

There are four types of constraints:

July 10	July 11	July 12	July 13	July 14	July 15	July 16	
Activity B: SNLT July 15 (activity can start anytime before 7/15)							
Activity A: SNET July 12 (activity can start on or after 7/12 but not before)							
Activity C: FNLT July 14 (activity can finish anytime before 7/14)							
Activity D: FNET July 15 (activity can finish anytime on or after 7/15 but not before)							

- Start No Earlier Than (SNET or SNE): The activity can't start until a predetermined date.
- Start No Later Than (SNLT or SNL): The activity must be started before but not later than a predetermined date.
- Finish No Earlier Than (FNET or FNE): The activity must be finished after a predetermined date.
- Finish No Later Than (FNLT or FNL): The activity must be finished before a predetermined date.

Float and slack

Float, also referred to as **slack**, is how much leeway an activity's duration has before it causes delays in successor activities or the project itself. There are three types of float we need to know as well as how to calculate them. Calculating float is discussed fully in the section on the Critical Path Method, but a brief overview is necessary here. To determine float, we have to return to project schedule network diagrams.

In this project schedule network diagram, Activity A has a duration of 10 days, Activity B has a duration of 12 days, and Activity C has a duration of 5 days. Activity C has a normal finish-to-start relationship with both Activity A and B (both A and B have to finish before Activity C begins). There are two progressions of activities that will occur on this project:

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- Start to activity A to activity C to End, which will take 15 days,
- Start to activity B to activity C to End, which will take 17 days.

Free Float

Free float or **free slack** is how much leeway an activity has before an extension to its duration delays the start of a successor activity. In the sample diagram, Activity A has a free float of two days before any delay impacts Activity C. This is because Activity B will take 12 days to complete, so Activity A can slide by up to two days before it causes a delay in starting work on Activity C. We should take notice that Activity B has no float because any delay in its completion will cause a delay to Activity C's start.

Total Float

Total float or **total slack** is how much leeway an activity has before an extension to its duration delays the end date of the project. By looking at the sample diagram, we can see that the total project duration is 17 days. Since the combined duration of Activity A and Activity C is 15 days, Activity A has a total float of two days as does Activity C because either or both can slide a total of two days without lengthening the duration of the project. Total float and free float are not always the same, as coincidentally they are in this example.

Project Float

Project float or **project slack** is how much leeway the overall project has before delays will cause it to exceed the ending constraint date. Continuing to use the example, if the customer required the project to be completed 20 days after it started, but total duration is only 17 days, the project has 3 days of project float.

Negative Float

Negative float can occur, but it's indicative of a schedule problem usually the result of unrealistic milestones or other constraints forced into the schedule. Negative float should be resolved by reworking the schedule or some form of schedule compression (crashing or fast-tracking). For example, a milestone for the signing of a contract is set for August 15th, but its preceding activity (drafting the contract) isn't schedule to complete before August 18th. The activity has a float of negative three.

Critical path

Many people mistakenly use the term critical path to refer to any important set of activities within a project. However, the **critical path** actually refers to the set of sequenced activities in which any extension to their durations will cause the project's duration to extend. In other words, the critical path is the set of sequenced activities that have no float. There can be multiple critical paths within a project, and it's possible for the critical path to change as schedule changes occur. It's important to know what the critical path is within a project so that its activities can be monitored closely.

We actually saw the critical path in the earlier free float example. The critical path in this project is Start - Activity B - Activity C - End because an extension to the duration in any of these activities will cause the project's duration to extend.

Finding the critical path is done by evaluating the combined durations of all the different paths, and finding the one with the longest duration. Continuing to use the same example, there are only two possible paths through this diagram:

- Start to A to C to End: 0 + 10 + 5 + 0 = 15
- Start to B to C to End: 0 + 12 + 5 + 0 = 17

With a duration of 17 days, activities B and C are on the critical path.

We'll start again by finding each unique path through the diagram:

- START A E H END
- START B D G H END
- START C F H END
- START B D E H END
- START B D F H END

Next, let's determine the duration of each path:

- START A E H END 0 + 6 + 8 + 4 + 0 = 18
- START B D G H END 0 + 4 + 2 + 1 + 4 + 0 = 10
- START C F H END 0 + 10 + 12 + 4 + 0 = 26
- START B D E H END 0 + 4 + 2 + 8 + 4 + 0 = 18
 START B D F H END 0 + 4 + 2 + 12 + 4 + 0 = 22
- START B D F H END 0 + 4 + 2 + 12 + 4 + 0 = 22

The path that is 26 periods is the longest in duration, so it is the critical path.

Both examples above used PDM diagrams, so let's look at the critical path using an AOA diagram even though these are rarely used.

Here are all the paths through this network diagram:

- START A B C END
- START D E F END
- START G H F END
- START G H I END

Notice that the dummy activity indicates that activity H needs to be completed before F can begin. There is no duration on this relationship, but it creates another path through the diagram.

Next, determine the duration of each path:

START - A - B - C - END	2 + 5 + 6 + 8 = 21
START - D - E - F - END	1 + 3 + 5 + 7 = 16
START - G - H - F - END	2 + 4 + 0 + 7 = 13
START - G - H - I - END	2 + 4 + 3 + 1 = 10
	START - A - B - C - END START - D - E - F - END START - G - H - F - END START - G - H - I - END

So the critical path is START to A to B to C to END with a duration of 21 periods.

Schedule compression techniques

Schedule compression is used to decrease the duration of the project or specific activities. It can also be used as a corrective action to bring what is actually occurring back in line with what was planned for in the schedule. There are two ways to compress the schedule:

- **Crashing**: Adding more resources to the activity or project.
- **Fast-Tracking**: Allowing activities to occur in parallel that would normally have been done sequentially.

Crashing

Crashing adds more resources, usually personnel, in order to decrease an activity's duration. For example, an activity assigned to one person with a duration of 10 days might be reduced to six days if two people were assigned to it. When crashing is an option, the decrease in the activity's duration is not always linear to the increase in resources. If it would take two people two weeks to complete an activity, adding four people to the activity does not automatically decrease its duration to one week. This is because there's almost always a productivity loss as more resources are added, and there is a point when additional resources will actually begin increasing the activity's duration. Crashing results in more cost, whether in labor or equipment, so there are also budgetary considerations.

Fast tracking

Fast-tracking allows multiple activities to occur simultaneously when they were previously sequential.

Fast-tracking essentially cheats the finish-to-start (FS) relationship by creating leads. For example, if the printing of a catalog cover is not normally started until after the catalog's contents have been printed, fast-tracking would allow the catalog cover to be printed before the catalog itself had been printed. Since fast-tracking is essentially adding leads to activities, it has the same drawbacks --namely increasing risks and the likelihood of quality and rework issues if the risks aren't properly managed.

A good rule of thumb is that sequential activities can sometimes be fast-tracked by up to 33%. In other words, if you're fast-tracking, you can start the second of two sequential activities when the first activity is 66% complete. There is risk involved. However, this seems to be a level of fast-tracking risk that is normally acceptable.¹⁰

Tom Mochal, PMP and President, TenStep, Inc.

What-if scenarios

Applying what-if and other scenarios against the schedule can be used to point out potential trouble spots should certain conditions occur. For example, inclement weather scenarios could be applied against a project schedule that relies on fair weather conditions to see what impact a 1-, 2-, or 3-day rain delay would have during portions of the project. Scenarios can also help identify alternate approaches.

Though more commonly discussed in terms of risk, Monte Carlo analysis is one schedule scenario technique. **Monte Carlo analysis** is a computer-driven simulation technique that applies different variables to the schedule, and the results can identify high-risk and vulnerable areas within the schedule. Monte Carlo analysis requires specialized skills to perform; however, effective scenarios for most projects can also be accomplished by making temporary changes to the schedule and viewing the results.

Resource leveling

In the activity resource estimating process the resource types needed for each activity were identified, and now that activity duration is known and the activity is sequenced on the schedule timeline, we can see when resource types will be needed. **Resource intensity** shows when and how many resources are needed at a particular time within the project.

For example, if we have three concurrent activities on the schedule that each need four programmers to complete, the resource intensity for programmers at that point in the project is 12.

	Programmers					
Week 1	Week 2	Week 3	Week 4			
		12				
			8			
	6					
2						

But what happens if only eight programmers are available? **Resource leveling** techniques match the resource needs of the project with the organization's ability to provide resources. When specific resource types are scarce, there are only a few options if the project budget doesn't allow for procuring them from outside the project. One is that the higher priority activities can have the scarce resources allocated to them first and the dates of the other activities staggered so that the resource intensity is lowered. Another option is to use different but underutilized resource types for some activities, though this is not always possible.

In the preceding example where 12 programmers are needed in week three but only eight are available, if activity A were most critical then four programmers would be assigned to it so that its duration and sequencing remains intact. How the remaining pool of four programmers would be allocated depends on the importance of the remaining two activities, how much float they have, and what resource requirements the successor activities need.

Especially in a projectized or strong matrix organization, it's generally a better use of resources to maintain some consistency between the supply of resources to the demand of resources during the periods when they are needed, and this is what resource smoothing tries to accomplish. **Resource smoothing** is a form of resource leveling, and it tries to maintain the most efficient use of the pool of resources types across the project by smoothing out the peaks and valleys of the resource intensity. By working within the float of individual activities, resource smoothing makes the demand for resource types more level across time periods.

Critical path method

The **critical path method (CPM)** involves identifying and analyzing the activities that have the least flexibility in the project schedule. We've already seen some simple examples of how to identify the activities on the critical path. But the critical path method combines many of the techniques we've seen along with some new analysis techniques. CPM requires us to be proficient in project schedule network diagramming, calculating float, and determining the early start, early finish, late start, and late finish for activities and the project.

Let's first review some terms and look at a few new ones.

- **Project schedule network diagram:** The schematic showing the sequenced project activities. There are two diagramming methods: Precedence Diagramming Method (PDM), which produces activity-on-node (AON) diagrams, and the Arrow Diagramming Method (ADM), which produces activity-on-arrow (AOA) diagrams.
- **Network path:** The sequence of activities from the start of the project to the end of the project. Only in the cases of very simple projects will there be only one network path.
- **Critical path**: The network path in which any lengthening of its duration will extend the project's end date. The common definition of the critical path is those set of sequenced activities that have zero float.
- **Critical activity**: Any activity that is on the project's critical path(s).
- **Float/Slack**: A general term that indicates how much flexibility there is in the activity's duration. Free float identifies how long the activity's duration can extend before successor activities are delayed. Total float refers to how much float the activity has without affecting the project's duration.
- Forward/Backward pass: Refers to whether we traverse forward through the network diagram, from start to end, or whether we traverse backward through the network diagram, from end to start. Some calculation methods for late start and late finish require backward passes.
- Early start (ES): The earliest an activity can begin without affecting any dependencies.
- Early finish (EF): The earliest an activity can complete without affecting any dependencies.
- Late start (LS): The latest activity can begin without affecting any dependencies.
- Late finish (LF): The latest an activity can complete without affecting any dependencies.

Critical chain method

While the critical path is the sequence of activities with the longest duration, the **critical chain** is the longest sequence of *dependent* (and not necessarily sequential) activities that prevent the project's duration from being any shorter¹¹. The **Critical Chain Method** (CCM) recognizes that crucial events may not be sequential nor may they be even within the same project. The primary difference between the critical chain method and the critical path method is its approach to the schedule. The critical chain method can be thought of as encouraging a relay race within the project team against the schedule while the critical path method focuses on maintaining and meeting the schedule.

First proposed in 1997 in the book *Critical Chain* by Eliyahu Goldratt¹¹, the critical chain is a continuum of his Theory of Constraints in manufacturing that focuses on addressing production bottlenecks in order to improve the throughput of the overall production system. When applied to project management, this constraint is most usually a scarcity of human resources, so critical chain puts **buffers** of reserve time at the end of the project and at important junctures on the critical chain.

Creating critical chain buffers is also a way to mitigate risks relating to resource scarcity. If we think about what we've learned thus far about When evaluating critical chain dependencies. be on the lookup for dependencies that rely on resources who may have a small but crucial role in downstream activities. For example, an executive, committee, or external resource who may have an approval role in an activity or a decision that needs made that subsequent activities rely upon. Because of so many demands on their time, directors, officers, executives, and managers can often be the source of bottlenecks.¹²

Tony Rizzo, The Critical Chain Model

scheduling, the methods available to us for dealing with uncertainty were to pad activity durations or use a large chunk of reserve time within the project. Buffers move this reserve time out of the activity duration estimates, and put it at strategic junctures on the critical chain. While both approaches have the same end in mind of adding slack within the schedule, the critical chain method takes this slack (as buffers) and makes it visible to all and explicitly managed.

Buffers also serve as an additional management tool. If activities extend their duration, they draw time

from a downstream buffer, and this shows up as a penetration into the buffer. This penetration, along with the work completed, establishes a "buffer burn-rate" letting us know at a glance at what might be a schedule performance problem. For example, if there's buffer penetration of 60% when the work completed on the critical chain stands at only 10% this

completed on the critical chain stands at only 10%, this would probably be an indication of a performance problem or a buffer that wasn't set too low for the potential risks.

There are many different approaches to the critical chain method. Below is only one suggested approach at establishing realistic buffers:

Durations

Drastically reduce activity duration estimates by up to 50%. Track the amount of time cut because it
will be the basis for buffers that will later be inserted into the schedule.

Resources

Eliminate resource contentions in the project.

Critical Chain

- Make several passes through the project looking for major dependencies and risks related to those dependencies.
- Build an initial critical chain of these dependencies from the start to the end of the project.
- Look for the minimum resource needs for critical chain activities.
- Thoroughly review deliverables, activity inputs and outputs, and risks with the resources of critical chain activities. This may uncover additional dependencies.
- Identify high-risk junctures in the critical chain, for instance, where a delay in a deliverable hand-off will adversely affect downstream activities.

Buffers

- From the "bucket" of time cut from the original duration estimates, reduce it by another 25-35%. For example, if the original duration estimates were reduced by a total of 100 days, reduce it to 75 days.
- Allocate the reserve time in two areas: At critical, high-risk junctures in the schedule, and as an overall project buffer just before the end of the project.

Buffer Management

Monitor the buffer penetration, consumption, or "burn-rate." Buffer consumption indicates that a
planned-for risk has occurred. Depending upon how much of the buffer has been consumed, and how
much more is expected to be consumed, it may be necessary for corrective actions to be taken.

Precedence diagramming method

Following is a step-by-step example that will lead us through creating a schedule network diagram using the precedence diagramming method. It's important for us to understand and be able to perform all these methods for the PMP examination.

Though there are different approaches to calculating early start, late start, early finish, and late finish, the method shown here is the "brute-force" method. It requires us to fully diagram the path and run through all the calculations. Overall, this takes longer, but it is less to memorize. As we get better and more familiar with the technique, there are lots of shorter methods we can learn.

When presented with a critical path, float, or ES, LS, EF, LF question, we're going to solve it by:

- 1. Creating the project PDM diagram.
- 2. Determining the critical path(s).
- 3. Calculating each activity's float.
- 4. Determining the early start and early finish of each activity.
- 5. Determining the late start and late finish of each activity.

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Creating a PDM diagram

To make our diagramming easier, we need to create a table of all the activities, their predecessors, and their durations. On the PMP examination, some questions may provide this information textually, so we'll need to convert it to tabular form.

Activity	Predecessor	Duration
START	-	-
Α	START	2
В	А	5
С	B,F	3
D	C,I	4
Е	START	4
F	Е	6
G	START	1
Н	G	1
Ι	Н	2
END	D	_

1. Begin by drawing the starting node.

2. Next, draw the activity nodes that have the starting node as their predecessor and connect the nodes. As activities are added, put the duration above the activity node.

3. Continue adding the successor activity nodes and drawing the relationships. Any time there are multiple predecessors, there'll be a dependency between the successor activity and one or more other paths in the diagram. The relationship should be assumed to be a finish-to-start unless otherwise indicated.

A few more activities from the table are shown in the diagram to the right.

START

g node. START

А

4

F

1

G

4. After the activities are diagramed, double-check everything against the table of activities.

Finding the critical path

The critical path is the network path with the longest duration, so we'll have to find each path in the diagram and sum the duration of each of its activities. We'll continue to use the PDM diagram we created in the earlier section throughout this example.

1. Start by making a forward pass (Start to End) through the diagram and find all the unique paths through it. There are three paths through this diagram.

- Start A B C D End
- Start E F C D End
- Start G -H I D End

2. Next, sum the duration of each activity on the path.

•	Start - A - B - C - D – End	2 + 5 + 3 + 4 = 14
•	Start - E - F - C - D – End	4 + 6 + 3 + 4 = 17
•	Start - G -H - I - D – End	1 + 8 + 2 + 4 = 15

3. The critical path(s) is the one that has the longest duration.

The path Start - E - F - C - D - End is the critical path with a duration of 17 units. The activities E, F, C, and D are thus critical activities and will have zero float.

The critical path is represented here in bold red lines connecting the nodes. However, on the PMP examination the critical path will not be highlighted as it is in these examples.

Calculating float

Calculating float requires either a completed node with some combination of early start, early finish, late start, and late finish supplied, or we have to utilize the network diagram.

There are three kinds of float: free float, total float, and project float.

Project Float

Project float is easy. It's only applicable when there's a duration constraint on the entire project. Using our continuing example, we know that the critical path (longest duration) is 17 periods. If the project had a constraint of 20 periods, then the project float would be three periods.

Free Float

Free float is how long an activity's duration can increase without impacting the start of any successor activities. Free float requires that we know the early start of activities because it's calculated by taking the early start of the successor activity minus the early start plus the duration of its predecessor activity.

The steps for calculating the early start are shown in the next section, but below is a completed diagram with the early starts for all activities filled in.

To calculate the free float for activity H:

Activity H Free Float = ES of Activity I – (Early Start of Activity H + Duration of Activity H) Activity H Free Float = 10 - (2+8)Activity H Free Float = 0

Activity H has no free float even though it isn't on the critical path.

Let's see the free float for activity I:

Activity I Free Float = ES of Activity D – (ES of Activity I + Duration of Activity I) Activity I Free Float = 14 – (10+2) Activity I Free Float =2

Total Float

For total float, we're looking for how much an activity's duration can extend without pushing out the project's duration. In order to get total float we have to know the duration of the critical path, and the duration of the network path the activity in question is on.

Total Float = (Duration of Critical Path – Duration of Network Path Containing the Activity in Question)

Let's return to the unique network paths through our diagram.

Start - A - B - C - D - End: Duration = 14 Start - E - F - C - D - End: Duration = 17 (critical path and project duration) Start - G -H - I - D - End: Duration = 15

What's the total float for activity B? It'll be 3 because the total float for any non-critical activity on the first path will three.

17 - 14 = 3

Activities G, H, and I would each have a total float of 2 because 17 - 15 = 2.

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What about the total float for activity C? Don't get fooled by questions such as this. Any activity on the critical path has zero float even if that activity is on other paths.

Calculating early start and early finish

The early start is calculated by making a forward pass through the diagram and adding the activity's duration to the early start of the predecessor activity and adding one. Let's look again our project schedule network diagram immediately after we added durations to the activities.

1. Starting with the left-most activities with the Start node as their predecessor, set their early start to 1.

2. The early finish of an activity is its early start plus its duration minus one. So for activity A, its EF is 1 + 2 - 1 = 2.

3. The early start of subsequent activities is the EF of its predecessor activity plus one. Activity B's ES is 3 (activity A EF of 2 plus 1).

4. When an activity has multiple predecessors (like activity C does), its ES is based on the greatest early finish of its predecessors. For activity C, we use the EF of activity F.

2

А 3

1

2

Below is the completed diagram with all the early starts and early finishes filled in.

5

в

3

3

Calculating late start and late finish

1. Unlike the earlier calculations where we worked forward through our diagram, we have to work backward through our diagram to get the late start and late finish for each activity. Let's begin with the network path with the longest duration (which is the critical path). First, we can easily address the late finish of the last critical path activity. In our example, activity D's late finish will be the same as its early finish (which is 17).

Activity D is the last activity node in our diagram, but if there were other non-critical activities that had the end node as their successor, their late finishes would also be the same as the LF for the last critical path activity (which is 17).

2. For the last critical path activity, its late start will also be the same as its early start, which is 14.

3. Now we can continue working backwards along the critical path. From activity D, we'll move backwards to activity C and calculate its late start and late finish.

- 3a. For activity C, its late finish is activity D's late start minus 1. Activity C's LF = 14 1 = 13
- 3b. Activity C's late start is its late finish minus its duration plus 1. Activity C LS = 13 - 3 + 1 = 12
- 3c. Activity F's late finish is activity C's late start minus 1. Activity D LF = 11 - 1 = 10

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- 3d. Activity F's late start is its late finish minus its duration plus 1. Activity F LS = 10 - 6 + 1 = 5
- 3e. Activity E's late finish is activity F's late start minus 1. Activity E LF = 5-1=4
- 3f. Activity E's late start is its late finish minus its duration plus 1. Activity E LF = 4 4 + 1 = 1

4. Now we'll do the same thing for the next longest path (Start - G - H - I - D - End) followed by the last path in our example (Start - A - B - C - D - End).

- If an activity's LS and LF have already been calculated from a prior backward pass, don't recalculate them; use the prior calculation and carry it on in your current backward pass.
- If an activity has multiple successors, we use the LF from the successor that is the least (as shown in step 5).

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Using activity nodes to calculate ES, EF, LS, and LF

If we have an activity node from the network diagram with enough elements supplied, we can calculate any of its missing elements.

ES	DUR	EF		
LEGEND				
LS	FLO	LF		

Total Float

2	5	7	LS - FS = Float	OR	LF - EF = Float
5	?	10	5 - 2 = 3	10 - 7	=3

Duration

2	?	7	FF FS – Duration	OP	IF IS - Duration
			2 = 5 = 5	UK	10 - 5 = 5
5	3	10			

Early Start

	5		E
5	2	10	7

CF - Duration = ES	OR	LS - Float = Duration
- 5 = 2		5 - 3 = 2

•

2

5

5

3

,	?	ES + Duration = EF	OR	LF - Float = EF
1	10	2 + 5 = 7		10 - 3 = 7

Late Start

2	5	7	LF - Durat
?	3	10	10 - 5 = 5

tion = LS	OR	ES + Float = LS
		2 + 3 = 5

Late Finish

2	5	7	IS Drugtion - IF	OD	
			LS + Duration = LF 5 + 5 = 10	UK	EF + Float = LF 7 + 3 = 10
5	3	?			

6.5 Process decomposition

Inputs

□ Activity list

The activity list is the complete list of project activities that are needed to produce the work packages. It's decomposed from the WBS work packages. It's the source document this process needs to identify what activities need put on the schedule.

□ Activity attributes

The activity attributes document is a companion to the activity list. It provides sufficient detail to fully describe the activity, and any supplementary information about activity, such as its relationships, constraints, assumptions, dependencies, and responsible people.

□ Project schedule network diagrams

Project schedule network diagrams (PND) are schematics that show the sequencing of activities and their interrelationships. These are created when activity sequencing takes place.

□ Activity resource requirements

The activity resource requirements document describes the resource needs at the activity level, which can be aggregated up to the work package level. It focuses on the resource types and quantities needed.

□ Resource calendars

This may be one or more calendars that identify when people, equipment, and material are available and for what lengths of time. For example, a resource calendar would indicate when supplies were expected to arrive and in what quantity. There is also a composite resource calendar that shows the availability of named human resources on the project as well as their skills. These calendars are useful during duration estimating because scarcity or unavailability of resources may increase the duration of activities.

□ Activity duration estimates

Activity duration estimates are the work periods required to complete a scheduled activity. There are many factors that influence duration, including resource availability, multi-tasking, and risks.

□ Project scope statement

Assumptions and constraints are factors in activity durations. The project scope statement details the measurable goals, objectives, deliverables, and requirements of the project, and what the acceptance criteria of deliverables will be. It also describes the work required to meet all objectives and deliverables of the project, and it also contains milestones, assumptions, risks, and costs.

□ Enterprise environmental factors

Any of the many enterprise environmental factors and systems that influence the project should be considered when developing the schedule, the most common of which is a scheduling application.

□ Organizational process assets

Organizational process assets are the source of existing policies, processes, organizational data and knowledge. These assets include the entire collection of formal and informal methodologies, policies, procedures, plans, and guidelines, as well as the organization's "knowledge base," which includes historical performance data, labor information, service and maintenance history, issue and defect history, project files, and financial data.

Tools and Techniques

□ Schedule network analysis

These are any analysis techniques applied to preliminary schedule models that result in a final project schedule. Techniques include the critical path method, critical chain method, resource leveling, resource smoothing, and schedule compression.

□ Critical path method

CPM is a schedule network analysis technique uses the critical path, early and late starts, and early and late finishes to manage critical activities within the schedule.

□ Critical chain method

CCM is a schedule network analysis technique that addresses resource scarcity. It uses buffers strategically placed on the critical chain to allow for potential bottlenecks.

□ Resource leveling

Resource leveling is a schedule network analysis technique that aims for a consistent and steady demand for resource types instead of having high demand periods followed by low demand periods.

□ What-if scenario analysis

What-if scenario analysis: A technique for schedule network analysis which applies simulations to the project schedule to assess the feasibility and agility of the project schedule under adverse situations. Monte Carlo analysis is a form of what-if scenario analysis.

□ Applying leads and lags

Leads and lags speed up and slow down when activities can start.

□ Schedule compression

Schedule compression uses crashing (adding more resources) or fast-tracking (allowing activities to be done in parallel) in order to reduce the duration of the project.

□ Scheduling tool

Project scheduling most often requires the use of automated scheduling tools to assist in developing, analyzing, and tracking scheduled activities.

Outputs

□ Project schedule

The project schedule specifies the planned start and finish date for each scheduled activity. As specific resources are assigned, the project schedule includes those assignments. Project schedules are presented in different manners, some in summary form and some in detailed form. These include project schedule network diagrams or bar charts, such as Gantt charts.

□ Schedule baseline

The schedule baseline is the approved project schedule that will continue to be updated as any scheduling change requests are approved.

□ Schedule data

The schedule data contains supporting information for the project schedule. It at least contains the milestones, activities, activity attributes, assumptions, and constraints.

□ Project document updates

Developing and managing the project schedule is likely to result in changes to project documents.

The **Control Schedule** process begins as soon as the schedule baseline comes into existence, which is the point when the project schedule is approved. Just like other controlling processes, this one is concerned with monitoring the schedule for progress and variances, managing approved changes to the schedule, and proactively influencing the factors that might lead to schedule changes. Activities performed in this process are framed by the schedule management plan, part of the project management plan.

Changes are very likely to be needed to the schedule, and this process makes sure that change procedures are followed and that all project documents are updated. Complex projects may have a **schedule change control system** that's devoted just to changes impacting the schedule. Approved changes coming out integrated change control will result in updates to the schedule baseline. Any updates to the schedule baseline, for whatever reason, require changes to all components involved, including the schedule model data, project schedule network diagrams, and the schedule management plan. The rationale behind schedule changes, whatever their cause, such as variances, external events, or corrective actions, should be reflected in the lessons learned so that later project managers and project teams can reference.

Performance reviews provide information on how the project is progressing, and will also alert the project manager and team to scheduling issues. Progress reporting, performance measurements, and variance analysis are also used during schedule control, but we'll explore those variance formulas in the Cost Management knowledge area.

6.6 Process decomposition

Inputs

□ Project management plan

The project management plan contains the schedule management plan, which describes how the project's schedule will be developed and managed.

□ Project schedule

The most recent version of the project schedule is needed for this project, as well as the schedule change log, completed activities, and the started activities as of the analysis date.

□ Work performance information

Work performance information is any data that can be considered related to the work which produces the project deliverables. Examples are schedule and progress status information, budget and cost status, quality status, estimates to complete, resource utilization information, and lessons learned.

□ Organizational process assets

Organizational process assets are the source of existing policies, processes, organizational data and knowledge. These assets include the entire collection of formal and informal methodologies, policies, procedures, plans, and guidelines, as well as the organization's "knowledge base," which includes historical performance data, labor information, service and maintenance history, issue and defect history, project files, and financial data.

Tools and Techniques

□ Performance reviews

Performance reviews are a variety of techniques that provide information on how the project is progressing. This can include reserve analysis, schedule variance, and the schedule performance index.

□ Variance analysis

Variance analysis uses techniques to see how the project's schedule progress compares to the original plan.

□ Project management software

Project management software aids in tracking activities and forecasting performance.

□ Resource leveling

Resource leveling is a schedule network analysis technique that aims for a consistent and steady demand for resource types instead of having high demand periods followed by low demand periods.

□ What-if scenario analysis

What-if scenario analysis: A technique for schedule network analysis which applies simulations to the project schedule to assess the feasibility and agility of the project schedule under adverse situations. Monte Carlo analysis is a form of what-if scenario analysis.

□ Adjusting leads and lags

Leads and lags speed up and slow down when activities can start.

□ Scheduling tool

The scheduling tool and schedule data are used along with manual methods to perform schedule network analysis

Outputs

□ Work performance measurements

This includes work performance information that specifically provides mathematical measurements of performance that is communicated to stakeholders.

□ Organizational process assets updates

Organizational process assets are the source of existing policies, processes, organizational data and knowledge. These assets include the organization's "knowledge base," which includes historical performance data and variance analysis.

□ Change requests

Reviews of schedule performance may necessitate the need for changes to the schedule, which are change requests that go through integrated change control.

□ Project management plan updates

Changes to the project schedule will impact the schedule baseline, and schedule compression techniques may result in additional costs.. Schedule analysis may also illuminate changes that are needed to the schedule management plan.

□ Project document updates

Documents that may undergo updates include schedule data and executive summary schedules, such as milestone charts.

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Chapter summary

The Project Time Management knowledge area is concerned with creating and managing the project's schedule. Its six processes are:

- **Define Activities:** Decompose the work packages into activities, producing the activity list and activity attributes.
- Sequence Activities: Putting the activities in the desired order of execution.
- Estimate Activity Resources: Estimating the resources needed for each of the project's activities.
- Estimate Activity Durations: Determining how long each project activity will take.
- **Develop Schedule:** Establishing the start and stop dates for all activities.
- **Control Schedule:** Managing and controlling the schedule and ensuring change control procedures are followed.

Define Activities

The activity list contains all activities necessary to produce the project's deliverables. The activity list is created by decomposing the work packages from the work breakdown structure. The activity attributes is a companion document that provides supplemental information about activities. Another important output of the Define Activities process is the milestone list. The milestone list is part of the project management plan, and it contains every project milestone.

Sequence Activities

Sequence Activities is concerned with ordering the activities. Activity sequencing results in project schedule network diagrams (PNDs) that are usually activity-on-node (AON or PDM) diagrams. Properly sequencing activities involves considering the mandatory, optional, and external dependencies, and also the activity relationships between each other. The most common activity relationship is the Finish-to-Start (FS). Leads and lags affect the sequencing of activities by either speeding up the start of activities (leads) or slowing down the start of activities(lags).

Estimate Activity Resources

The types of resources needed for the project and in what quantities are determined through this process. Resources include personnel, equipment, licenses, facilities, or anything that costs money. The resource breakdown structure is also created in this process, and it's a hierarchical representation of the resource needs, and it is useful for cost estimating.

Estimate Activity Durations

Through this process we'll determine how long each activity will take. There are many factors that affect duration, and these include resource availability, risks, resource types, and resource workload. Duration estimates can be improved by using analogous or parametric estimating when possible. Analogous estimating uses the duration from similar past activities as the basis for estimating. Parametric estimating uses mathematical formulas involving production rates and quantities. Another way of addressing uncertainty is to use three-point estimates. A three-point estimate uses the optimistic, pessimistic, and most likely estimates in order to produce a weighted average.

Develop Schedule

Our objective in this process is to establish an approved schedule showing the start and end dates for all activities. Once approved, the schedule baseline is established. The baseline is always the latest schedule version that includes approved changes. There are many schedule network analysis techniques, which include resource leveling, applying what-if scenarios to identify vulnerabilities in the schedule, applying leads and lags, and the schedule compression techniques of fast-tracking and crashing. The project manager needs to know what activities and sets of activities are critical to manage closely for the project schedule to remain on track. The critical path method involves finding the critical path through the project schedule network diagram. The critical chain method uses buffers placed at strategic locations within the schedule to address potential bottlenecks that might occur due to result of resource scarcity.

Control Schedule

This process is concerned with managing, monitoring, and controlling the schedule baseline. It involves performance monitoring, variance analysis, and may result in requested changes to the schedule or corrective actions in order to bring what is actually occurring back in line with the project schedule. The schedule management plan, a component of the project management plan, is the guiding document for schedule control.

Exam summary

□ The Define Activities process results in the activity list, activity attributes, and milestone list.

 \Box The activity list is decomposed from the work packages in the WBS.

 \Box The activity attributes contains supplemental information about activities. It is a companion document to the activity list.

□ The Sequence Activities process establishes the order for activities.

□ Activity dependencies may be mandatory, discretionary, or external.

□ There are four activity relationships: Finish-to-Start (FS), Finish-to-Finish (FF), Start-to-Start (SS), and Start-to-Finish (SF). Finish-to-Start is the most common activity relationship.

 \Box Leads speed up the start of activities.

 \Box Lags slow down the start of activities.

 \Box The project schedule network diagram (PND) graphically shows the flow of sequenced activities from the project start to project end.

□ Hammock activities are summary, high-level activities.

□ A portion of the PND is called a subnetwork or fragment network.

□ There are two diagramming method: Arrow Diagramming Method (ADM) and Precedence Diagramming Method (PDM). PDM is the most common.

 \Box ADM produces activity-on-arrow (AOA) diagrams, which can only show finish-to-start relationships through zero-duration "dummy" activities.

D PDM produces activity-on-node (AON) diagrams.

□ The primary output of the Sequence Activities process is the project schedule network diagram.

 \Box The Estimate Activity Resources process identifies the types of resources needed for the project and in what quantities.

□ Resource calendars show the resource quantities available and when resources can be active or idle.

 \Box The resource breakdown structure (RBS) is a hierarchical, graphical, categorized representation of the resource types and quantities needed for the project. It's similar in appearance to the WBS.

 \Box The main outputs of the Estimate Activity Resources process are the activity resource requirements and the resource breakdown structure.

 \Box There are three general classifications for estimate accuracy:

- Rough order of magnitude: -25% to +75% accuracy
- Budget estimate: -10% to +25% accuracy
- \circ Definitive estimate: -5% to +10% accuracy.

 \Box Approaches to estimating can be classified as top-down estimating or bottom-up estimating. Bottom-up estimating is the most reliable.

□ Analogous estimating relies on similar activities from past projects as the basis for estimating.

□ Parametric estimating uses mathematical formulas as the basis for estimating.

 \Box The Estimate Activity Durations process determines how many work periods each schedule activity will take.

 \Box Effort is the level of work required for an activity while duration is how many work periods the activity will take.

□ Parkinson's Law states that work expands to fill the time available.

□ Standard deviation identifies how diverse the data population is.

 \Box A simplified standard deviation formula is:

(Pessimistic - Optimistic)

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 \Box Three-point estimates provide a weighted average. The formula for three-point estimates is:

$\frac{(\text{Pessimistic estimate} + (4 \text{ x Most Likely estimate}) + \text{Optimistic estimate})}{6}$

 \Box Contingency reserves (also called buffers) are additional time allocated to the project or to activities that can be drawn from if durations exceed their estimates.

□ The Develop Schedule process results in the approved project schedule, known as the schedule baseline.

□ Schedule data is supplemental information about the schedule used to establish the project schedule.

 \Box Schedule network analysis is the various techniques applied to the schedule. This includes scenarios, schedule compression, and resource leveling.

□ Constraints restrict when activities can begin or end. The four types of constraints are:

- Start no earlier than (SNET)
- Start no later than (SNLT)
- Finish no earlier than (FNET)
- Finish no later than (FNLT)

 \Box Float (or slack) is how much an activity's duration can extend without delaying successor activities or extending the project's duration.

□ Schedule compression uses crashing or fast-tracking to reduce the duration of the project or activities. Crashing adds more resources to the project while fast-tracking allows activities to run in parallel that would not normally do so.

□ Crashing increases costs while fast-tracking increases risks.

□ Monte Carlo Analysis is a computerized scenario technique that identify vulnerabilities in the schedule.

□ Resource leveling matches resource use to the organization's ability to provide those resources.

 \Box The Critical Path Method identifies and analyzes the activities that have the least flexibility in the project schedule.

 \Box The critical path is the sequence of activities that have no float. It's the longest path(s) within the project schedule network diagram.

 \Box A critical activity is an activity on a critical path in the project.

 \Box The Critical Chain Method focuses on potential bottlenecks in the scheduled activities due to scarce resources. Buffers of reserve time are placed at crucial junctures on the critical chain that can be drawn from if durations are exceeded.

□ The Control Schedule process focuses on monitoring the schedule for variances and progress, managing approved changes, and controlling the schedule from unnecessary changes.