Schedule Development Guidelines

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Contents

Development Guidelines – Planning & Scheduling[1]

Introduction

The following 10 scheduling best practices are to serve as the foundation for criteria that will be used in the development and assessment of project schedules. The first section of each Practice introduces the concept of the best practice and provides an overview of assessment criteria. *Key Questions* and *Key Documentation* represent information that should be collected through interviews and surveys in order to assess the schedule against the criteria. *Impacts* address the "so what," or the effect if criteria are not met. Finally, a required documents section is provided at the end of the Schedule Development Guidelines as a checklist of appropriate documentation that should be part of any well-crafted project schedule.

[1] Based on the U.S. Government Accountability Office GAO-4115068-v2 (draft)

Best Practice 1: Capturing activities

The schedule should reflect all activities as defined in the project's work breakdown structure (WBS), which defines in detail the work necessary to accomplish a project's objectives, including activities to be performed by both the owner and contractors.

A schedule is a set of instructions on how the project has been agreed to be executed. Therefore, the current and baseline schedules should reflect all activities (steps, events, work required, outcomes) to accomplish the deliverables described in the project's current work breakdown structure (WBS). As the project matures and passes onto sequential phases, a detailed schedule for the next phase should be developed to better plan and manage the work. It is in this detailed schedule where the WBS should reflect the current understanding of the statement of work (SOW) and be further broken down into specific activities - deliverables. When properly planned, the schedule should clearly reflect the WBS which defines what is required as well as the activities which address how to produce and deliver each of the WBS elements. The detailed schedule should capture all time variable costs – labor, rentals, etc.

Key questions

1. **Does the detailed schedule reflect the WBS?** Is the current estimate organized by WBS?
2. Does the WBS define all deliverables? Are activities extracted from the WBS and do they define how the deliverables will be produced?
3. Are key milestones identified in the order of occurrence and are they consistent with the contract dates in the baseline schedule?
4. Are all activities and deliverables defined in the Work Breakdown Structure (WBS) and the Statement of Work (SOW) accounted for in the schedule?
5. Are activity names unique and descriptive? Are activities phrased using verb-noun formats (e.g. "Develop documentation")?
6. Are milestones named verb-noun or noun-verb formats (e.g., "Start project" or "Project Finished")?
7. Are level-of-effort activities clearly marked?[2] Are they necessary?
8. Do the owner, contractor, and subcontractors have different scheduling software systems? If so, how is integrity preserved and verified when converting the schedule?
9. **Is total schedule activity count less than 3000**? Do you need the current level of detail?[3]

Key documentation

1. Work Breakdown Statement (WBS), WBS Dictionary[4], Schedule Basis, current project Estimate, and Project Statement of Work (SOW) - objectives/requirements/stakeholders/etc.)

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[2] If LOE activities are included with deterministic durations and logical relationships to other schedule activities then problems can arise in a schedule; see the following sections for identifying these common problems. Strictly speaking the LOE activity is attached as a hammock to the beginning and ending activities it supports. The LOE does not have a deterministic duration itself and will take the duration implied by those detailed tasks. In this way the LOE cannot drive the schedule. Often LOE resources are placed on LOE tasks. For more information on LOE tasks in schedules see DOD's *Integrated Master Plan and Integrated Master Schedule Preparation and Use Guide*.

[3] Resource loaded activities need to be statused directly from timecards. If contractor/subcontractor timecards cannot provide data at the activity level, either the timecard coding system must change or activity detail reduced.

2. SOW mapping to the project work breakdown structure (WBS)
3. Contractor WBS to Owner WBS correspondence, additional detail only
4. Activity and resource codes used, in addition to the WBS, to organize and filter the activities into useful categories to facilitate understanding and develop/maintain focus

Impacts if criteria not fully met

1. If activities are missing from the schedule, then other best practices will not be met. Without accounting for all necessary activities, it is uncertain whether: all activities are scheduled in the correct order, resources are properly allocated, missing activities would appear on the critical path, or a schedule risk analysis accounts for all risk.
2. If the project schedule does not fully and accurately reflect the project, it will not serve as an appropriate basis for analysis and may result in unreliable completion dates, time extension requests, and delays.
3. If the Owner's work is not reflected in the schedule, it may increase the risk of Owner caused delays.
4. Since the schedule is used for coordination, missing elements will hinder coordination efforts increasing the likelihood of disruption and delays.
5. If the schedule lacks sufficient detail (all activities), then opportunities for process improvement (e.g., identifying redundant activities) and risk mitigation will be missed.
6. If extraneous detail (not supported by timecards) is included in the schedule there will be no effective/efficient method to determine the time spent on the activity and gauge craft productivity
7. Too many activities cloud the issue – forest for the trees – and waste precious analytical resources. Certainly never go into greater detail than supported by the current estimate or timecard status capability

Best Practice 2: Sequencing activities

The schedule should be planned so that critical project dates can be met. To meet this objective, activities need to be logically sequenced—that is, listed in the order in which they are to be carried out. In particular, activities that must be completed before other activities can begin (predecessor activities), as well as activities that cannot begin until other activities are completed (successor activities), should be identified. This helps ensure that interdependencies among activities that collectively lead to the accomplishment of events or milestones can be established and used as a basis for guiding work and measuring progress.

The logic of the schedule should be determined by the leadership of the teams that will be executing the work. Any change in the execution plan should be implemented in the schedule to keep it up to date. The logic should be complete so that the dates and critical paths are correctly calculated even when durations change. While a baseline project is planned to achieve its deliverables by certain important project timeframes, dates do not drive logic. Instead, dates are an output of critical path method scheduling. Therefore, any date constraints that are inserted into the schedule potentially override the consequences of the logic and must be justified by events external to the schedule. Because the logic and durations of the activities drive when the work can be performed, if the work

[4] A document that describes each element in the work breakdown structure (WBS) including a statement of work (SOW), describing work content of each WBS element, and a basis of estimate (BOE), documenting each element's budget. Additional information may include responsible organization, contract number, etc. The WBS dictionary will often result in a project or contract statement of work (SOW). See: WORK BREAKDOWN STRUCTURE (WBS). (6/07)

cannot be logically completed by the key dates, then remedial actions such as adding resources, performing work in parallel or cutting scope may be necessary in order to meet those dates.

Key questions

1. Have the activities and logical relationships been determined by those executing the project?
    a. Are the activities sequenced logically according to the current plan?
    b. Is the current plan feasible to execute given the resources available, the planned sequence of the work and any external dependencies involved?
    c. If activities are planned in parallel, are sufficient resources available to accomplish them simultaneously?
    d. d. Have the activities and logic been kept up to date as the project is executed?
2. Are the logic relationships of the tasks established in the schedule tool?
    a. Does each activity (except the start milestone) have an F-S or S-S predecessor that drives its start date? Are the predecessors the immediately prior activities in the sequence (that is, necessary to the start of the activity)? Are there any predecessors that are redundant or not necessary?
    b. Does each activity (except the finish milestone and deliverables that leave the project without subsequent impact on the project) have an F-S or F-F successor that it drives? Are these successors the activities that will be pushed out if the activity is delayed? Are there any redundant or unnecessary successors?
3. Are there date constraints other than "As soon as possible" (ASAP) in the schedule? Is each of these justified in documentation provided? Do the constraints represent events outside the project that are determined by the calendar?[5]
4. Is the concurrency (e.g., several parallel tasks) that is reflected in the schedule required by the project plan? Is the concurrency feasible in terms of work practices and resource availability?
5. At key points where schedule paths merge, are all the paths that are logically linked to those points required to merge at those points?
6. Are LOE activity durations determined by the activities they support?
7. Is any work represented by milestones rather than activities?
8. Are negative lags used? Why?[6] Try to find an alternative logic arrangement.
9. Is any negative float present? Why not addressed? **Not acceptable**
10. Has redundant logic been eliminated?

[5] Backward pass constraints are used during schedule development to tell where negative float exists and scheduling needs to be improved. However, some may use constraints incorrectly to place activities on specific dates or to insert buffers for risk. These latter constraints should be eliminated since: (1) dates should be determined by the schedule's logic and activity durations, and (2) total schedule risk should be associated with all of the risks in the schedule and hence appear as a contingency at the end of the schedule. A constraint placed on a computer file does not constrain the project in the real world. Soft or hard constraints may be used during schedule analysis, but they should be removed to the greatest extent possible in order to have a dynamic schedule model.

[6] Positive lag may be associated with time needed for something to happen (e.g., cure concrete) while a negative lag shows lead time needed (e.g., start writing report 10 days prior to management review). All successors and predecessors with positive lags should be analyzed to see if the lag is necessary (i.e., the lag cannot be avoided and must be there with that duration in every project situation or scenario). For the same reasons, negative lags should be examined and avoided because they can be confusing. Activities with F-S successors should not have positive lags that stand in for a buffer. If the buffer is deemed necessary the activity duration should be extended to include it. A risk buffer should only be represented at the end of the project schedule.

Key documentation

1. Determination of whether the work is sequenced logically and according to the current plan. Ideally this requires review by experienced professionals familiar with the type of project being scheduled.
2. Justification for using hard and soft date constraints instead of activities' duration and logic
3. Justification for lags and leads instead of activities' duration and logic
4. Justification for any activity that has no F-S or S-S predecessor or no F-S or F-F successor

Impacts

1. The logical sequencing of events is directly related to float calculations and the critical path. If the schedule is missing dependencies or if activities are linked incorrectly, float estimates will be miscalculated. Incorrect float estimates may result in an invalid critical path and thus will not be reliable indicators of where resources can be shifted to support delayed critical activities.
2. The presence of "open ended activities" (sometimes called "broken logic") reduces the credibility of the calculated activity start and finish dates and the identity of the critical path(s). The slip or elongation of an activity that has no logical successor will not reflect its effect on the scheduled start dates of successor activities. "Open ended activities" are those activities with logic that does not give the right activity start and finish dates when durations change.
    a. If an activity—other than the start milestone—does not have an F-S or S-S predecessor that drives its start date, the activity will start earlier if its duration is projected to be longer than originally believed. An earlier start may be illogical.
    b. If an activity—other than the finish milestone or deliverable that leaves the project—does not drive a successor via an F-S or F-F link, the implications of it running late or long are not passed on to any successor activity.
3. In other words, the common rule of "each activity needs a successor" is not specific enough. Each activity needs a successor from its finish date.
4. All constraints should be justified because they confine the schedule.[7] "Finish not later than" (FNLT) constraints do not limit the date of the activity's finish but can create negative total float if the calculated finish is beyond the constraint date.[8] In another example, a task with a "Start-Not-Earlier-Than" (SNET) constraint cannot begin earlier even if upstream work has completed ahead of schedule. These constraints do not allow the network to calculate freely so it reduces the effectiveness of a CPM schedule.
5. A customer-mandated date is not a legitimate reason to constrain an activity. A schedule is intended to be a dynamic, pro-active planning and risk mitigation tool that models the project and can be used to track actual progress towards important project milestones. Schedules with constrained dates can portray an artificial or unrealistic view of the project plan.

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7 Backward pass constraints are used during schedule development to tell where negative float exists and scheduling needs to be improved. However, some may use constraints incorrectly to place activities on specific dates or to insert buffers for risk. These latter constraints should be eliminated since: (1) dates should be determined by the schedule's logic and activity durations, and (2) total schedule risk should be associated with all of the risks in the schedule and hence appear as a contingency at the end of the schedule. A constraint placed on a computer file does not constrain the project in the real world. Soft or hard constraints may be used during schedule analysis, but they should be removed to the greatest extent possible in order to have a dynamic schedule model.

6. Lags must be justified because they may represent work or a delay that may be variable, yet the lags are hard-coded into the schedule. Lags should not be used to represent activities since they cannot be easily monitored or included in the risk assessment and do not require resources. Activities represented by lags are not, in fact, risk free. The use of a lag with F-S logic is generally not good practice. Negative lags are generally not valid and must be justified.
7. Lags are often used to cause activities to start or finish on a specific date or to insert a buffer for risk. These lags persist even when activities delay (use up the intended buffer) when their use is no longer valid and must be eliminated. Lags should only be used to show how two tasks must interact because of physical reasons.[9]
8. Representing supplier or subcontractor deliverables as date-constrained milestones rather than summary activities may understate the risk in the procurement process.
9. A schedule should be validated to ensure that there are no additional redundant logic links. Such redundancy is unnecessary, adds unwarranted complexity to the schedule, and slows the process of de-bugging.
10. The convergence of several paths at a single task means that all those paths must finish in order to start the converged task. If there are several or many merging paths this raises the risk of performance and completion of that task.

Best Practice 3: Assigning resources to activities

The schedule should reflect all time variable resources (e.g., labor, rentals, overhead, etc.) are needed to do the work, whether all required resources will be available when needed, and whether any funding or time constraints exist.

The current estimate/budget is the source for all resource assignments. The quantities (hours/days) identified in the estimate divided by the expected crew size for the activity will determine the activity duration. The schedule should realistically reflect what resources are needed to do the work and—compared to total available resources—be able to determine whether all required resources will be available when they are needed. Fixed costs such as bulk material, equipment should be carried off schedule. Overhead may be represented by a LOE activity or as an element of the labor units rates (preferred).

Key questions

1. Which resources are specified and assigned to the activities?
2. Is the current estimate the basis for resource identification and cost (unit rates)?
3. Are units and costs defined at the activity level through resource assignments?
4. Are there separate resources identified for different types of tasks, such as trade contractors, or position descriptions?
5. Is there evidence that the resources assigned have been used as a factor in determining the

[9] Positive lag may be associated with time needed for something to happen (e.g., cure concrete) while a negative lag shows lead time needed (e.g., start writing report 10 days prior to management review). All successors and predecessors with positive lags should be analyzed to see if the lag is necessary (i.e., the lag cannot be avoided and must be there with that duration in every project situation or scenario). For the same reasons, negative lags should be examined and avoided because they can be confusing. Activities with F-S successors should not have positive lags that stand in for a buffer. If the buffer is deemed necessary the activity duration should be extended to include it. A risk buffer should only be represented at the end of the project schedule.

duration of the schedule activities?

6. At what level of detail are resources specified? Resources based on categories are easier to work with than resources identified to the individual. Do the resources have logical resource calendars assigned?
7. Has analysis been performed to ensure that resources are sufficient and available in each work period when needed?
    a. Are there any potential difficulties in obtaining or using the required resources to accomplish the work?
    b. Is the balance between resources required and resources available considered in the schedule?
    c. Are there work periods for which more resources are required than are available? What is the plan for resolving resource deficiencies (e.g., stretch out the work, get more resources, or both)?

Key documentation

1. Basis of estimate (BOE) for resource assumptions.
2. Resource allocation planning document. Resource profiles and tables for unique resources derived from the schedule.
3. Resource output from scheduling software
4. Resource allocation output from scheduling software

Impacts

1. If the current schedule does not allow for insight into current or projected allocation of resources, then the risk of the project slipping is significantly increased. Over-allocated resources result in inefficiency (e.g., diminished productivity due to extended overtime and/or overcrowding) or project delay due to unavailable resources.
2. Resources must be considered when creating a schedule because the availability of resources directly impacts an activity's duration.
3. If the baseline schedule does not identify the planned resources, it cannot be used to make important management decisions, such as reallocating resources from activities with significant float to critical activities that are behind schedule.
4. If the schedule does not have resource assignments, it cannot be used to pay invoices based on work accomplished.
5. If the schedule does not have resource assignments, management's ability to monitor crew productivity, allocate idle resources, monitor resource-constrained activities, and level resources across activities is severely limited.
6. Identifying separate resources for different types of tasks (such as trade contractors or position descriptions) is vital in order to identify resource totals and overloading, especially when similar activities overlap.

Best Practice 4: Establishing the duration of activities

The schedule should realistically reflect how long each activity will take to execute. Durations should be determined by crew size and estimated/budgeted hours assigned to the activity. This edict will not apply to many activities in the 'pre-design' or planning stage that are not generally estimated. Here durations will be determined by historical precedents.

Activities should be specified in sufficient detail to permit accurate updating. Excessively long durations should prompt further decomposition of the activity into shorter activities, if not controlled by alternative means[10]. Conversely, if durations are too short, it might require excessive effort to update the schedule and may cause unnecessary detail for planning and logical linking of the work. Activity start and end dates should be calculated using the durations and logic of the schedule, and should rely on realistic calendars.

Key questions

1. For a detailed schedule, are durations short enough to be consistent with the needs of effective planning and execution of the project? Are activity durations too short? Are durations of more than two reporting periods monitored by alternative means (soft logic)?
2. Which activity durations have the most risk?
3. Were the durations determined using the work to be done and realistic documented assumptions about resources available, productivity, normal interferences and distractions and reliance on others?
4. Are durations based on appropriate calendars? Are there any specific conditions that necessitate special calendars, and are they addressed (religious holidays, non-work periods for climate, shift work, unavailability of resources)?

Key documentation

1. Documentation of the way the durations of work activities were estimated.
    a. For instance, the Basis of Estimate (BOE) should include the assumptions made to justify the durations assumed for the cost. These should be consistent with the durations at the same level of detail.
1. Documentation justifying non-standard working calendars
2. Documentation justifying long duration activities (e.g., off-schedule spreadsheets)
3. Identification of LOE activities and justification for how they are scheduled.

Impacts

1. Schedules determined by imposed target completion dates rather than work and logic are often unrealistic and can be infeasible.
2. If tasks are too long (i.e., greater than 44 days), the schedule may not have enough detail for project management or progress measurement and reporting.
3. If tasks are too short, the schedule may be too detailed leading to excessive work to maintain the logic, update the status of activities, and manage the many short-duration tasks.
4. Often durations are determined solely by the time available to complete the project. Instead, durations should be based on the effort required to complete the activity, the resources available, efficiency or production estimates, and other factors such as previous experience on similar tasks. Therefore, the dates in the schedule should be determined by the project plan logic and durations. If the duration and logic do not support some target deliverable date there must be a discussion between the project manager and the teams about how realistically to compress the schedule, add more resources, or adjust scope.

[10] Many bulk installations – pipe, electrical, instrumentation, and in some instances steel and concrete – and engineering design can best be controlled through off-schedule spreadsheets maintained by craft superintendents /engineering leads. This concept is called Soft Logic. See for additional details.

5. Durations should be estimated under normal conditions, not optimal or "success-oriented" conditions. If durations are not realistic the project delivery dates and critical paths are not reliable.

Best Practice 5: Schedule is traceable

The schedule should be link deliverables and outcomes associated with other sequenced activities. These links are commonly referred to as "handoffs" and serve to verify that activities are arranged in the right order to achieve aggregated products or outcomes. The schedule should also be vertically mapped, meaning that the dates for starting and completing activities in the project schedule should be aligned with the dates for supporting tasks and subtasks. Such mapping or alignment among levels enables different groups to work to the same schedule.

Horizontal traceability demonstrates that the overall schedule is rational, planned in a logical sequence, accounts for interdependencies between work and planning packages, and provides a way to evaluate current status. Horizontally traceable schedules support the calculation of activity and milestone dates and identification of the critical and near-critical paths. Vertical traceability demonstrates the consistency of data between different levels of the schedule —master, intermediate, detailed. When schedules are vertically traceable lower-level schedules are clearly consistent with upper-tiered milestones, allowing for total schedule integrity and enabling different teams to work to the same schedule expectations.

Key questions

1. Has the schedule been accepted by all stakeholders as representing the plan for the project? How are key hand-off dates negotiated among teams?
2. Are major hand-offs and deliverables easily identified in the schedule? How are major hand-offs and deliverables monitored and managed? Are there fields within the schedule that record the responsible parties?
3. Do all lower level activities roll up into higher WBS levels?

Key documentation

1. Provide all representations of the schedule as of a specific time.

Impacts

2. If the schedule is not horizontally traceable there may be little confidence in the calculated dates or critical path(s). Schedules that are not horizontally integrated may not depict relationships between different project elements and product handoffs leading to less effective management of the project.
3. Vertical traceability provides assurance that the representation of the schedule to different audiences is consistent and accurate. Without vertical traceability there may be little confidence that all users of the schedule are getting the same correct schedule information.

Best Practice 6: Establishing the critical path

Scheduling software should be used to identify the critical path, which represents the chain of dependent activities with the longest total duration. Establishing a project's critical path is necessary to examine the effects of any activity slipping along this path. Potential problems along or near the critical path should also be identified and reflected in scheduling the duration of high-risk activities.

A critical path is defined as either the longest path through the schedule or the path with the lowest total float.[11] In general, activities on the critical path are those that, if delayed, cause future important milestone(s) to be delayed. The establishment of a critical path is necessary for examining the effects of any activity slipping along this path. If there are several important deliveries there should be critical paths to each one. The project manager should identify the key milestone(s) in the schedule and the path that is considered critical in driving the milestone date(s). The establishment of a project's critical path is necessary to focus the team energy and the attention of management on the activities that will lead to project schedule success.

Key questions

1. Are the activities driving the dates of key deliveries and milestones dates identified by the scheduling software?
2. Does the critical path include LOE activities? Is the critical path driven by other unusually long duration activities?
3. Are risky activities, potentially including major critical subcontract work, included in the project critical path?
4. Is the critical path a contiguous path from the status/data date to the major completion milestone(s)?
5. Does the critical path start with a constraint so that other activities are unimportant in driving the milestone date? If so, is there justification for that constraint?
6. Is the critical path driven in any way by lags or leads?
7. If there are several important milestones, are the critical paths to those milestones clearly identified, continuous and free of constraints, LOE activities, leads and lags?

Key documentation

1. Identification of the important project deliverables or milestones for which critical path(s) should be established
2. Identity of the critical path activities as determined by the project leadership to those key deliverables or milestones. Do these critical paths have the characteristic that a delay of an activity will delay the important delivery or milestone?
3. Printouts of the logic diagram indicating the longest path(s) to the important milestone(s), as well as critical path based on total float to all major milestones.
4. Identification of near critical paths, defined as activities with total float no longer than the reporting period.
5. Percentage of activities that appear on the critical path compared to the total count of activities in the schedule.
6. Identity of the critical path(s) as determined by the scheduling software

[11] A critical path calculated from lowest float assumes that the last activity in the schedule computer file is the key milestone of the schedule, which is not always the case.

Impacts

1. Successfully identifying the critical path(s) relies on capturing all activities (Best Practice #1), proper sequencing of activities (Best Practice #2), horizontal traceability (Best Practice # 5), and the reasonableness of float (Best Practice #7). Unless the schedule is fully horizontally traceable, the effects of slipped tasks on successor tasks cannot be determined. Note that the critical path is directly related to the logical sequencing of events and float calculations. If the schedule is missing dependencies or if activities are not linked correctly, float estimates will be miscalculated. Incorrect float estimates will result in an invalid critical path and will hinder the ability of management to allocate resources from non-critical activities to those that must be completed on time.
2. LOE activities should not drive the schedule. LOE and repetitive activities support effort and their durations are determined by detail activities. For example, a project's length will not be determined by bi-weekly meetings or project management. If the schedule has discrete durations and driving logic for LOE activities, it will potentially confuse the identification of, and deflect project attention away from, the critical path.
3. Without a valid critical path, management cannot focus on those tasks that will have detrimental effects on the key project milestones and deliveries if they slip.
4. Risk in activities on the critical path(s) should be examined and mitigated since it has the potential to delay key project deliveries and milestones.
5. The review and analysis of near-critical paths is important because these activities are may overtake the existing critical path and drive the schedule.

Best Practice 7: Reasonable total float

The schedule should identify the float (or slack)—the amount of time by which a predecessor activity can slip before the delay affects the major milestone(s)—so that a schedule's flexibility can be determined. As a general rule, activities along the critical path have the least float. Total float indicates how much flexibility there is in the schedule to the major milestone(s). Large total float on an activity or path indicates that the activity or path can be delayed by the amount of the float without jeopardizing the finish date.

Typically total float is calculated by the scheduling software to the last activity in the schedule files, but other activities or milestones may be important as well. The scheduling software calculates float so that schedule flexibility can be determined. Total float can be positive, zero, or negative. If total float is positive, it indicates the amount of time that tasks can be delayed without delaying the project finish date or key (constrained) delivery or milestone. If total float is negative, it indicates the amount of time that must be saved so that the key project event is not delayed. Negative total float is created when constrained activities are delayed so that they push important milestones beyond their intended dates. Another type of float is called free float which is the time a predecessor activity can slip before the delay affects the successor activity. Free float is a subset of the total float that is calculated. Free float is important because some resources of the affected activities may only be available during certain time periods, which could be detrimental to the completion of subsequent activities and even the entire project.

The Project Manager should be aware of total float. For example, when an activity is delayed, this causes total float to decrease which increases the risk of not completing the activity as scheduled. In addition, activities with the lowest float values represent the highest risk to the schedule completion or interim milestones. If zero-float activities or milestones are not finished when scheduled, they will delay the project in an equal amount of their delayed finish (unless successor activities on the critical path can be completed in less time than originally planned). Moreover, incomplete, missing, or incorrect logic or invalid activity durations will distort the value of total float so that it does not accurately represent the amount of flexibility in the schedule. Thus, it is imperative that project managers (for both the owner and the contractor) proactively manage float[12] and adjust any schedule contingency as activities are completed. Doing so will ensure that the project schedule represents an accurate depiction of project status and enable management to make appropriate decisions before the project gets into trouble.

Key questions

1. Is the total float value calculated by the scheduling software reasonable (i.e., less than X% of total project duration) and does it accurately reflect true schedule flexibility? Does the project really have the amount of schedule flexibility indicated by the levels of float or are activity float values excessive?
2. Is total float calculated to the main deliveries and milestones as well as to the project completion? Does the latest activity in the project schedule file represent project completion as understood by the project team? If not, has a target activity been identified and total float calculated correctly to that activity?
3. Do the activities stack up unreasonably at the end of the milestones or project completion when sorted on late dates?

Key documentation

1. List of activities sorted by their total float values can be used by the project team to determine if the total float values correctly reflect the flexibility in the project schedule.
2. Alternatively, high values of total float can be the result of incomplete logic (see Best Practice # 2 above).

Impacts

1. Float is directly related to the logical sequencing of events and the critical path. If the schedule is missing activities, dependencies, or links activities incorrectly, float estimates will not be accurate. Incorrect float estimates may result in an invalid critical path and an inaccurate assessment of project completion dates. In addition, inaccurate values of total float result in a false depiction of true project status which could lead to decisions that may jeopardize the project. For example, if activities are not linked correctly to successors, total float will be greater than it should be.
2. Accurate values of total float can be used to identify those activities that could be permitted to slip and thus release and reallocate resources to tasks that require more resources to be completed on time. This knowledge helps to reallocate resources optimally.
3. Negative float indicates that there is not enough time scheduled for the task and is usually caused by activities taking longer or starting later than planned, making target dates infeasible.

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12 Total float ownership and management typically resides with the project manager (PM) or is shared by the PM and the main contractor(s).

4. Low total float critical paths that are comprised of many activities suffer a higher risk of slippage than low float critical paths with fewer activities because the more activities on the path, the lower the likelihood that activities near the end of the path will have float available.

Best Practice 8: Conducting a Schedule Risk Analysis

A schedule risk analysis should be performed using statistical techniques to predict the level of confidence in meeting a project's completion date. This analysis focuses not only on critical path activities, but also on activities near the critical path, since they can affect the project's status.

Scheduling software calculates the schedule completion date based on the premise that activity durations are discrete values. Even when a schedule meets all best practices, the durations are at best viewed as estimates that have some uncertainty around them and may be impacted by risk events. This level of uncertainty about durations implies that the project completion date is also uncertain. The objective of conducting a schedule risk analysis (SRA) is to estimate the impact of risk and uncertainty on the completion date. Statistical and simulation approaches provide a probability distribution of possible completion dates which is more realistic than a single date from the schedule that does not incorporate an explicit analysis of risk.

An SRA is based on a critical path method schedule that follows best practices, data collected about project schedule risks, and Monte Carlo type simulation techniques. The results of an SRA include:

a) the likelihood of meeting the schedule dates,
b) the dates that provide the level of confidence desired by the project in meeting milestone or total project completion,
c) the amount of time contingency needed for a level of confidence if the schedule and plan are followed, and
d) the identification of high-priority risks.

This analysis focuses not only on critical path activities, but also on other schedule paths that may become critical, because a risk's occurrence may make a non-critical path critical.

A schedule risk analysis captures the risk that schedule durations may vary due to, among other things: lack of or inaccurate data, optimistic estimating, technical challenges, lack of qualified personnel, and other external factors. Schedule contingency reserve for risk should be calculated by performing a schedule risk analysis; it is not just filling up the difference (if any) between the final delivery and the "need date." Applying the necessary time contingency reserve may cause negative total float.

As a general rule, the reserve should be held by the project manager and applied as needed to those activities that take longer than scheduled because of the identified risks. Contingency reserves of time can be applied before major milestones based on the SRA to those milestones. Reserves of time should not be apportioned in advance to any specific activity since the risks that will actually occur and the magnitude of their impact are not known in advance. The reserve allocated to any activity may be too much if the risks do not occur or too little if they do occur. The contingency reserve is only appropriate to the total impact of all risks in the schedule, so it should be placed at the end of the schedule and held by the project manager.

The results of the SRA are best viewed as inputs to project management rather than as forecasts of how the project will be completed. The results indicate when the project is likely to finish without the project team taking additional risk mitigation steps, so the SRA provides a guide to risk mitigation planning.

A schedule risk analysis answers questions that Critical Path Method schedules cannot directly address, such as:

a) How likely is it that the project will be completed on time given the deterministic CPM schedule?
b) How much schedule risk contingency is needed to provide an acceptable level of certainty in a completion date? In other words, what new date would better meet the project's risk tolerance?
c) Which risks are most likely to delay the project? How much of the required contingency do they contribute?
d) Which paths are most likely to delay the project? Since activity durations cannot be known with certainty, the identity of the critical path is also uncertain. Therefore, identifying the paths that are most likely to delay the project (i.e., paths that are "risk critical" and may become critical as the project progresses) is imperative to successfully managing the project.

Key questions

1. Was an SRA performed to determine the confidence level in achieving the project schedule?
2. Was a risk register used as an input to schedule development?
3. Was a simulation conducted to provide the probability distribution of total project completion and other important dates?
4. Are the SRA data and methodology available and documented?
5. Did the SRA identify which tasks during the simulation most often ended up on the critical path, so that risk-critical path activities can be closely monitored?
6. Was the schedule debugged based on the best practices described above before the simulation was conducted?
7. Are risk mitigation activities apparent in the schedule?
8. Have the risk inputs been validated?
9. Are the ranges reasonable and based on information gathered from knowledgeable sources?
10. Was the Risk Register developed before running the SRA? Did all stakeholders have input to the Risk Register? Was a formalized Risk Workshop(s) held?
11. Is the link between the risk register and the SRA input data clear and documented? Is there evidence of bias in the risk data?

Key documentation

1. Risk register with prioritized risks. The use of a risk register, especially when developed from a maintained master risk register, allows for lessons learned from the combined experience of all stakeholders involved in the risk workshop. This is a great advantage over a casual development of the risk register.
2. SRA documentation, including assumptions, methodology, data, data normalization techniques, and findings.
3. A list of people who were interviewed or included in a risk workshop, including their organization, position or expertise.

4. The schedule risk analysis file so the reviewers can perform what-ifs on the SRA.

Impacts

1. If the schedule does not follow best practices in general then there will be a lack of confidence in the SRA results.
2. Without schedule reserve, the project faces the risk of delays to the scheduled completion date if any delays were to occur on critical path activities.
3. Since any task can become critical if it is delayed long enough, complete schedule logic and a comprehensive risk assessment are essential tools for decision makers.
4. Without an SRA, management will not know how likely it is to complete the project on time.
5. An SRA is necessary for determining the amount of schedule risk contingency needed to meet an achievable completion date.
6. Without an SRA, management will not know which risks are most likely to delay the project or how much contingency is required to mitigate the risks.
7. Because activity durations are not certain, the identity of the critical path is not certain. An SRA will identify the paths that are most likely to delay the project (i.e., paths that are "risk critical" and may become critical as the project progresses).
8. If the logic indicates that many paths are to merge into a single activity or milestone, the probability of a task starting on time with a high number of predecessors becomes very low due to the multiplicative product of the probabilities of each of the activities' finishing on time [Merge Bias].

Best Practice 9: Updating the schedule

The schedule should be continuously updated using logic and durations to determine realistic start and completion dates for project activities. The schedule should be analyzed continuously for variances to determine when forecasted completion dates differ from planned dates. This analysis is especially important for those variations that impact activities identified as being on a project's critical path and can impact a scheduled completion date.

The schedule should be correctly updated (or statused) to reflect actual progress on the project. Updating the schedule should occur periodically, usually monthly or weekly. Status updates replace planned dates with actual dates for activities that have started or finished since the last update. This process may replace remaining duration with new estimates of remaining duration. During statusing, the project may experience out-of-sequence progress, or activities that occur in a different sequence than originally planned. Out-of sequence progress should be resolved. If the actual progress implies a slip in the schedule then a recovery plan should be developed. To ensure that the schedule is properly updated, individuals trained in critical path method scheduling should be responsible for statusing the schedule.

Key questions

1. Is the schedule progress recorded periodically? Has the schedule been updated recently as planned? Is the status/data date recorded?
2. Are there any activities with start or finish dates in the past but without actual start or finish dates? Are there any activities with actual start or finish dates in the future?
3. For tasks that are behind schedule as of the status/data date, what is the remaining duration and how will this slip impact succeeding tasks in the network? Is there a plan to recover the schedule slip that is implied?

4. Is responsibility for changing or statusing the schedule assigned to someone who has the proper training and experience in critical path method scheduling?
5. Is there a list of logic changes that were made to the schedule during the update?
6. Is the historical status of the previous update captured by a separate file or some other baseline assignment?
7. Was a written narrative submitted with the schedule update that discusses reasons for delays, logic changes, addition of new activities, deletion of activities, etc.?
8. What are the activity trends, such as missed starts and finishes? Are they increasing or decreasing from the previous update?
9. What are the float trends? Are they increasing or decreasing?
10. What are the actual duration trends? Are they taking longer than planned on the average? Is any specific trade or responsible party suffering this trend?

Key documentation

1. Schedule showing actual and planned dates, remaining duration for in-process activities and the data date
2. List of out-of-sequence (broken logic) activities and plans to resolve the logic
3. Reports of trends such as total float, missed milestones that may indicate problems
4. Copies of project review briefings to check whether schedule status is discussed and consistent with what the schedule is showing and what risk mitigation efforts are underway

Impacts

1. A schedule that has not been updated will not reflect what is actually occurring on the project, and hence may have inaccurate completion dates and critical paths. When this is the case, management cannot use the schedule to monitor progress and make decisions regarding risk mitigation, resource allocations, etc.
2. A schedule with remaining out-of-sequence progress may have the wrong logic in place and hence have inaccurate critical paths and completion dates.
3. Unless the schedule is kept updated, trend reports and analysis that highlight problems will not be useful in mitigating future delays.

Best Practice 10: The Schedule Basis and Baseline Schedule

The Baseline Schedule is the approved project schedule, frozen in time, against which project performance can be measured, compared, monitored and reported. A corresponding schedule basis document explains the overall approach to the project, defines custom fields used in the schedule file, details ground rules and assumptions used in developing the schedule, and provides justifications for constraints, lags, long activity durations, and any other unique features of the schedule.

The effective management of a project is enhanced by the establishment of a baseline of the approved project schedule against which performance can be measured. The baseline schedule can be changed when major scope or performance impacts make the original schedule unachievable, but all changes must be accomplished via a documented and consistently applied change control process. In addition, a schedule basis document should be created along with the baseline schedule that explains the approach, defines how to use the electronic schedule file, and identifies defined fields.

The schedule basis:

a) provides a description of any unique features of the schedule and a description of the change management process
b) should also provide an overview of the assumptions and ground rules used in developing the project schedule,
c) and provides justification for any calendars used and any lags, constraints, or long duration tasks.

Key questions

1. Is the project schedule based upon scheduling best practices?
2. Is the project schedule consistent with the project execution plan?
3. Is there a consensus agreement on the project schedule?
4. Are the responsibilities of the project performers clearly defined and acknowledged? Then, and only then, should the baseline schedule be assigned/designated.
5. Is the baseline schedule the basis for measuring performance?
6. Are changes to the baseline schedule being reviewed and approved consistent with the change control process?
7. Does schedule basis document exist?

Key documentation

1. Designated baseline schedule
2. Change control process
3. Schedule change control log
4. Schedule Basis document

Impacts

1. If there is no formally established baseline schedule to measure performance against, the ability to recognize the impacts of unfavorable performance are difficult to identify and therefore to mitigate.
2. Without a documented, consistently applied schedule change control process, it is possible for project performers to continually revise the schedule to match performance, which hinders the project manager's insight into the true performance of the project.
3. Good documentation helps with analyzing changes in the project schedule and identifying the reasons for variances between estimates and actual results thereby contributing to the collection of cost, schedule, and technical data that can be used to support future estimates.
4. Thorough documentation is essential for validating and defending a baseline schedule. That is, a well-documented schedule can present a convincing argument of a schedule estimate's validity and can help answer decision makers' and oversight groups' probing questions. A well-documented schedule is essential if an effective independent review is to ensure that it is valid and credible.

Project Documentation Checklist

1. The Project Schedule, including all related embedded project schedules (if applicable). These should be in native format (e.g. Microsoft Project .mpp, Primavera P6 .xer, etc.). PDF or PowerPoint files are not considered valid schedule file formats.
2. Schedule dictionary or similar documentation that includes definitions of custom fields, especially those that contain information on level of effort activities; contractor versus Owner effort; and statement of work, statement of objective, work package, integrated master plan, and/or control account mappings.
3. Work Breakdown Structure (WBS) and WBS Dictionary.

4. Statement of Work (SOW) or Statement of Objectives and Mission Requirements.
5. Mapping between the WBS, SOW, and the schedule activities.
6. Identification of the main deliverable(s) including the designation of the path(s) that the project considers critical.
7. Schedule Basis documentation.
8. Basis of Estimate or other documentation used to estimate activity durations and assigned resources.
9. Relevant scheduling guidance, such as contract line item numbers or paragraph references, that govern the creation, maintenance, structure, and statusing of the schedule.
10. Schedule Risk Analysis (SRA) documentation, including the analytical approach, assumptions, and results.
11. Risk Management Plan (Risk Register with mitigation plan) and a copy of current risk watch list.