Project Time Management

Project Skills

Team FME

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Preface

This eBook describes the process of time management in projects. Most project management software programs will help you with time management however they are no substitute for being able to identify activities, sequence them and estimate the time and resources required to complete them.

You will learn:

- The six project time management processes
- How to draw a network diagram
- The principle of rolling wave planning
- How to estimate the resources and duration of your project
- The principles of float and resource leveling

The Free Management eBooks 'Project Skills' series are structured around the ten key knowledge areas of project management detailed in the 'Project Management Institute, A Guide to the Project Management Body of Knowledge, (PMBOK® Guide)—Fifth Edition, Project Management Institute Inc., 2013'. ISBN-13: 978-1935589679.

The eBooks in this series follow the structure of the PMBOK® Guide because it represents a tried and tested framework. We have tried to ensure full alignment of our eBooks with the Guide by using the numbering convention as well as the naming convention.

If you need more detailed explanation of a particular subject then you can simply refer to the related chapter and paragraph number in the PMBOK® Guide. Remember, many of the generic project management methodologies available refer to the PMBOK® Guide as a basic framework.

A knowledge of the PMBOK® processes will go a long way towards giving you an understanding of almost any project management methodology that your organization may use.

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About this Knowledge Area

Project Time Management includes processes required to manage the timely completion of the project. It involves determining the delivery dates and milestones whilst taking all of the known constraints into account.

The PMBOK ' Project Time Management' knowledge includes 7 of the 47 process groups recognized by the PMBOK.

Process	Project Group	Key Deliverables
6.1 Plan Schedule Management	Planning	Schedule Management Plan
6.2 Define Activities		Activity List Activity Attributes
6.3 Sequence Activities		Project Schedule Network Diagrams
6.4 Estimate Activity Resources		Activity Resource Requirements Resource Breakdown Structure
6.5 Estimate Activity Durations		Activity Duration Estimates
6.6 Develop Schedule		Schedule Baseline Project Schedule
6.7 Control Schedule	Monitoring and Controlling	Work Performance Information Schedule Forecasts

The first six processes take place iteratively because it is most effective when all six have been determined at a high level and then refined until the point where sufficient detail to execute the task is reached.

Generally speaking the level of detail needed is proportional to the level of risk and uncertainty associated with the activity. For this reason time management planning should be carried out with the input of the project team that is going to actually do the work.

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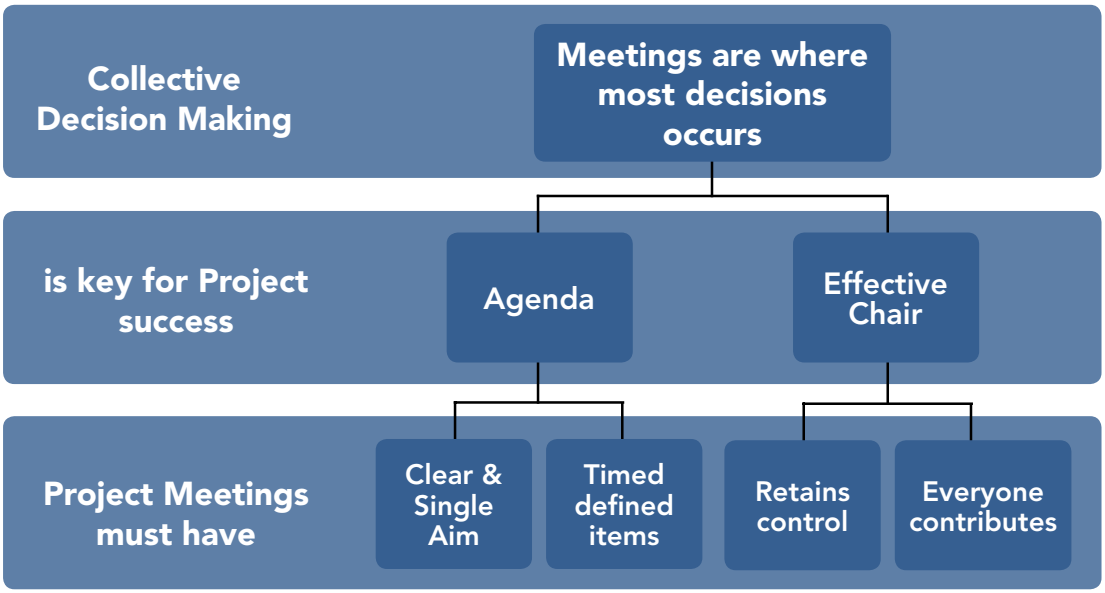
This ensures that the sequencing and activity duration estimates are as realistic as possible as just as importantly, that the team feel as though have some ownership of them rather than seeing them as something that has been imposed on them.

Introduction

Project time management is sometimes seen as the core discipline of project management and some software tools focus almost exclusively on this aspect. This process group is a logical way of taking the project plan and creating a sequence and schedule for producing the project deliverables.

It is required through all phases of the project lifecycle. It is normally derived a high level during the initiation phase in order to provide a framework in which the project plan can evolve as the project iterates between planning, execution and monitoring.



Collective decision-making is very important area of project management that the PMBOK does not go into any detail about but which can make or break this part of the project. Almost all of the processes that form part of project time management will involve meetings between the project manager, the team and other stakeholders in order to make decisions about the activity definitions and associated estimates. How well these meetings are conducted will have a major impact on how smoothly the project runs.

These meetings need to have a clear agenda and a chairman who can keep them running on schedule. If you do not take steps to make this happen then these meetings can easily become bogged down and fail to produce the required outputs when they are needed.

When estimating work it is inevitable that there will be disagreements about the time required and the resources needed. People will have different opinions of how much effort is involved to complete an activity based on similar work they have undertaken in the past. This type of disagreement is to be expected and only becomes a problem when discussions are allowed to drag on beyond the point when a 'reasonable' estimate could be made.

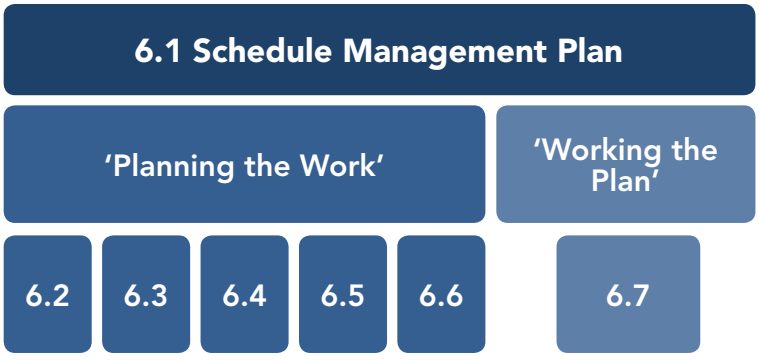
For example,

> ***Early on in this process it really does not matter if an estimate for an activity duration is 5 days or 8 days.***
>
> ***This is something that will become clear once the work starts.***

A good chairman working to a properly timed agenda can ensure that 'good enough' decisions are made in a timely manner and that project team members are not left idle because the planning process is overrunning.

If you feel as though your project meetings could be improved then you can download the 'Meeting Skills' eBooks from http://www.free-management-ebooks.com/skills-meeting.htm. These free eBooks cover all aspects of meetings including how to set an agenda that will ensure that the meeting achieves it's aims and how to chair a meeting so that it is as productive as possible.

The project time management processes are described in detail in the remainder of this eBook.



The PMBOK® Project Time Management Processes

The seven PMBOK Project Time Management Processes are iterative outputs may be refined as the project progresses.

- 6.1 Plan Schedule Management
- 6.2 Define Activities
- 6.3 Sequence Activities
- 6.4 Estimate Activity Resources
- 6.5 Estimate Activity Durations
- 6.6 Develop Schedule
- 6.7 Control Schedule

These are dealt with in detail in the following chapters of this eBook.

6.1 Plan Schedule Management

The aim of this process is to establish the policies, procedures, and documentation for planning, developing, managing, executing, and controlling the project schedule.

Before the 5th Edition PMBOK® Guide, there was no time management process which covered the creation of this plan, which was done as part of the Integration Management knowledge area under the Develop Project Management Plan process.

The inputs, tools and techniques, and outputs of this process are summarized in the table below.

Inputs	Tools & Techniques	Outputs
Project Management Plan	Expert Judgment	Schedule Management Plan
Project Charter	Analytical Techniques	
Enterprise Environmental Factors	Meetings	
Organizational Process Assets		

6.1.1 Plan Schedule Management: Inputs

This process requires the following inputs:

6.1.1.1 Project Management Plan

The main component used is the scope baseline developed in the Project Scope Management Process. This includes the project scope statement and the work breakdown structure (WBS) details used for defining activities, duration estimation, and schedule management.

In addition, other scheduling related cost, risk, and communications decisions from the project management plan will also be needed to develop the schedule.

6.1.1.2 Project Charter

This will give the high-level time constraints and the list of critical milestones to be achieved on the project, some of which may actually be tied to project approval requirements. For example, the final delivery date may be fixed.

6.1.1.3 Enterprise Environmental Factors

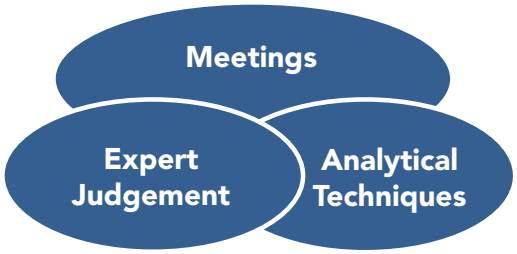
The main consideration is probably going to be the project management software used to create the schedule but other factors include, the organizational culture and structure, resource availability and skills that may influence schedule planning, and any productivity information that is applicable.

6.1.1.4 Organizational Process Assets

The main consideration will be the historical information on prior similar projects that can be used to help estimate the schedule, but other factors include the monitoring and reporting tools, schedule control tools, and any existing formal and informal schedule control related policies, procedures, templates and guidelines.

6.1.2 Plan Schedule Management: Tools and Techniques

There are three interrelated techniques that can be used.



6.1.2.1 Expert Judgment

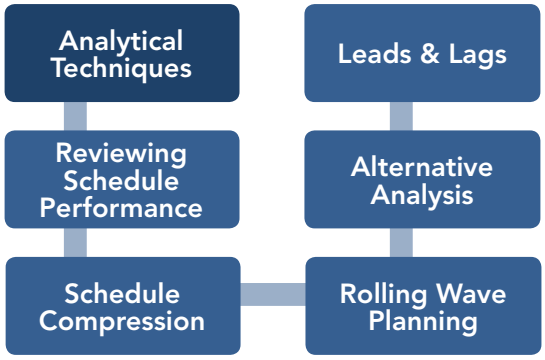
This can involve any member of the project management team with expertise in scheduling, particularly in the domain area of the project.

6.1.2.2 Analytical Techniques

This may involve choosing strategic options to estimate and schedule the project such as: scheduling methodology, scheduling tools and techniques, estimating approaches, formats, and project management software.

The analytical techniques that can be used with specific reference to the schedule include:

1. Schedule compression
2. Rolling wave planning
3. Leads and lags
4. Alternatives analysis
5. Reviewing schedule performance



These techniques are not actually used in this process, because the schedule itself has not been developed at this point. This is simply a list of tools and techniques that can be used later on in the scheduling processes.

6.1.2.3 Meetings

These involve people who are responsible for scope management including the project manager, the project sponsor, selected project team members, selected stakeholders, anyone with responsibility for any of the time management processes, and others as needed.

6.1.3 Plan Schedule Management: Outputs

This process will create the following output:

6.1.3.1 Schedule Management Plan

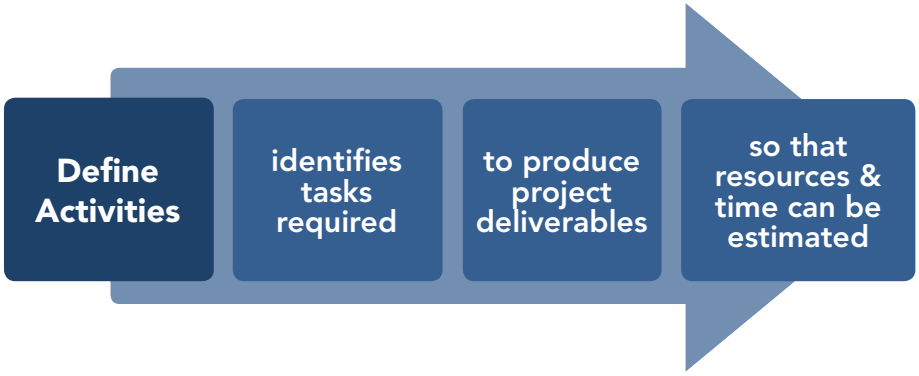
This is a component of the project management plan that establishes the criteria and the activities for developing, monitoring, and controlling the schedule.

Element of Plan	Description of Element	Process
Project Model Schedule Development	Specifies scheduling methodology and scheduling tool to be used.	6.3 Sequence Activities 6.6 Develop Schedule
Level of accuracy	Acceptable range of accuracy of activity duration estimates.	6.5 Estimate Activity Durations
Units of measure	For each resource, units are defined.	6.4 Estimate Activity Resources
Organizational procedures links	WBS is used as framework in order to provide consistency with estimates.	6.2 Define Activities
Project schedule model maintenance	Process used to update status and record progress.	6.7 Control Schedule
Control thresholds	Amount of variance in schedule performance allowed before action is taken.	6.7 Control Schedule
Rules of performance measurement	Earned value measurement (EVM) rules are set.	6.7 Control Schedule
Reporting formats	Formats, frequency of schedule progress reports.	6.7 Control Schedule
Process descriptions	Descriptions of each schedule management process.	ALL

It sets up the framework for all of the other time management processes as follows. It may be formal or informal, with a level of detail based upon the needs of the project.

6.2 Define Activities

The purpose of this process is to identify the specific tasks needed to be done in order to produce the project's deliverables. This needs to be done in sufficient detail to estimate what resources and time will be required to complete them. The main inputs are the scope baseline consisting of the approved project scope statement, the work breakdown structure, and the WBS dictionary.



This process uses decomposition to take the work packages identified in the WBS, which are *nouns*, and to identify the activities (which are verbs) required in order to complete them. It is essentially the bridge between the planning involved in scope management, and the planning involved in time or schedule management.

The inputs, tools and techniques, and outputs of this process are summarized in the table below.

Inputs	Tools & Techniques	Outputs
Schedule Management Plan	Decomposition	Activity List
Scope Baseline	Rolling Wave Planning	Activity Attributes
Enterprise Environmental Factors	Expert Judgment	Milestone List
Organizational Process Assets		

6.2.1 Define Activities: Inputs

This process requires the following inputs:

6.2.1.1 Schedule Management Plan

A key input from the schedule management plan is the prescribed level of detail necessary to manage the work.

6.2.1.2 Scope Baseline

The scope baseline is a component of the project management plan. It is made up of:

- The scope statement, which includes the products scope description of the project deliverables and defines the product user acceptance criteria.
- The work breakdown structure, which defines each deliverable and the decomposition of the deliverable into work packages.
- The WBS dictionary, which contains a detailed description of work and technical documentation for each WBS element.

6.2.1.3 Enterprise Environmental Factors

These are used as an input for many planning processes. The PMBOK definition reads as follows:

> ***'Enterprise environmental factors refer to both internal and external factors that surround or influence a project's success. These factors may come from any or all of the enterprises involved in the project. Enterprise environmental factors may enhance or constrain project management options and may have a positive or negative influence on the outcome. They are considered as inputs to most planning processes.'***

The PMBOK® Project Scope Management Processes

These factors include things like:

- Organizational Processes—For example: personnel administration policies are considered because your company may have a limit on how many permanent staff can be assigned to a particular project or policies regarding the use of contract staff.
- Industry Standards—For example: industry standards, legal requirements and product standards.
- Organizational Culture and Structure—For example: guidelines for hiring, firing, and performance reviews.
- Infrastructure and resources—For example: project management information systems, software tools, available skills and expertise, standardized cost estimating data and risk databases.
- Internal and external conditions—For example: the risk tolerances of the project stakeholders, market conditions relevant to the project and the political climate.

6.2.1.4 Organizational Process Assets

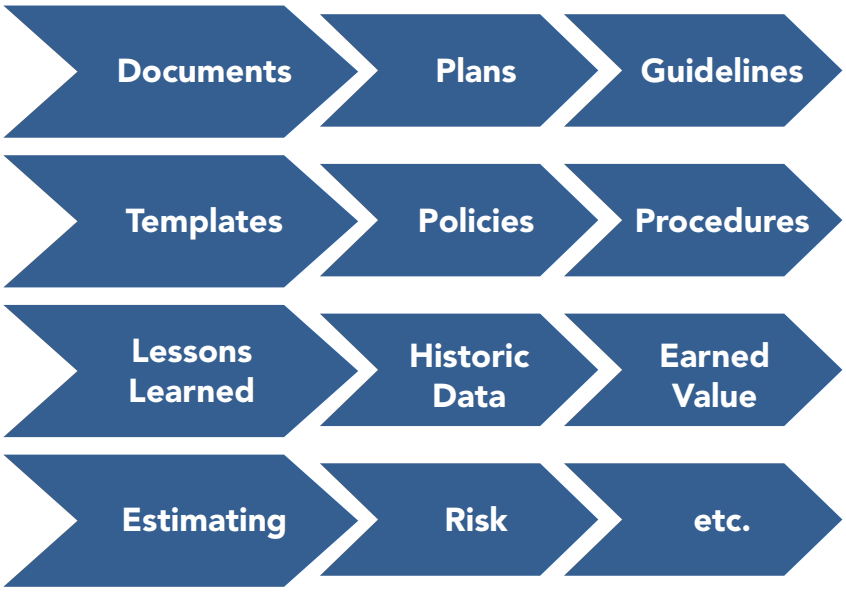
These are the processes or process-related assets that can be used to help this project succeed. They can be grouped into two categories:

1. Processes and procedures for conducting work, and
2. A corporate knowledge base for storing and retrieving information.

Examples,

> ***The organization might have its own guidelines, policies, and procedures, whose effect on the project must be considered.***
>
> ***The knowledge and experience gained from previous projects—this would typically include: documents, templates, policies, procedures, plans, guidelines, lesson learned, historical data and information, earned value, estimating, risk etc.***

These assets would typically include: documents, templates, policies, procedures, plans, guidelines, lesson learned, historical data and information, earned value, estimating, risk etc.



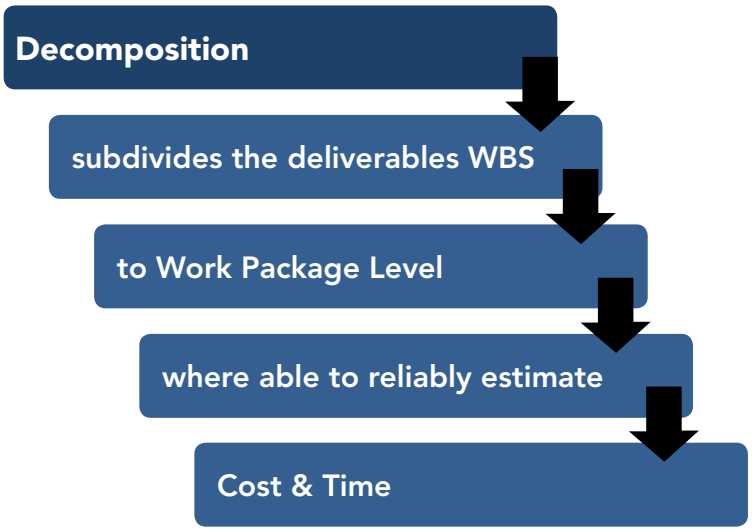
6.2.2 Define Activities: Tools and Techniques

The Scope Baseline is used as a starting point to breakdown the documented deliverables, as well as a guide to assure that the entire scope of the project is covered, but that the activities do not extend beyond the agreed boundaries.

It is described in the eBook 'Project Scope Management' which can be downloaded free from this website http://www.free-management-ebooks.com/dldebk/dlpm-scope.htm and comprises three things—the WBS, WBS dictionary and the Project Scope Statement. There are three interrelated techniques that can be used in this process.

6.2.2.1 Decomposition

In order to produce the activity list it is necessary to examine each work package and break it down into individual work schedule activities. As the name suggests the Activity List, is a list of all the activities that must be performed within the project and each one should tied back to just one work package (although each work package may have several activities within it).



The work package is the lowest level of the WBS is achieved when the work can be accurately estimated (both cost and duration) and can be managed by one individual. The key word here is 'managed', although the work package can be managed by one person, the actual work within the work package may be completed by several people.

For example,

One individual could manage work package 'Select and Appoint Contractor'.

However, the work package could be decomposed into the following activities each of which could be undertaken by a different person:

1. *Specify Task Requirements*
2. *Identify Potential Contractors*
3. *Send Invitation to Tender*
4. *Review Tenders*
5. *Interview Contractors*
6. *Choose Contractor*
7. *Check References*
8. *Agree Contract Terms*
9. *Appoint Contractor*

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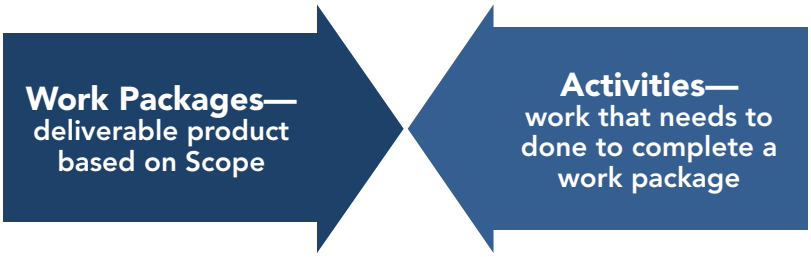
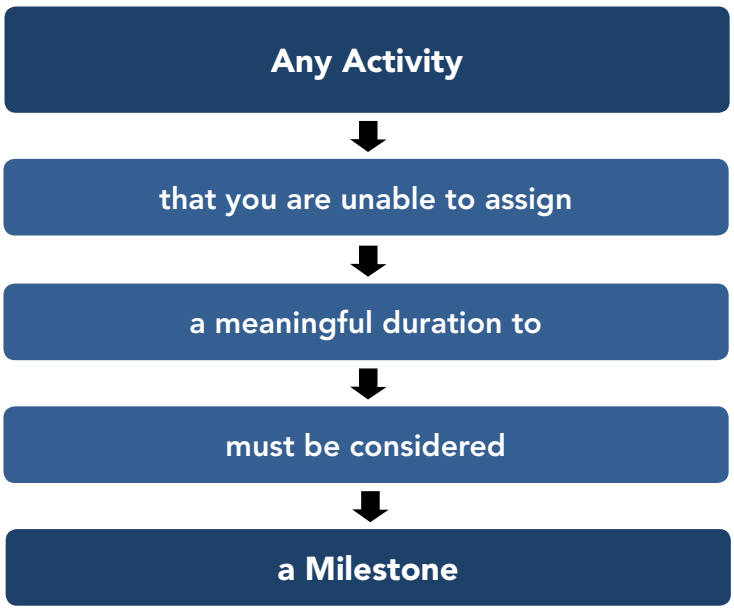
Each activity must be complete and accurate, because it will be used to develop the project schedule. An activity is typically described using a noun and verbs such as 'Specify Task Requirements'.



As you can see, when the work packages are decomposed into activities in this way the result is to create an activity list, which can then be used to develop the project schedule. Remember that work packages are product or deliverable based to deliver the scope of the project, whereas activities' focus on the work that needs to be carried out in order to execute such work packages.

An activity has an expected duration and consumes resources in terms of manpower and/or budget. If duration cannot be meaningfully assigned to it then it should be considered a milestone.



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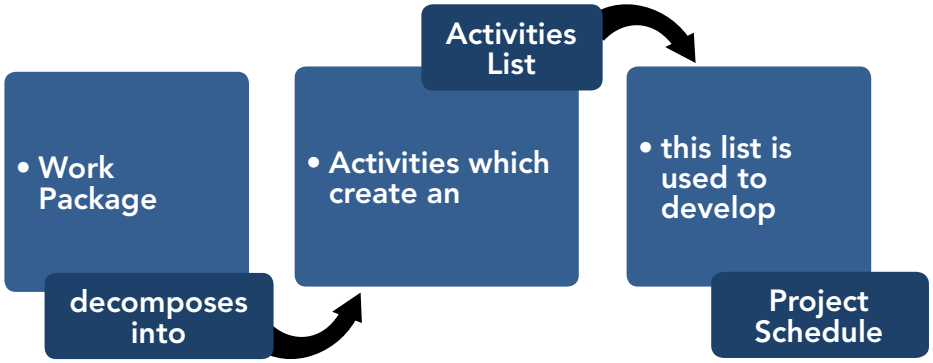
In the example above:

'Step 3—Send Invitations to Tender and

'Step 9—Appoint Contractor

would be considered a milestone rather than an activity .

The technique of decomposition, as applied to defining activities, involves subdividing the project work packages into smaller, more manageable components called activities. Activities represent the effort needed to complete a work package. The Define Activities process defines the final outputs as activities rather than deliverables, as done in the Create WBS process.



The activity list, WBS, and WBS dictionary can be developed either sequentially or concurrently, with the WBS and WBS dictionary as the basis for development of the final activity list. Each work package within the WBS is decomposed into the activities required to produce the work package deliverables. Involving team members in the decomposition can lead to better and more accurate results.

This decomposition will usually be carried out as part of a planning workshop involving as much expertise as necessary to ensure that the activities are accurately identified and it should be of sufficient detail to create a realistic and feasible schedule. This list would also have extra information about each activity such as constraints, assumptions, logical relationships, etc.

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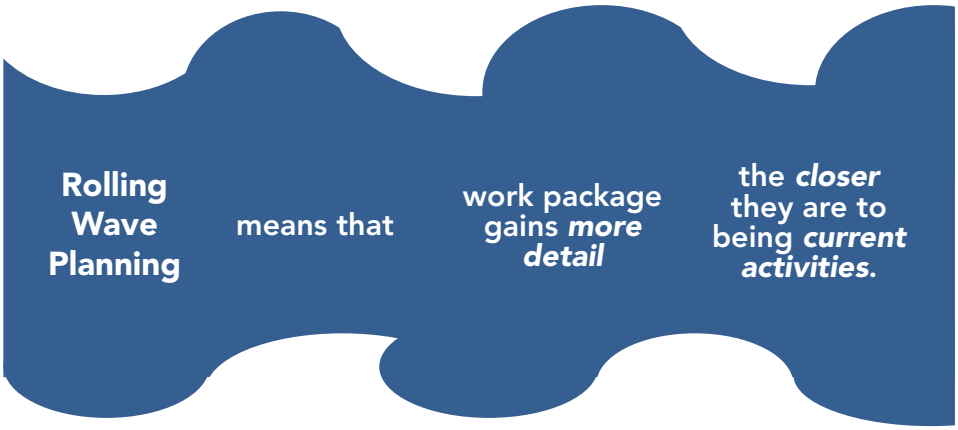
6.2.2.2 Rolling Wave Planning

As well as decomposing the WBS work packages, there is another technique that can help with defining the activities. Rolling Wave Planning (RWP) is the process of project planning in waves as the project proceeds and later details become clearer. It involves progressive elaboration and is based on the fact that activities required in the immediate future will be known in greater detail than those further into the future. This means that WBS components will exist in different level of detail in the structure.

Progressive Elaboration means that the work packages are refined in greater detail over time. RWP is particularly useful in projects of high uncertainty like software development or R&D projects, where the project goal is known, but the final deliverable may change somewhat as the project progresses.



Attempting to create detailed task-oriented plans for project teams in these types of environments is likely to lead to plans that are abandoned soon after being published and a great deal of project management time spent endlessly re-planning rather than actually managing the project.

Rolling wave planning is more often used within IT type projects but less so within the construction industry where lack of detail in initial plans may cause huge expense later. Unfortunately many IT projects undertake the bulk of their planning too early in the life-cycle, when little concrete data is known about the problem domain, business environment, or how the team will work together.

6.2.2.3 Expert Judgment

Expert judgment is most likely to come in the shape of individuals who have been responsible for decomposing the work packages down into a set of activities on previous projects.

A standard activity list or a portion of an activity list from a previous project is often usable as a template for a new project. The related activity attributes information in the templates can also contain other descriptive information useful in defining activities. Templates can also be used to identify typical schedule milestones.

The PMBOK lists expert judgment under the tools and techniques that can be used in this process but many of these could just as easily be seen as part of the organizations process related assets.

For example,

> ***If your organization has a project office, then they may keep templates from similar previous projects or they may be structural templates available within a particular organization or industry.***

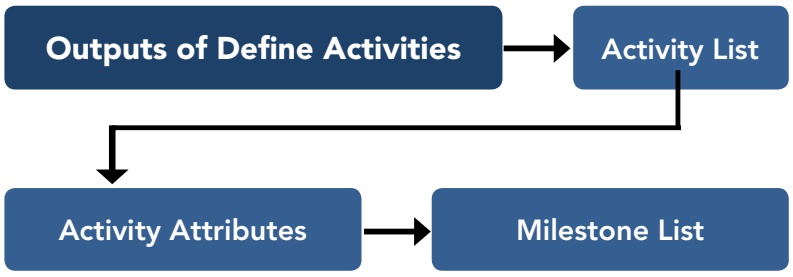
The value here is that templates can be used to fast track the identification of all activities' in the define activities process, normally required for this type of project.

6.2.3 Define Activities: Outputs

The following outputs generated by this process:

6.2.3.1 Activity List

The activity list is a comprehensive list including all schedule activities required by the project. The activity list includes the activity identifier and a scope of work description for each activity in sufficient detail to ensure the project team members understand what work is required to be completed.



6.2.3.2 Activity Attributes

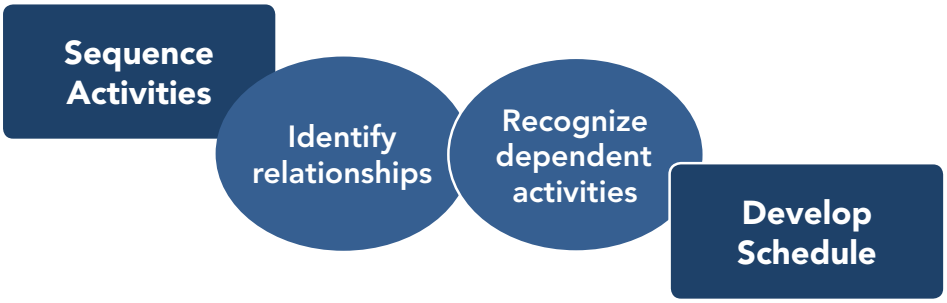
Activity attributes extend the description of the activity by identifying the components associated with each one. The components for each activity evolve over time. Activity attributes can be used to identify the person responsible for executing the work, where the work will be performed and the activity type. They are used for schedule development and for selecting, ordering and sorting the planned scheduled activities in various ways within reports.

6.2.3.3 Milestone List

A milestone is a significant point or event in the project. A milestone list identifies all milestones and indicates whether it is mandatory such as those required by contract or optional.

6.3 Sequence Activities

Once the activities have been identified the next stage is to sequence them according to their dependencies. In other words, any relationships between activities need to be identified so that dependent activities can be scheduled to follow those that they are dependent upon.



It is important to classify any dependencies properly because they indicate the sequence in which activities must occur. There are four types of dependency relationships.

A *finish-to-start relationship exists if one activity must finish before another activity starts.*
A start-to-start relationship exists if one activity cannot start until another activity starts.
A *finish-to-finish relationship exists if the one activity cannot finish until another activity finishes.*
Finally, a start-to-finish relationship exists if one activity must start before another can finish.

Dependencies may be external or internal. For example, an organization may subcontract the production of some deliverable from a supplier organization and the delivery of this would represent an external dependency, one that involves some relationship outside of the project and its control.

Some dependencies may exist within the project. For example, an engineer may only be able to contribute half of his time to a project, although his skills could potentially be used full time.

The inputs, tools and techniques, and outputs of this process are summarized in the table below.

Inputs	Tools & Techniques	Outputs
Schedule Management Plan	Precedence diagram method (PDM)	Project Schedule Network Diagrams
Activity List	Dependency Determination	Project Document Updates
Activity Attributes	Leads and Lags	
Milestone List		
Project Scope Statement		
Enterprise Environmental Factors		
Organizational Process Assets		

6.3.1 Sequence Activities: Inputs

This process requires the following inputs:

6.3.1.1 Schedule Management Plan

This identifies the scheduling method and tool to be used.

6.3.1.2 Activity List

This is an output of process 6.2 Define Activities and includes all scheduled activities on the project.

6.3.1.3 Activity Attributes

This is an output of process 6.2 Define Activities and describes the predecessor and successor activities, as well as possible leads and lags, associated with each activity.

6.3.1.4 Milestone List

This is an output of process 6.2 Define Activities and gives specific dates for any milestones.

6.3.1.5 Project Scope Statement

The project scope statement contains the product scope description, which includes product characteristics that may affect activity sequencing such as the physical layout of a plant to be constructed or subsystem interfaces on a software project.

While these are often apparent in the activity list, the product scope description is generally viewed to ensure accuracy. This is described in detail in the project scope management eBook (download free from online library **http://www.free-management-ebooks.com/dldebk/dlpm-scope.htm**).

6.3.1.6 Enterprise Environmental Factors

These include government and industry standards, and the project management information system and scheduling tools being used.

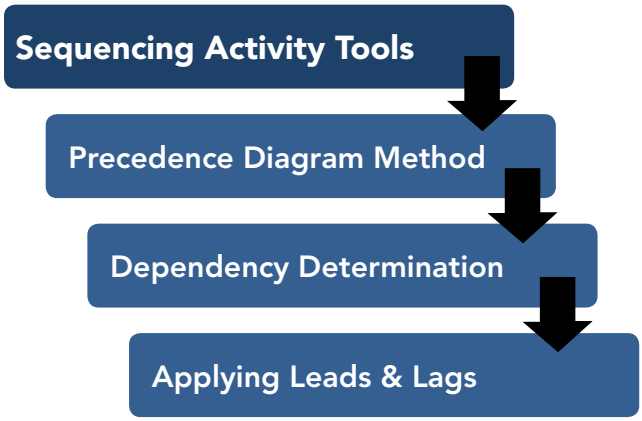
6.3.1.7 Organizational Process Assets

Organizational process assets are described earlier in this eBook in the Define Activities process. These include project files as well as policies, procedures and guidelines, templates used with the scheduling methodology.

6.3.2 Sequence Activities: Tools and Techniques

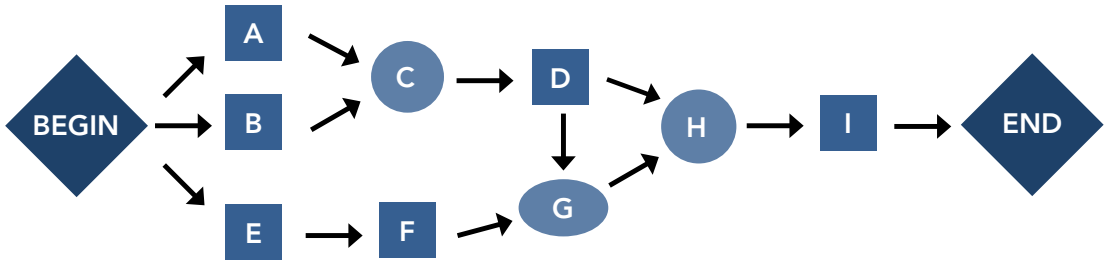
The principal output from this process is a network diagram showing the sequence of activities and their relationships. Always bear in mind that the purpose of this process is simply to find and illustrate dependencies, there are assumed to be no resource constraints.

There are three interrelated techniques that can be used in this process.



6.3.2.1 Precedence Diagram Method

This is a graphical tool for scheduling activities in a project plan. The precedence diagram method used in critical path methodology constructs a project schedule network diagram. This uses boxes or rectangles, referred to as nodes to represent activities and connects them with arrows to show the logical relationships that exist between them. This technique is also called activity on node AON and is the method used by most software project management packages.



In this example,

'Begin' and 'End' are both milestones.
Activities A and B are not dependent on each other.
Activity C **is dependent** on both A and B (shown as a circle).

Many of the project planning software packages available use this method, which simply plots the tasks to be completed and connects them with arrows that show the dependencies. Note that each activity has an input arrow and an output arrow.

The only two elements that do not are the 'Begin' and 'End' milestones (which are not really activities). If an activity within a diagram has only one arrow then this is represents an error and needs to be corrected.

6.3.2.2 Dependency Determination

Three types of dependencies are used to define the sequence among the activities:

- Mandatory
- Discretionary
- External

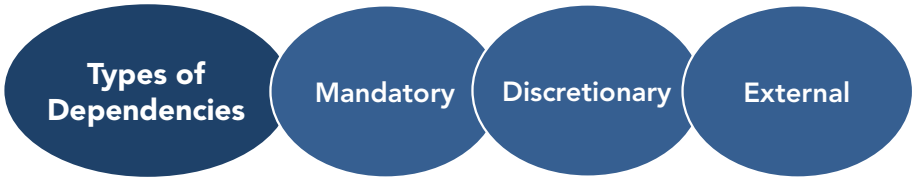
The table below shows the dependency and gives an explanation for this.

Category	Dependency	Explanation
Mandatory vs. Discretionary	Mandatory (hard logic)	Involves physical limitations Contractual or legal obligations
	Discretionary (soft logic)	Based on knowledge of best practices
External vs. Internal	External	Outside of project team's control. Based on relationship of project activities and activities outside project
	Internal	Within project team's control. Based on relationship between project activities

Mandatory dependencies are inherent in the work or process e.g. when constructing a new building, building the walls is dependent on laying the foundations. The project team determines which dependencies on Monday to reach during the process of sequencing the activities. They are also sometimes referred to as hard logic.

Discretionary dependencies are those defined by the project manager and their team. They should be defined based on best practice or previous experience within the particular area. Discretionary dependencies are sometimes referred to as preferred logic and based on knowledge of best practices within a particular application area or some unusual aspect of the project where a specific sequence is desired even though there may be of the acceptable sequences.

Discretionary dependencies should be fully documented since they can create arbitrary total float values and can limit later share dealing options.



External dependencies involve a relationship between project activities and non-project activities. These dependencies are usually outside the project teams control. For example the testing activity in a software project can be dependent on the delivery of hardware from an external source.

Once the dependencies are agreed they can be mapped into a Precedence Diagram (on PC, on paper, or using post-it notes). When drawing the precedence diagram the project team needs to decide:

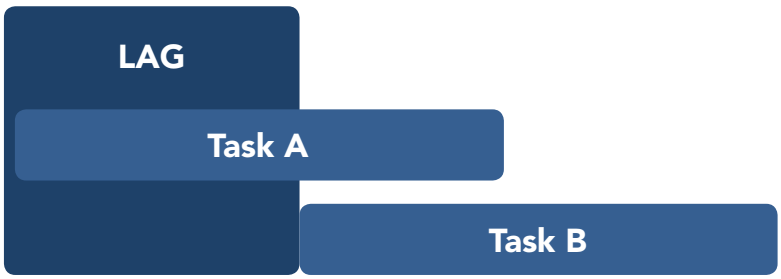
- Which tasks can only be completed after another task
- Which tasks can be done at the same time
- Which tasks don't depend on other tasks at all (e.g. project review meetings)

It can be useful to work backwards when compiling the Precedence Diagram and ask yourself what do we need to have done immediately before this task?

6.3.2.3 Applying Leads and Lags

A lag directs a delay in the successor activity. For example, an IT project requires two different but similar user interfaces to be designed, interfaces A and B. Each task is scheduled to take 5 days. There is no reason why these tasks cannot be started at the same

time, but it makes sense to design A first and obtain user agreement before starting work on interface B which can then be largely based on A.



Therefore, the time between the start dates of the two tasks can be defined as a lag (The project manager has specified two days in this case). It is important to note that task B does not need to be completed before task A can begin but because some of the lessons learned in the design stage of task A can be directly applied to task B it will reduce the overall amount of work required if this lag is specified.

Lead refers to a relationship whereby the successor activity begins before the predecessor activity has completed. Lead is only found activities with finish-to-start relationships: A must finish before B can start. In order to leverage a lead, which will compress the total combined duration of both activities, the dependency must be discretionary, meaning that there is no physical limitation on completing A before B begins.

Standardized schedule network diagram templates can be used to expedite the preparation of networks of project activities. They can include an entire project or only a portion of it. Portions of a project schedule network diagram are often referred to as a sub-network or a fragment network.

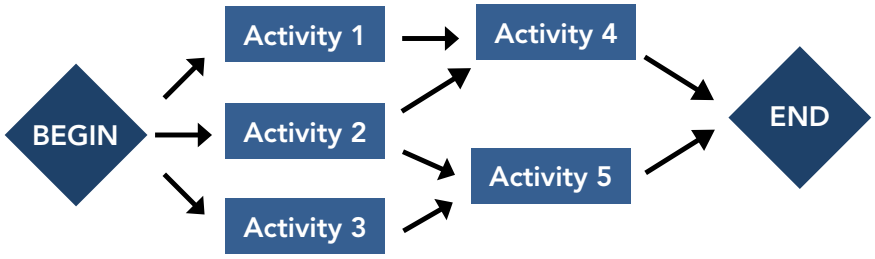
Sub-network templates are especially useful when a project includes several identical or nearly identical deliverables, such as floors on a high-rise office building, clinical trials on a pharmaceutical research project, coding program modules on a software project, or the start-up phase of a development project.

6.3.3 Sequence Activities: Outputs

The following outputs generated by this process:

6.3.3.1 Project Schedule Network Diagrams

Project schedule network diagrams are schematic displays of the project's schedule activities and the logical relationships among them, also referred to as dependencies.



A project schedule network diagram can be produced manually or by using project management software. It can include full project details, or have one or more summary activities. A summary narrative can accompany the diagram and describe the basic approach used to sequence the activities. Any unusual activity sequences within the network should be fully described within the narrative.

6.3.3.2 Project Document Updates

These include activity lists, activity attributes, milestone register and risk register.

6.4 Estimate Activity Resources

This step involves making an estimate of the resources required to complete each activity. The previous processes described what is to be done and in what order. This process describes who will do the work.

Don't spend too much time worrying about factors that you simply don't know. Remember, the key word here is 'estimate', whilst you should try to be as accurate as you can, remember that any figures you come up with can and will be revised during later processes.

The inputs, tools and techniques, and outputs of this process are summarized in the table below.

Inputs	Tools & Techniques	Outputs
Schedule Management Plan	Expert Judgment	Activity Resource Requirements
Activity List	Alternatives Analysis	Resource Breakdown Structure
Activity Attributes	Published Estimating Data	Project Document Updates
Resource Calendars	Bottom-up Estimating	
Risk Register	Project Management Software	
Activity Cost Estimates		
Enterprise Environmental Factors		
Organizational Process Assets		

6.4.1 Estimate Activity Resources: Inputs

There are eight inputs that are to be used in the process of activity resource estimating:

6.4.1.1 Schedule Management Plan

This identifies the level of accuracy and the units of measure for the resources to be used.

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6.4.1.2 Activity List

This is a documented tabulation of schedule activities that shows the activity description, activity identifier, and a sufficiently detailed scope of work description so project team members understand what work is to be performed.

6.4.1.3 Activity Attributes

These are the various attributes associated with each activity. The attributes can be codes, predecessor and successor activities, logical and other relationships, leads and lags, resource requirements, target dates, constraints and assumptions.

6.4.1.4 Resource Calendars

These provide information on the type of resource, its location and its availability. The accuracy of this information depends on the length of the project. You will need to exercise a healthy degree of skepticism about its accuracy if your project is expected to exceed 12-18 months in duration because so much can change in that sort of timespan.

6.4.1.5 Risk Register

Risk events may impact resource selection and availability. Updates to the risk register are included with project documents updates from Plan Risk Responses.

6.4.1.6 Activity Cost Estimates

The cost of resources may impact resource selection.

6.4.1.7 Enterprise Environmental Factors

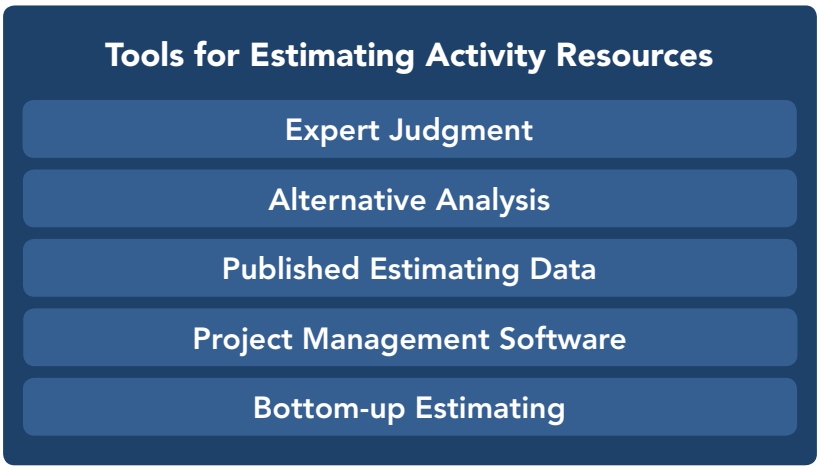
These include resource location, availability, and skills.

6.4.1.8 Organizational Process Assets

These include policies and procedures regarding staffing, policies and procedures relating to rental and purchase of supplies and equipment, and historical information regarding types of resources used for similar work on previous projects.

6.4.2 Estimate Activity Resources: Tools and Techniques

There are a number of tools that can be used to estimate the required activity resources.



6.4.2.1 Expert Judgment

This refers specifically to judgment based upon a specific set of criteria and/or expertise that has been acquired in a specific knowledge area. This can be provided by members of the project team or by a team leader. However, it often requires an expertise that is not present within the project team and an external group or person with a specific skill set or knowledge is brought in.

6.4.2.2 Alternatives Analysis

This technique looks at the resource requirements and tries to determine if there are alternative means of achieving the same result. For example, sub-contracting the work rather than doing it in-house or vice versa.

6.4.2.3 Published Estimating Data

You may be able to make use of estimating data published by other organizations, which can provide regularly updated unit costs of a wide range of human and material resources. In this technique, the activity is compared to the activities for which data exists and the actual cost or durations of the closest comparable activity is selected from the data and used as the estimate.

The advantage of this technique is that it is accurate when the project conditions match the conditions under which the published data was generated.

The disadvantages are that data does not exist for many activities and that the published data that does exist is based upon the characteristics of the organizations that compiled and published it, which may not correspond to your own.

6.4.2.4 Bottom-up Estimating

This technique involves further decomposition of the component tasks can be individually resourced. It is basically an iteration of the activity definition and sequencing process groups in which each task is broken down into smaller components. Then, individual estimates are developed to determine what specifically is needed to meet the requirements of each of these smaller components.

The estimates for the smaller individual components are then aggregated to develop a larger estimate for the entire task as a whole. As a general rule, the smaller the scope of a task, the more accurately you can estimate it. The disadvantages of this technique is that it is very time consuming, and it may be impossible to decompose activities that cannot be easily defined.

6.4.2.5 Project Management Software

Depending upon the sophistication of the resource requirements and the capabilities of the available features, project management software might be useful in estimating and managing the resources.

6.4.3 Estimate Activity Resources: Outputs

The resulting outputs from this process include:

6.4.3.1 Activity Resource Requirements

The main purpose of the activity resource estimating process is to determine the resource requirements for each activity, and therefore this is the major output item from this process.

You identify the types of resources required to perform each activity and estimate the required quantity of each identified resource. If a work package in the WBS has multiple activities, the resource estimates for those activities can be aggregated to estimate the resource requirements for the work package.

The requirement documents may also include information such as the basis for each estimate, the assumptions made for the estimate, and the availability of the resources.

6.4.3.2 Resource Breakdown Structure (RBS)

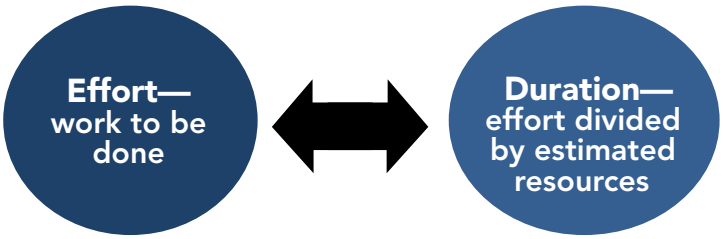
This is a hierarchical structure of resource categories and types required to complete the schedule activities of a project. The RBS can be used to identify and analyze the project human resource assignments.

6.4.3.3 Updates to Project Documents

The identified types of required resources for an activity and the estimated quantity for each identified resource become activity attributes and must be added to the attribute list for the activity. Activity resource estimating might generate modifications to the activity list. It may also cause you to change the resource calendar.

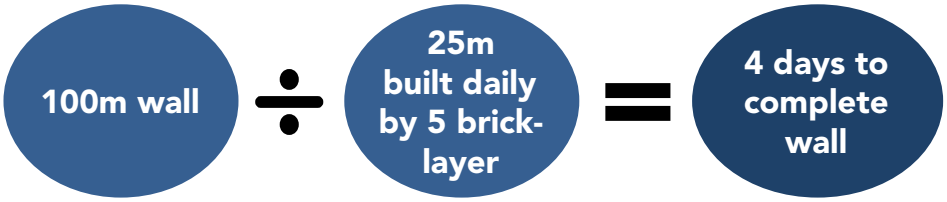
6.5 Estimate Activity Durations

This step involves estimating the amount of effort required for each activity and then calculating the duration. Effort is the work to be done whereas duration is this figure divided by estimated resources.



For example,

> *If there is a requirement to build one hundred meters of wall and a bricklayer can build 5 meters of wall in a day.*
>
> *The duration of the task can be calculated by dividing the length of the wall by the number of bricklayers that will be assigned to the task. Then five bricklayers could be expected to complete the task in 4 days.*



All estimates, are to some extent uncertain at the beginning of a project and need to be progressively updated as you gain a better idea of how efficiently work is being done and exactly what resources you have available.

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The inputs, tools and techniques, and outputs of this process are summarized in the table below.

Inputs	Tools & Techniques	Outputs
Schedule Management Plan	Expert Judgment	Activity Duration Estimates
Activity list	Analogous Estimating	Project Documents Updates
Activity Attributes	Parametric Estimating	
Activity Resource Requirements	Three-point Estimates	
Resource Calendars	Group Decision Making Techniques	
Project Scope Statement	Reserve Analysis	
Resource Breakdown Structure		
Enterprise Environmental Factors		
Organizational Process Assets		

6.5.1 Estimate Activity Durations: Inputs

This process requires the following inputs:

6.5.1.1 Schedule Management Plan

This defines the method used and the level of accuracy along with other criteria required to estimate activity durations including the project update cycle.

6.5.1.2 Activity List

This list identifies the activities that will need duration estimates.

6.5.1.3 Activity Attributes

These provide the primary data input for use in estimating durations required for each activity in the activity list.

6.5.1.4 Activity Resource Requirements

The time required to complete an activity depends on the resources assigned to it but there are some limitations to this. For example,

> *Suppose it will take one operator with an earthmover four days to dig the foundations of a building. It is tempting to believe that two operators with an earthmover each could do it in two days.*

However, this assumption does not take account of the fact that they would need to spend time coordinating their efforts and in reality would probably keep getting in each other's way, greatly reducing their individual efficiency.

When assigning additional resources to an activity, always consider the possibility that assigning additional resources might reduce the overall efficiency and productivity and that most activities have a threshold beyond which assigning additional resources does not reduce the duration because of the additional overhead of communication and co-ordination.

6.5.1.5 Resource Calendar

The resource calendar, finalized (or modified) during activity resource estimating, contains the type, quantity, availability, and capability of each resource, including the skills of a human resource, which must be considered during activity duration estimating.

Capability and quantity of available resources, both human and material, can affect the activity duration estimate.

6.5.1.6 Project Scope Statement

Some assumptions and constraints in this document can affect activity duration estimates and therefore must be considered. For example, there might be an assumption that part of the work related to an activity has already been performed in a previous project and can be used in this project.

6.5.1.7 Enterprise Environmental Factors

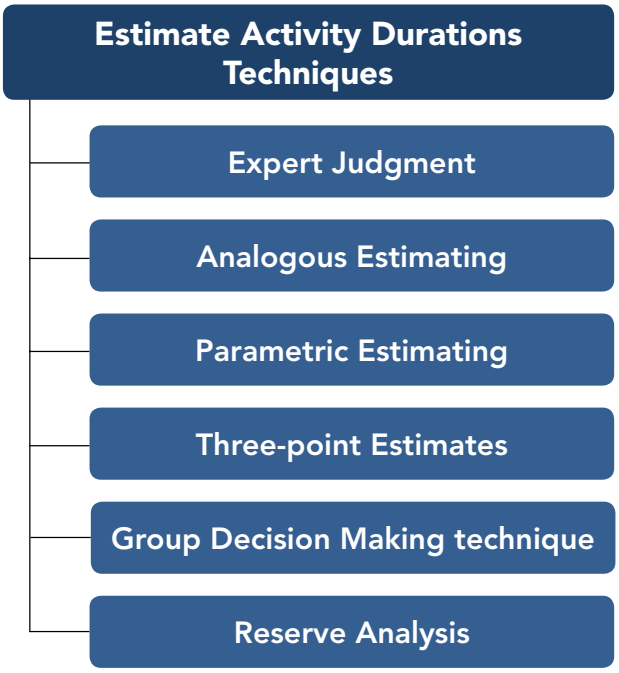
These include duration estimating databases and other reference data, productivity metrics, published commercial information, and the location of team members.

6.5.1.8 Organizational Process Assets

These include historical duration information, project calendars, scheduling methodology, and lessons learned.

6.5.2 Estimate Activity Durations: Tools and Techniques

The relevant tools and techniques are:



6.5.2.1 Expert Judgment

Expert judgment using historical information from similar projects can provide duration estimates. It can also used to reconcile different estimating methods. It can be used to estimate the whole duration of an activity when not enough information is available.

This technique can be used to estimate some parameters to be used in other methods. For example, what percentage of the original activity duration estimate should be used as a contingency reserve, and in comparing an activity to a similar activity in a previous project during analogous estimation?

6.5.2.2 Analogous Estimating

Analogous estimating techniques estimate the duration of an activity based on the duration of a similar activity in a previous project. The accuracy of the estimate depends upon how similar the activities are and whether the team member who will perform the activity has the same level of expertise and experience as the team member from the previous project.

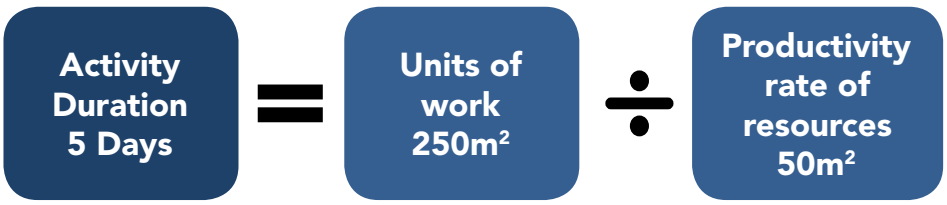
Analogous estimating is typically a form of expert judgment that is most reliable when the previous activities are similar to the current activity and when the team members preparing the estimates have the necessary experience.

6.5.2.3 Parametric Estimating

This is a simple technique used to calculate the activity duration when the productivity rate of the resource performing the activity is available. You can use the following formula: Activity duration = Units of work in the activity / Productivity rate of the resources.

For example,

> ***If a groundwork gang consisting of six operatives plus their equipment can lay 50 square meters of reinforced concrete in a day, the duration calculation can be performed as follows:***
>
> ***Activity duration = 250 square meters / (50 square meters/day) = 5 days***



This technique relies on the statistical relationship that exists between a series of historical data and the variables in question. When this data is being drawn from a large body of historical data taken from similar projects, then it can yield accurate estimates.

It provides several advantages as an estimating technique for example they:

- Allow estimates to be prepared in much less time than required by more detailed techniques.
- Require quantitative inputs that are linked to algorithms providing quantitative outputs. All costs are traceable.
- If two estimators input the same values for parameters, they will get the same resulting cost.
- Provide a consistent estimate format and estimate documentation.

- Provide costs for a range of input values, extrapolating to derive costs for projects of a different size or nature than you may have history for.
- Highlights the design parameters used.
- Able to provide key statistical relationships and metrics for comparison with other projects.

The disadvantages of this method are:

- Models will not exist for activities until there is a sufficiently large experience base for the activity. Basing estimates on work that is only vaguely comparable will yield inaccurate estimates.
- Physical parameters, for example 'number of bricks laid', 'area of trees cleared' or 'number of widgets produced' are far more meaningful than non-physical parameters for example, the 'number of lines of code' in a software project.

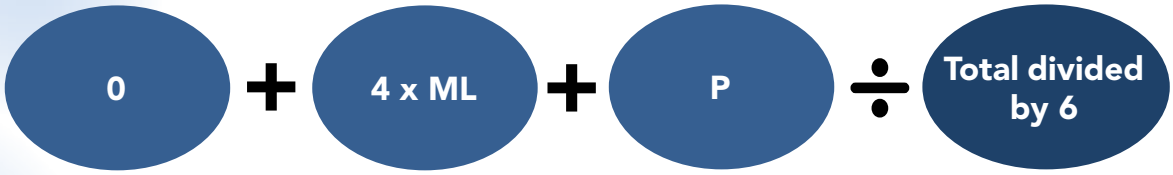
For example,

> ***An electrician's productivity is constrained by the speed at which he can 'chase out' channels in the walls in which to lay cables, a job that used to be done with a hammer and chisel.***
>
> ***The invention of an affordable power tool to do this job resulted in a significant increase in the amount of cable that could be laid per day.***

6.5.2.4 Three-point Estimates

This method addresses the issue of uncertainty in estimating the activity duration. This uncertainty can be calculated by making a three-point estimate in which each point corresponds to one of the following estimate types:

- **Most Likely Scenario (ML)**—the activity duration is calculated in most practical terms by factoring in resources likely to be assigned, realistic expectations of the resources, dependencies, and interruptions.
- **Optimistic Scenario (O)**—is the best-case version of the situation described in the most likely scenario.
- **Pessimistic Scenario (P)**—is the worst-case version of the situation described in the most likely scenario.

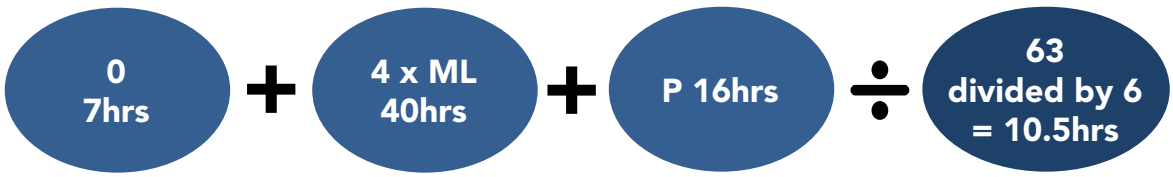


We then find the average, but we first weight the Most Likely estimate by 4. The formula is (O + (4*ML) + P) / 6. We must divide by six because we in effect have six different estimates (although three of these estimates are the same number). This is because we are averaging (O + ML + ML + ML + ML + P) / 6.

Here's an example.

> ***A roofing contractor is replacing all of the tiles on the roof of a house. He estimates that the job will take his team 10 hours based on the expectation that they will need to replace some of the underlying timbers. This is his Most Likely Estimate.***
>
> ***If none of the timbers need replacing then the job will take 7 hours, this represents his Optimistic estimate.***
>
> ***If most of the timbers need replacing then the job will take 16 hours, this represents his Pessimistic estimate.***

This formula is most useful in estimating time or cost of activities for projects that are especially unique, such as in research and development where there are many unknowns.



6.5.2.5 Group Decision-Making Techniques

Team-based approaches can be useful for improving duration estimates.

6.5.2.6 Reserve Analysis

Reserve analysis is used to incorporate a time cushion into your schedule; this cushion is called a:

- Contingency Reserve,
- Time Reserve, or
- Time buffer.

The whole idea is to accommodate the possibility of schedule risks. One method of calculating the contingency reserve is to take a percentage of the original activity duration estimate, although it can also be estimated by using quantitative analysis methods.

When more information about the project becomes available, the contingency reserve can be reduced or eliminated. Usually, while estimating for large projects, managers would like to keep a buffer of 5% or so of the total estimate for the project to account for project schedule risks, like delays in procuring hardware or unexpected personnel problems.

6.5.3 Estimate Activity Durations: Outputs

The resulting outputs from this process include:

6.5.3.1 Activity Duration Estimates

These are quantitative assessments of the time required to complete an activity. They may specify a range of possible results.

For example,

> *8 days 4 2 days.*
>
> *They can also specify the duration in terms of probability.*
>
> *E.g. if there is a 10% probability of an activity exceeding 10 days, this would indicate a high probability (90%) that the activity will be completed in 10 days or fewer.*

6.5.3.2 Project Documents Updates

These include activity attributes and assumptions made in developing the activity duration estimate, such as skill levels and availability.

6.6 Develop Schedule

By this stage, you should have all of the data you need to develop the project schedule. The process itself is invariably done using a scheduling tool, which can immediately produce a preliminary result based on:

- Defined activities
- Estimate of resources available
- Estimates of duration
- Logical relationships between activities

The inputs, tools and techniques, and outputs of this process are summarized in the table below.

Inputs	Tools & Techniques	Outputs
Schedule Management Plan	Schedule Network Analysis	Schedule Baseline
Activity List	Critical Path Method	Project Schedule
Activity Attributes	Critical Chain Method	Schedule Data
Project Schedule Network Diagrams	Resource Optimization Techniques	Project Calendars
Activity Resource Requirements	Modeling Techniques	Project Management Plan Updates
Resource Calendars	Leads and Lags	Project Document Updates
Activity Duration Estimates	Schedule Compression	
Project Scope Statement	Scheduling Tool	
Risk Register		
Project Staff Assignments		
Resource Breakdown Structure		
Enterprise Environmental Factors		
Organizational Process Assets		

The development of a project schedule is always an iterative process requiring review and revision of duration and resource estimates. Once the initial schedule has been developed it must be subjected to a network analysis to determine float and slack. This is usually done using the critical path method or CPM, in which the earliest possible end-date is calculated by summing up the activity durations specified on the network.

6.6.1 Develop Schedule: Inputs

This process requires the following inputs:

6.6.1.1 Schedule Management Plan

This is an output of process 6.1 Plan Schedule Management and identifies the scheduling method and tools to be used, and how the schedule is to be calculated.

6.6.1.2 Activity List

This is an output of process 6.2 Define Activities and identifies activities that will be included in the schedule model.

6.6.1.3 Activity Attributes

This is an output of process 6.2 Define Activities and provides details to be used to build the schedule model.

6.6.1.4 Project Schedule Network Diagrams

This is an output of process 6.3 Sequence Activities and contains the logical relationships between predecessor and successor activities used to calculate the schedule.

6.6.1.5 Activity Resource Requirements

This is an output of process 6.4 Estimate Activity Resources and identifies types and quantities of resources required for each activity used to create the schedule model.

6.6.1.6 Resource Calendars

This is an output of process 6.4 Estimate Activity Resources and contains information on the availability of resources.

6.6.1.7 Activity Duration Estimates

This is an output of process 6.5 Estimate Activity Durations and contains quantitative assessments of the likely number of work periods required to complete an activity.

6.6.1.8 Project Scope Statement

This is an output of process 5.6 Define Scope and contains assumptions and constraints that can impact development of the project schedule model.

6.6.1.9 Risk Register

This is an output of Risk Management and is used to assess how identified risks and their characteristics affect the schedule model.

6.6.1.10 Project Staff Assignments

This is an output of Human Resources Management and specifies which resources are assigned to each activity.

6.6.1.11 Resource Breakdown Structure

This is an output of process 6.4 Estimate Activity Resources and provides details by which resource analysis can be performed.

6.6.1.12 Enterprise Environmental Factors

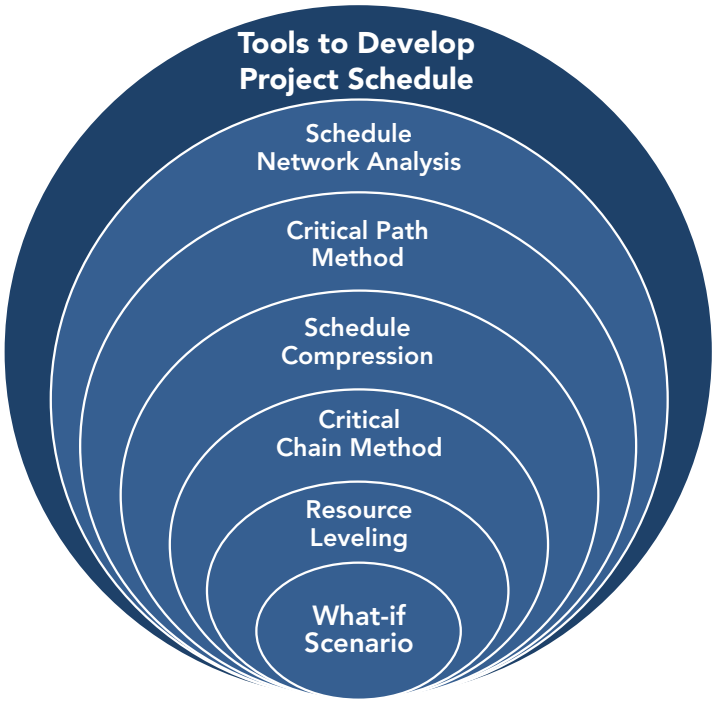
These include scheduling standards and tools.

6.6.1.13 Organizational Process Assets

These include project calendars and the scheduling methodology.

6.6.2 Develop Schedule: Tools and Techniques

There are several different tools and techniques that can be used to develop the project schedule. Most organizations have a preferred method or methods and these can vary depending on the project and the individual project manager. These methods are described briefly below:



6.6.2.1 Schedule Network Analysis

Schedule network analysis is a technique that generates the project schedule. It employs a schedule model and various analytical techniques, such as critical path method, critical chain method, what-if analysis, and resource leveling to calculate the early and late start and finish dates, and scheduled start and finish dates for the uncompleted portions of project schedule activities.

Activity networks are made up of a series of activity boxes, each of which depicts a discrete activity or task. Each activity box may contain up to 7 items of information.

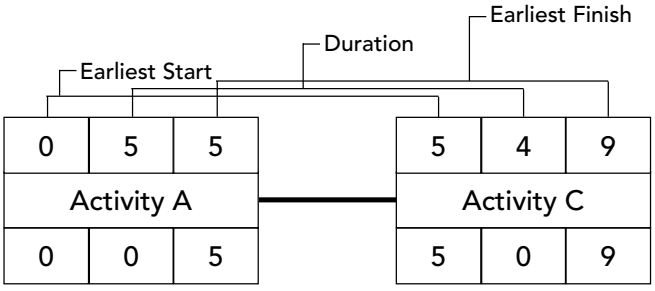
Earliest Start	**Duration**	**Earliest Finish**
Activity Description & Identifier		
Latest Start	**Float**	**Latest Finish**

The top line of the box reflects the earliest point at which the activity could start and finish. The centerline should contain descriptive information about the activity and the bottom line should be used to reflect the latest start and finish times. For example,

> ***Activity A must be completed before activity C can begin (indicated by the line that joins the two activity boxes).***
>
> ***Activity A requires 5 days and Activity C requires 4 days (this part of the project will therefore last 9 days).***

The earliest start time for activities right at the beginning of the network are set to zero (shown in bold).

The earliest finish time for whichever input activity is the latest is used to establish the earliest start time for the dependent activity.



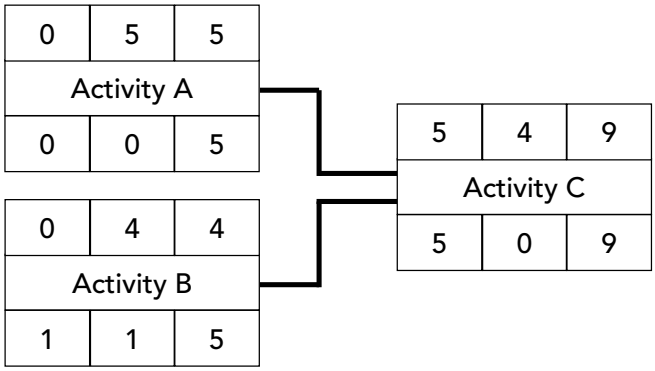
In this example,

> ***Activity A is scheduled to be completed on day 5. Only then can activity C begin.***

In many cases an activity will be dependent on the completion of more than one preceding activity. In the example shown:

- ***Activities A & B must both be completed before activity C can begin.***
- ***A requires 5 days,***
- ***B requires 4 days and***
- ***C requires 4 days.***
- ***Activities A and B can be carried out in parallel as they are not dependent upon each other.***

In this example this part of the project will also last 9 days.



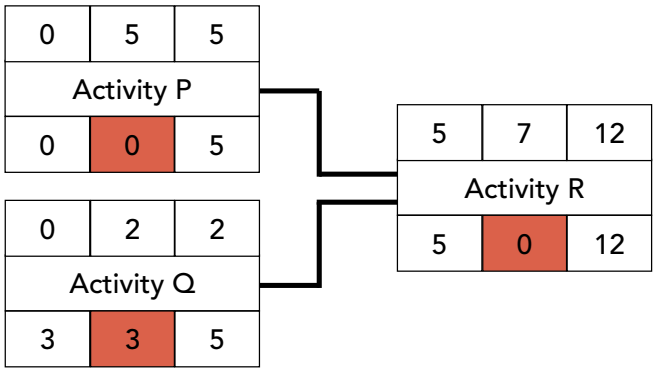
Determining the relationships between activities can be a complicated process and may require a substantial amount of discussion involving numerous personnel across the various departments that may be concerned.

The process of identifying relationships between the activities should only be concerned with logical requirements, in other words it should be assumed that there are no resource constraints when drawing the Activity network. This issue has then to be addressed and appropriate adjustments made. Resolving resource shortfalls and conflicts is the scope of resource planning and scheduling.

You may well find it useful to produce sub-diagrams and use these to conduct a brainstorming approach to identifying all possible relationships, prior to building the final network. The project will need to be monitored at various points to ensure that its business and technical integrity is being maintained—the Activity network should also reflect these activities.

Float is a measure of the amount of time an activity can be delayed without affecting subsequent activities. The amount of float indicates the extent of time that the activity can be delayed without putting back the end date of the overall project (or sub-project). Activities that have an associated float are natural candidates to be delayed when other activities are suffering from problems or overruns.

Reading through the Activity network from left to right gives the total duration of the plan. Reading back through the network, subtracting each duration, shows those activities that have any spare time. This spare time, known as float (shown in red below), is a very useful concept in relation to resource scheduling and smoothing.



In the example shown:

> ***Activity R is dependent upon the completion of both of the activities P and Q. However activity P is scheduled to take 5 days whilst Q should be completed in 2 days.***

The area of work represented by this part of the network should last 12 days.

Activity Q has a float of 3 days so:

- *Q could start up to 3 days late or*
- *Q can take an extra 3 days to complete*

Without delaying the start of the subsequent activity R

Once the resources required to complete each product have been identified and the Activity network updated to reflect these, then the start and finish dates can be added. With the shape and size of the project now visible, the total cost of the resources for each planning period can be calculated.

The Activity network also clearly identifies the critical path, which is the sequence of related activities that will take the longest time. The critical path is an invaluable concept in project planning—as it defines that sequence of activities that should take the longest time.

The critical path is defined as the series of activities that have zero float. There will always be a critical path running through a project from the first activity to the last.

However, any task, if subjected to sufficient delay; may itself become critical. This occurs at the point when its float has been entirely consumed by the passage of time. In larger projects, particularly as the project nears completion a number of the arms of the network may contain zero float i.e. the project may contain numerous critical paths.

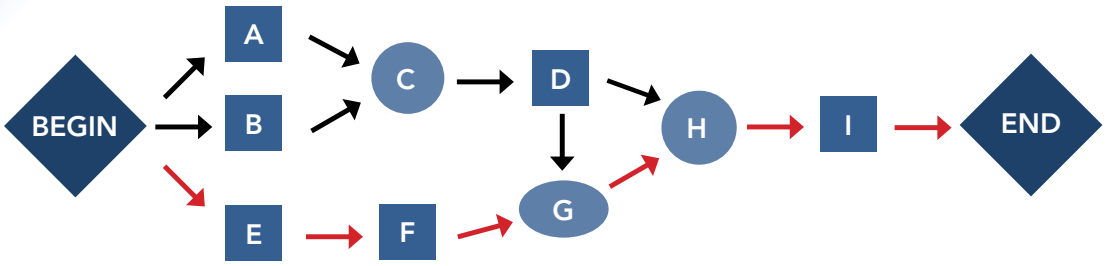
The critical path is an important feature in project planning and control and is usually highlighted on the network in some manner—e.g. bold print, red or a different style of line. It is important to remember that the critical path is not defined at the initial planning stage and then set in stone.

As the project progresses and planned activities overrun the network should be frequently updated to ensure that it continues to reflect the true status of the project. The failure to do this is a common reason for projects going out of control and ultimately failing.

6.6.2.2 Critical Path Method

The critical path method calculates the longest path of planned activities to the end of the project—the "critical path"—and the earliest and latest date that each activity can start and finish without extending the project. Any activity delay on the critical path impacts the planned project completion date.

A network diagram visually conveys the critical path. This visibility into the critical path allows project managers to prioritize activities and take appropriate corrective actions to meet schedule deadlines.



An understanding of the critical path also allows project managers visibility as to which schedule activities are flexible—that is, those activities that are not on the critical path. By looking at a network diagram, project managers can determine when they have float or slack, which is the amount of time that any given schedule activity can be delayed without causing a delay to the start date of subsequent activities (free float) or to the project completion date (total float).

Knowing when a project has float allows a Project Manager to understand what tasks may slip and by how much before they have an impact on the project schedule.

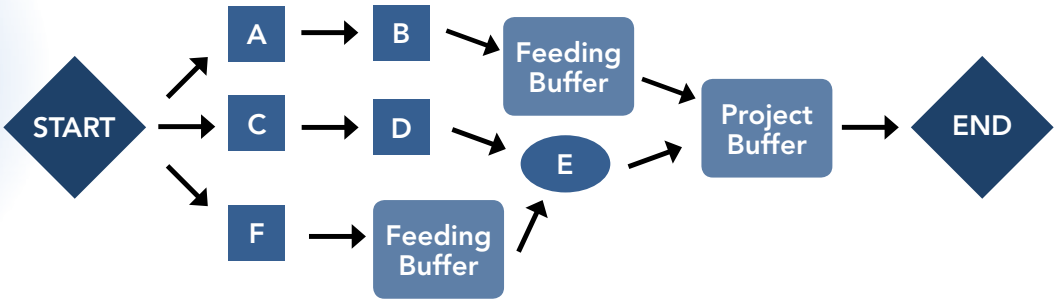
A final point worth noting in the area of resource planning, especially in relation to resource smoothing concerns the critical path. Some planners tend to see the critical path as a sacred sequence of activities that should be left untouched whilst other activities are 'smoothed'.

An alternative point of view is that the critical path results from a series of activities which have suffered from a lack of resources being allocated to them and therefore should be seen as the first line of attack.

The correct interpretation will vary, depending on the characteristics of each project.

6.6.2.3 Critical Chain Method

The basis for the critical chain method is the same as the basis for the critical path method but with one key difference; the critical chain method accounts for resource limitations.



By adding resource limits to the analysis, the result is that critical path is generally longer. The resource-constrained critical path is known as the critical chain. If resources are allocated in the scheduling tool, the network diagram will display the critical chain.

Using the critical chain method involves adding duration buffers to project schedules to protect the targeted finish date from slippage. Duration buffers are added to the schedule as non-work schedule activities—one at the end of the critical chain and others at the end of each sequence of tasks that feeds into the critical chain.

As a result, "buffer" time is integrated throughout the project schedule to account for duration uncertainty. Later in the project, project teams monitor project progress by reviewing the consumption rate of the buffers.

6.6.2.4 Resource Optimization Techniques

These are used to adjust schedule due to demand and supply of resources and include resource leveling and resource smoothing.

Resource leveling is the process of changing schedule resource allocation to resolve over-allocations or conflicts. It is applied to a schedule that has already been analyzed by the critical path method. This technique is used to adjust a project schedule if shared resources are only available at certain times, or in limited quantities, or if a Project Manager wants to maintain resource usage at a constant level.

It is often used to correct resource over-allocations and will often change the critical path. The network diagram should be recreated after resource leveling to assess the updated critical path.

Resource leveling is necessary when resources have been over-allocated, such as when a resource has been assigned to two or more activities during the same time period, when shared or critical required resources are only available at certain times or are only available in limited quantities.

6.6.2.5 Modeling Techniques

These include What-if scenario analysis, which is used to assess feasibility of the project schedule under adverse conditions and simulation, which calculates multiple project durations based on different sets of assumptions (Also known as Monte Carlo analysis).

What-If Scenario Analysis examines the schedule impact of various scenarios, such as the delayed delivery of a major deliverable. What-if scenario analysis may include simulation that calculates multiple project durations with different sets of activity assumptions.

Multiple network diagrams may be generated to visually convey the impact of varying scenarios. Project managers can use the results of this analysis to determine schedule feasibility under adverse conditions and prepare relevant contingency plans.

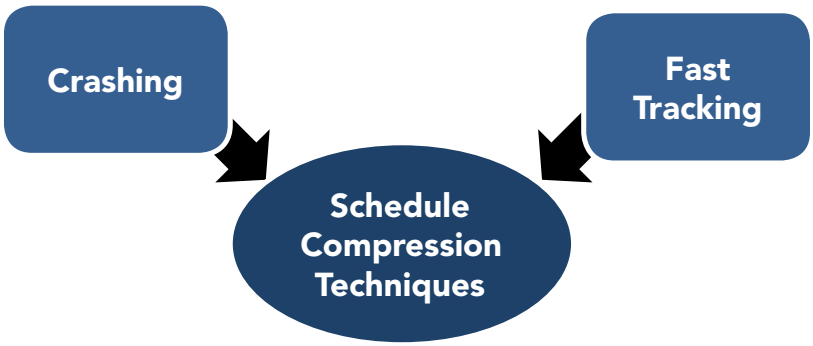
The outcome of the what-if scenario analysis can be used to assess the feasibility of the project schedule under adverse conditions, and in preparing contingency and response plans to overcome or mitigate the impact of unexpected situations.

6.6.2.6 Leads and Lags

These are used to develop a viable schedule by adjusting the start time of successor activities. Leads are used in limited circumstances to advance a successor activity with respect to the predecessor activity, and lags are used in limited circumstances where processes require a set period of time to elapse between the predecessors and successors without work or resource impact.

6.6.2.7 Schedule Compression Techniques

As a result of network diagram analysis, project teams may identify a need to compress the schedule. Schedule compression shortens the project schedule in order to meet schedule deadlines without reducing the project scope.



Schedule compression techniques include crashing and fast tracking. If utilized, project teams should recreate and reassess the network diagram to ensure that no new schedule issues have emerged.

- **Crashing** involves either adding resources or increasing work hours (overtime, weekends) to shorten task duration. Shorter task durations typically result in higher task costs, so project teams must determine, prior to crashing, whether the total costs savings is enough to justify the higher costs. Crashing almost always requires cost increases because it usually necessitates new tasks.

  This is a controversial technique because adding project resources can increase project complexity or risk and may ultimately have a negative impact on the schedule. Crashing does not involve reducing project scope or eliminating project tasks.

- **Fast tracking** is a schedule compression technique in which project phases or activities usually conducted sequentially are performed in parallel to reduce duration. Care must be taken to ensure that parallel work does not create additional work or increase risk. Fast tracking frequently results in increased complexities in task dependencies, so additional project controls must be implemented to ensure ongoing and accurate insight into schedule performance.

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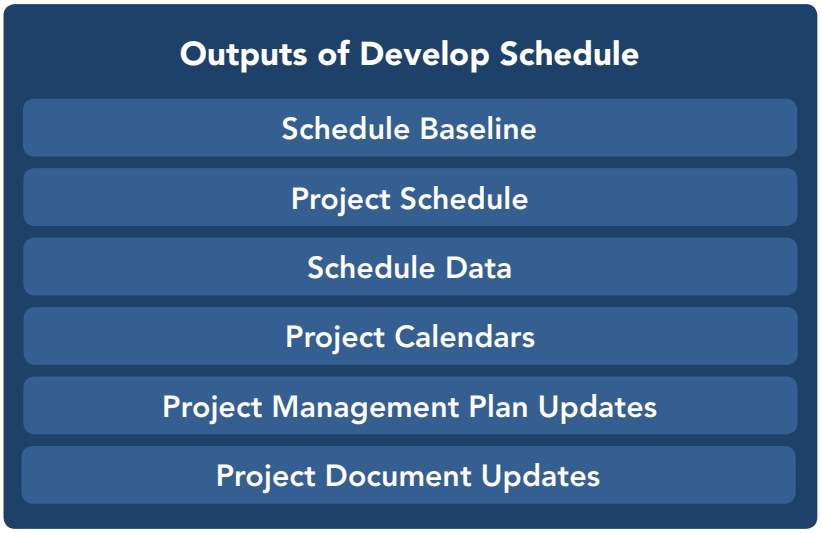
6.6.2.8 Scheduling Tool

There are dozens of project management software packages available and most will include some or all of the following features:

- *Planning, tracking and monitoring*—these most common features provide for planning and tracking of the projects tasks, resources and costs. Usually the software also provides impact assessments of planned deviations and resource and schedule projections.
- *Management reports* supported by Gantt charts, network diagrams, tabular summaries and other business graphics.
- *A project calendar* that enables the specification of non-working periods such as weekends and holidays. These calendars usually become the basis for all computer assisted resource scheduling.
- *A what-if analysis facility.* Some packages can perform a comparative analysis and display the new against the old project plan, enabling easy management review of the options.
- *A multi-project analysis facility.* Some of the more sophisticated packages feature a single, comprehensive database enabling cross-project analysis and reporting.

6.6.3 Develop Schedule: Outputs

The following represent outputs from this process:



6.6.3.1 Schedule Baseline

A schedule baseline is a specific version of the project schedule developed from the schedule network analysis. It is accepted and approved by the project management team as the schedule baseline with baseline start dates and baseline finish dates. It is a component of the project management plan.

6.6.3.2 Project Schedule

The project schedule includes a planned start date and planned finish date for each activity. If resource planning is done at an early stage than the project schedule would remain preliminary until resource assignments have been confirmed and schedule start and finish dates are established. This process usually happens no later than completion of the project management plan.

A project target schedule may also be developed with a defined target start and target finish for each activity. The project schedule may be presented in summary form sometimes referred to as the master schedule or milestones schedule or it may be presented in detail. It is usually presented graphically using one or more of the following formats:

- Milestone charts are similar to bar charts but only identify the schedule start or completion of major deliverables and key external interfaces.
- Bar charts use bars representing activities to show activity start and end date as well as expected durations.

  The logical bar-chart shows the logical relationships between the activities. Whilst this technique is useful, be aware that on larger projects the volume of activities may result in a cluttered presentation.

  Many variations of Gantt chart can be used to represent a broad spectrum of project information and in spite of its limitations the Gantt chart remains the most common presentation format for senior management.

Project management staff need to calculate how many resources a specific activity will require. They also need to establish the overall resource requirements of the project, for any given period—possibly including the resources needed on a daily basis. The type of diagram that facilitates this is called a histogram (or bar chart) and is another widely used project planning aid.

Histograms enable this information to be portrayed clearly. They can be derived from the Gantt chart representing the period in question. The only additional information that may be required is the type of specialist resource required for each activity.

Project Schedule Network Diagrams show both the project network logic and the projects critical Path schedule activities. These diagrams can be presented in the activity on no diagram formats or presented in the times you'll schedule network diagram format that is sometimes called a logical bar chart.

6.6.3.3 Schedule Data

The schedule data for the project schedule included least the schedule milestones, schedule activities, as activity attributes and documentation off all identified assumptions and constraints. The amount of additional data varies by application area.

6.6.3.4 Project Calendars

These identify working days and shifts available for scheduled activities of the project.

6.6.3.5 Project Management Plan Updates

These include updates to the schedule baseline and the schedule management plan.

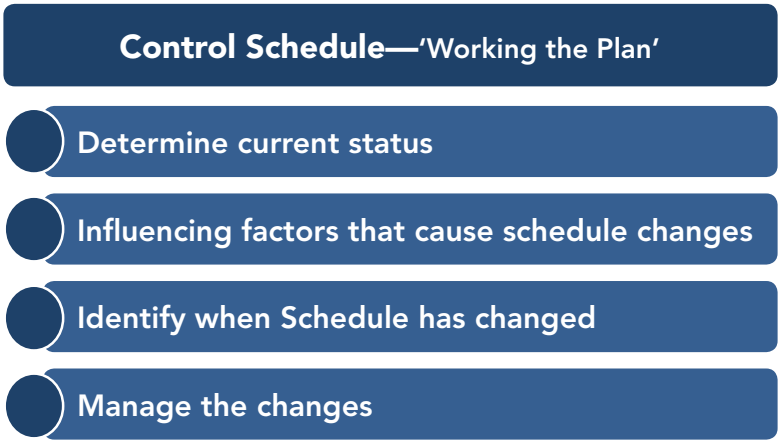
6.6.3.6 Project Document Updates

Whilst the activity network is one of the most useful aids to effective project management, senior managers will not usually want to see this level of detail. When project management staff need to communicate information to senior management; Gantt charts, histograms and other graphical techniques are the preferred presentation format.

Any plan, schedule or specification that will be circulated should be represented in a clear and unambiguous format. The notation used should be clear to both an in-house and an external audience. In order to do this, the three vital planning and control parameters—time, cost and performance should be summarized at an appropriate level of detail.

6.7 Control Schedule

This process is used to monitor the status of and manage changes to the schedule baseline. A schedule baseline is needed if the schedule is going to be controlled and this baseline must be maintained so that it reflects the current status of the project.



This process is part of monitoring and controlling and is sometimes referred to as 'working the plan' in contrast with the first five processes which are all to do with 'planning the work'.

It is concerned with:

- Determining the current status
- Influencing factors that could cause schedule changes
- Identifying if the schedule has changed
- Managing changes as they occur

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The inputs, tools and techniques, and outputs of this process are summarized in the following table.

Inputs	Tools & Techniques	Outputs
Project Management Plan	Performance Reviews	Work Performance Information
Project Schedule	Project Management Software	Schedule Forecasts
Work Performance Data	Resource Optimization Techniques	Change Requests
Project Calendars	Modeling Techniques	Project Management Plan Updates
Schedule Data	Leads and Lags	Project Documents Updates
Organizational Process Assets	Schedule Compression	Organizational Process Assets Updates
	Scheduling Tool	

6.7.1 Control Schedule: Inputs

The following are the inputs into the schedule control process:

6.7.1.1 Project Management Plan

The project management plan contains the schedule management plan and the schedule baseline. The schedule management plan describes how the schedule will be managed and controlled. The schedule baseline is used to compare with actual results to determine if a change, corrective action, or preventive action is necessary.

6.7.1.2 Project Schedule

The most recent version of the project schedule with notations to indicate updates, completed activities, and started activities as of the indicated data date.

6.7.1.3 Work Performance Data

Information about project progress, such as which activities have started, their progress, and which activities have finished.

6.7.1.4 Project Calendars

A schedule model may require more than one project calendar to allow for different work periods for some activities to calculate the schedule forecasts.

6.7.1.5 Schedule Data

This will be reviewed and updated in the Control Schedule process.

6.7.1.6 Organizational Process Assets

The organizational process assets that influence the Control Schedule process include existing formal and informal schedule control-related policies, procedures, and guidelines, schedule control tools, and monitoring and reporting methods to be used.

6.7.2 Control Schedule: Tools and Techniques

There are several different tools and techniques that can be used to control the project schedule.

6.7.2.1 Performance Reviews

Performance reviews measure, compare, and analyze schedule performance such as actual start and finish dates, percent complete, and the remaining duration for work in progress. If earned value management (EVM) is utilized the schedule variance and schedule performance index are used to assess the magnitude of schedule variations.

An important part of schedule control is to decide if the schedule variation requires corrective action. For example, a major delay on any activity not on the critical path may have little effect on the overall project schedule, while a much shorter delay on a critical or near-critical activity may require immediate action.

If using the critical chain scheduling method, comparing the amount of buffer remaining to the amount of buffer needed to protect the delivery date can help determine schedule status. The difference between the buffer needed and the buffer remaining can determine whether corrective action is appropriate.

Schedule performance measurements are used to assess the magnitude of variation to the original schedule baseline. The total float variance is also an essential planning component to evaluate project time performance.

Important aspects of project schedule control include determining the cause and degree of variance relative to the schedule baseline and deciding whether corrective or preventive action is required.

6.7.2.2 Project Management Software

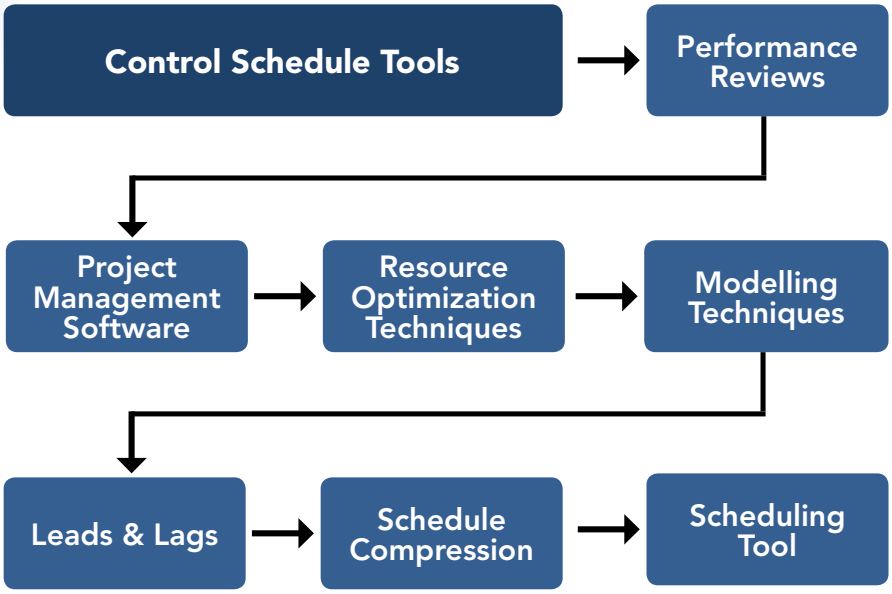
Project management software for scheduling provides the ability to track planned dates versus actual dates, and to forecast the effects of changes to the project schedule.

6.7.2.3 Resource Optimization Techniques

These are used to adjust schedule due to demand (project time) and supply of resources (resource availability). They include resource leveling and resource smoothing, which were described earlier.

6.7.2.4 Modelling Techniques

These are used to review various scenarios used in risk monitoring to bring schedule model in alignment with project management plan and schedule baseline. What-if scenario analysis is used to assess feasibility of the project schedule under adverse conditions. Simulation calculates multiple project durations based on different sets of assumptions.



6.7.2.5 Leads and Lags

Adjusting leads and lags (as described in the previous process) is used to find ways to bring project activities that are behind into alignment with plan.

6.7.2.6 Schedule Compression

The schedule compression techniques described earlier are used to find ways to bring project activities that are behind into alignment with the plan. It includes crashing, which adds resources and fast-tracking, in which activities normally done in sequence are now performed in parallel for part of their duration.

6.7.2.7 Scheduling Tool

Schedule data is updated and compiled into the schedule to reflect actual progress of the project and remaining work to be completed. The scheduling tool and the supporting schedule data are used in conjunction with manual methods or other project management software to perform schedule network analysis to generate an updated project schedule.

6.7.3 Control Schedule: Outputs

The most crucial outputs are the work performance information in the form of:

- Schedule variance (SV) and
- Schedule performance index (SPI).

These can be used to forecast future performance of the project based on the performance to date. If this information indicates that there is a significant variance of the performance of the project as compared to the performance baseline, then this may suggest changes to either the project itself in the form of corrective action or preventive action, or changes to the schedule baseline itself if it is determined that the original baseline was unrealistic.

Any of these change requests are then fed as inputs into the change control process, which as you may recall takes place under Integration Management. If there is an eventual change to the schedule baseline, then that will generate a new project schedule. If schedule compression techniques are used, this may create changes in other management areas: cost (in the case of crashing) and risk (in the case of fast-tracking).

Finally, if the reason for the variances is uncovered, this is noted in the lessons learned so that further scrutiny can be given to this throughout the rest of the project. The following represent outputs from this process:

6.7.3.1 Work Performance Information

Measurements can include planned vs. actual technical performance or other scope performance measurements. This information is documented and communicated to stakeholders.

6.7.3.2 Schedule Forecasts

These are estimates of the future conditions of the project based on the work performance information provided.

6.7.3.3 Change Requests

Schedule variance analysis, along with review of progress reports, results of performance measures, and modifications to the project schedule can result in change requests to the schedule baseline and/or to other components of the project management plan.

Change requests are processed for review and disposition through the Perform Integrated Change Control process (4.5). Preventive actions may include recommended changes to reduce the probability of negative schedule variances.

6.7.3.4 Project Management Plan Updates

Elements of the project management plan that may be updated include:

- *Schedule baseline* changes are incorporated in response to approved change requests related to project scope changes, activity resources, or activity duration estimates.
- *Schedule management* plan may be updated to reflect a change in the way the schedule is managed.
- *Cost baseline* may be updated to reflect changes caused by compression or crashing techniques.

6.7.3.5 Project Document Updates

Project documents that may be updated include:

- *Schedule Data.* New project schedule network diagrams may be developed to display approved remaining durations and modifications to the work plan. In some cases, project schedule delays can be so severe that development of a new target

schedule with forecasted start and finish dates is needed to provide realistic data for directing the work, and for measuring performance and progress.

- *Project Schedule.* An updated project schedule will be generated from the updated schedule data to reflect the schedule changes and manage the project.
- *Risk register:* schedule compression technique of fast-tracking may generate new risks

6.7.3.6 Organizational Process Assets Updates

These include causes of variances, corrective action chosen and the reasons, and other types of lessons learned from project schedule control.

Summary

Project Time Management includes the processes required to manage timely completion of the project. The Project Time Management processes are as follows:

- **6.1 Plan Schedule Management**—the process of establishing the policies, procedures, and documentation for planning, developing, managing, executing, and controlling the project schedule.
- **6.2 Define Activities**—the high-level requirements are broken down into high-level tasks or deliverables. These are than broken down into activities and presented in the form of WBS (Work Breakdown Structure).
- **6.3 Sequence Activities**—the activities identified in the previous step should be sequenced based on the order in which they need to be done depending on their interdependencies.
- **6.4 Estimate Activity Resources**—the estimation of the amount and the types of resources required for activities is done in this step. The project management team will need a clear understanding of resource availability and capability.
- **6.5 Estimate Activity Durations**—this is a key step in the project planning process and there are a number of tools that can also be utilized to help you to estimate the required activity resources. Most of the organizations follow either Work Breakdown Structure (WBS) based estimating or Function Points based estimates in this step. Once the activity estimates are completed, the critical path

of the project should be identified in order to determine the total project duration. This is one of the key inputs for the project time management.

- **6.6 Develop Schedule**—in order to create an accurate schedule, several parameters from the previous steps are required including: the activity sequence, duration of each activity, and the resource requirements. Software packages, like as Microsoft Project, can help you to develop a project schedule including planning diagrams that can help to present the relevant information in a way that makes it easy to understand.
- **6.7 Control Schedule**—this process is part of monitoring and controlling and is sometimes referred to as 'working the plan' in contrast with the first five processes which are all to do with 'planning the work'. No project can be executed without changes to the original plans and schedules and this process will run throughout the project.

These processes interact with each other and with processes in the other Knowledge Areas. Each process can involve effort from one group or person, based on the needs of the project and occurs at least once in every project and occurs in one or more of the project phases (if the project is divided into phases).

Although the processes are presented here as discrete components with well-defined interfaces, in practice they can overlap and interact in ways not detailed here.

Some advanced practitioners distinguish the printed project schedule information (schedule) from the schedule data and calculations that produce the schedule, by referring to the scheduling engine populated with project data as the schedule model. However, in general practice the schedule and the schedule model are referred to as the schedule. Therefore, the PMBOK® Guide uses the term schedule.

On some projects, especially those of smaller scope, defining activities, sequencing activities, estimating activity resources, estimating activity durations, and developing the schedule are so tightly linked that they are viewed as a single process that can be performed by a person over a relatively short period of time. These processes are presented here as distinct processes because the tools and techniques for each are different.

Although not shown here as a discrete process, the work involved in performing the six processes of Project Time Management is preceded by a planning effort by the project management team. This planning effort is part of the Develop Project Management Plan

process, which produces a schedule management plan that selects a scheduling methodology, a scheduling tool, and sets the format and establishes criteria for developing and controlling the project schedule.

A scheduling methodology defines the rules and approaches for the scheduling process. Some of the better-known methodologies include critical path method (CPM) and critical chain.

The project time management processes and their associated tools and techniques are documented in the schedule management plan. The schedule management plan is contained in, or is a subsidiary plan of the project management plan. It may be formal or informal, highly detailed or broadly framed, based upon the needs of the project, and includes appropriate control thresholds.

Developing the project schedule uses the outputs from the processes to define activities, sequence activities, estimate activity resources, and to estimate activity durations in combination with the scheduling tool to produce the schedule.

The finalized and approved schedule is the baseline that will be used in the Control Schedule process. As the project activities are being performed, the majority of effort in the Project Time Management Knowledge Area will occur in the Control Schedule process to ensure completion of project work in a timely manner.

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