Risk Simulation in Project Management System

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Abstract: *The Risk Management System of a Project Management System should be able to simulate, to evaluate and to display possible risks in critical collaboration processes for future time periods. The evaluation results are then used to achieve effective automation of business processes, to reduce costs and to limit project duration. Collaborating business processes are presented by workflow, so the obtained risk results lead to redesign and optimizing of the workflow. The article presents a program framework for risk simulation of collaborating business processes based on 2-dimensional Monte Carlo Simulation.*

Keywords: *Risk Management System, Project Management, Monte Carlo Simulation, Risk Calculation, Risk Calculation Engine, Simulation Representation, Simulation Implementation*

1. Introduction

A process (project or workflow) consists of several tasks which need to be carried out. However, tasks can be subdivided into a list of activities to define a finer granularity of work items. The Project Management System Workflow Definition Database contains all statistic relevant information and workflow definitions for the simulation, analysis, planning of capacities, costs and efforts, start and end date and continuous probabilities of the workflow progress of each workflow task. Workflow definition data are passed to Risk Management System where the workflow is constructed along the time axis in accordance with the process definition and then it is scanned periodically and simulated using structured Monte Carlo simulation in order to observe or forecast the behavior and interaction of process instances and to detect the potential bottlenecks for optimizing the work load, cost and time.

Workflow Simulation

The Risk Management System simulates workflow statistically and generates distributions for every task or subtask and for every future time slice. The simulation is based on analytical models for development of important task properties such as effort, duration, costs and usage of associated resources. The analytical models are formulated using free algebraic definitions (expressions) that are parameterized by time slices and are able to define different aspects of enterprise risks. The workflow is represented in 2D table structures (hierarchic tree node structure of tasks, sub-tasks, activities, resource allocation and risk factors on the Y-axis and periodic development of future time divided into analytical time slices on the X-axis).

The algebraic expressions are applied to obtain all single future values of task properties while static calculation. A set of risk factors such as material prices, effort indices, etc. is simulated by Monte Carlo simulation that generates a large set of correlated value paths (possible value developments or scenarios) [3]. The algebraic expressions are evaluated for every scenario producing value distributions for desired dependent attributes such as estimated task effort and duration. The risk are obtained from value distributions after the simulation runs are done.

Workflow Forecasting

Forecasting in the Risk Management Systems is for predicting the value development of important task properties and aggregated workflow properties in their expected (most probability) values and risk characteristics at assumed confidence level according to general workflow goals to reduce or to limit costs and project duration and to use effectively of available resources. The forecasting is done upon the all the process definitions, where the workflow resource is involved. A workflow resource can be: a person, a machine, or an automatic tool (a piece of program, for example).

According to the process definitions applied in the Workflow Management System, it can be forecasted whether some workflow activities will be assigned to a certain workflow resources and how the resources assume the process effort within forecasted duration along the time axis. It a usable praxis to define first a set of independent risk factors that influence the dependent properties through the algebraic definitions and to forecast the risk factors instead of task properties self. The advantages are:

- The whole simulation framework is controlled by a small set of stochastic variables.
- It is possible to forecast value development and statistic properties such as volatility (standard deviation) and correlation (auto and cross correlation) of such factors.
- Normal distributions can be assumed for the risk factors that allows to use the multi-variate approach for the Monte Carlo simulation.

The results of forecasting refer to:

- First, what expected value development will expose every given risk factor in the future allowing to obtain correlation between factors and what will be the standard deviation term structure for every factor and
- Second, using the algebraic definitions for all dependent task attributes, what expected value development will expose every task property for expected exposure of the risk factors [3].

<u>Periodic Scheduled Costs:</u>
The simulation of the workflow is made based on analytical periods (time slices), for Example monthly or weekly within a near future (forecasting interval), for example 1 Year. Thus, the workflow and corresponding costs are scanned according to chosen time slicing. The foreseen task effort is assumed by resources in small pieces in this case, so the calculation of all scheduled costs is done for every analytical period.

2. Definition of risks

Risk: The risk is a probable loss occurring on future time points at a confidence probability level related to expected value of a measure. Losses can be assumed because of none expected behavior of component or resource or working environment of a critical process.

Measure: Amount, cost, time, speed, performance, output, etc. of a critical process.

Expected value: The mean of the probability distribution of a measure on a future point.

Confidence level and Value: Percent or Value of the distribution square on the left side of the distribution. This percent determines the confidence value of measure distribution.

Probable loss: Probable Loss = Expected value – Confidence value.

Example: The performance of a critical process unit within a workflow is forecasted monthly for the first 6 months within next plan year using probability distribution. The expected value of the distribution at end of first month is 13.5%, the confidence level is 5% implying a confidence value of 12,1% at some assumed distribution. The risk is measured by the probable loss = 13,5% - 12,1% = 1,4% which can occur with a probability of 5%.

3. Syntax rules for node expressions

A set of rules define the syntax node expressions that are used to obtain periodic attribute values such as cost or duration of dependent nodes (tasks). Examples of node expressions are given in next sections.

Expression => Term ('+' | '-') Expression | Term

Term => Factor ('*' | '/') Term | Factor

Factor => '(' Expression ')' | NumberConst | 'Last' | Node | Sum | Mean | IF | 'n'
Factor => Exp | Ln | Power

Node => '{' NodeId.NodeNr'}' Structure Node

Node => '{' NodeId.NodeNr’[’Column’]’’}' Structure Node of a Column

Column => Integer Column number

Column => 'n-' Integer | 'n+' Integer relative to current Column ‘n’

Sum => 'Sum' '(' Node ')' Sum of all Node Children

Mean => 'Mean' '(' Node ')' Mean of all Node Children

IF => 'If' '(' Condition ';' Expression ';' Expression ')'

Condition => Expression CompareOp Expression

CompareOp => '>' | '>=' | '=' | '<' | '<=' | '<>'

Exp => 'Exp' '(' Expression ')'

Ln => 'Ln' '(' Expression ')'

Power => 'Power' '(' Expression ';' Expression ')'

The syntax defines arithmetic expressions including parenthesis, functions and compare operators on node values and constants. The expressions are build in a template manner, i.e. they are expanded automatically over all future periods. The expressions for a future period can access data of other periods using absolute or relative period index (period number). For example, following expression is valid for Node3:

Node3 = if (n=0; 500; Node3[n-1] + 200)

The expression means that the value of Node3 at start is 500 and accumulates 200 for every next period, i.e. 500, 700, 900, 1100, ...

4. Evaluation and analysis of risks

4.1 Calculation of risks

The risks are defined on a set of hierarchic nodes within a plan or workflow structure where a set of algebraic expressions determine the node values for every desired future time point. The plan or workflow structures including algebraic expressions are defined by user as templates allowing for creation of individual plan instances and for plan simulation using different future risk horizon and evaluation time points within that are determined in the most cases automatically by the analysis frequency.

Monte Carlo simulation:
Statistic of basic risk factors for future time points: standard deviation (volatility) term structure, cross-correlation (time point x basic factor) is used to create cross-covariance matrix needed for the simulation. The statistic is calculated on discrete time points (T1, T2, T3, ... , s. Fig. 1) where covariance matrixes are derived from value and volatility forecast (s. Fig. 2).

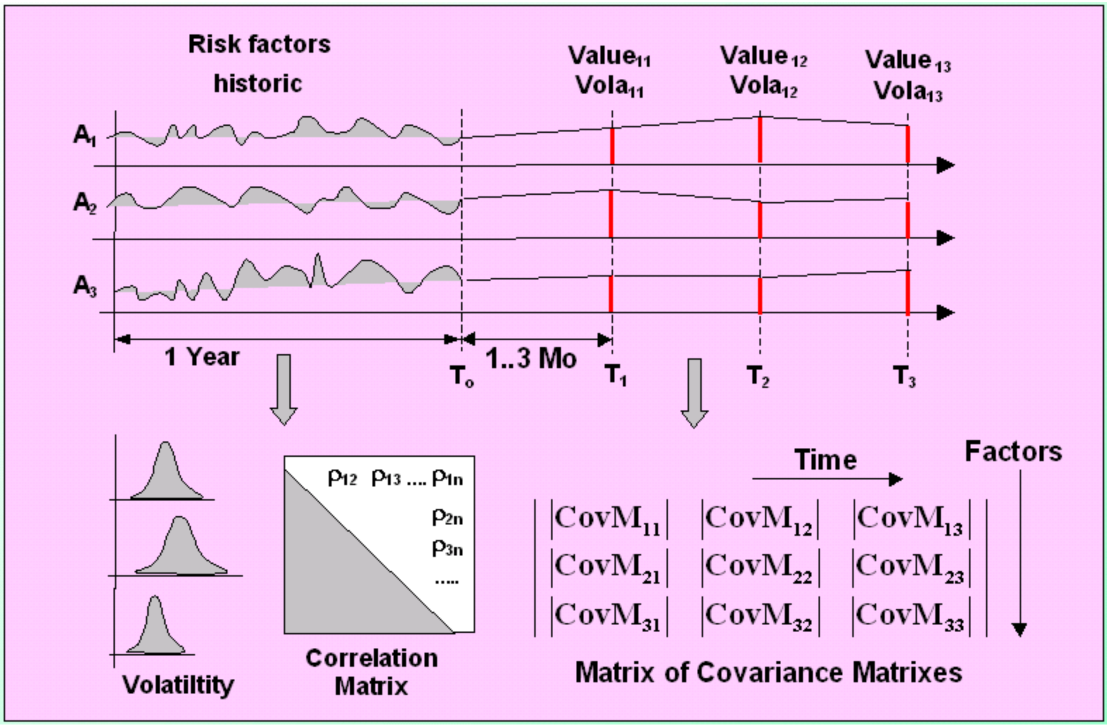

Fig. 1. Calculation of simulation data on future time points

A set of normal distributed Monte Carlo scenarios (for example 5000) are generated for every risk factor and time point by random generator, the result is a scenario matrix: (factors x time points) x scenarios, for example 5 factors x 12-time points x 5000 scenarios. The matrix is then multiplied by Cholesky decomposition of the covariance matrix to receive correlated minor changes of basic factors on time points. The simulation produces a large set of possible developments for the risk factors.

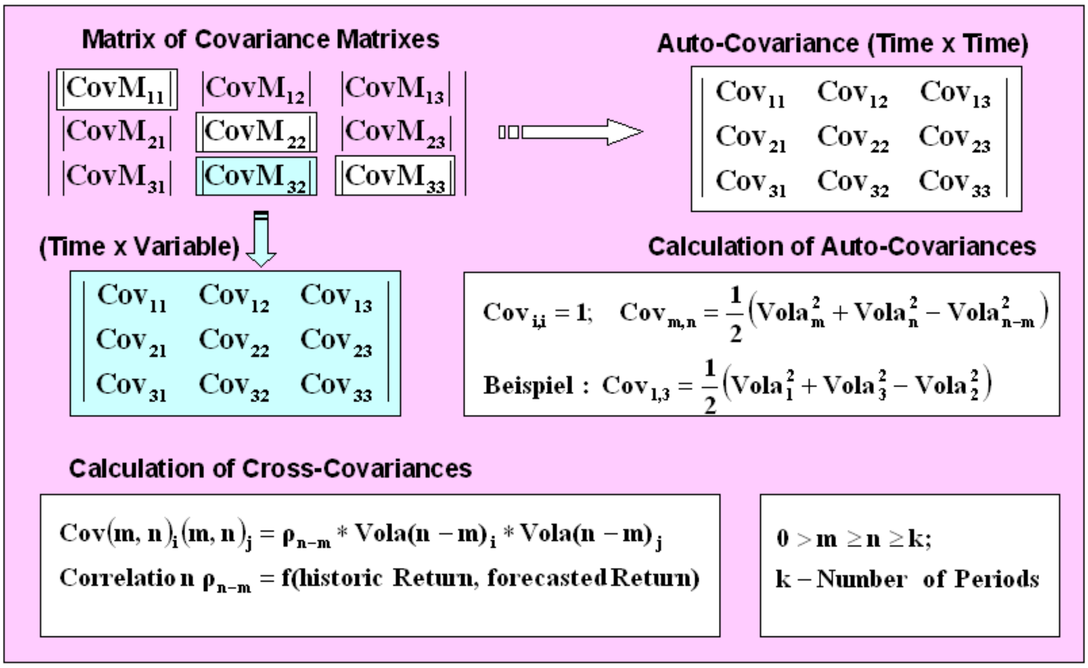

Fig. 2. Calculation of Covariance Matrixes

The algebraic expressions are calculated for every workflow node, for every future time point and for every Monte Carlo scenario, so value distributions are created for every workflow node on every future time point. Risk measures are then obtained from distributions allowing to observe the risk of whole workflow and to check where are the critical points on the simulated time development. Risk measures are shown on visual components such as grids and graphics.

4.2. Workflow cost simulation example

Following example should demonstrate the workflow simulation approach. A workflow describing an example software development project is analyzed and simulated for 1 Year (from 01.09.2005 to 01.09.2006) on monthly basis, i.e. for 12 analytical periods. The workflow consists of 3 consecutive main tasks (Product Specification, Product Development and Product Implementation) with associated fixed costs, efforts and duration. The Product Development and Product Implementation tasks are compound tasks consisting of parallel partial overlapping sub-tasks with following example fixed costs and efforts:

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Table 1: Costs and duration of sub-tasks

Product Development	Fixed Costs	Effort (hours)	Duration (hours)
1. Product Specification	5.000	680	340
2. Product Development			
Data Base Structure	4.000	500	500
Business Logic Programming	3.000	2.250	750
GUI Design	6.000	1.500	750
3. Product Implementation			
Test and Documentation	3.000	680	680

Customer Training	2.000	680	340

Three resources should assume the work. The hourly rates of the resources given in the Section Resource Allocation changes for different months. The Resource 1 and the Resource 3 are busy and don't work for two months. The resources are assigned to project tasks as shown in Table 2.

Two stochastic factors (Task Effort Index and Task Duration Index) should influence the calculation and the simulation of project costs, but in the example only the first factor is connected to simulation model. The stochastic factors represent the uncertainly of estimated task efforts, resource performance and task duration. Every stochastic factor exposes a forecasting for future development and for volatility so the effort for the analysis period i of the first task can be written as:

{1. Product Specification[0]} = - 5000 and
{1. Product Specification[i]} = {1. Product Specification[i-1] } -
({1. Resource Hrate[i]} + {2. Resource Hrate[i]}) * 340 *
{1. Task Effort Index (%)[i]} * 0.01,

where 5000 is the fixed cost, 340 is the monthly task effort and the {1. Task Effort Index} is the stochastic factor.

The development of the expected scheduled total costs of the workflow is given in the Scheduled Total Effort Row (s. Table 2). The results of the Monte Carlo simulation and calculated cost risks are given on screen shots in Section 5.

Table 1: Workflow Cost Simulation Example

Project Workflow Example, [12.09.2005]

Project Workflow Plan 001, 12.09.2005

Start Date:	**01.09.05**
End Date:	**01.09.06**
Period:	**Month**
Values In	**Money Units**

1. Product Specification
Effort = 680 Hr
Duration = 340 Hr

1. Product Development
Effort = 4250 Hr
Duration = 1200 Hr

3. Product Implementation
Effort = 1340 Hr
Duration = 680 Hr

2.1 DB Structure
Effort = 500 Hr
Duration = 500 Hr

2.2 Business Logic
Effort = 2250 Hr
Duration = 750 Hr

2.3 GUI Design
Effort = 2250 Hr
Duration = 750 Hr

Workflow Item(Task,Resource)	01.09.05	01.10.05	01.11.05	01.12.05	01.01.06	01.02.06	01.03.06	01.04.06	01.05.06	01.06.06	01.07.06	01.08.06	01.09.06
Scheduled Total Effort	-5.000	-18.317	-39.853	-43.853	-55.817	-103.199	-180.896	-293.972	-421.758	-480.848	-492.517	-514.874	-553.302
1. Product Specification	-5.000	-13.317	-21.535										
2. Product Development				-4.000	-11.964	-47.382	-77.697	-113.076	-127.786	-56.089			
2.1 Data Base Structure				-4.000	-8.964	-13.909							
2.2 Business Logic Program.					-3.000	-27.474	-54.008	-71.697	-79.052				
2.3 GUI Design						-6.000	-23.689	-41.379	-48.734	-56.089			
3. Product Implementation										-3.000	-11.669	-22.357	-38.428
3.1 Test and Documentation										-3.000	-11.669	-20.357	-29.062
3.2 Customer Training												-2.000	-9.366
Resource Allocation													
1. Resource HRate		15	15	15	15	12	12			12	12	12	12
2. Resource HRate		9	9	9	11	11	11	11	10	10	10	10	10
3. Resource HRate		13	13	10	10	10	13	13			13	13	13
Stochastic Factors													
1. Task Effort Index (%)		101,93	100,71	100,00	99,29	98,88	98,27	98,27	98,07	98,07	98,07	98,27	98,48
2. Task Duration Index (%)		100,00	99,62	99,47	99,31	99,31	100,00	100,53	101,14	101,60	102,06	102,36	102,36

{1. Product Specification[0]} = - 5000 and
{1. Product Specification[i]} =
{1. Product Specification[i-1] } –
({1. Resource Hrate[i]} + {2. Resource Hrate[i]})
*** 340 * {1. Task Effort Index (%)[i]} * 0.01**

5. Graphical User Interface

The Graphical User Interface of Windows based Risk Management System includes trees, grid controls, property lists and business graphics. Tasks, sub-tasks, resources and risk factors can be ordered on a hierarchic tree structure.

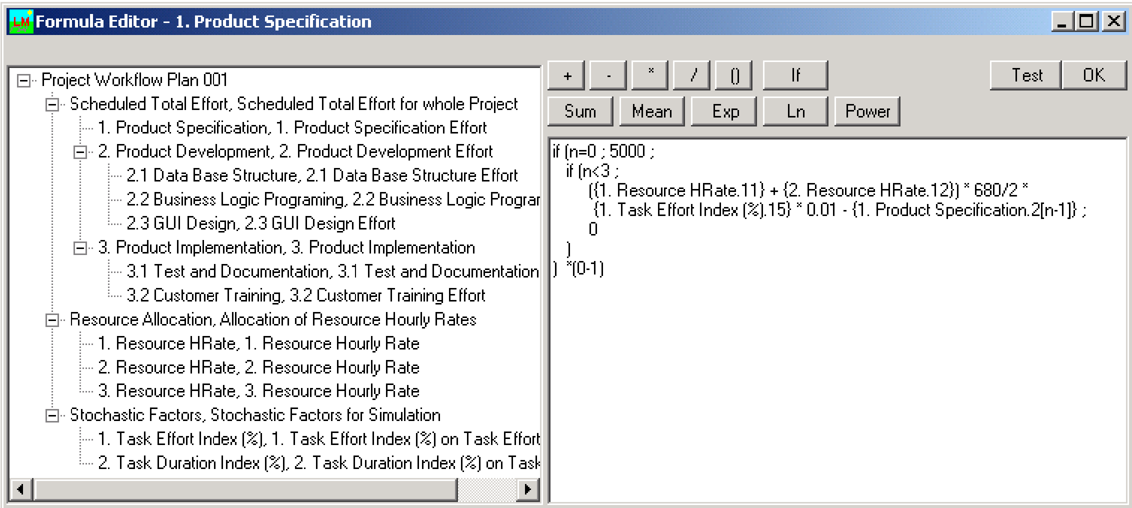

Fig. 3. Definition Hierarchical Tree and Algebraic Expressions

Algebraic expressions that define the value of a dependent workflow node as a function of values of other nodes can be free edited using edit box and function buttons.

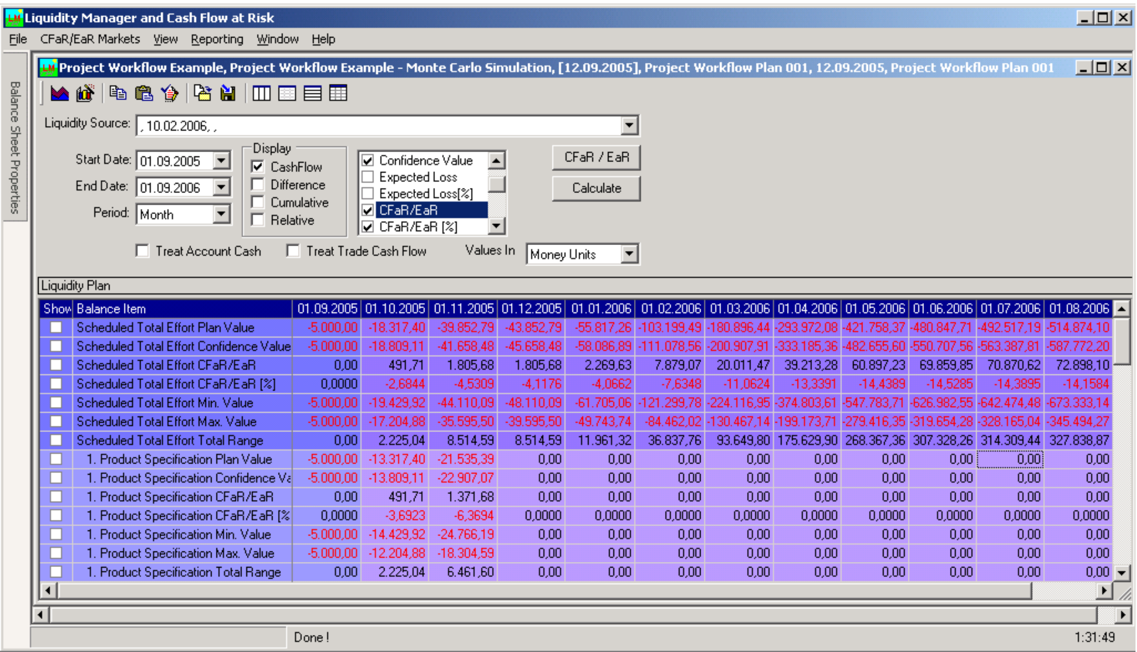

Fig. 4. Simulation Results of Workflow

The workflow is calculated and simulated for every future period using the algebraic expressions. Simulation results such as mean of value development, confidence value and risk as value distributions are presented on graphics and on reports.

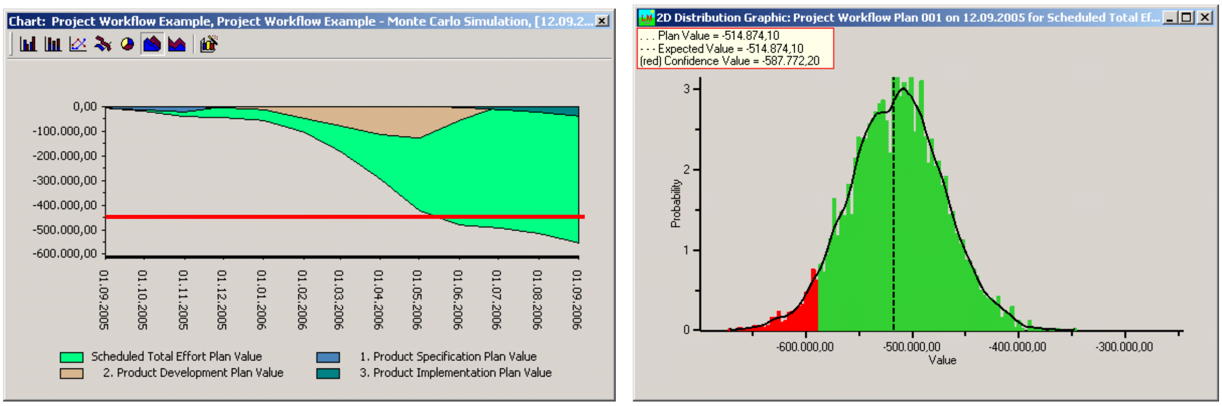

Fig. 5. Graphics for Value Development and Probability Distribution

Future development of risk factors is forecasted using interactive graphic (s. Fig. 6).

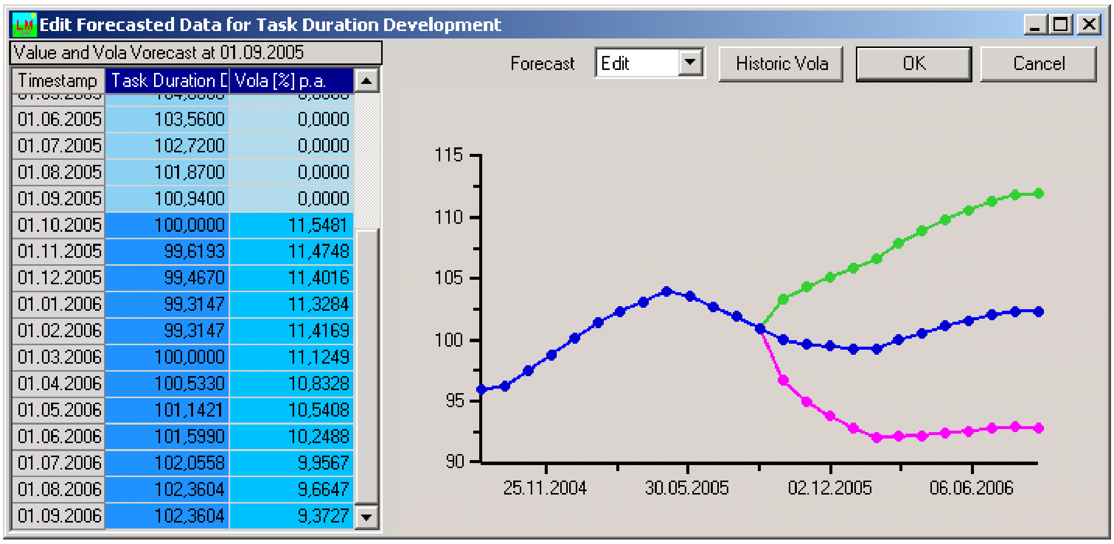

Fig. 6. Forecasting of future development of risk factors

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