Project Control with ProTrack

by

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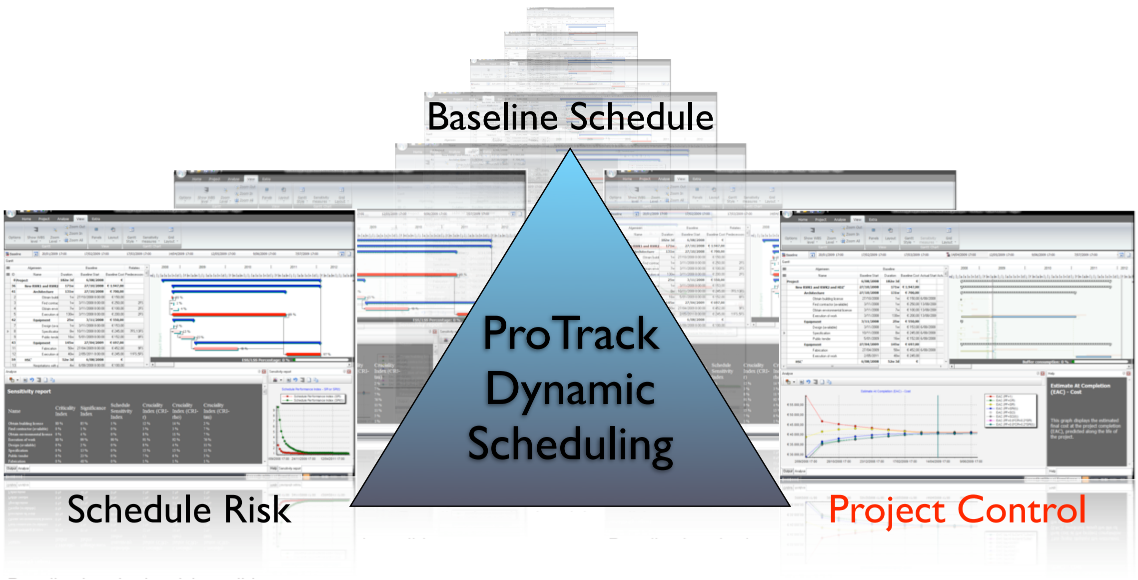

Project control (often referred to as project monitoring or project tracking) is the process performed to observe project execution in order to identify potential problems and/or opportunities in a timely manner such that corrective actions can be taken when necessary. The key benefit is that the current project status is observed on a regular basis, which enables the calculation of the project performance variance that is equal to the gap between actual performance and the baseline schedule. Since the current project performance is measured by variances from the project management plan, the baseline schedule plays a central and unambiguous role during the project tracking process.

ProTrack employs a strict definition of a unique baseline schedule for each tracking period, such that it is always clear during the complete project execution what the active baseline schedule is. ProTrack allows the user to define multiple tracking periods in order to get a clear view of the progress of the project over time. Each tracking period is linked to a unique status date and a corresponding baseline schedule, and measures the current progress up to the status date of the project compared to the active baseline schedule.

Note that the user needs to select a *single baseline schedule* for each tracking period. Consequently, this strict baseline schedule definition guarantees a clear and unambiguous interpretation of the current performance (i.e. the current performance compared to the active baseline schedule at the status date) and guarantees that only one baseline schedule is active at the same time.

Many project control features discussed in this tutorial can be used in all ProTrack versions. However, some specialized features, such as the schedule adherence, forecast accuracy and automatic tracking features discussed later are specifically linked to the **Time Shuttle** option in ProTrack. The Time Shuttle option is available in two ProTrack versions: the Time Shuttle Version and the Smart Version.

1 Tracking periods

ProTrack's project tracking can be done by creating a new tracking period for each review period. These tracking periods appear as tabs above the tracking Gantt chart (see figure 1). Each tab is linked to a unique status date and baseline schedule, and multiple tabs allow the user to get back in time and review previous tracking periods. It is therefore wise and necessary to create a new tab each time a new tracking update is done by the user.

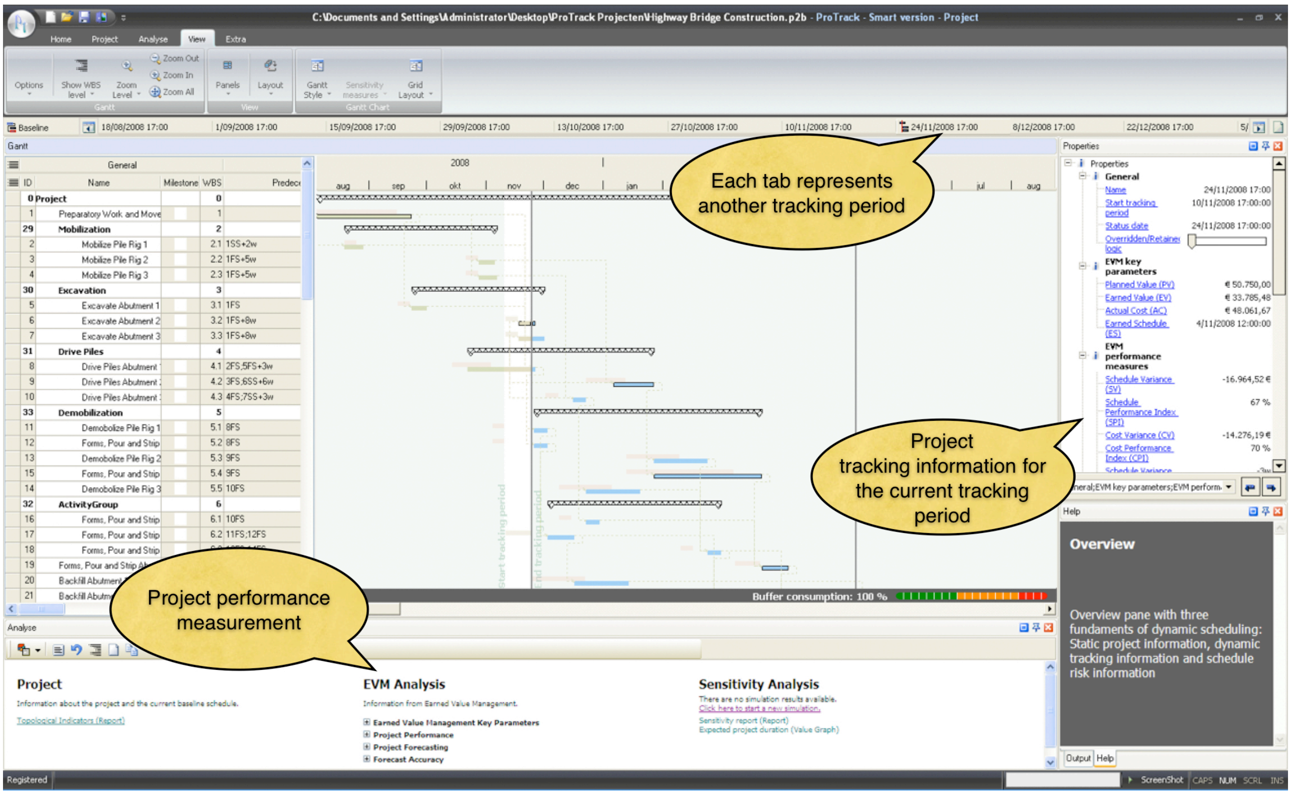

Figure 1. Tracking periods (tabs) in ProTrack

The creation of periodic tracking periods can be done through two manual interventions, as follows:

- Save baseline schedule: After the creation of the first tracking period tab, ProTrack assumes that your project has started. Consequently, the baseline schedule, which serves from this moment on as a point-of-reference for project control, cannot be changed anymore. Click on **Project - Save Baseline**.
- Create new tracking period: Each time a period is closed, the user can define a new project tracking period. In doing so, ProTrack allows the user to save intermediate tracking periods to see the evolution of the project progress over time. Click on **Project - Add Period**.

After saving the baseline, the user can periodically create tracking tab periods to enter updated information of the project progress. It is wise and necessary to create a new tracking period tab for each progress update. In doing so, the user can always go back in time to previous tabs to see the evolution of his/her project's progress. Moreover, all performance and earned value graphs (see section “3 EVM Analysis”) will calculate progress information for each tab you create. Consequently, the more you periodically update your project's progress, the more data points and the more reliable your performance graphs will be.

Each tracking period is characterized by a start date and an end date. The start date is equal to the project start for the first tracking period or equal to the end date of the previous tracking period for all other project tracking periods. The end date, known as the status date (i.e. the day on which the project status has been finished) needs to be approximated at the creation of each tracking period, and needs to be changed and confirmed when finishing the tracking period (i.e. upon creation of a new tracking period). This simple method is outlined in figure 2.

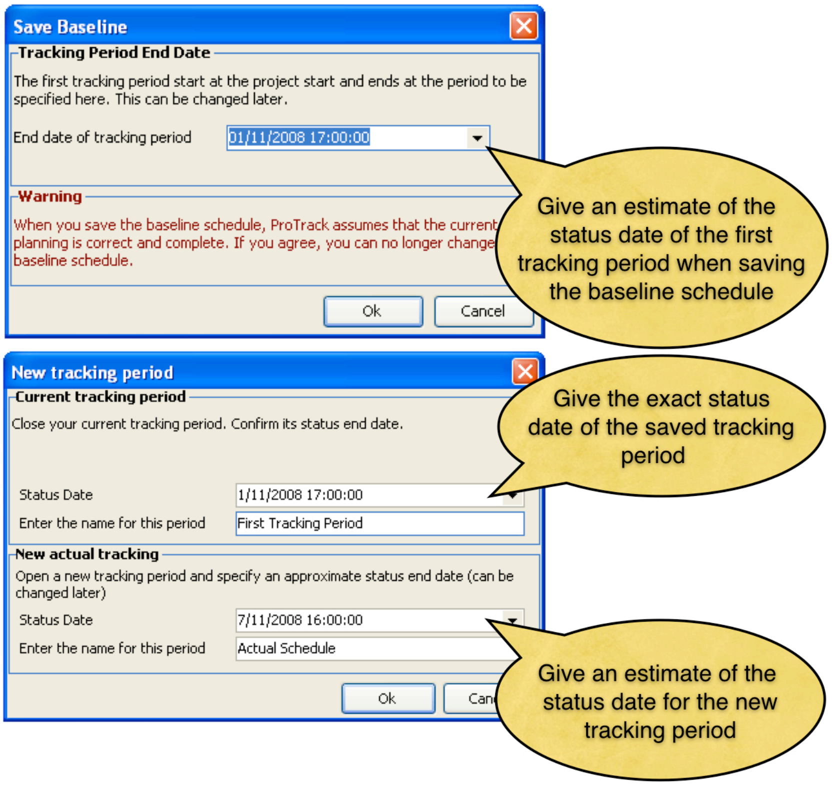

Figure 2. Setting the status date in ProTrack (saving the baseline schedule or creating a new tracking period)

Each project tracking period tab contains data about the progress of the project which will be used to update the tracking Gantt chart prediction (section 2) and to measure project performance and predict future project behavior using Earned Value Management (see section 3). Correct earned value based calculations depend on the quality and accuracy of the input parameters, which can be summarized along the following lines:

- **Actual Start**: Actual starting time of an activity on or before the status date which might differ from the original baseline start time.
- **Actual Duration (AD)**: The time spent on an activity between its actual start time and the current status date. Hence, the actual duration can be smaller than, equal to or larger than the time span between the actual start and the current status date, and is used to represent the workload already spent on this activity until now.
- **Remaining Duration (RD)**: A forecast of how many time units (hours, days, weeks, years) an activity will need from the status date forward to finish its remaining work.
- **Actual Cost (AC)**: The actual cost for the work already done. Normally, this actual cost should have a clear relation with the workload already done by the various resources as given by the actual duration, but the user is free to adapt the actual cost to any monetary value.

- **Remaining Cost (RC)**: A forecast of how many additional monetary resources (euro, dollars, ...) an activity will need to finish the portion of remaining work.
- **Percentage Completed (PC)**: The portion of the total workload that is estimated to be finished. The Earned Value metric EV is based on this estimate as EV = PC * BAC (with BAC = Budget At Completion). Note that neither the actual/remaining duration nor the actual/remaining cost need to have a link with the PC estimate and will not be explicitly used for the calculation of the EV metric. More information is given in section 5.

Note that some of these project tracking key metrics can be calculated automatically using ProTrack's predefined EVM input models. These Project Tracking input models can be accessed from Extra - Input Models, and will be discussed in section 5 "Advanced Options".

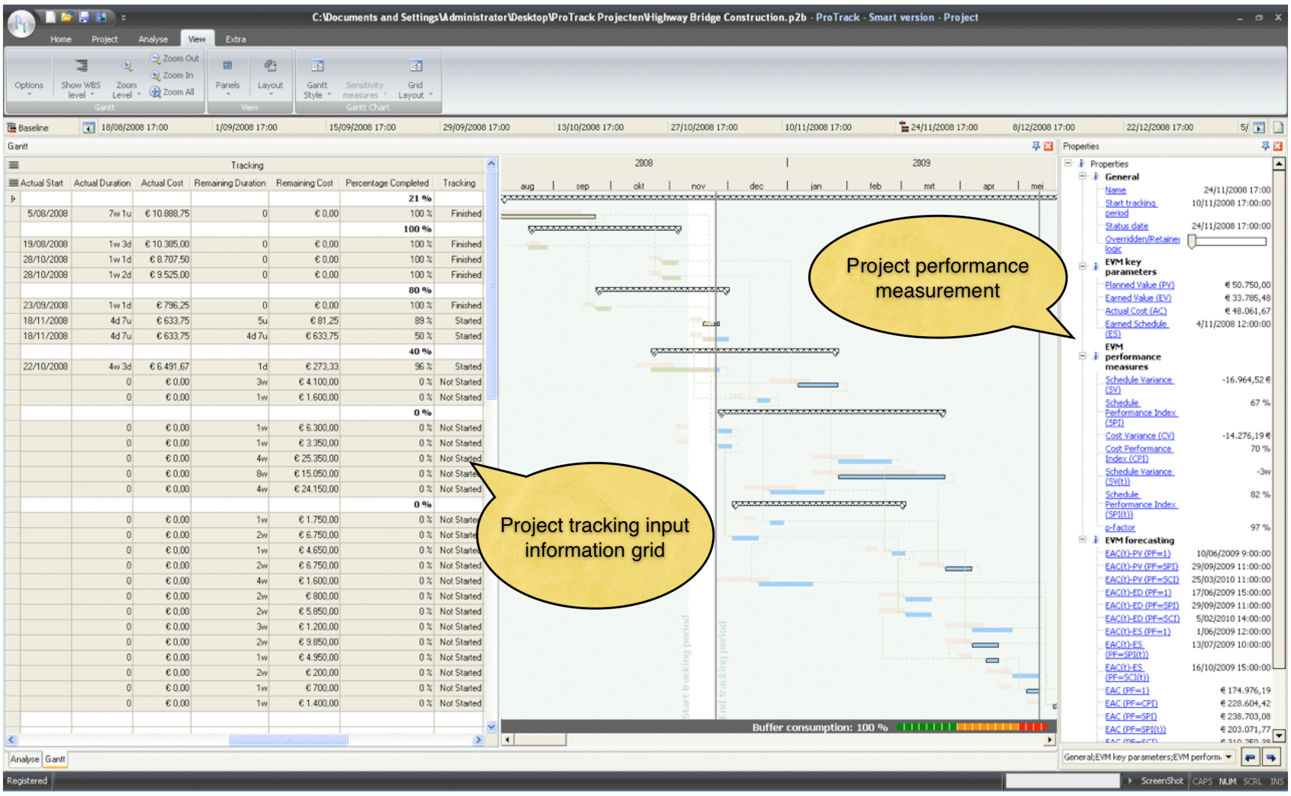

Figure 3. Tracking grid and tracking Gantt chart views

Note

- ✳ You can easily switch between the baseline schedule data and the tracking period data by clicking on **View - Grid Layout.** The best view to monitor the progress of your project can be obtained at **View - Grid Layout - Default Tracking**.
- ✳ Once project tracking has started, the baseline schedule can no longer be changed. Delete all tracking periods to change the baseline schedule again.

2 Schedule predictions

One of the primary tasks during project tracking is periodically updating the baseline schedule to reflect the actual progress of the work done and to present a realistic forecast of the remaining work. The tracking Gantt chart gives a prediction of the future schedule based on the inputs of actual and remaining durations/costs. However, it is important to realize that the schedule prediction of the tracking Gantt chart discussed here might differ from the schedule predictions using Earned Value Management (see the EAC(t) formulas of section 3). Both contain a schedule prediction but differ as follows:

- **Tracking Gantt chart prediction**: The schedule prediction displayed in the tracking Gantt chart displays the remaining project schedule, given the actual start dates of the started activities and their actual and remaining durations. The remaining duration of the unstarted activities is equal to their baseline duration.
- **Earned Value Analysis prediction**: The schedule predictions using the EVM metrics of section 3 completely rely on the percentage completed (PC) estimates and their corresponding earned value metrics. Obviously, the PC estimate might completely differ from the actual and remaining duration estimates.

Since work is often performed *out-of-sequence*, the original logic captured by the precedence relations between activities as specified in the baseline schedule is often violated. This situation can cause unrealistic deviations between the baseline scheduling logic and the project tracking Gantt chart, and often leads to unnecessary adaptations and modifications to the baseline schedule. ProTrack has two options to handle out-of-sequence progress during the tracking phase, as follows:

- **Retained logic** assumes that the original precedence relations are still valid, even when activity overlaps during progress have taken place. This logic respects all precedence relations of the remaining work, but often leads to unrealistic long project duration forecasts.
- **Overridden logic** assumes that an activity that started with a certain overlap will violate the original precedence relation logic completely. This logic assumes that the remaining work of an activity in progress can be done without being affected by its incomplete predecessor activities, but it often leads to unrealistic short project duration forecasts. This logic is also known as out-of-sequence progress.

While the option between the retained and overridden logic is standard in most commercial software tools, ProTrack has extended this option to all possibilities in-between these two extremes:

- **Overridden/Retained logic percentage**: Since both the overridden and the retained logic display a schedule forecast taking both the actual activity durations (the work done) and the remaining activity durations (the work yet to be done) into account, ProTrack has the option to construct a schedule forecast for the remaining work yet to be done in between the overridden and retained logic. Motivated by the observation that the Gantt chart of the remaining work is nothing more but a schedule forecast, the option to shift between the two extreme logics allows the user to fine-tune the forecast according to his/her own wishes. A simple slider, similar to the ESS/LSS slider (see the “Project Baselining with ProTrack” tutorial), gradually shifts the tracking Gantt chart from an overridden logic to a retained logic situation. This overridden/retained logic slider plays an important role in the buffer management approach set during the scheduling phase. During the project scheduling phase, a buffer is set as a well-considered choice of a certain degree of safety time on top of the project duration. This buffer acts as a simple project tracking dashboard, since project tracking leads to possible buffer consumption and hence visualizes the likelihood of violating the predefined deadline. The options between the overridden and retained logic obviously affects the buffer consumption and can be used to predict and influence the estimated project finish.

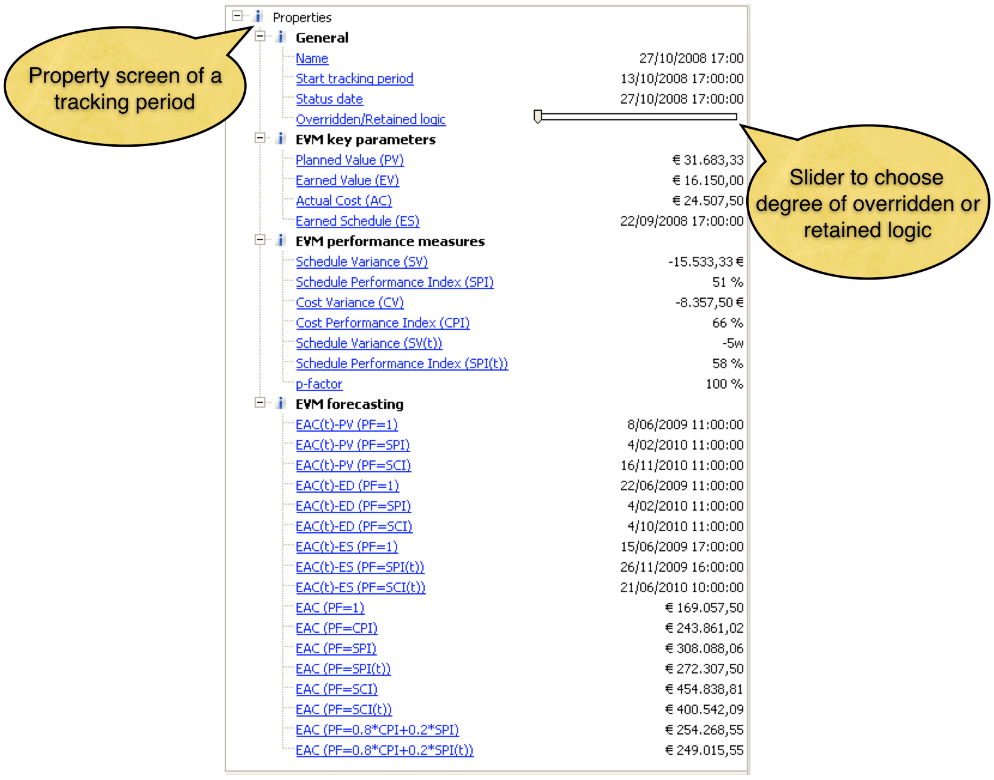

Figure 4. Retained versus Overridden logic in ProTrack

Note

- ProTrack offers two alternative views on the project progress Gantt chart. The default view can be shown via the **View - Gantt Style - Tracking View** menu and shows two Gantt charts in one screen. The progress Gantt chart shows the progress of the activities that are completed or in progress and shows a prediction of future work as discussed in this section. Moreover, this view also shows the original baseline schedule (displayed in light at the background) for comparison purposes. Alternatively, the **View - Gantt Style - Baseline ES View** menu transforms the progress data into a single Gantt chart and shows the time progress relative to the baseline schedule. This view serves as an ideal tool to monitor your time progress relative to the baseline schedule, as measured by the Earned Schedule (ES) metric as discussed in section 3. This Gantt chart view is discussed in the 'schedule adherence' topic of section 3.2.

3 EVM Analysis

Earned Value Management (EVM) systems have been set up to deal with the complex task of controlling and adjusting the baseline project schedule during execution, taking into account project scope, timed delivery and total project budget. It is a well-known and generally accepted management system that integrates cost, schedule and technical performance and allows the calculation of cost and schedule variances and performance indices and forecasts of project cost and schedule duration. The earned value method provides early indications of project performance to highlight the need for eventual corrective actions

The ProTrack tracking options mainly follow the standard EVM principles and techniques described in numerous references. Many of the ProTrack EVM features have been implemented in most standard software tools, but others are completely new and rely on the results of a large Earned Value simulation study. The main EVM features are briefly summarized along the following lines:

- **Earned Value Management**: Automatic calculation of the standard EVM key metrics and extensions to earned schedule project tracking and performance measurement.
- **Schedule adherence**: Automatic calculation of the p-factor to dynamically measure schedule adherence.
- **Time/Cost forecasting**: EVM forecasting based on the three methods presented throughout literature.
- **Forecast accuracy**: ProTrack is an ideal EVM learning tool and contains simulation engines to simulate fictive project progress to measure the accuracy of time and cost forecasts.
- **Gantt chart tracking**: A choice between retained logic and overridden logic (all intermediate levels inclusive) to predict the remaining work shown in a tracking Gantt chart (see section 2). This Gantt chart can replace the current baseline schedule (i.e. re-baselining) when necessary.
- **Reporting**: A wide range of flexible reports customized with various logos can be easily made.

Table 1 summarizes the EVM measures used in ProTrack, classified in the Earned Value Management Key Parameters, the metrics to measure the Project Performance, the Project Forecasting techniques (both for time and cost) and the Forecast Accuracy metrics to measure the quality of the forecasts. These four EVM classes are discussed along the following subsections. All measures are available via the **Analyse - Overview** menu.

Table 1. EVM measures used in ProTrack

Graph name	Meaning
Earned Value Management Key Parameters	
S-curve	This graph displays the Planned Value (PV), the Actual Cost (AC) and Earned Value (EV) along the life of the project.
PV curve	This graph displays the Planned Value (PV) as shown in the S-curve. Since the Planned Value curve is available at the construction of the baseline schedule (before the EVM tracking), this graph is accessible separately from the S-curve.
Quick EVM overview	Gives all performance measurement information.
Earned Schedule (ES)	This graph displays the Earned Schedule (ES) calculated from the Earned Value and Planned Value graph along the life of the project.
Project Performance	
EVM Performance Dashboard	This graph displays both the time and cost performance and divides the project performance into four regions showing time and cost performance.
Cost Variance (CV)	This graph displays the Cost Variance (CV = AC - EV) along the life of the project.
Cost Performance (CPI)	This graph displays the Cost Performance Index (CPI = AC / EV) along the life of the project.
Schedule Variance (SV and SV(t))	This graph displays the Schedule Variance (SV or SV(t)) along the life of the project. Formulas used: SV = PV - EV and SV(t) = ES - AT.
Schedule Performance (SPI and SPI(t))	This graph displays the Schedule Performance Index (SPI or SPI(t)) along the life of the project. Formulas used: SPI = EV / PV and SPI(t) = ES / AT.

Graph name	Meaning
Schedule Adherence (p-factor)	This graph displays how good the project progress follows the baseline schedule philosophy. This is known as schedule adherence and measures by the p-factor. Tip: p-factor = % schedule adherence (100% = perfect adherence).
Project Forecasting	
Cost Estimate At Completion (EAC)	This graph displays the estimated final cost at the project completion (EAC) predicted along the life of the project. Eight forecasting versions are used, in line with research from literature.
Time Estimate At Completion (EAC(t))	This graph displays the estimated final duration at the project completion (EAC (t)) predicted along the life of the project. Three methods are used (PVM, EDM and ESM), each using three variants (see table 2).
EAC(t) report	This report shows a summary of the nine time forecasting methods (EAC(t)) at a certain point during the progress of the project.
Forecast Accuracy	
MAPE	This graph displays the Mean Absolute Percentage Error as a measure of the forecast accuracy of time predictions.
MPE	This graph displays the Mean Percentage Error as a measure of the forecast accuracy of time predictions.

3.1 Key Parameters

EVM relies on three key parameters which can be shown in one graph, known as the *S-curve*. These three parameters are:

- The **Planned Value (PV)**: Time-phased budget baseline as an immediate result of the baseline schedule, often called the Budgeted Cost of Work Scheduled (BCWS).
- The **Actual Cost (AC)**: The cumulative actual cost spent at a given status date, often referred to as the Actual Cost of Work Performed (ACWP).
- The **Earned Value (EV)**: Represents the amount budgeted for performing the work that was accomplished by a given status date, often called the Budgeted Cost of Work Performed (BCWP) and equals the total activity (or project) budget at completion multiplied by the percentage activity (or project) completion (PC) at this particular point in time (= PC * BAC).

ProTrack incorporates a fourth EVM metric derived from the PV and EV metrics, known as the Earned Schedule metric, as follows:

- The **Earned Schedule (ES)**: Translation of the EV of a given status date into time units by determining when this EV should have been earned in the baseline schedule.

Consequently, the Earned Schedule metric measures your project progress in a time dimension and varies between 0 time units (at the start of the project) to the baseline Planned Duration (PD) at the end of the project. Hence, at the end of the project, EV = PV and ES = PD.

The AC, EV and ES metrics are gradually built up by adding tracking periods and updating project progress over time. The PV metric, however, is built during the baseline scheduling phase, and is therefore accessible via a separate graph under the **Analyse - Show Graph - EVM Key Parameters - PV Curve** menu.

These EVM metrics can be summarized in the Quick EVM overview or can be displayed through various graphs, as shown in figure 5.

Figure 5. EVM key parameters in ProTrack

Note

- The Planned Value graph can be graphically displayed and changed by making changes at the baseline schedule. Easy and quick modifications can be done by shifting between an Earliest Start Schedule (ESS) and a Latest Start Schedule (LSS) (see baseline property screen) which allows you to investigate your cash outflow position under different baseline scenarios. More information can be obtained from the "Baseline Scheduling with ProTrack" tutorial.
- A more detailed graph view can be obtained by marking a part of the graph with the mouse from the left upper corner to the right bottom corner.

3.2 Performance measurement

Project performance, both in terms of time and costs, is determined by comparing the key parameters PV, AC, EV and ES, resulting in four well-known performance measures.

- **Cost Variance (CV)**: Shows the variance in cost (AC - EV) expressed in monetary terms
  - > 0: over budget
  - = 0: on budget
  - < 0: under budget
- **Schedule Variance (SV)**: Shows the variance in time (PV - EV) expressed in monetary terms
  - > 0: project ahead of schedule
  - = 0: project on time
  - < 0: project delay

- **Cost Performance Index (CPI)**: Shows the performance of cost (AC / EV) in a unitless dimension
  > 100%: over budget
  = 100%: on budget
  < 100%: under budget
- **Schedule Performance Index (SPI)**: Shows the performance of time (PC / EV) in a unitless dimension
  > 100%: project ahead of schedule
  = 100%: project on time
  < 100%: project delay

Since the Earned Value metric EV is always equal to the Planned Value metric PV at the end of the project, the SPI always ends at 100%, regardless of the real project state (early, on time or late). This unreliable trend of the SPI has been the topic of many discussions and research projects[1] , which has eventually resulted in two new time measures, similar to the SV and SPI, as follows:

- **Schedule Variance (SV(t))**: Shows the variance in time (ES - AT) expressed in monetary terms
  > 0: project ahead of schedule
  = 0: project on time
  < 0: project delay
- **Schedule Performance Index (SPI(t))**: Shows the performance of time (ES / AT) in a unitless dimension
  > 100%: project ahead of schedule
  = 100%: project on time
  < 100%: project delay

with AT = the current Actual Time, which is given by the *status date* of the tracking period tab. Example graphs are given in figure 6.

[1] See the articles by Lipke (Schedule is different. The Measurable News, Summer:31-34, 2003) and by Vandevoorde and Vanhoucke (A comparison of different project duration forecasting methods using earned value metrics. International Journal of Project Management, 24:289-302, 2006).

Figure 6. Project performance measurement (time and cost) in ProTrack

Time and cost performance can be shown in a single graph using the **Analyse - Show Graph - EVM Performance Measures - EVM Dashboard** menu (figure 7). The dashboard displays the CPI and SPI(t) evolution for the different tracking periods.

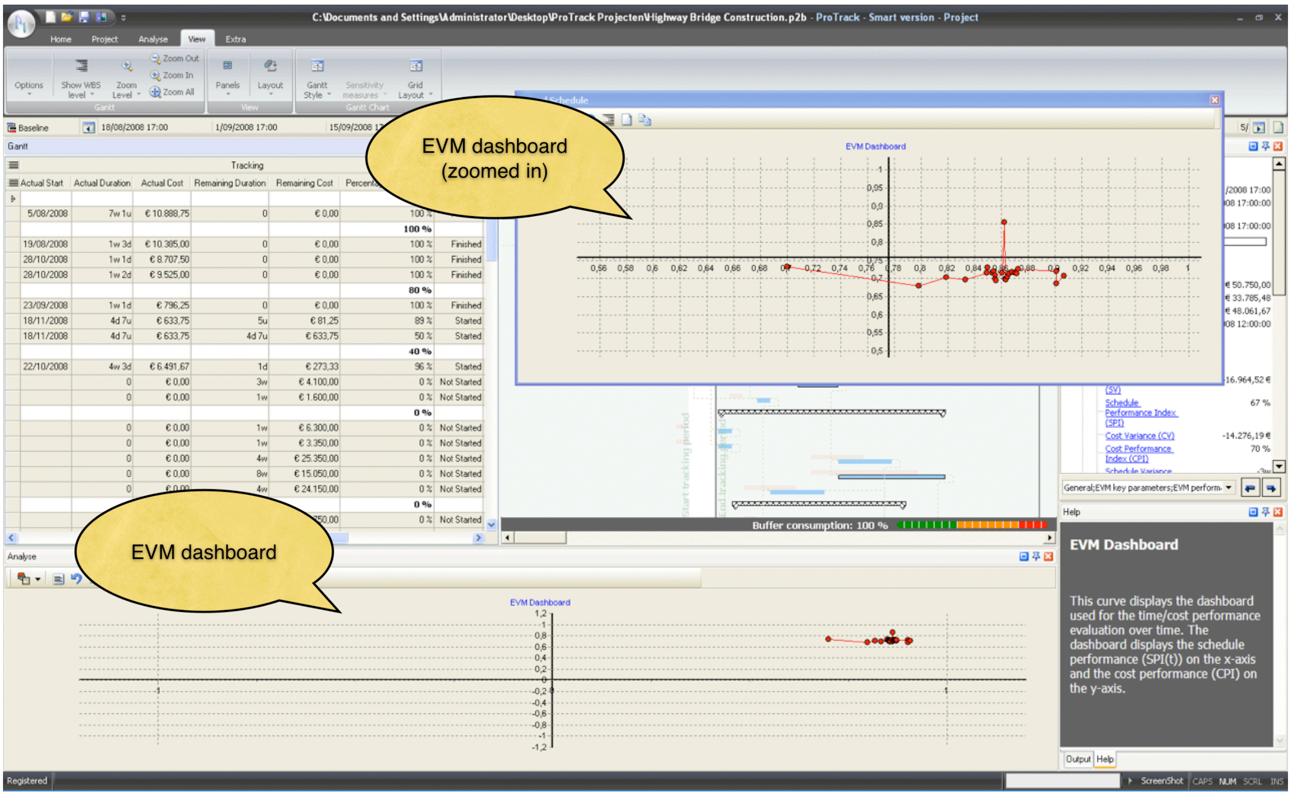

Figure 7. EVM dashboard in ProTrack

ProTrack's performance measurement contains a new EVM concept, known as Schedule adherence[2], which completely relies on the ES definition. It is measured by the p-factor metric and makes the connection of project output to EVM, as follows:

- **Schedule adherence (p-factor)**: Ratio of the Earned Value corresponding to the baseline schedule at time period ES divided by the total planned value at time period ES.

The p-factor measures adherence to the baseline schedule relative to the current time performance measured by the ES. It shows to what degree the baseline schedule logic is followed at the time period measured by the ES metric. More precisely, it is equal to the ratio of the Earned Value corresponding to the baseline schedule (i.e. if the current activity EV exceeds the activity PV at the time period ES, the EV is limited to the corresponding PV at time ES) divided by the total planned value at time instance ES. Since the nominator takes the minimum of the planned value at time unit ES and the earned value accrued at the actual time, the p-factor obviously always lies between zero and one, inclusive. Hence, the p-factor measures to what degree the earned value is accrued according to the baseline schedule (100% means a perfect schedule adherence).

The alternative tracking Gantt chart view can be shown by clicking on the **View - Gantt Chart - Baseline ES view** menu (figure 8). It shows the difference between the status date and the Earned Schedule metric (i.e. the SV(t)) and reveals that the project is behind (ES < Status Date) or ahead (ES > Status Date) of schedule, as well as the adherence of the current work done relative to the ES metric. The black bars show the EV accrue for the individual activities, which can lie to the left or to the right of the ES line. The p-factor is equal to the portion of earned value accrued in congruence with the baseline schedule, i.e. the tasks which ought to be either completed or in progress. A perfect (i.e. 100%) schedule adherence should show a Gantt chart where the EV accrue ends at or exceeds the ES line for all project activities.

[2] Based on an article written by Lipke (Connecting earned value to the schedule. The Measurable News. Winter:1, 6–16, 2004).

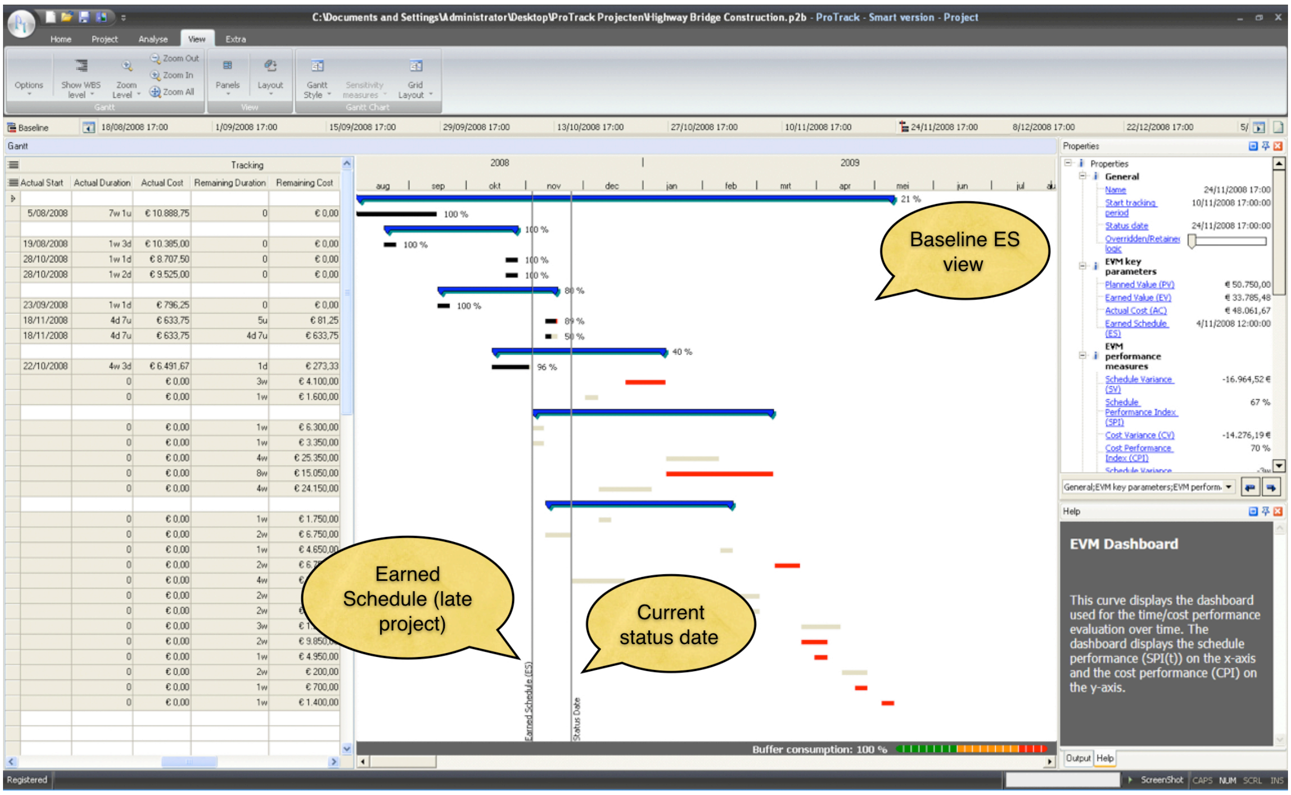

Figure 8. Baseline Earned Schedule view

3.3 Predictions

EVM uses the current project performance, measured by the SPI and SPI(t) metrics for time and the CPI for cost, to predict the final duration and cost of a project. The general abbreviations to forecast time and cost in ProTrack are as follows:

- Expected At Completion - Cost (EAC): Forecast of total project cost at the current status date, which might be different from the original budget or Budget At Completion (BAC).
- Expected At Completion - Time (EAC(t)): Forecast of final project duration at the current status date, which might differ from the baseline Planned Duration (PD).

All EAC and EAC(t) predictions can be shown on graphs or a report for each tracking period can be generated via the **Analyse - Show Graph - EVM Forecasting** menu (see figure 9).

Figure 9. Time and cost predictions in ProTrack

3.3.1 Time forecasting EAC(t)

Predicting the final duration of the project during its progress is one of the main targets of EVM. ProTrack relies on 3 forecasting methods, and each method can be used under 3 versions (see table 2). Each version relies on another performance factor (PF) which refers to the assumption about the expected performance of the future work, as follows:

- PF = 1: Future performance is expected to follow the baseline schedule.
- PF = SPI or SPI(t): Future performance is expected to follow the current time performance.
- PF = SCI or SCI(t)[3]: Future performance is expected to follow the current time and cost performance.

All these methods provide an estimate for the total project duration, and offer a range of possibilities and hence a lower and upper bound on your predicted total time. The choice of a specific forecasting method depends on project, your expertise and many other unknown factors. Information on the quality of the EAC(t) forecasts can be found in literature[4] or can be obtained by using the Time Shuttle option as discussed in section 4.

[3] SCI = Schedule Cost Index (SCI = SPI * CPI and SCI(t) = SPI(t) * CPI)

[4] See the article by Vanhoucke and Vandevoorde (A simulation and evaluation of earned value metrics to forecast the project duration, Journal of the Operational Research Society, 58, 1361–1374, 2006).

Table 2. Time predictions in ProTrack

Forecasting method	Version 1: according to plan	Version 2: according to current time performance	Version 3: according to current time/cost performance
Planned Value Method (PVM)	$EAC(t)_{PV}$ (PF = 1)	$EAC(t)_{PV}$ (PF = SPI)	$EAC(t)_{PV}$ (PF = SCI)
Earned Duration Method (EDM)	$EAC(t)_{ED}$ (PF = 1)	$EAC(t)_{ED}$ (PF = SPI)	$EAC(t)_{ED}$ (PF = SCI)
Earned Schedule Method (ESM)	$EAC(t)_{ES}$ (PF = 1)	$EAC(t)_{ES}$ (PF = SPI(t))	$EAC(t)_{ES}$ (PF = SCI(t))

3.3.2 Cost forecasting EAC

Predicting the final cost of the project during its progress can be easily done in ProTrack using four main predefined methods. Most of these methods have been validated in literature, and are summarized in table 3. Each method relies on another performance factor (PF) which refers to the assumption about the expected performance of the future work, as follows:

- PF = 1: Future performance is expected to follow the baseline schedule (version 1).
- PF = SPI or SPI(t): Future performance is expected to follow the current time performance (version 2).
- PF = CPI: Future performance is expected to follow the current cost performance (version 3).
- PF = SCI or SCI(t): Future performance is expected to follow the current time and cost performance. This method can be used under two versions, i.e. PF is equal to the current SCI performance (version 4) or to a weighted time and cost performance (version 4').

Note that versions 3, 4 and 4' can be used under the traditional Schedule Performance Index (SPI) assumptions, or with the new Earned Schedule based Schedule Performance Index (SPI(t)). All these methods provide an estimate for the total predicted cost at the end of the project, and offer a range of possibilities and hence a lower and upper bound on what you can expect to spend on your project. The choice of a specific forecasting method depends on project, your expertise and many other often unknown factors.

Table 3. Cost predictions in ProTrack

<table>
<tr><th></th><th>Version 1: according to plan</th><th>Version 2: according to current cost performance</th><th>Version 3: according to current time performance</th><th>Version 4: according to current time/ cost performance</th><th>Version 4': according to weighted time/cost performance</th></tr>
<tr><td>Traditional SPI</td><td rowspan="2">EAC (PF = 1)</td><td rowspan="2">EAC (PF = CPI)</td><td>EAC (PF = SPI)</td><td>EAC (PF = SCI)</td><td>EAC (PF = 0.8*CPI + 0.2 SPI)</td></tr>
<tr><td>Traditional SPI (t)</td><td>EAC (PF = SPI (t))</td><td>EAC (PF = SCI (t))</td><td>EAC (PF = 0.8*CPI + 0.2 SPI(t))</td></tr>
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3.4 Forecast accuracy

Predicting the total time and cost of a project using the different EAC and EAC(t) formulas might be subject to errors, and the quality of the predictions depends on many factors (quality of input data, characteristics of the project, etc.). The study "Measuring Time - An Earned Value Simulation Study" has measured the quality of time predictions, known as the forecast accuracy, using an extensive simulation study. The study has been awarded by the Belgian chapter of the Project Management Institute (the research collaboration fund of PMI Belgium[5]) and the International Project Management Association (the IPMA 2008 research award[6]).

ProTrack has built a **Time Shuttle** option (see next section) to incorporate the research simulation study by connecting the two simulation engines (the standard and advanced simulation engines as discussed in the "Schedule Risk Analysis with ProTrack" tutorial) with the EVM analysis tool discussed here. The forecast accuracy is measured by the difference between all predictions along the project progress (the EAC(t) formulas) and the final real project duration, and reports two accuracy measures:

- Mean Absolute Percentage Error (MAPE): Average absolute deviation between all EAC(t) forecasts and the final project duration (lower values denote higher forecast accuracy).
- Mean Percentage Error (MPE): Average deviation between all EAC(t) forecasts and the final project duration (negative values denote average underestimates and positive values denote average overestimates).

The forecast accuracy study allows the user to measure how accurate the different EAC(t) project duration forecasts will be for their specific project under different controlled circumstances. In this respect, ProTrack serves as an ideal learning tool for practitioners and academics to learn how EVM predictions vary under specific project circumstances. The MAPE and MPE results are illustrated in figure 10.

[5] See the PMI Research Collaboration Fund (2007) at www.pmi-belgium.be

[6] See the IPMA Research Awards (2008) at www.ipma.ch

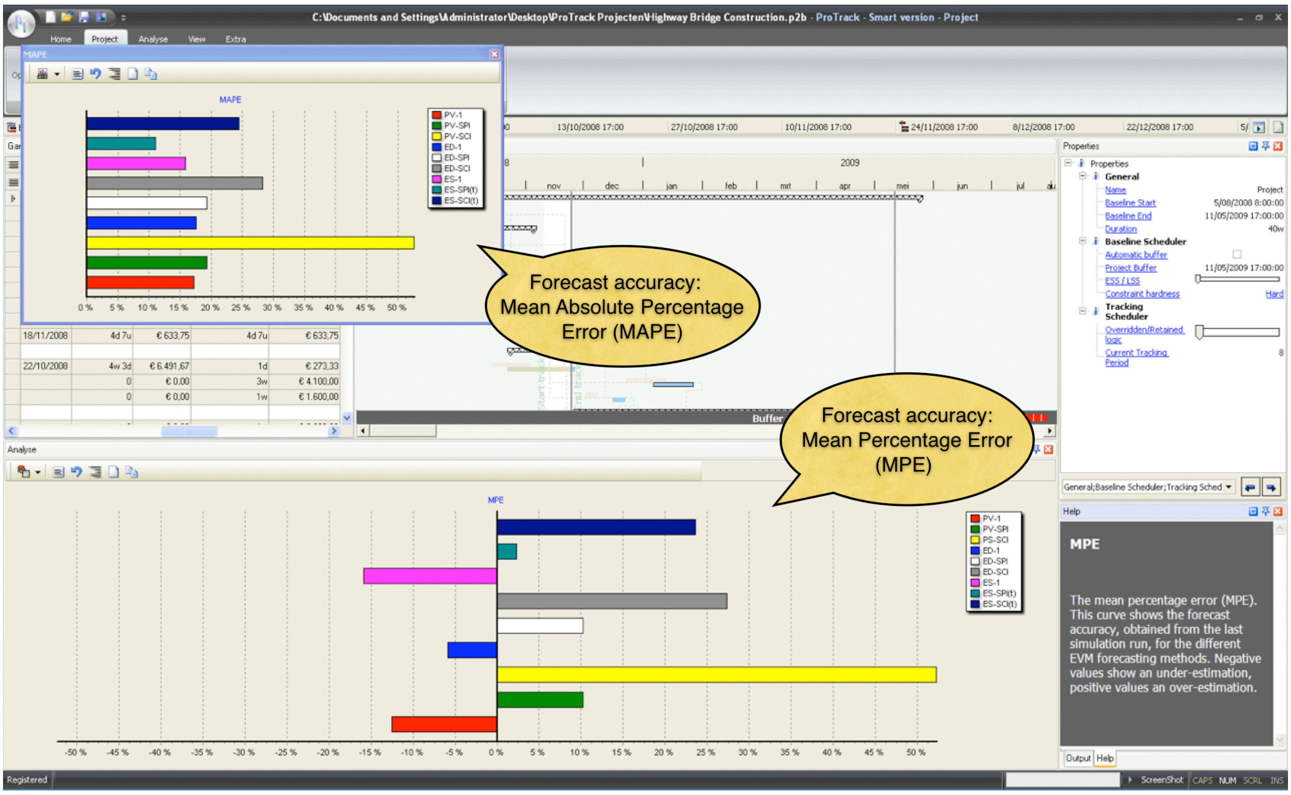


Figure 10. Time forecast accuracy results in ProTrack

The Time Shuttle option integrates Schedule Risk Analysis (see the "Schedule Risk Analysis with ProTrack" tutorial) with Earned Value Management (this tutorial), and is discussed in the next section.

4 Time Shuttle

ProTrack's Time Shuttle allows the user to perform a project performance and forecast accuracy study using Earned Value Management as well as generate automatic project tracking reports. The Time Shuttle can be accessed by means of the two simulation engines incorporated in the simulation screen of ProTrack. Both engines serve different needs, and can be accessed by a simple click on **Project - New Simulation - Simulation Type**. Details and specific features of both engines are described in the "Schedule Risk Analysis with ProTrack" tutorial.

- **Standard simulation engine**: Allows the user to start a quick and easy simulation tool without a thorough study on the risk profiles of the various project activities.
- **Advanced simulation engine**: Requires a more detailed risk quantification for each project activity, and constitutes the heart of the schedule risk analysis in ProTrack.

The Time Shuttle option connects the two simulation engines with the tracking periods of the project control phase, and can be used for two purposes:

- **Forecast accuracy study**: The Time Shuttle option allows to replicate simulation studies for specific projects to measure the quality of the time predictions using the nine EAC(t) formulas by reporting the MAPE and MPE as discussed earlier (see section 4.1).
- **Automatic tracking**: Creation of automatic fictive tracking periods to create artificial project progress and fictive EVM graphs and reports that serve as a learning tool for your project (see section 4.2).

Table 4 displays a summary graph showing the two different simulation engines and their relation to the Sensitivity Scan and the Time Shuttle option. In the next subsections, only the Time Shuttle option is discussed.

Table 4. The relation between ProTrack's simulation engines and its Sensitivity Scan and Time Shuttle options

	Sensitivity Scan	**Time Shuttle**
Standard Simulation	Use one of the 9 predefined simulation scenarios in order to scan the sensitivity of all project activities (Time Shuttle option will be automatically on).	Use one of the 9 predefined simulation scenarios in order to measure the EAC(t) forecast accuracy or to generate automatic tracking periods.
Advanced Simulation	Use the distribution drawer to define activity duration uncertainty in order to scan the sensitivity of all project activities.	Use the distribution drawer to define activity duration uncertainty in order to measure the EAC(t) forecast accuracy or to generate automatic tracking periods.
	See the "Schedule Risk Analysis with ProTrack" tutorial.	See the "Project Control with ProTrack" tutorial.

4.1 Forecast accuracy

A forecast accuracy study makes use of the simulation engines that are accessible by clicking on **Project - New Simulation - Simulation Type**. The properties screen lets you choose between the **Standard Simulation** or **Advanced Simulation** engines, as explained in the "Schedule Risk Analysis with ProTrack" tutorial.

The forecast accuracy calculations can be called by putting the **Time Shuttle (EVM)** option on. In the settings of the properties screen, the user can change the **Number of Runs** from 100 (default) to another value.

The properties screen contains three Time Shuttle settings as follows:

- Tracking Interval: Defines the number of tracking periods for each individual project simulation run.
- % Completion Start: Defines the starting point to track your project expressed as a percentage completed (PC = EV / BAC). The default start is set at 0%, which denotes that all EVM calculations start at the beginning of the project.
- % Completion Finish: Defines the starting point to track your project expressed as a percentage completed (PC = EV / BAC). The default start is set at 100%, which denotes that all EVM calculations finish at the completion of the project.

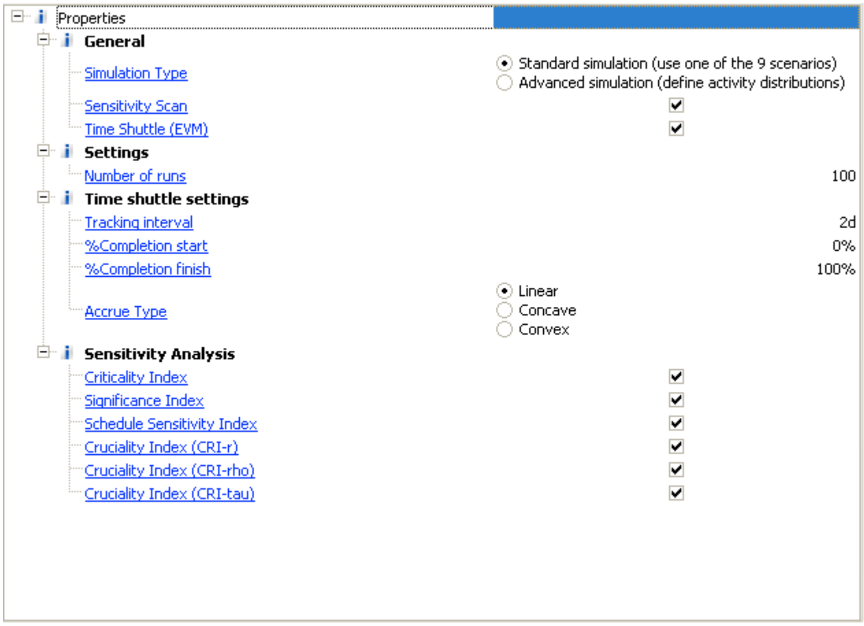


Figure 11. Simulation properties in ProTrack

☝ **Note** ☝

- ✳ Beware of changing the number of simulation runs to high values. The simulation engines of the Time Shuttle repetitively simulate project progress by creating tracking periods and calculating all EVM metrics to measure the quality of the EAC(t) predictions under controlled simulation scenarios. Consequently, the time shuttle requires extensive computations which can lead to a high CPU time.
- ✳ Beware of small Time Shuttle tracking intervals. The interval between tracking periods determines the total number of tracking periods per simulation run and consequently influences the computational burden of the Time Shuttle. As a general rule of thumb, it is wise to follow the suggestion proposed by ProTrack to keep the number of tracking periods to a reasonable number.
- ✳ The interval between % Completion Finish - % Completion Start is default 100%, which denotes that the EVM metrics are calculated along the whole project progress. It is, however, possible to reduce that interval to smaller time windows, to measure the accuracy at certain time regions of the project life. Beware that the interval can be put so small that it contains no observations. In this case, the forecast accuracy variables MAPE and MPE will be misleading or will simply not exist.

4.2 Automatic tracking

The Time Shuttle can be used to create automatic tracking periods that allows the user to learn how the tracking input and EVM outputs work and interact for a specific project example. Since ProTrack's project tracking approach relies on EVM, the automatic tracking period option only works with the standard simulation engine that allows a choice between 9 simulation scenarios using the SPI(t) indicator. Details and specific features of the standard simulation engine are discussed in the "Schedule Risk Analysis with ProTrack" tutorial.

The automatic tracking option can be accessed via the **Project - Simulate Tracking** menu that displays the standard simulation engine with the 9 simulation scenarios. At the bottom of this screen, the user can define a tracking interval between which tracking information will be generated.

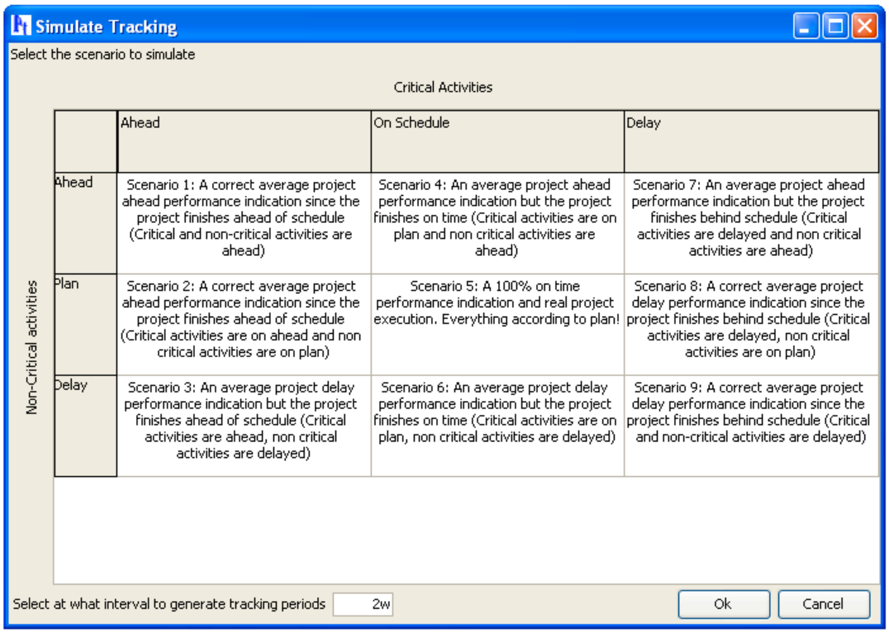


Figure 12. Automatic project tracking: the standard simulation engine screen

5 Advanced options

Project tracking can be a time intensive task when every activity needs a periodic update. Moreover, the EVM calculations rest on a number of assumptions which need to be followed to make the EVM output understandable and relevant. ProTrack has incorporated a number of EVM input models to assure that most assumptions are automatically checked and to facilitate the manual input for the user.

The EVM input models are optional and can be accessed via the Extra - Input Models menu. ProTrack contains five input models that can be optionally selected to support and facilitate the project tracking phase.

- **EVM Validation Model**: This validation model contains general tracking rules that need to be followed in order to assure that the EVM interpretations make sense.
  - Since EVM relies on baseline cost information, a tracking generation for a project without baseline cost information is invalid.
  - The Actual Cost, Actual Duration and Percentage Completed measures must be greater than or equal to their corresponding value in the previous tracking periods.
  - The Remaining Cost can only be positive when the Remaining Duration is positive.
- **Initialize Actual/Remaining Duration**: When the Actual Start for an activity is entered, ProTrack automatically calculates the Actual and Remaining Durations given the status date of the tracking period and the baseline duration as follows:
  - Actual Duration = MIN(Status Date - Actual Start, Baseline Duration)
  - Remaining Duration = Baseline Duration - Actual Duration
- **Initialize Actual/Remaining Cost**: When the Actual Start for an activity is entered, ProTrack automatically calculates the Actual and Remaining Costs given the status date of the tracking period and the baseline duration and cost as follows:
  - Actual Cost = MIN(Status Date - Actual Start, Baseline Duration) * (Baseline Cost / Baseline Duration)
  - Remaining Cost = Baseline Cost - Actual Cost

- **Percentage Completion According to Duration**: The Percentage Completion (PC) is a crucial estimate that determines the Earned Value EV. Although this value can differ from the actual and remaining activity duration, this EVM input model allows automatic PC calculations based on Actual and Remaining Duration estimates, as follows:
  - PC = Actual Duration / (Actual Duration + Remaining Duration)
- **Percentage Completion According to Cost**: Similar to the previous EVM input model, a similar EVM input model allows automatic PC calculations based on Actual and Remaining Cost estimates, as follows:
  - PC = Actual Cost / (Actual Cost + Remaining Cost)

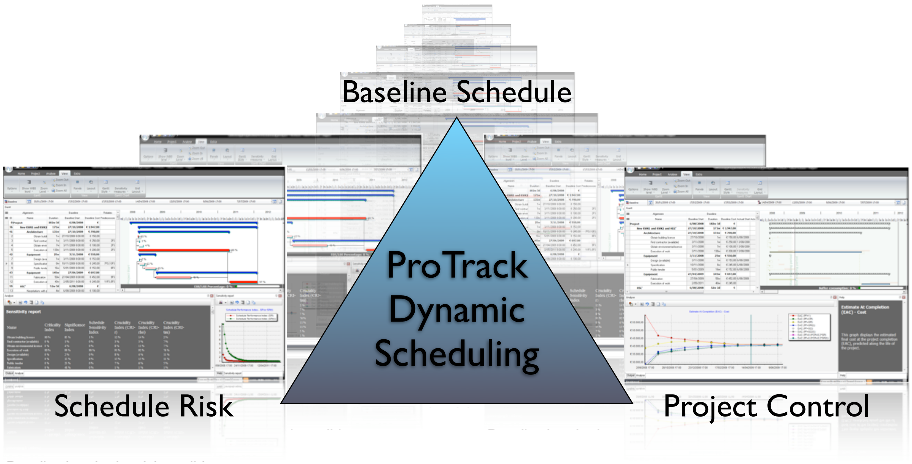
Obviously, all automatic ProTrack calculations are only performed to speed up the tracking input effort and can be changed at all times during the project tracking period. All the underlying assumptions of the EVM input models that have been switched on are automatically checked when closing a tracking period (to open a new tracking period or to finish the project). If violations against the assumptions occur, ProTrack will report a warning and allow the user to change the inputs before continuing. However, the user can also perform an intermediate feasibility check with closing the tracking period check via the Project - Check Tracking Period menu.

Conclusion

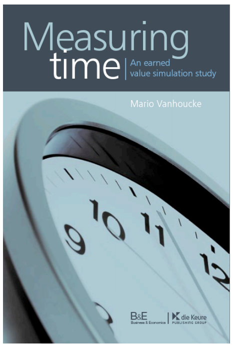
Project tracking and control constitute the heart of any scheduling tool and play a central role in all ProTrack versions. They all combine Gantt chart schedule forecasts and Earned Value Management performance measurements to control the progress of your project and to make accurate predictions about the future. All versions make use of the new Earned Schedule approach to measure the time performance of your project in a reliable way.

ProTrack's Time Shuttle version allows you to create schedule adherence information, to easily set up a forecast accuracy study and to automatically create project tracking periods. It connects the standard simulation engine of ProTrack's Sensitivity Scan with a time forecasting study and allows the users to obtain information about the quality of the various time predictions for their specific project.

Note that project tracking and control relies on the baseline schedule data. Ideally, a project tracking approach should use all relevant information that project managers have obtained during the planning phase, and should rely on data from the baseline scheduling step as well as information from the schedule risk analysis phase. More information can be found in the "Baseline Scheduling with ProTrack" and "Schedule Risk Analysis with ProTrack" tutorials.



More information?



More background information can be found in the book "Measuring Time - An Earned Value Simulation Study". Read chapters 1 to 3 for the EVM tracking period calculations and chapter 4 for the forecast accuracy study. Visit www.protrack.be/protrack_measuringtime.php for information about the progress of the book[7].

[7] Cover picture might be subject to change upon publication.