RiBA

A quantitative risk assessment and tracking tool

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Risk-taking might imply the possibility of losing, but does there have to be a loser? The answer is no. As more and more service and retrofit projects become performance-based, risk assessment is developing into a valuable bidding instrument for ABB *and* its customers.

RiBA (Risk-Based Assessment) is a software tool developed by ABB to provide a sound platform for risk management and the development of mitigation strategies for competitive projects.

Anyone who has ever walked along a street filled with restaurants on a summer's evening will know the feeling. Choice is a great thing, but it can also be a dilemma. Eager restaurant staff try to entice you to enter their establishments, promising you the best food and service in town. As you listen to their pitch, inspect the menu and look at the restaurant, the chances are you will be influenced by one or the other of these factors.

Getting you to the table is one thing, ensuring the promised good food and good service quite another. If the restaurant can't deliver on either, you won't be going back to that restaurant, and neither will anyone you know. None of this is good for business.

Now let's stretch our imagination and suppose that the restaurant has to pay a penalty if the food arrives late or isn't as good as promised – suddenly the idea of offering incentives to attract customers becomes a gamble that could make or break the restaurant owner.

And so it is in the industrial world. Companies compete with each other to secure business by offering attractive contract tenders to potential customers. One way to substantially reduce the contract bidding price is to consider the profit margin in terms of performance-related bonuses. This means that the contract includes clauses specifying a bonus or penalty for exceeding or missing certain targets. Sometimes, however, in trying to make a tender attractive certain risks are not properly

“The risk analysis results produced by RiBA are a sound basis for contract optimization and negotiations with the customer”. RiBA pilot user

identified and quantified, while some may even be overlooked, with costly consequences later. So doing this is safe only if the associated risks (eg, schedule risks and liquidated damages that could result) are well understood and project plans are adjusted accordingly.

Risk analysis for project planning generally requires skillful, expert analysts on the one hand and sound software tools on the other. An experienced analyst may be able to do the job, but expert resources are usually limited. For an efficient analysis a sound risk analysis software tool is a must.

‘Win-win’ performance contracts

Performance-based contracts benefit customers and ABB alike. They are good for customers because they lift the burden of uncertainty from their shoulders; and they are good for ABB because risk mitigation has a financial value. ABB companies therefore consider it very important to be able to produce truly competitive contract tenders in which bonus and penalty clauses constitute an integral part of the contract value.

A good example of a performance-type contract is one recently awarded to ABB by a US utility for a retrofit project covering five high-voltage substations in a busy industrial area. The project was managed by ABB Utility Services in the USA. More than 30 other companies contributed to the project as subcontractors and subsuppliers, and past experience indicated that they might introduce project delays. During the contract planning the expected performance of each of them was therefore estimated on the basis of reliability, experience and the type of work to be performed. This estimate was then taken into account when evaluating the project risk.

Originally, the utility company proposed a contract value that would have reduced ABB’s margin to less than 1%! The compromise eventually reached by the parties was a performance-based contract containing performance-related financial clauses that made the margin dependent on ABB being able to earn several bonuses. On the other hand, losses could be incurred if certain penalty clauses were triggered due to delays or outages. It created conditions for a ‘win-win’ situation in which ABB’s interest in generating a high margin was closely tied to the utility’s desire to have the project completed as soon as possible, without any inconvenience to its customers. The actual contract proposal had to be drawn up in just four workdays.

Working out this win-win situation is significantly easier with RiBA (Risk-Based Assessment). The result of collaboration between the Polish and Swiss ABB Corporate Research Centers, with active participation by Business Area Utility project managers, this state-of-the-art, web-based project assessment tool is unique in that it combines the analysis of schedule, financial impact and quality risks.

RiBA – general overview

RiBA was developed to quantify risk, develop risk mitigation plans (before bidding on performance contracts, eg in the service and retrofit business) and allow continuous tracking of projects. It is a project simulator that describes a project as a set of interdependent tasks whose duration is known to be uncertain within given limits, and whose completion before or after a specified deadline may carry a prescribed bonus or penalty. The tool sets up a large number of different (stochastic) possible scenarios according to the probability distributions of the uncertain variables. The results are consolidated as histograms (of time and costs), which are then smoothed to reduce the effect of the statistical dispersion.

As mentioned, the strength and uniqueness of RiBA comes from the combined analysis of schedule, financial impact and quality risks. It is a client-server software tool with a central subcontractor and project models database and a risk calculation engine that uses a combination of numerical methods such as Monte Carlo simulation and software components (eg, the MATLAB calculation engine and JAVA Enterprise Beans technology). An essential feature of RiBA is that its front end is seamlessly integrated with Microsoft Project, a universally recognized environment for project modeling and management. In the future it will also interface with other project modeling software.

The development objective, successfully embodied in RiBA, was to create a tool for easy and efficient 'what-if' scenario analyses. Another prerequisite was that it should allow project schedule planning and risk analysis to be performed in a common software environment.

The principal features of RiBA are:

- *Schedule-oriented risk* assessment based on the duration uncertainty for project tasks.
- *Value-oriented risk* assessment based on task- or milestone-related performance clauses (bonus/penalty).
- Inclusion of *quality risk* factors.
- Modeling and web-sharing of *performance profiles* of subcontractors and subsuppliers.
- Database of web-shared *project templates*.
- Schedule and cost *sensitivity analysis*.

This set of features makes RiBA a sound platform for risk management and the development of mitigation strategies for competitive projects, eg during contract planning and negotiations, when executing the project and for handling suppliers and subcontractors.

Modeling with RiBA

Duration uncertainty

To keep things simple for users, the probability density functions used in RiBA are expressed in terms of five parameters: upper and lower percentiles, upper and lower quantiles and mode. Fixing the lower and upper percentiles (eg, to 5% and 95%, respectively) further reduces the number of parameters to be entered. In fact, RiBA users only have to enter three parameters per task, called *planned*, *optimistic* and *pessimistic* estimates 1. *Planned* means 'according to schedule', *optimistic* means that (for the figures given above) there is only a 5% chance that ABB will do better than the optimistic value, and *pessimistic* means that in 95% of the cases ABB will

Probability distributions and Monte Carlo simulations

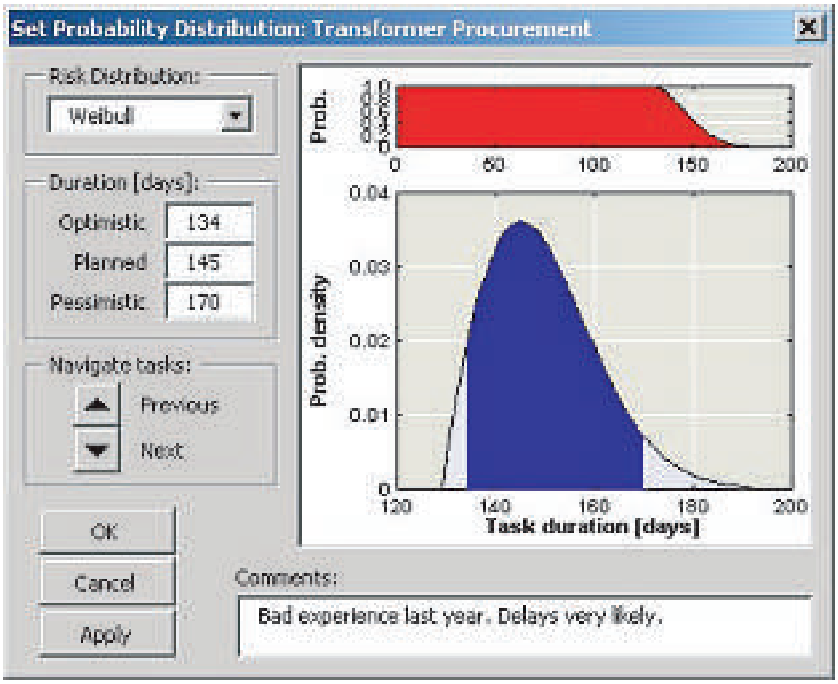
Monte Carlo (MC) methods belong to numerical simulation techniques that utilize sequences of random numbers to model complex systems without the need to formulate a physical description (eg, differential equations) of the system's behavior. Instead, they require that the system be described by a set of probability density functions (pdf – also known as *distributions*), such as a Weibul pdf. Using MC simulations RiBA evaluates a large number of project realizations according to the specified probability distributions of the task durations. The resulting project evolution in each case is simulated by drawing each task's duration from that task's probability distribution or, more generally, from the joint distribution if conditional dependencies between durations need to be introduced. The total project duration is evaluated using the task interdependence rules (eg, task A cannot start before task B has been completed). Penalties are calculated for each task and summed to obtain the overall project bonus/penalty value. Thus, for each realization there are two results: the total project duration and the total project penalty. The results from all the different realizations are combined to produce two histograms: the overall project duration distribution and the overall project value distribution.

Sensitivity analysis

The sensitivity calculation function allows RiBA users to visualize how the uncertainty of a particular task affects the overall project completion time and value. In other words, it shows how much the project depends on the unknown outcome of each task. This is possible as the actual impact of every task's duration distribution is considered.

In this scheme a task on the critical path but having no uncertainty has zero sensitivity, even if it is a 'critical task'. The rationale is that if the distribution is deterministic (certain) there is no room to improve it further. A task with a very broad distribution can, on the other hand, have a significant sensitivity (even a critical one in some iterations). Separate sensitivities are computed for the project duration distribution and project value distribution.

1 Modeling task duration uncertainty



do no worse than the pessimistic value. In other words there is a 90% chance that we will fall between the optimistic and pessimistic estimates.

Subcontractor performance

Often, the expected task duration uncertainty will depend on the performance of an external partner. RiBA therefore allows a quantification of the consequential impact of subcontractor performance on the overall project result. If the simulations indicate this will be excessive and thus risky, appropriate measures can be taken.

Like the task duration uncertainty, an external partner's 'reliability profile' is also expressed as a probability distribution function. It is based on qualitative judgement of the past performance record along with the actual task profile, which, by its very nature, may be prone to delays. RiBA offers access to a web database 2 listing all contract partners (with their respective probabilistic performance profile), from which the partner best suited for that task can be chosen.

Performance clauses

Normally, performance (bonus/penalty) clauses are attached to the project milestones, but they can be assigned to any task. The clauses specify a bonus or penalty, depending on whether the task is completed before or after a specific deadline. In RiBA they are expressed as non-linear functions, as the example in 3 shows. Here, the horizontal axis represents the task completion time (in days), and the vertical axis the financial impact (in kUSD). Completing the task 100 days after the project used in this example has started carries neither a bonus nor a penalty. An early finish results in a bonus as specified by the bonus slope (0.25 kUSD/day), but a time overrun carries a penalty that increases up to the 120 days mark and then levels off. The maximum penalty of 35 kUSD is attached to completion after 145 days or later.

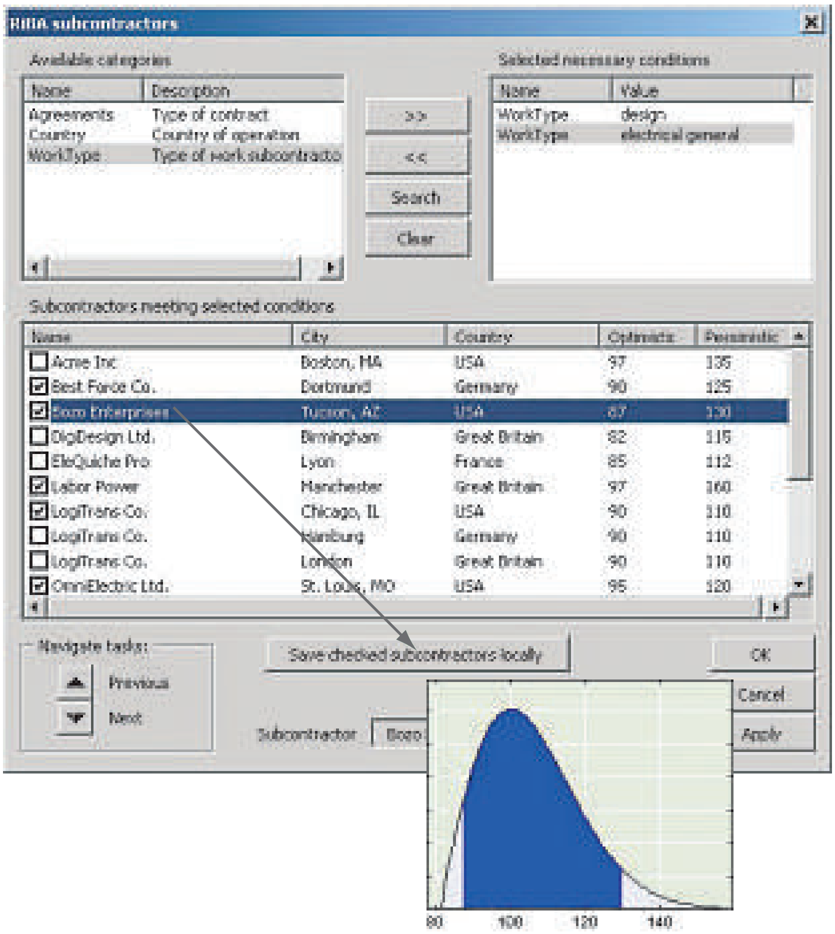
When computing the duration of a task, its bonus/penalty (if specified) is evaluated by interpolating between the corner points. The bonuses/penalties of the individual tasks are combined to obtain the overall bonus/penalty for the project.

Task-related costs are thus explicitly modeled as a function of task completion or duration. This is unlike the existing risk analysis software tools in which costs are modeled as being resource-dependent or simulated as random variables correlated with tasks.

A typical RiBA schedule with duration uncertainties and a performance function is illustrated in 4.

Quality risks

A project may contain a number of discrete events that could incur penalties. For an unexpected transformer failure, for example, the penalty might be 50 kUSD. Such events come under the umbrella of quality risks and are represented in the model as tasks with zero length, so they do not affect the overall project duration. Their probability distribution is defined as a uniform distribution between 0 and 1, and a



2 Shared subsupplier database with performance profiles used in modeling task duration uncertainty
(Inset: reliability profile)

penalty function maps this distribution to the specified penalty with a given probability. For example, a penalty function with a penalty of 50 kUSD between 0 and 0.1 and no penalty between 0.1 and 1 would, considering the mentioned uniform distribution, indicate a 10% chance of the failure event taking place, and therefore of the 50 kUSD penalty being imposed.

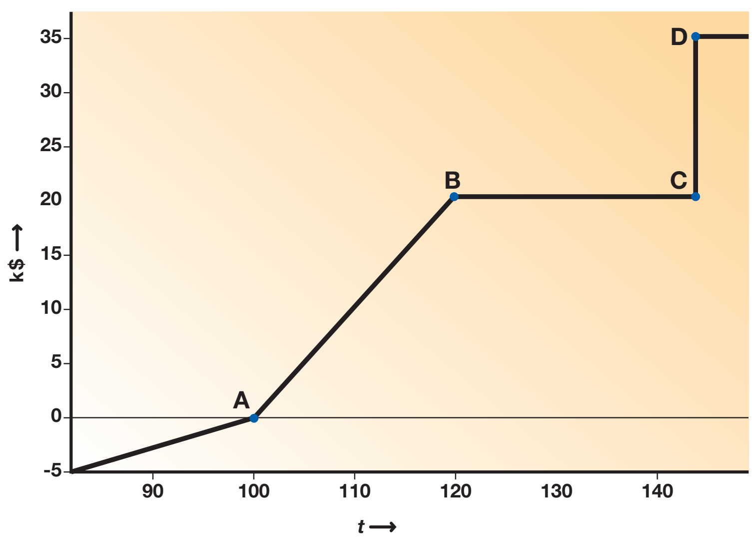
Risk calculation – 'gut feeling' with a quantitative touch

Once the model is set up, risk analyses can be run. The Monte Carlo method is used for the simulations (see side-bar on page 59). This involves computing a large number of iterations, each one representing a plausible set of task durations and quality risks drawn from their specified distributions. Overall project duration and cost are computed in each iteration.

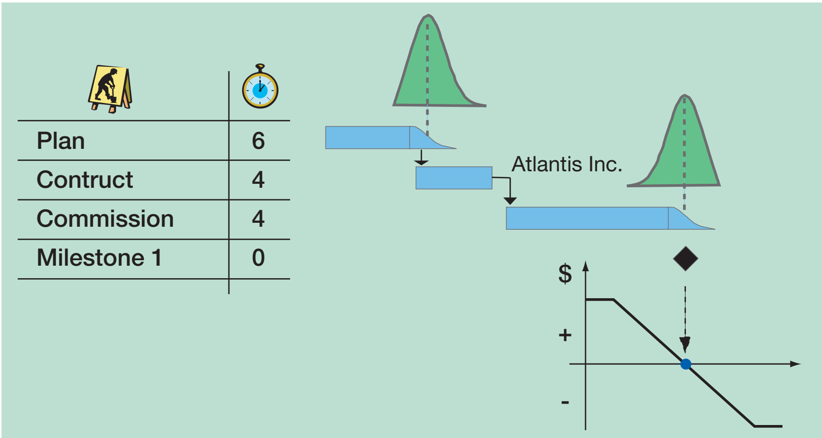
The task duration distributions are presented as probability density graphs (histograms) of duration and value distribution 5. In order to reduce the number of iterations required to reach a certain precision, the histograms are smoothed with a kernel. (The effect of statistical dispersion is, in fact, reduced by convolving the histogram with a kernel function. In this particular case a normalized gaussian is used as the smoothing kernel.) The most relevant statistics (eg, pessimistic and optimistic estimates) are reported as well.

To see how the results are interpreted, let's look at the Project Duration Distribution graph in 5. The planned project duration is 230 days, ie if all the tasks are completed exactly as planned (no sooner and no later) it would take this long to complete the project. The time of 230 days also concurs with the total project duration reported by Microsoft Project. However, we have

3 Modeling performance clauses - bonus/penalty function



4 Visualization of a project schedule with RiBA extensions (duration uncertainties and a performance clause)



allowed for some uncertainty in the task durations; generally, a task is more likely to overrun than to finish early. Not surprisingly, the overall project duration is likely to be exceeded as well. We can see from the results that the average duration is 236 days – six days longer than planned. The other two numbers reported are the optimistic and pessimistic durations, representing the 5% and 95% probability limits, respectively. This means that the project has a 5% chance of lasting less than 221 days and a 95% chance of being completed in less than 254 days. To put it another way, the shortest possible and the longest possible durations are 221 and 254 days, respectively (within a 5% confidence limit). It is worth noting that the optimistic project duration is *not* the result of all individual tasks being completed within their optimistic duration (this similarly holds true for the pessimistic duration). It is here that we see the advantage of RiBA over a simple (eg, arithmetic) calculation of the total project duration based only on minimum and maximum task durations. The likelihood of all tasks in a project being completed within their minimum, or their maximum, duration is very small, so such a simple system would yield erroneous results, for example a much wider duration range than the actual probability would indicate. On the other hand, a delay during one of the first tasks can have an 'avalanche effect', ie a significant impact on all penalties relating to subsequent tasks. RiBA gives the user an objective overview of the situation.

Another feature of the results display is the probability reading. It is shown that the probability of completion within 230 days is only 25%. Using the slider, any target duration can be set and its probability read off. This is useful, for example, when the user wants to quote a safe project completion date to a client. Of course, this will depend on the definition of 'safe', so let's say a one-in-ten chance of falling behind schedule is still considered reasonable. The slider can be used to find the target duration giving a 90% probability of completion. This project duration (say 248 days) can then be safely quoted to the client, although 230 days is still used for the internal planning.

The lower graph in 5 provides similar information (planned, optimistic, average and pessimistic values) for the Project Value Distribution. The slider has the same function as in the top graph. This graph will usually be more complicated than the bell-curve-like shape of the project duration graph because of the various penalty functions involved.

Some caution is needed when interpreting these graphs. In general, it cannot be deduced that a given project duration implies a certain project cost. This is because a particular project duration can be reached in several different ways (eg, task A takes less time and task B more time, or vice versa), and each of these ways can result in a different penalty.

A word about sensitivity and optimization

Once the project duration and cost probabilities have been computed, the

"RiBA adds value through the fine tuning of performance incentives or penalties to be included in the contract tender." RiBA pilot user

next step could be to try and optimize the project schedule. For example, the task sequence could be changed, or tasks could be assigned to more reliable subsuppliers. To do this effectively it would be helpful to know which tasks are most problematic. RiBA offers a sensitivity analysis function that helps users here by analyzing the impact of the different tasks.

The purpose of the sensitivity analysis is to show how much the uncertainty of a task's duration affects the overall project duration and value. It yields two numbers for each task, one expressing its *duration sensitivity* and the other its *value sensitivity*. These are different because a task can contribute to the overall project duration yet have no overall value impact, and vice versa.

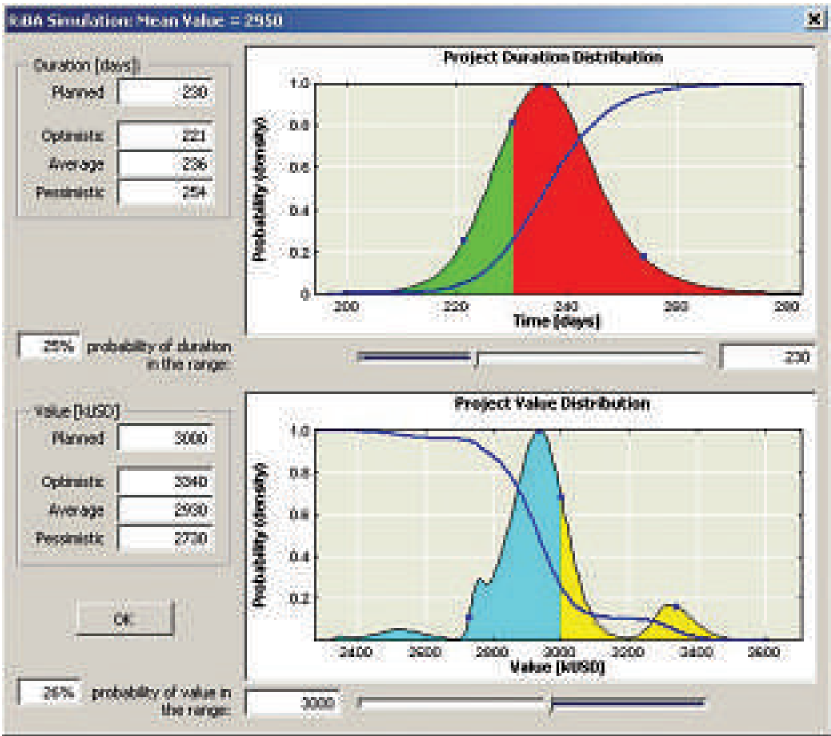
The duration sensitivity describes the impact of the individual task's duration distribution on the overall project duration uncertainty. If a project consists of only one task with a completion date spread of about two days, then the project will have the same two-day spread and the sensitivity will be two days. Reducing the task's spread to one day will also reduce the sensitivity to one day. If, on the other hand, a project includes a task that never affects the project duration (eg, it runs in parallel with a much longer-lasting task), its sensitivity will be zero.

An analogous situation exists for the value sensitivity. Its magnitude, again, expresses how much a task's uncertainty influences the project value uncertainty. Value sensitivity could be independent of the duration sensitivity; for example, a non-time-critical task (zero-duration sensitivity) could have a penalty function assigned to it, so it has non-zero value sensitivity.

The computed duration and value sensitivities are plotted together for all the tasks 6. This allows the user to focus on streamlining the project with respect to those tasks that affect the project the most.

Another option is available for turning individual penalty functions on and off while running the analysis. This allows the user to see which penalty functions have the largest impact and to reformulate them when possible.

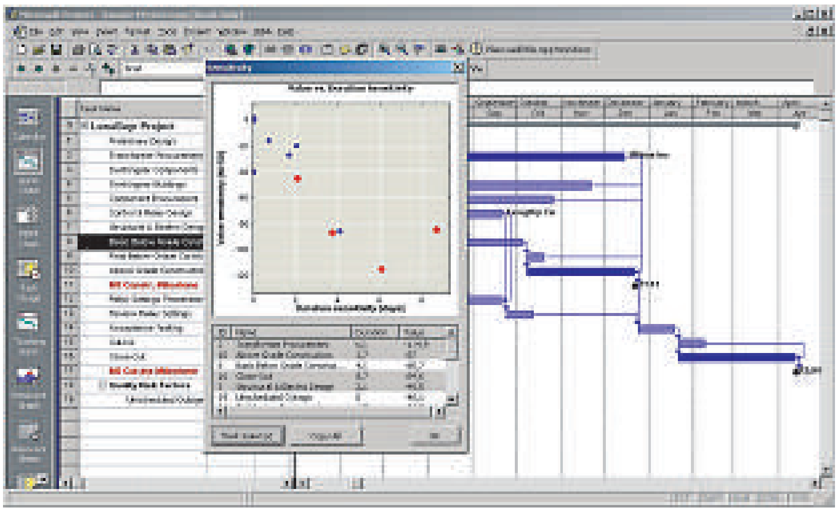
5 RiBA simulation results – probability distributions for overall project duration (top) and value (bottom)



Non-critical critical path

Many scheduling programs highlight the critical path, but when task duration uncertainties are taken into account the critical path concept becomes more fluid. Imagine two household tasks running in parallel: To bake a cake you set the oven timer for 30 minutes, and then run to the corner store to buy chocolate topping. Only when both these tasks are completed successfully can the topping be spread on the cake. Normally, a round trip to the corner store takes only seven minutes, so it appears at first sight that baking the cake is on the critical path and purchasing the chocolate is not. However, while there is no uncertainty in the baking time, the trip to the store could take much longer; for example, it

6 Sensitivity analysis chart. Selected tasks are highlighted in red.



might be out of chocolate and you have to drive to the nearest supermarket. Now, the critical path would include the task of purchasing rather than baking.

This simple example shows how allowing for uncertainty in project planning can result in a critical path which is very different from the one produced by a project plan, in which a task's duration is assumed to be fixed and no uncertainty is reckoned into the equation. What RiBA does is calculate the critical path correctly even when uncertainties are present in the model.

As a rule, the duration sensitivity for a task not on the critical path is low. However, when uncertainty is considered, a task may or may not be critical. The less often it is critical, the lower the duration sensitivity.

Mutual benefits

While various software tools are available for quantitative risk assessment, RiBA stands out for the advantages it offers in the following areas:

- Integration with existing tools (MS Project); the common scheduling environment means that no additional tools or software skills are required.
- Central database of subcontractors/subsuppliers for performance control and optimization.
- Model re-use (RiBA uses standard Microsoft Project models); generic sets of subproject templates can be created for sharing project-planning experience within the company.
- No duplicate modeling effort required as project planning and risk analysis take place in the same environment.
- Project optimization support provided by duration and cost sensitivity analysis.
- Fast, easy scenario analysis ('what-if' testing).
- Straightforward interpretation of analysis results.
- Ease of use; intuitive dialog (mathematics are invisible to the user).

Looking forward

RiBA can be used for planning as well as tracking. In the latter case, as certain tasks are completed and no longer uncertain, the task durations are set to their actual values. Subsequent repetition of the risk analysis simulation then updates project risk profiles based on the latest information. A progressively narrowing risk profile indicates that the project is right on track; if it doesn't look as if it will meet its targets, the project manager is alerted.

Although originally developed for service and retrofit projects, RiBA can easily find application in many other ABB businesses and for a wide range of projects. It is currently being deployed in 13 pilot installations in the USA, UK and Switzerland, and feedback from these pilot users will flow into future upgrades.

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