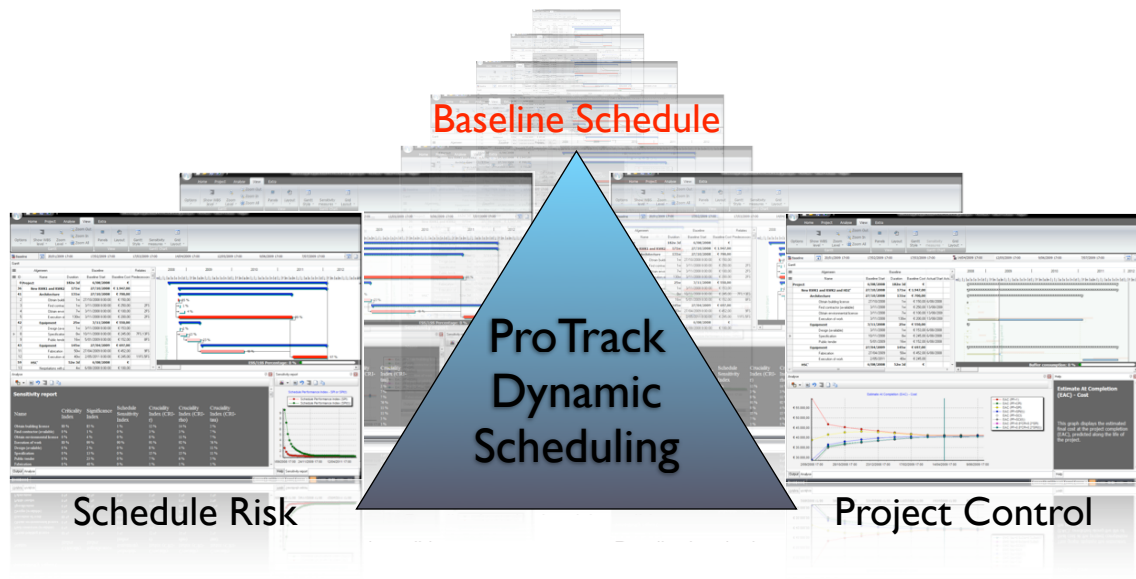


# Baseline Scheduling with ProTrack

by

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The construction of a project baseline schedule is often a time-consuming and cumbersome task. However, the central role of the baseline schedule in a Schedule Risk analysis and in the Project Control phase cannot be underestimated. It should indeed be generally accepted that the usability of a project schedule is to act as a point of reference in the project life cycle, and hence, a project schedule should especially be considered as nothing more than a predictive model that can be used for resource efficiency calculations, time and cost risk analyses, project tracking and performance measurement, and so on.

ProTrack's Standard Version contains most of the basic baseline scheduling options discussed in this tutorial. The more advanced ProTrack versions (Sensitivity Scan, Time Shuttle and Smart Version) make the connection between Baseline Scheduling, Schedule Risk and Project Control.

## 1 Project data

### 1.1 Project generation

Generating a project file can be done in four ways:

- Open a recent project that you saved during a previous ProTrack session.
- Start from scratch and build your own input project file.
- Generate a project file from the Random Network Generator (RanGen).

- Import a file from MS Project.

### 1.1.1 Build your own project

A project requires some data that need to be manually entered in the Gantt chart data grid of ProTrack, as will be discussed in section 1.3. Obviously, any project can be saved and reopened at a later ProTrack session, as shown in figure 1.

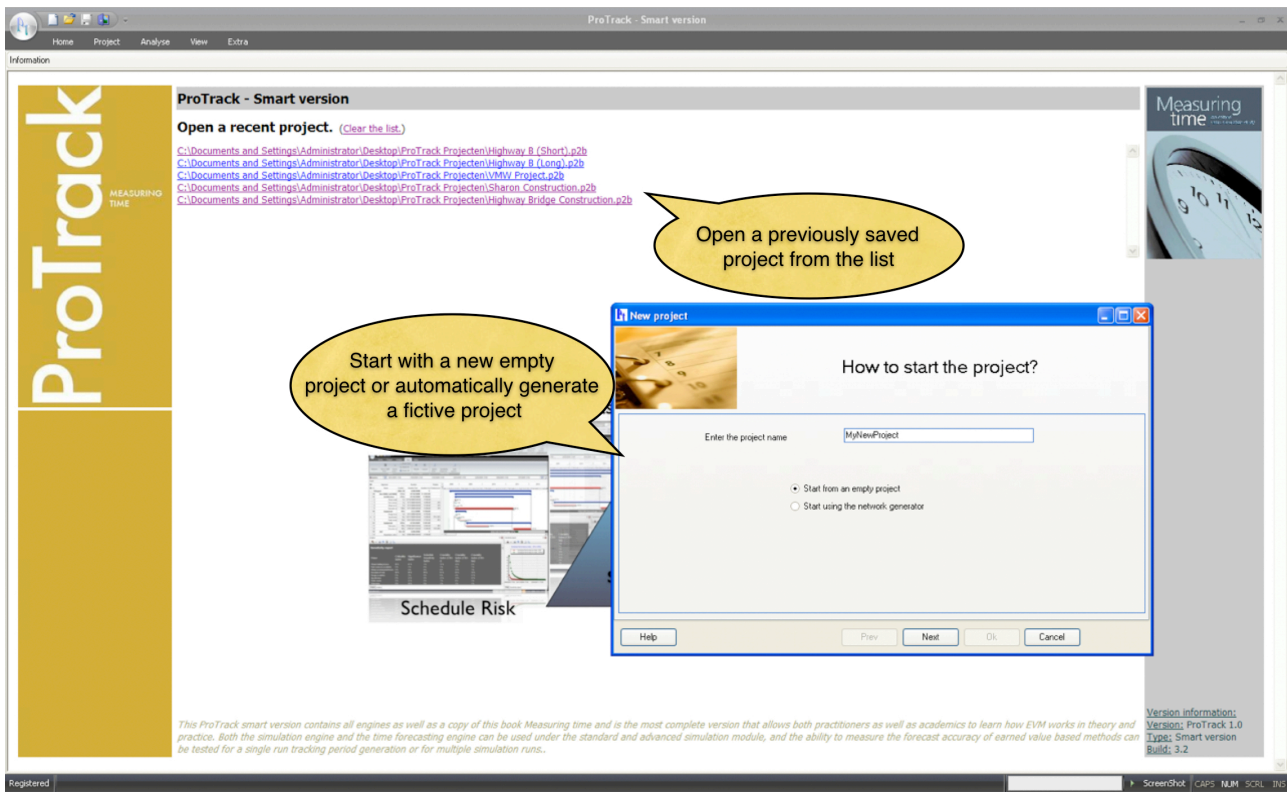


Figure 1. The ProTrack welcome and input screen

### 1.1.2 Automatic project data generation

The generation of fictive project data is an easy and powerful tool to let you start immediately with ProTrack to gain experience with all its features even before entering real project data. The project data required for ProTrack's baseline scheduling is discussed in section 1.3 and can be generated automatically using the following data field:

- Number of activities: Number of tasks in the project network.
- Precedence relations: The number of links between activities is measured by the Serial/Parallel (SP) indicator which indicates how close the project network lies to a complete parallel (no links) or complete serial (maximum number of links) project.
- Time and cost estimates: The time and cost estimates for each activity will be generated randomly from a user-defined interval.
- Activity constraints (see section 1.4):
  - Percentage of tasks with constraints (0 - 100%): Randomly adds activity constraints to project activities.
  - Violate project deadline (min - max): Activity constraints imply a certain date in the project life. The minimal project time window is equal to the critical path (*min*). This time window can be extended to

maximum the double of the critical path (*max*), and the constraints will be randomly assigned in this time window interval.

- **Feasible (yes/no):** Activity constraints can lead to scheduling conflicts and infeasibilities. Putting the feasible option on avoids these constraints conflicts. In section 2.2, the activity constraint hardness options to deal with constraint conflicts are discussed in detail.

The screenshot shows the 'New project' dialog box with the 'Network generator' tab selected. The settings are as follows:

- How many activities do you want in the project? 10
- Choose the percentage of parallel branches (slider)
- Enter the minimal duration 2d
- Enter the maximal duration 1w
- Enter the minimal cost € 200,00
- Enter the maximal cost € 1.500,00
- ☐ Generate constraints
- Percentage of task with constraint (slider)
- ☐ Violate project end date
- ☒ Feasible

Buttons at the bottom: Help, Prev, Next, Ok, Cancel.

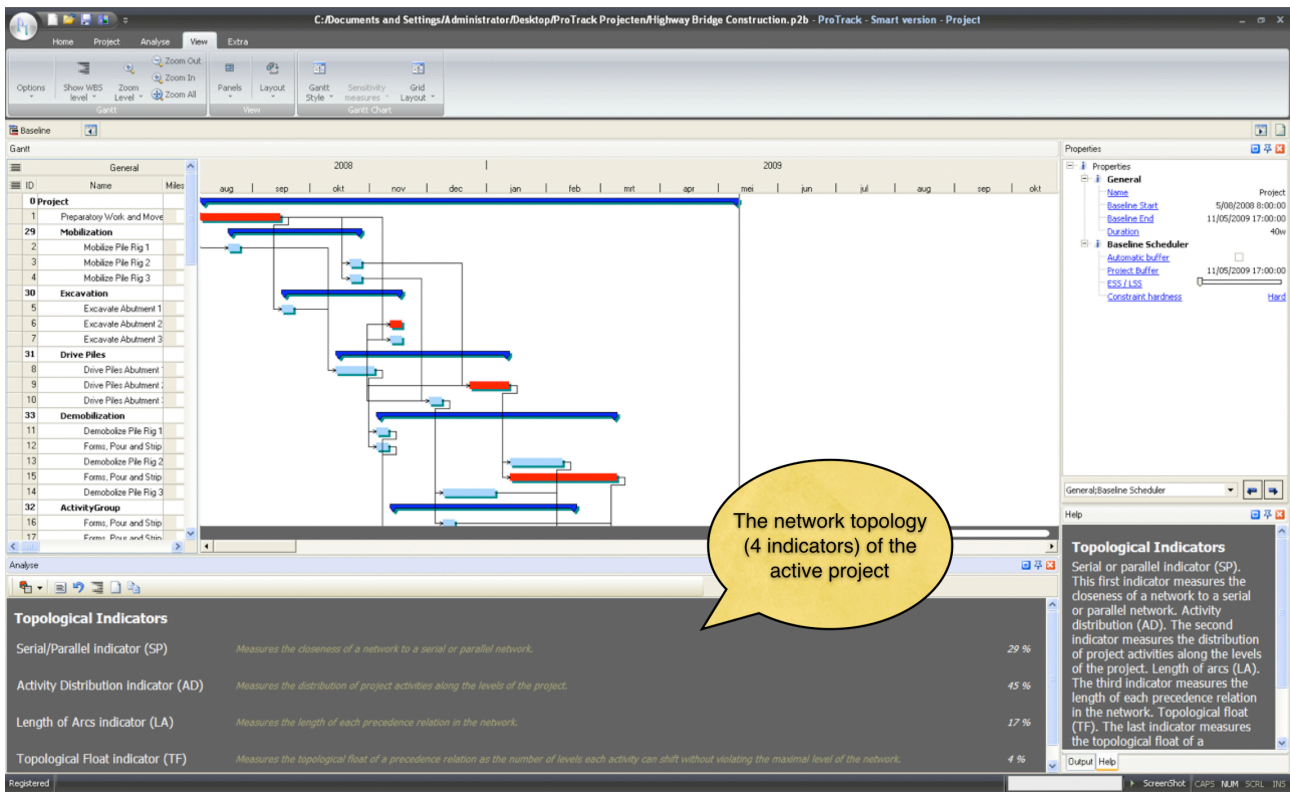
**Figure 2.** The settings of the automatic project network generator

The structure of a project network is measured and determined by the set of project activities and precedence relations (links) between them. ProTrack calculates this so-called *topological network structure*<sup>1</sup> using four indicators between 0 and 1. The intuitive meaning of the four indicators is briefly discussed along the following lines. An indication is given of their meaning for the extreme values 0 and 1, but obviously, all intermediate values can be generated in ProTrack.

- **Serial/Parallel Indicator (SP):** Measures how closely the project network lies to a 100% parallel (SP = 0) or 100% serial (SP = 1) network. This indicator can be considered as a measure for the amount of critical and non-critical activities in a network.
- **Activity Distribution (AD):** Measures the distribution of the activities along the network, from a uniformly distribution across the project network (AD = 0) to a highly skewed distribution (e.g. a lot of activities in the beginning, following by only a few activities near the end) (AD = 1). Consequently, the AD indicator serves as a measure for the workload variability.
- **Length of Arcs (LA):** Measures the length of each precedence relation between two activities as the distance between two activities in the project network. A project network can have many precedence relations between two activities lying far from each other (LA = 0) and hence, most activities can be shifted further in the network. When all precedence relations have a length of one (LA = 1), all project activities have only immediate successors with little freedom to shift.
- **Topological Float (TF):** Measures the degrees of freedom for each activity as the amount of slack or float an activity has in the project network. TF = 0 when the network structure is 100% dense and no activities can be shifted within its structure. A network with TF = 1 consists of one serial chain of activities without topological float (this chain defines the SP value) while the remaining activities have a maximal float value.

<sup>1</sup> The topological structure of a network is determined by the set of activities and the precedence relations between these activities.

The value of these four topological structure indicators can be called for each project network via the [Analyse - Show Graph - Baseline - Topological Indicators](#) menu (figure 3).



**Figure 3.** The topological network structure calculations in ProTrack

The use of indicators to measure the structure of a project network has been illustrated in numerous research papers. ProTrack's accompanying book "Measuring Time - An Earned Value Simulation Study" makes use of these indicators to determine the ideal level of project control in the Work Breakdown Structure (WBS). More information can be found at the references mentioned at the end of this tutorial.

### 1.1.3 Import project data from MS Project

The import function is not shown on the start screen, but is accessible via the [Home - Import](#) menu. Note that importing an MS Project file in ProTrack requires that MS Project is installed on your computer.

## 1.2 Project calendar

Each project needs a calendar where days-on and days-off, and working and non-working hours can be specified in advance. The project calendar will be shown automatically upon the start of a new project, or is accessible at any time via the [Project - Agenda](#) menu.



**New project**

**Working Calendar**

Enter the project start date: 1/11/2008 Working days: Monday;Tuesday;Wednesday;Thursday;Friday

Working hours: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

<< >> One month Two months Three months Four months Working Non Working

November 2008							December 2008							January 2009						
Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
3	4	5	6	7	8	9	1	2	3	4	5	6	7	1	2	3	4	5	6	7
10	11	12	13	14	15	16	10	11	12	13	14	15	16	12	13	14	15	16	17	18
17	18	19	20	21	22	23	17	18	19	20	21	22	23	19	20	21	22	23	24	25
24	25	26	27	28	29	30	24	25	26	27	28	29	30	26	27	28	29	30	31	

Help Prev Next Ok Cancel

**Figure 4.** The project working calendar

### 1.3 Project network


A project requires data needed to construct a baseline schedule, which can be summarized along the following lines:

- ID: Automatically generated activity ID.
- Name: Manual chosen activity name.
- Milestone: An activity milestone has a zero duration and cost.
- WBS: Work Breakdown Structure ID of the activity.
- Critical: Indication whether an activity lies on the critical path or not.
- Duration: Estimate of baseline duration expressed in hours, days, weeks or years, e.g. 5h, 5d, 5w or 5y.
- Cost: Estimate of baseline cost expressed in various monetary units, e.g. 3500€.
- Start: Activity start date in the baseline schedule.
- End: Activity finish date in the baseline schedule.
- Predecessors: List of activities that immediately precede the current activity through precedence relations.
- Successors: List of activities that immediately succeed the current activity through precedence relations.

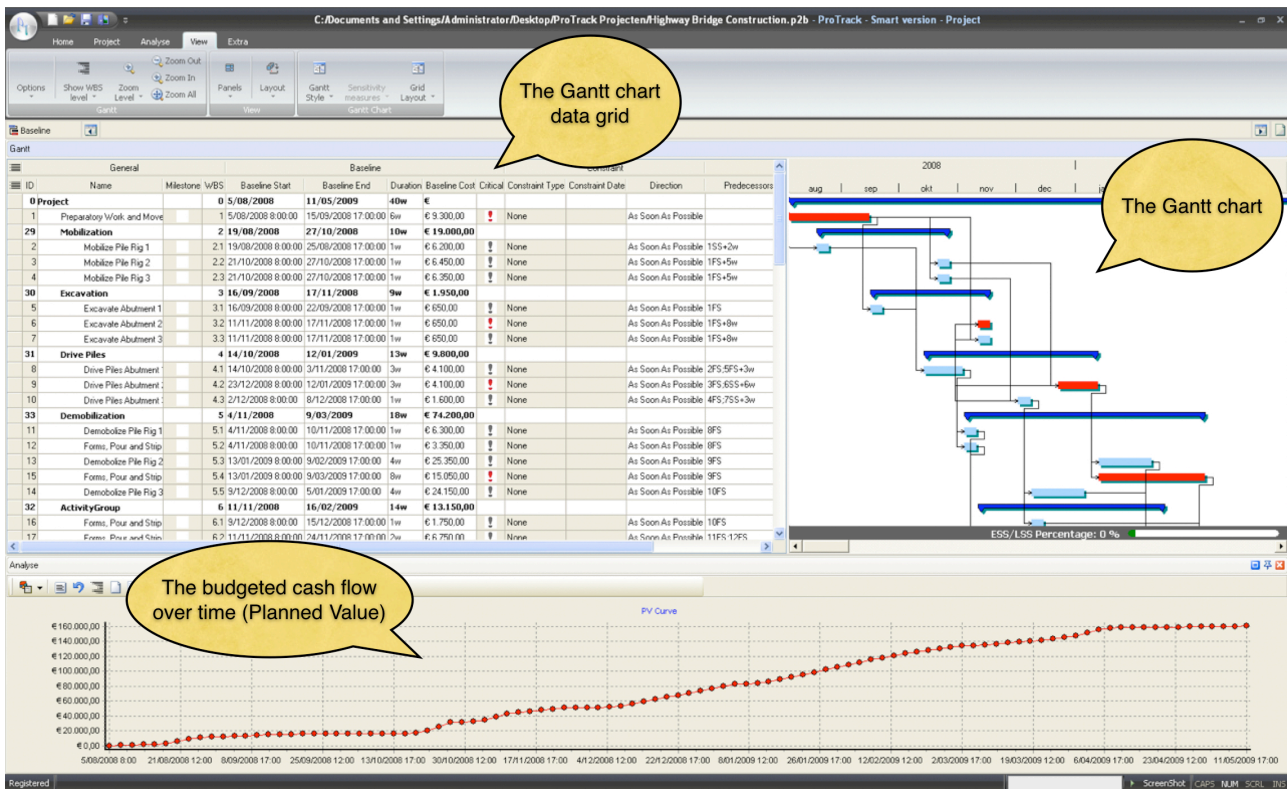
The predecessor and successor fields determine the precedence relations between project activities, which can be categorized into four classes. Each category requires a minimal time-lag of  $x$  time periods (e.g. 2d, 3w, etc).

- Finish-Start (FS): An activity can only start  $x$  days after the finish of its predecessor activity.
  - e.g.  $1FS+xd$  (predecessor field) or  $FS2+xd$  (successor field).
- Finish-Finish (FF): An activity can only finish  $x$  days after the finish of its predecessor activity.
  - e.g.  $1FF+xd$  (predecessor field) or  $FF2+xd$  (successor field).
- Start-Start (SS): An activity can only start  $x$  days after the start of its predecessor activity.
  - $1SS+xd$  (predecessor field) or  $SS2+xd$  (successor field).
- Start-Finish (SF): An activity can only finish  $x$  days after the start of its predecessor activity.

- 1SF+xd (predecessor field) or SF2+xd (successor field).

Precedence relations can be entered manually in the Gantt chart grid or by drawing the relation between two activities on the Gantt chart (when the  symbol appears on the activity, ProTrack is ready to add a new relation).

The project data can be displayed in the Gantt chart grid ([View - Options - Show Grid](#)) or on the Gantt chart view ([View - Options - Show Gantt](#)). The settings for the time zone and cost formats (e.g. currency format) can be changed in the [Project - Options](#) menu.



**Figure 5.** The baseline input grid, the Gantt chart and the Planned Value graph

#### Note

- \* Time-lags between activities can be positive as well as negative (e.g. 1FS-2w).
- \* Be careful with activities without predecessors or successors. They are considered as activities without any relation, and can be shifted from the start till the finish of the complete project duration.
- \* Activities can be combined in activity groups by selecting the activities and using the [Project - Group Tasks](#) menu. Adding a new activity to a group can be done by right clicking on the activity and selecting the indent option (only works if the task above the selected activity belongs to a group). Removing an activity from a group can be done by right clicking on the activity and selecting outdent.
- \* The fields of the Gantt chart grid (i.e. the table to the left of the Gantt chart) can be changed in the left upper corner of the grid. The first row of the left upper corner shows different data classes (general, baseline, tracking, etc.), while the second left upper corner displays the fields that can be shown in the data grid (see figure 6).

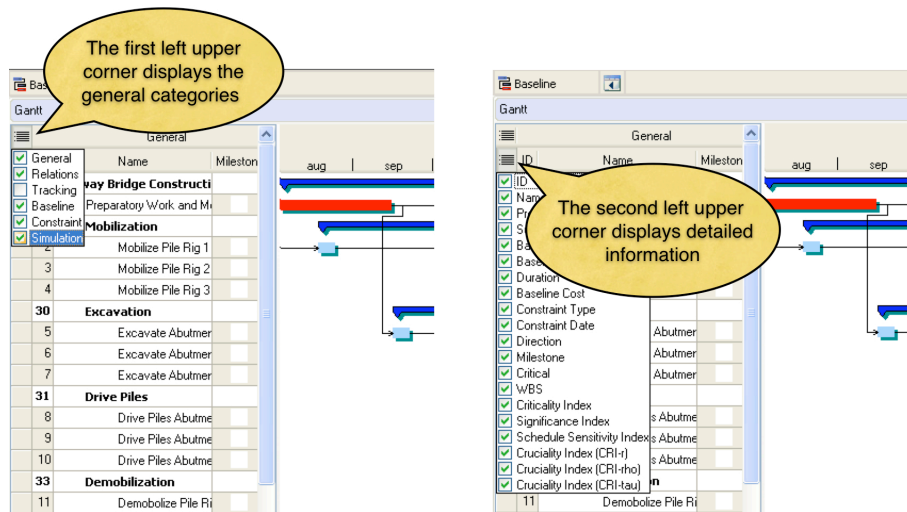


Figure 6. Changing the display of the Gantt chart grid

## 1.4 Activity constraints

Activity constraints can be imposed when there is a need to control the start or finish of an activity. ProTrack contains three types of activity constraints, each having a start and a finish version, as follows:

- **Ready dates** imply earliest start or finish times on activities and hence force the activity to start/finish no earlier than the defined time instance. These constraints are known as ready start time (RST) or ready finish time (RFT).
- **Due dates** imply latest start/finish times on activities and force activities to start/finish no later than a predefined time instance. In ProTrack, these constraints are referred to as due start time (DST) or due finish time (DFT).
- **Locked dates** imply a fixed time instance and force the activity to start/finish on a predefined time instance, known as locked start time (LST) or locked finish time (LFT).

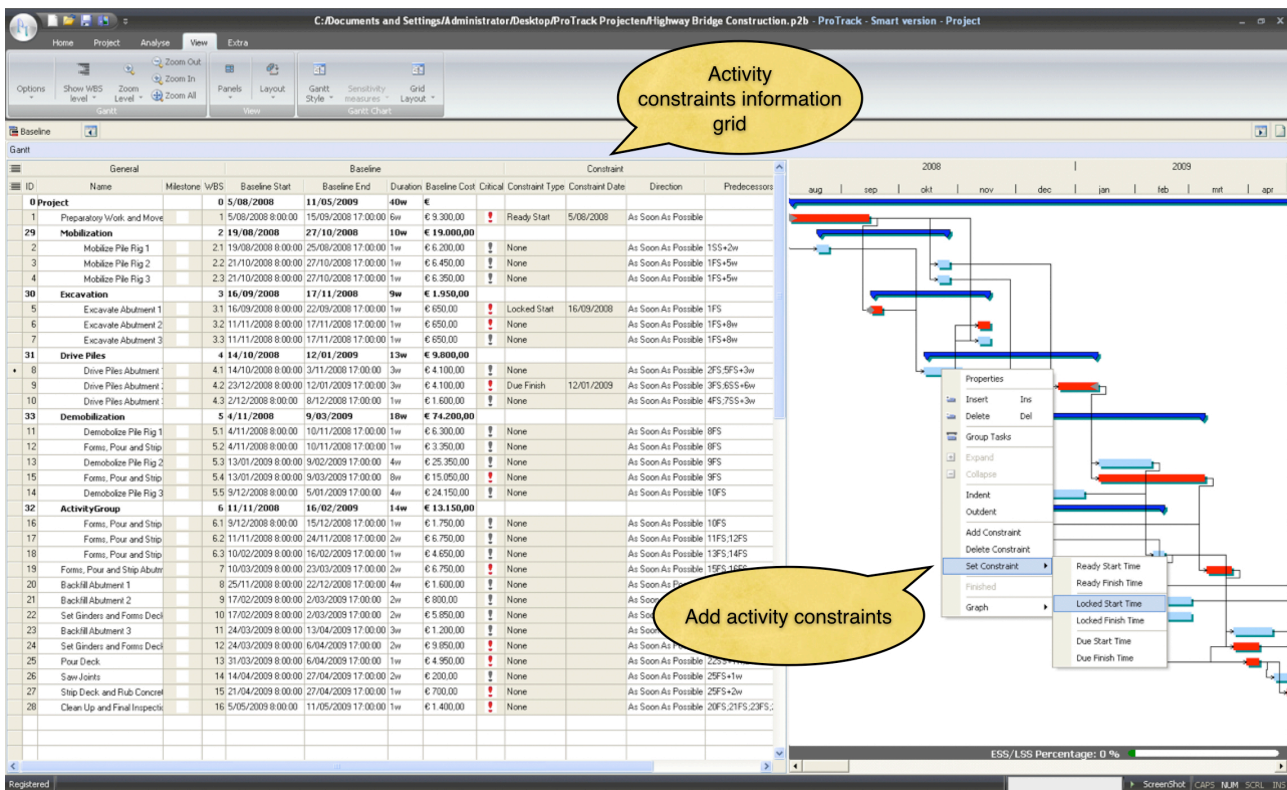


Figure 7. Adding activity constraints in ProTrack

### Warning

- \* Activity constraints are optional and need to be used with care. They limit the scheduling degrees of freedom and restrict ProTrack to make automatic adaptations.
- \* The effect of adding constraints on a project schedule varies along the four possible *constraint hardness* modes in ProTrack. These effects are discussed in section 2.2.
- \* A constraint can be easily added by right clicking on the activity and setting the possible constraints at the current start or finish time of the activity (see figure 7).

## 2 Project scheduling

The target of project scheduling is to construct a timetable where each individual activity receives a start time and a corresponding finish time within the predefined precedence relations and the various predefined activity constraints. The scheduling process is based on the traditional critical path based forward (to create an earliest start schedule) and/or backward (to create a latest start schedule) project scheduling calculations aiming to construct a project schedule with a minimal project lead time.




### 2.1 Manual shifts

The Gantt chart is a central display where ProTrack users can easily modify their project data. Adding constraints, changing activity durations and start or finish times or adding precedence relations can be easily done with a few mouse clicks. Manual shifts to reschedule the project can be done to change activity start and end times in two directions, as follows:

- Forward shift: Activity shift towards the project end (leads to buffer consumption or to a change of the buffer time).

- **Backward shift:** Activity shift towards the project start (cannot start earlier than the project start given in the agenda).

If the mouse pointer appears in front of an activity on the Gantt chart, three actions can be taken, depending on the symbol that appears, as follows:

-  : Add a connection (precedence relation) with another activity
-  : Increase/decrease the activity duration
-  : Shift the activity forwards (to the end) or backwards (to the project start) in time

## 2.2 Constraint handling

The use of activity constraints increases your own control to the project schedule but leads to a flexibility decrease for the project scheduling algorithm. Although it can be generally recommended to restrict the use of activity constraints to prevent the construction of a rigid project schedule, ProTrack makes use of four ways to handle constraints in a project schedule, varying the degree of constraint hardness. These hardness options influence the result of user interventions (e.g. a manual activity shift in time, adding a constraint or precedence relation, changing an activity duration, etc.) or software interventions (e.g. rescheduling the baseline schedule, update of tracking information, etc.) on the project schedule. The four constraint hardness modes are as follows:

- **Hard constraint mode:** All activity constraints need to be satisfied at all times. When ProTrack interventions tend to lead to constraint violations, ProTrack will automatically return to the previous schedule and undo the infeasible (user or software) intervention.
- **Moderate constraint mode:** All activity constraints need to be satisfied at all times. When ProTrack interventions tend to lead to constraint violations, the precedence relations will be overruled by allowing a certain degree of overlap between project activities. Consequently, a moderate activity constraint has a higher priority than a precedence relation between two activities.
- **Soft constraint mode:** Activity constraints can be violated due to user or software interventions at any time. However, ProTrack will try to prevent the total number of violations by searching for the best possible schedule to satisfy constraints. In case of violations, a report with the violated constraints will indicate where the overridden requirements occur. This is known as ProTrack *constraint based scheduling*, as discussed later in this section.
- **Forward constraint mode:** Activity constraints are only satisfied into one direction and are treated as forward activity constraints. Consequently, all activity ready times are explicitly taken into account, while locked times and due dates are often ignored: locked times are treated as ready times, which will only be satisfied unless it is not possible due to predecessor activities while due dates are completely ignored and will possibly be violated by user or software interventions at any time.

The constraint hardness mode can be changed by clicking on the [Project - Constraint Mode](#) menu. The activity constraint hardness modes are often a powerful tool to guide and influence your schedule into the right direction, but they need to be taken with care. Three important remarks on these constraints are summarized along the following lines:

**Forward constraint mode:** This constraint mode often violates certain activity constraint requirements. More precisely, it completely ignores due dates and treats locked times as ready times. Therefore, ProTrack always reports where violated activity requirements occur. This constraint hardness mode is the only available option during project simulation and project tracking, where certain activity constraints (due dates and locked times) set during the construction of the baseline schedule can often not be satisfied due to



delays in predecessor activities. More information can be found in the “Project Control with ProTrack” and the “Schedule Risk Analysis with ProTrack” tutorials.

**Soft constraint mode:** Combinations of activity constraints often lead to conflicts that cannot be satisfied all together. While the moderate constraint mode resolves these conflicts by allowing overlaps between activities, the soft mode tries to construct a project schedule where the conflicts are minimized. Consequently, this mode constructs a baseline schedule without activity overlaps such that the deviation between activity constraints and start or finish times is minimal. Each time a change in the schedule occurs (manual shift, adding an activity, etc.), ProTrack recalculates the complete schedule and adds a constraint to each activity that has been manually shifted. This is referred to as *constraint based scheduling* which automatically adds activity constraints to the schedule as follows:

- Forward shift (= towards the project finish): set a ready time at the start of the new activity starting time (RST).
- Backward shift (= towards the project start): set a due date at the finish of the new activity finish time (DFT).

This option is particularly useful when multiple conflicting activity constraints are set. ProTrack automatically generates a baseline schedule which satisfies these constraints in the best possible way, without violating the original precedence relations logic.

**Switching from constraint mode:** Changing the constraint hardness mode for a current schedule might lead to unexpected activity shifts, complete schedule changes or infeasible schedule solutions and need therefore to be done with care. Since the hard constraint mode is the most strict constraint hardness, switching to this mode can lead to three possibilities:

- The switch can be done without any changes and the constraint hardness is set to the hard mode.
- The switch is not possible with the start times of the current schedule due to constraint conflicts, but leads to no constraints conflicts when every activity is set to its earliest possible start (known as an Earliest Start Schedule (ESS)). In this case, the user has the choice to either undo the constraint hardness mode switch or to switch to an ESS.
- The switch is neither possible with the start times of the current schedule nor with the ESS: undo the constraint mode switch.

## 2.3 Earliest Start or Latest Start

A project schedule consists of a set of activity start and finish times which can vary between the project start date (as given in the agenda) and the project buffer (which is equal to the project finish plus an optional extra buffered safety time). A default project schedule consists of an *Earliest Start Schedule* (ESS) where all activities are scheduled as soon as possible, given the activity constraints (default constraint hardness mode: hard). A *Latest Start Schedule* (LSS) contains a set of activities scheduled as late as possible within the predefined project buffer. Shifting activities forward or backward results in modified schedules according to the wishes and needs of the user in-between an ESS and LSS. The user always has the option to return to the earliest start schedule or latest start schedule, given the current project duration (buffer inclusive).

ProTrack contains two ways to return to an earliest start or latest start: one on the activity level and one on the schedule level (i.e. ESS or LSS):

### 2.3.1 Activity level

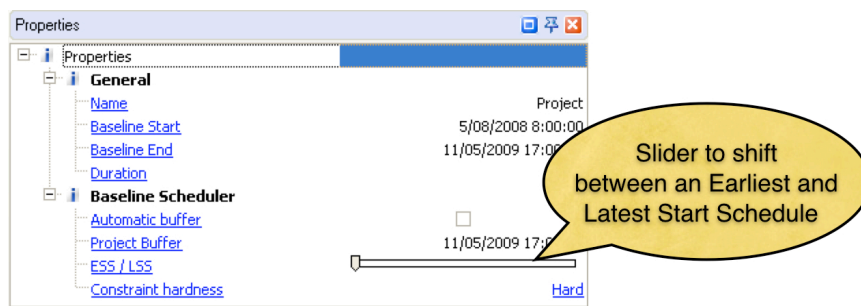
The property screen of each individual activity (show by clicking on the [View - Panels - Properties](#) menu) shows that each activity has a direction, as follows:

- **As Soon As Possible (ASAP):** Schedules the activity on its earliest possible start time without affecting the start and finish times of all its predecessor activities and/or its own activity constraints.
- **As Late As Possible (ALAP):** Schedules the activity on its latest possible start time without affecting the start and finish times of all its successor activities and/or its own activity constraints.

While an activity constraint is an optional field for each activity, the as-soon-as-possible (ASAP, default option) or as-late-as-possible (ALAP) option is required, even without the presence of an activity constraint.

### 2.3.2 Project level

In order to provide full flexibility to the user, ProTrack offers the possibility to construct schedules in between an earliest start schedule (ESS) and a latest start schedule (LSS). A slider (see figure 8) allows the user to automatically shift all activities forwards or backwards within their activity slack (taking into account the current (buffered) project duration as well as possible activity constraints). This creates the possibility to automatically generate project schedules in between an ESS and LSS and is a very useful tool to manipulate your project's cash flow position over time as shown via the [Analyse - Show Graph - EVM Key Parameters - PV Curve](#) menu. Optimizing cash flows in project scheduling often leads to advantages and creates net present value optimization<sup>2</sup> opportunities. As an example, when cash flows are delayed when shifting towards an LSS, capital intensive investments can be postponed to the future leading to an overall better total project net present value.



**Figure 8.** Sliding between an ESS and LSS in ProTrack

## 2.4 Project buffer

A project buffer is an extra time buffer above the project finish reported by the Gantt chart and can be used as an ideal tool for project control during the project tracking phase (see the “Project Control with ProTrack” tutorial).

- **Automatic Buffer:** The project buffer is always equal to the project finish, even after project forward and backward shifts.
- **Manual Buffer:** The project buffer is a pre-specified date, and only shifts forwards in time when the project finish exceeds the predefined project buffer.

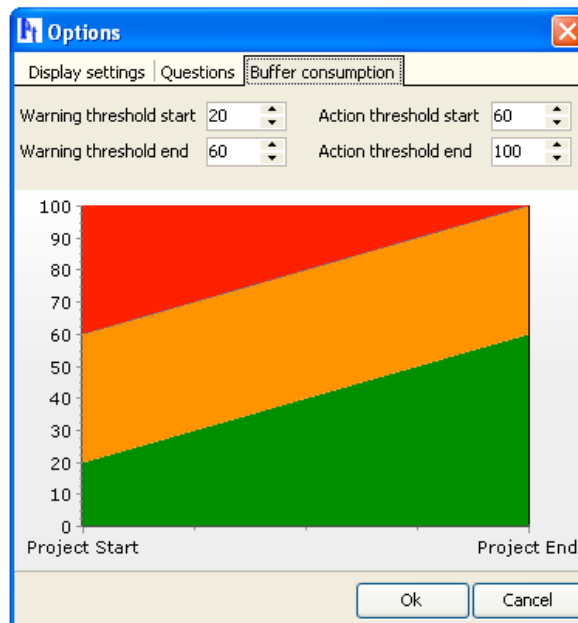
The role of the project buffer during baseline scheduling is limited to a visualization tool to indicate where the current project schedule lies between the ESS and LSS extremes. However, the project buffer can play a central role during project tracking and serves as a warning signal for buffer consumption to indicate when action is necessary to bring your project back on track. The [Project - Options - Buffer Consumption](#) menu

<sup>2</sup> See the article by Vanhoucke, M. and Demeulemeester, E., 2003, “The Application of Project Scheduling Techniques in a Real-Life Environment”, Project Management Journal, 34 (1), 30-42.

can be used to create a dynamic buffer warning signal tool that divides the buffer consumption into three regions during the tracking periods, as follows:

- Green: Buffer consumption is normal and accepted
- Orange: Buffer consumption is more than normal and deserves attention
- Red: Buffer consumption is critical and actions are necessary

Obviously, the acceptance/attention/action threshold depends on the project's percentage completion, and differs from project to project. Figure 9 shows how these thresholds can be set to a user's individual needs.



**Figure 9.** Setting buffer acceptance/attention/action threshold in ProTrack

### 3 Baseline schedule

The development of a detailed baseline schedule for measuring schedule performance (time, cost, resources, etc.) as well as to perform risk analyses to detect a project's most sensitive parts is a crucial step in project scheduling and tracking. The main purpose of the baseline schedule is to act as a point of reference for project tracking (see the "Project Control with ProTrack" tutorial) and schedule risk analysis (see the "Schedule Risk Analysis with ProTrack" tutorial). In ProTrack, the baseline schedule can be saved by the user, or will be automatically saved from the moment that the first tracking period schedule is constructed.

The current ProTrack version 1.0. supports no rebaselining possibilities, but this will be implemented in the near future. Check our roadmap on [www.protrack.be/protrack\\_roadmap.php](http://www.protrack.be/protrack_roadmap.php) to see future development intentions and current work in progress. In the new expected release, ProTrack 2.0 will be able to save as many baseline schedules as the computer memory allows but a strict distinction between the construction of a baseline schedule and the tracking process during project execution will be made. Making changes to the original baseline schedule during project tracking will only be possible by re-baselining the original baseline schedule (i.e. overwrite the current active baseline schedule) and adding it to the current and possible future tracking periods (see the "Project Control with ProTrack" tutorial). In doing so, each tracking period schedule will be linked to a single and unique baseline schedule, resulting in a unique and unambiguous point-of-reference for Earned Value metric calculations. However, it should be noted that one should be careful with

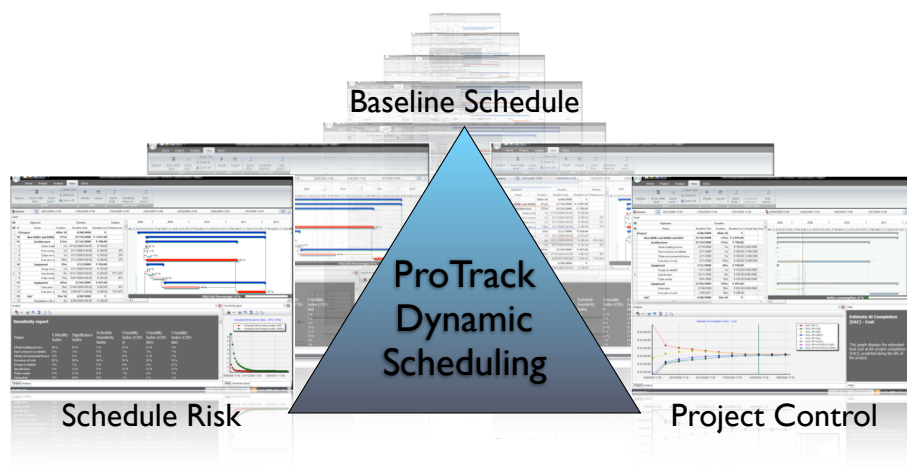
unwise re-baselining decisions, since this involves a change in the tracking point-of-reference, and hence, previous tracking results are no longer comparable with the current tracking progress state.

## Conclusion

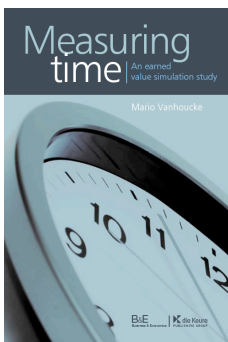
Baseline scheduling is a cumbersome task that relies on a project manager's knowledge about the project scope, activity characteristics and constraints, technological activity relations and reliable time and cost estimates. Although the baseline schedule often fails to reflect reality during the whole project horizon, it plays a crucial role during project monitoring and for a schedule risk analysis.

ProTrack's baseline scheduling offers a balance between project flexibility and schedule constrainedness by offering a combination of automatic scheduling calculations and manual activity restrictions. ProTrack's basic version offers all baseline scheduling functionalities and many of the project control features. The more advanced versions (Sensitivity Scan, Time Shuttle and Smart Version) combine all baseline scheduling properties with the more advanced schedule risk analysis and project monitoring features.

It should be noted that the role of a baseline schedule is to act as a dynamic point-of-reference for schedule risk and project control calculations, as implemented in ProTrack's Sensitivity Scan and Time Shuttle versions. For more information, consult the "Schedule Risk Analysis with ProTrack" and "Project Control with ProTrack" tutorials.



## More information?



More background information can be found in the book "Measuring Time - An Earned Value Simulation Study". Visit [www.protrack.be/protrack\\_measuringtime.php](http://www.protrack.be/protrack_measuringtime.php) for information about the progress of the book<sup>3</sup>.

<sup>3</sup> Cover picture might be subject to change upon publication.