EVALUATING SCHEDULES OF ITERATIVE/INCREMENTAL SOFTWARE PROJECTS FROM A REAL OPTIONS PERSPECTIVE

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Abstract: In an iterative/incremental software project, software is built in a sequence of iterations with each of them providing certain parts of the required functionality. To better manage an incremental delivery plan, iterations are usually performed during pre-specified time boxes. In a previous work, we addressed the problem of optimizing the schedule of incremental software projects which follow an iterative, timeboxing process model (TB projects). We approached scheduling as a multi criteria decision problem that can be formulated by a linear programming model aimed to overcome some "rigid" simplifications of conventional timeboxing, where durations of time boxes and stages are equal and a priori fixed. In this paper, we move this decision making process one step forward by applying real options theory to analyze the investment risks associated with each alternative scheduling decision. We identify two options in a TB project. The first is to stall (abandon) the development at a pre-defined iteration, while the second is to continue (expand) development and deliver the full functionality. Thus, we provide the manager the flexibility to decide the most profitable (valued) combination of delivered functionalities, at a certain iteration, under favourable or unfavourable conditions.

1 INTRODUCTION

A common management approach in iterative/ incremental software development projects is timeboxing, i.e., to perform iterations during pre-specified time periods, so called time boxes (Stapleton, 2003). Timeboxing emphasizes on improving the predictability of software delivery times and avoiding, as much as possible, risks of missing project deadlines, as these are determined by the iteration time boxes (Jalote *et al.*, 2004). A timeboxed iteration delivers a working software system that is generally an increment to the previous delivery. Thus, the manager of a software project which employs timeboxing (TB project) faces the problem to specify the functionality to be delivered within the context of each time box. By following a "mini" waterfall approach, development work is divided into a sequence of stages (e.g., requirements, design, implementation, testing and deployment) that are repeated iteratively and executed by small dedicated development teams. Iterations in a TB project can be rolled out in parallel to further improve the project performance and reduce the overall project duration. Parallelism is achieved by following a "pipelined" execution that is similar to instructions execution from hardware architectures. When a team completes the tasks of a stage, it hands over the intermediate deliverables to another team executing the next stage and then starts executing the same stage in the next timeboxed iteration.

In previous work we have defined a multi objective linear programming (LP) model for scheduling TB projects (Gerogiannis and Ipsilandis, 2007). We have proposed a model that overcomes some limitations of conventional timeboxing, where timeboxes are ad hoc fixed, precedence constraints between stages are simple sequential relationships and possible work discontinuities due to coordination overheads between stages in successive iterations are not considered. This LP model supports the software project manager to consider a list of objectives regarding the overall project performance (e.g., to minimize project duration, iteration delays and work discontinuities). Sensitivity analysis can provide some useful

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information regarding cost trade-offs between these scheduling decisions. The final outcome is a set of alternative schedules (a portfolio of schedules), each one characterized by a corresponding ratio between iteration delay and work discontinuity costs.

In this paper, we build on this previous research work and we apply a Real Options approach to further enhance the overall decision making process in TB projects. Real Options is a financial/decision theory which addresses uncertainties inherent in project investments over time and facilitates adaptation of project management decisions to dynamic environments (Myers, 1977). The possibility to consider Real Options analysis is particularly suitable in case of software projects (Sullivan *et al.*, 1999; Tiwana *et al.*, 2006), when the project manager has the opportunity (but not the obligation) to make decisions in response to external or internal events (e.g., defer the development, expand the system functionalities, abandon the project etc.).

In order to present our approach, we describe the scenario of an R&D department of a software company that undertakes a software project in an iterative/incremental, timeboxing development fashion. We assume that the selection of the appropriate schedule is a decision process that involves the R&D management and the company's management board. The R&D management team employs the LP model and identifies a set of candidate schedules. These are then passed to the managers of the board where they perform Net Present Value (NPV) calculations to identify the profitability of each alternative schedule. By performing Real Options analysis, we will show how the management board is benefited, in contrast to the NPV approach, to undertake the proper project scheduling decision that addresses potential investment risks and uncertainties. Real Options analysis can be applied to examine, at a certain iteration, the value of the delivered functionalities. Thus, the management board has the flexibility to decide the most profitable (valued) combination of functionalities, under favourable or unfavourable conditions.

The paper is structured as follows: In section 2, we briefly present the results conducted in our previous work. In Section 3, we present an overview of Real Options applicability in software project management. In Section 4, we define the real options to be analyzed in an iterative/incremental project example. In section 5, we employ a set of schedules for the example project and we apply a Real Options approach in order to demonstrate how the selection process of the most suitable schedule can be supported. In the last section, we present conclusions and directions of future research.

2 PREVIOUS WORK

In previous work we approached the problem of finding optimum schedules for a TB project, from the perspective of multi criteria decision analysis, and we proposed alternative project schedules and cost trade-offs as tools to be employed in order to arrive at a suitable project scheduling decision (Gerogiannis and Ipsilandis, 2007). A TB project manager is assisted in selecting among alternative schedules according to the relative magnitude of each scheduling cost element (iteration delay costs vs. work discontinuity costs). Thus, our approach differs from other decision analysis methods applied to release planning of iterative projects, since they focus mainly on providing support for the selection and prioritization of software requirements (Greer and Ruhe, 2004; Akker *et al.*, 2008).

In any TB project, we can identify that there is a set of *M* stages and *P* project dependency relationships (with or without time-lag). The project is divided into *N* separate iterations in a "linear" way, where, without loss of generality, the following assumptions (originated from the timeboxing process model) hold:

all stages are performed in all iterations,

a stage cannot be performed before the same stage is completed in the previous iteration,

precedence dependencies remain the same in all iterations (i.e., the same planning method is followed).

By adopting an AON (Activities on Nodes) network representation for the project life cycle, stages are represented as nodes and dependency relationships among stages are represented as arcs in the project network. Precedence dependencies can be of any type of the known relationships (Start-to-Start/SS, Finish-to-Start/FS, Start-to-Finish/SF, Finish-to-Finish / FF).

Let $i = 1, 2, \ldots, M$ denote the project stages and $j = 1, 2, \ldots, N$ denote the project iterations. Scheduling of a TB project can be defined by a linear programming (LP) model as follows.

I. Model Variables and Parameters. Define:

d_{ij} , the duration of stage i in iteration j,

s_{ij}, f_{ij} , the start and finish time respectively of stage i in iteration j,

l_{ij} , the minimum elapsed time for starting stage i in iteration j+1 after finishing stage i in iteration j,

P_i , the set of predecessor stages to stage i,

E , the set of all stages without successors,

WB_i , the total time of work breaks for stage i because of work discontinuities in successive iterations,

UC_j , the completion time of iteration j,

D_j , the promised delivery/release time for the software part produced in iteration j,

c_j , the cost (per time unit) of delay in finishing iteration j after the deadline,

f_i , the cost (per time unit) of work breaks / discontinuities in stage i.

II. Constraint definitions. Define:

Stage duration constraints:

$f_{ij} = s_{ij} + d_{ij}$ ∀ i = 1, 2, …, M, j = 1, 2, …, N

Project linearity constraints:

$s_{ij+1} \geq f_{ij} + l_{ij}$ ∀ i = 1, 2, …, M, j=1, 2, …, N-1

Technological dependencies:

$s_{ij} \geq f_{kj}$ ∀ i = 1, 2,…, M, j = 1, 2, …, N, k ∈ P_i

Iteration completion time:

$UC_j \geq f_{kj} \, \forall \, j = 1,2, \ldots, N, k \in E$

UC_j is the completion time for iteration j and UC_N is the project duration.

Resource delays (work breaks / discontinuities):

$$WB_i = \sum_{j=1}^{N-1} (s_{ij+1} - f_{ij}), \quad \forall \; i = 1,...,M$$

$$WB = \sum_{i=1}^{M} WB_i$$

III. Global Objective Function. Depending on the values of the cost parameters c_j and f_i, the following general objective function:

$$\text{Minimize} \sum_{j=1}^{N} c_j.(UC_j - D_j) + \sum_{i=1}^{M} f_i.WB_i$$

can be used to achieve different objectives or analyze trade-offs between the cost parameters. Examples include: i) minimize the project duration (set c_N equal to 1, rest of c_j and f_i equal to 0), ii) minimize the total work break / discontinuity time (set all f_i equal to 1 and all c_j equal to 0), iii) minimize the completion time of iterations (set all f_i equal to 0 and all c_j equal to 1), iv) minimize the total cost of work breaks / discontinuities (set all c_j equal to 0), and v) minimize delay costs (set all f_i equal to 0).

Sensitivity analysis on the parameters of this objective function can be used to establish optimum schedules at different levels of cost relations by considering the ratio of iteration delay costs to the costs of work breaks.

3 REAL OPTIONS IN SOFTWARE PROJECTS

It is a common belief that the value for a given software product is directly affected by its development cost. However, research that has been conducted since the mid of 90s, oriented towards the employment of financial theories in software engineering application areas, has highlighted the needs for separating the value of a software product from its cost, maximizing the value added by a given software project investment as well as valuing the hidden intangibles behind software development. An example of such research initiatives are the Economic Driven Software Engineering annual workshops (EDSER, 2006).

Within this research context, there are efforts towards the exploitation of the prominent economic theory of Real Options (Myers, 1977) in order to analyze, in a monetary fashion, the economic value that different software investments could generate (Amram and Kulatilaka, 1999; Benaroch, 2002). The problem can be stated as follows: what is the most appropriate option (from a portfolio of options) that can result in the best value of a software product, process or project? Hence, the problem of software valuation can be viewed as a decision making process that takes place under uncertainty and incomplete knowledge. These uncertainties include the cost and schedule required to develop a software product, the software requirements which are likely to change in the future, the presence of software faults and failures, the impact of process/technology changes on cost and scheduling elements, etc. (Sullivan *et al.*, 1999). The core idea is to cope with these exogenous and endogenous uncertainties and mitigate the corresponding risks in the project investment. Such prediction is necessary for valuing the long-term investment of adopting a particular software development life cycle.

Classical financial techniques, such as Discounted Cash Flow (DCF) and Net Present Value (NPV) analysis, fall short in dealing with flexibility and uncertainty in decision making (Schwartz and Trigeorgis, 2000). The main problem with these techniques is that they are best valid when valuing an ongoing business or an immediate investment. Real options theory (Myers, 1977) was developed to address the inability of these conventional budgeting techniques to address the strategic value of a project investment. A real option gives the "option holder" (e.g., the software project manager) the right, but not the obligation, to evolve the software system and enhance the project opportunities by making follow-up investments (e.g., consider cases of reuse, expand the range of provided functionalities, follow-up or terminate the project, explore new markets etc.). If conditions favourable to investing arise, the project manager can exercise the option by investing the strike price defined by the option. Therefore, real options have been found a suitable approach to introduce flexibility, facilitate active software project management, and, consequently, handle the dynamic nature and uncertainty of a given software project investment (Wu *et al.*, 2007).

The approach of planning an iterative TB software project by taking into account multiple factors (like iteration completion times, project duration and work discontinuities for teams) and trade-offs between them, offers the TB project manager with the flexibility to consider a set of optimum schedules. However, when selecting an appropriate schedule for a project, based only on the cost trade-offs and the project static expected value (NPV), the TB project manager fails to consider future uncertainties and, hence, to tally for project risks. These uncertainties may range from internal ones, such as an unexpected delay of a specific stage in a certain iteration, to external ones, such as the introduction to the market of a new development tool/ technique that can ease the workload or minimize cost. Counting the unexpected, the software project manager has to be flexible.

Entering the Real Options realm, by utilizing the LP model, presented in the previous section, we can offer a portfolio of alternative scheduling options for the TB project manager to choose. Each scheduling option has a different inherent value (an option value) which is the value of the produced software, if this schedule is to be adopted. The manager has the right to exercise this option and he/she can do so, if certain business conditions become favourable for the project success.

4 MAKING VALUE OUT OF A TB SOFTWARE PROJECT

We will discuss the proposed approach through a hypothetical scenario of a software company's R&D department. Timeboxing is a suitable process model for developing projects which present a strong need to deliver a working system quickly as well as for projects of medium complexity which have a stable architecture (Jalote *et al.*, 2004). We assume that the company's R&D department executes this type of projects in a timeboxing fashion. Before a project commences, the R&D management utilizes the LP model presented in section 2, identifies a set of alternative schedules and justifies them since, under certain conditions, a different schedule can be the most suitable (in terms of project duration, iteration / work discontinuity delays, cost elements, delivered functionalities etc.).

After the schedules identification, the company's management board will be responsible to estimate the best schedule profitability. When the most profitable of the schedules is selected, the development work in this iterative TB project will begin. One possible solution is to calculate statically the NPV for all candidate schedules, based on the estimated project development costs (including delay costs) and the expected free cash flows. However, a combined Real Options–NPV approach can provide a better way to deal with project uncertainties and "discover" the "hidden value" within all possible schedules. The management board builds a step wise scenario, for each candidate schedule, that involves a review of the incremental delivery plan, to examine the delivered functionality (i.e., the number of requirements developed) at a certain point of the development life-cycle (i.e., at a certain iteration) when a working pilot application is planned to be available.

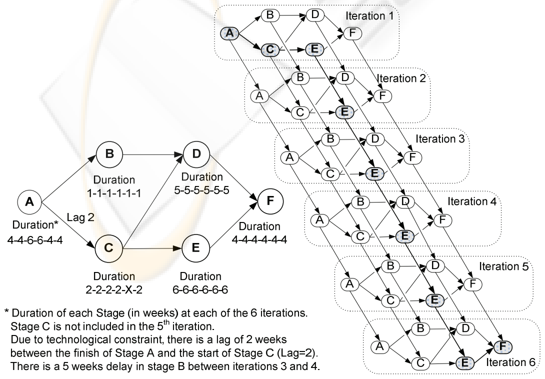
In the following, to simplify discussion, we make the assumption that in the presented example all necessary preparatory tasks (i.e., before identifying and analyzing the real options to be investigated) have been already performed, prior to the presented analysis. These steps typically include, but are not limited, to (Sullivan *et al.*, 1999; Tiwana *et al.*, 2006):

identify the real assets of a software project to be analysed by real options (e.g. development costs and future cash flows), monitor the important project uncertainties and approximate the probability distribution of these uncertainties.

We consider an example TB project life cycle that follows a set of 6 stages which are executed in an iterative/incremental approach. These stages are Domain Modeling (stage A), Use-Cases Analysis (stage B), Requirements Review (stage C), Preliminary Design & Review (stage D), Detailed Design & Review (stage E) and Coding & Testing (stage F). The work of each stage is done by a small stage-specific team (2-3 experts) and all iterations should be timeboxed. The final software application is originally scheduled, according to the incremental delivery plan, to be delivered after 6 iterations of these 6 discrete stages. The AON diagram in Figure 1 depicts all stage relationships (they are FS relationships) along with the most likely estimate (in weeks) of the duration of each stage, at each of the 6 iterations. The critical path of the entire project consists of stages A and C in iteration 1, the sequence of stage E in all iterations, and stage F in iteration 6.

We also consider that in this case project an intermediate review will take place before the beginning of the third iteration. If the delivered functionality at that point is the promised and the conditions (external: market competency, economic situation etc. / internal: company status, company policy, product uncertainty, resources uncertainty etc.) are favourable, then the management board decides to continue with the development of the rest of the iterations. Otherwise, the board decides to stall development and seek for salvage portion of the costs. The first option (to stall development) is the *Option to Abandon*, while the second (to proceed with the full product development) is the *Option to Expand* (Wu *et al.*, 2007).

The application of such approach within the context of an incremental/iterative life cycle might support the successful development of a pilot software application in a tight schedule. The management board conceives the first batch of iterations as a pilot application for the whole project. If the pilot application meets the company's standards/customer's expectations and the conditions for its full development are favourable, the company continues funding and proceeds to the full scale/full functionality product.



* Duration of each Stage (in weeks) at each of the 6 iterations.
Stage C is not included in the 5th iteration.
Due to technological constraint, there is a lag of 2 weeks between the finish of Stage A and the start of Stage C (Lag=2).
There is a 5 weeks delay in stage B between iterations 3 and 4.

Figure 1: Project AON network.

5 ANALYZING THE CASE STUDY

In this section, we present the application of our approach to the fictitious project discussed in the previous section. Having defined the project life cycle network structure (Figure 1), the project duration (48 weeks) as well as the number of iterations/increments (6), the development work is constrained by a strict time plan of 1 year (48 working weeks) and a fixed budget (initial outlay) of 30,000€. The R&D management will suggest the management board to evaluate three candidate schedules, in terms of their profitability: i) scheduling stages according to their Earliest Start (Finish) time, ii) scheduling stages according to their Latest Start time, and iii) scheduling stages to minimize work discontinuities without extending the overall project duration (48 weeks).

5.1 Alternative Schedules

As a first step, the R&D management, by setting in the global objective function presented in section 2 set all f_i equal to 0 and all c_j equal to 1, obtains the schedule that minimizes both the project duration and the completion time (i.e., the release time for software parts) of all iterations. This is actually the schedule produced by the Critical Path Earliest Start (Finish) Method (CPM EFT). Figure 2 presents a linear scheduling diagram that describes CPM EFT. The progress of each stage through the project iterations is represented by a piecewise straight line. The slope of this line corresponds to the "production rate" in a specific stage at each of the 6 iterations. Horizontal segments on the progress line correspond to work discontinuities between executions of the same stage in successive iterations. Vertical segments represent cases where a stage is planned not to be performed in the corresponding iteration (e.g., this is the case for the Requirements Review stage (C) in the fifth iteration).

CPM EFT can be considered as an "under-estimate" schedule that provides a minimum time bound for the time box duration of each iteration (i.e., the earliest time that iteration 1 should be completed is before 18 weeks, iteration 2 should be before 24 weeks etc.). The danger with an under-estimate schedule is the effect on software quality, since obtaining partial software deliveries, as early as possible, could affect negatively the software quality. CPM EFT is actually a baseline schedule for the rest of the analysis. It is a "too optimistic" project plan that results in minimum values of completion times for all iterations.

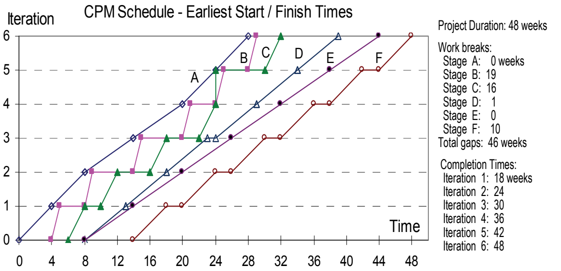


Figure 2: CPM Earliest Start/Finish Time – CPM EFT.

Next, the R&D management considers scheduling tasks according to their Latest Start (LS) times, as it is demonstrated in Figure 3. CPM LS schedule is obtained by pushing stages to their latest start times and transferring work discontinuities from the last project stages to those in the beginning.

The LP model can be solved towards the objective of total work discontinuity minimization. This is achieved by introducing the 48 weeks of CPM duration in the global objective function and setting all f_i equal to 1 and all c_j equal to 0. The resulting schedule is shown in Figure 4 (CPM WD). The minimum project duration of 48 weeks can be achieved with a minimum of 26 weeks of work discontinuities at stages B and C. A further reduction of work discontinuity times is not possible without extending the project duration beyond 48 weeks. Iteration delays, in both CPM LS and CPM WD schedules, have been calculated from the corresponding minimum iteration completion time values (i.e., the minimum time boxes) derived from the baseline schedule (CPM EFT).

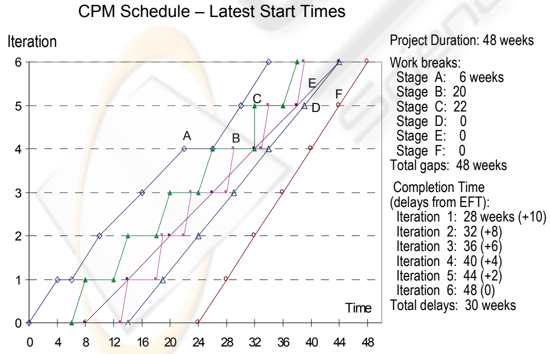


Figure 3: CPM Latest Start Time – CPM LS.

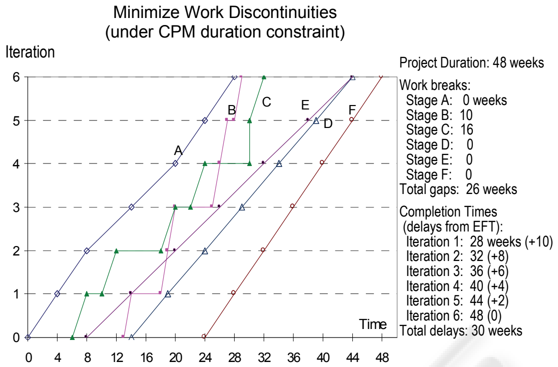


Figure 4: Minimizing work discontinuities – CPM WD.

5.2 Calculating Net Present Values

The R&D management delivers to the company's management board the baseline schedule (CPM EFT) and the two alternative schedules. The board initially calculates the NPV for the project by considering an one-off implementation for each schedule. As CPM EFT minimizes the project duration, by obtaining the software delivery as early as possible, this selection could affect positively the financial performance of the project, especially in the particular project case, where the management board reviews the first batch of iterations, to decide continuing funding the full scale/full functionality product development. Hence, the NPV of CPM EFT will be an indication of the desired (ideal) expected profit.

We also assume that time series analysis or multivariate regression of historical or comparable project data (past undertaken projects employing CPM EFT, CPM LS and CPM WD schedules with similar time constraints and overall budget) has been applied to forecast the free cash flows at each iteration as well as the terminal expected values of the project for each schedule. A terminal expected value for the whole project refers to the value of the project at the end of the growth period (48 weeks).

For the 6 project periods (iterations/ increments), assuming that the annualized discount rate is equal to 12%, the compound discount rate can be calculated equal to 12,61%, by using the following expression:

$$\left(1+\frac{discount}{periods}\right)^{periods}-1$$

We finally assume that the free cash flows at each time box are the revenues coming from diffusion of project results to other development company streams. The management board estimates a 50%

Table 1: NPV for CPM EFT Schedule.

Iteration Number	0	1	2	3	4	5	6
Initial Outlay	30.000						
Cash flow		10.000	15.000	16.000	14.000	13.000	11.000
Terminal Value							120.000
Net Cash Flow	30.000	10.000	15.000	16.000	14.000	13.000	131.000
Discounted Rate	0%	12,61%	12,61%	12,61%	12,61%	12,61%	12,61%
Present Value	30.000	8.880,2	11.829,6	11.204,4	8.706,4	7.182,3	64.247,1
Net Present Value	82.050						

probability for the software product marketing success, due to market uncertainty and the very strict estimate of the development duration (48 weeks).

The NPV calculation for CPM EFT (Table 1) results in an expected revenue discounted by 50% (the success probability), that is equal to 41.025€ (82.050€ x 0.5), a 50% discount of the initial outlay that is equal to 15.000€ (30.000€ x 0.5), and a final expected value for CPM EFT that is equal to 26.025€ (41.025€ - 15.000€). Accordingly, the NPV calculation for CPM LS (Table 2) results in an expected revenue that is equal to 35.620,1€ (71.240,3€ x 0.5) and a final expected outlay that is equal to 15.000€ (30.000€ x 0.5). Thus, the expected value for CPM LS is equal to 20.620,1€ (35.620,1€ - 15.000€). Finally, calculating the NPV for CPM WD (Table 3) results in an expected revenue equal to 37.784,2€ (75.568,4€ x 0.5), a final expected outlay equal to 15.000€ (30.000€ x 0.5) and an expected value for CPM WD that is equal to 22.784,2€ (37.784,2€ - 15.000€).

5.3 Applying Real Options

In this step, the management board considers that the project can be deferrable and additional development can be undertaken only if favourable conditions are valid in the future. In terms of Real Options, the value of two options will be evaluated for both CPM LS and CPM WD schedules: i) to stall development at a specific iteration (Option to Abandon) or ii) to proceed with the full product development (Option to Expand). In particular, the management board examines what would be the profits of the schedules in case when, instead of having the project implemented continuously from iteration 1 to iteration 6, development executes the first two iterations and then, if there are “favourable” conditions, the company has the option to continue funding the project and further implement the next four iterations. If not, then the management board has the option to abandon the project and loose only the initial investment for the first two iterations. From the total amount of the initial investment (30.000€), the management board will consider the decision to further invest an amount of 20.000€ after the second iteration. The initial cash outlay for the first two iterations is considered equal to 10.000€ for both CPM LS and CPM WD schedules.

The binomial decision tree in Figure 5 demonstrates the real options approach to the CPM LS schedule. The estimation of failure/success probabilities for a software project, in terms of the economic value of the various project decision elements, can be performed by empirical analysis on historical data from previous company projects. This process can be also supported by automated instrumentation tools (Costa *et al.*, 2007). In our example, the management board has estimated, when considering the CPM LS schedule, a 33% probability of failure for the initial project phase (iterations 1-2) and a 67% probability of success. If the management board gives the approval for the additional 20.000€ fund, then it is estimated a 25% probability of failure and a 75% probability of success. The future cash flows for the project under the CPM LS schedule are presented in Table 4. The expected outlay of the option to abandon is equal to 3.300€ (10.000€ x 0.33), while the expected outlay of the option to expand is equal to 5.100€ (30.000€ x 0.17). The expected revenue for CPM LS has been previously calculated by NPV analysis that is equal to 35.620,1€. Thus, the expected final value for CPM LS is equal to 27.220,1€ (35.620,1€ - 8.400€).

Table 2: NPV for CPM LS Schedule.

Iteration Number	0	1	2	3	4	5	6
Initial Outlay	30.000						
Cash flow		10.000	12.000	15.000	12.000	11.000	10.000
Terminal Value							110.000
Net Cash Flow	30.000	10.000	12.000	15.000	12.000	11.000	120.000
Discounted Rate	0%	12,61%	12,61%	12,61%	12,61%	12,61%	12,61%
Present Value	30.000	8.880,2	9.463,7	10.504,2	7.462,6	6.077,3	58.852,3
Net Present Value	71.240,3						

Table 3: NPV for CPM WD Schedule.

Iteration Number	0	1	2	3	4	5	6
Initial Outlay	30.000						
Cash flow		10.000	13.000	16.000	14.000	13.000	11.000
Terminal Value							110.000
Net Cash Flow	30.000	10.000	13.000	16.000	14.000	13.000	121.000
Discounted Rate	0%	12,61%	12,61%	12,61%	12,61%	12,61%	12,61%
Present Value	30.000	8.880,2	10.252,3	11.204,4	8.706,4	7.182,3	59.342,8
Net Present Value	75.568,4						

Similarly, the tree in Figure 6 examines both real options, when considering CPM WD schedule. The management board acknowledges an 80% probability of success for the initial project phase (iterations 1-2), and hence a 20% probability of failure. The reason for this optimistic estimate is that CPM WD presents less “slack times” and thus may result in achieving a high level of work continuity and a smooth flow of development work over the initial two iterations. If the board takes the option to expand and invest the additional 20.000€ fund, then it is estimated a 25% probability of failure and a 75% probability of success.

Table 5 presents the estimated future cash flows for the project under the CPM WD schedule. The expected outlay of the option to abandon is equal to 2.000€ (10.000€ x 0.20), while the expected outlay of the option to expand is equal to 9.000€ (30.000€ x 0.30). The expected revenue for CPM WD has been calculated previously by the NPV analysis that is equal to 37.784,2€. Therefore, the expected final value for CPM WD is equal to 26.784,2€ (37.784,2€ - 11.000€).

5.4 Retrospect the Analysis

We notice that applying the real options and giving the management board a different view of the potential risks - and hence the flexibility to adjust the incremental delivery plan - we have a totally different suggestion compared to the corresponding indication produced by calculating NPVs. With NPV, the management board is advised to select the CPM WD schedule, as it is expected to result in an amount of profit equal to 22.784,2€, instead of 20.620,1€ expected from CPM LS. With Real Options though, the decision should be different. Estimating the risks accordingly, the expected value of CPM WD (26.784,2€) is less than this of CPM LS (27.220,1€). This can be explained by closely considering the two schedules’ characteristics (Figures 3 & 4). Even though, both CPM WD and CPM LS present the same iteration delays, CPM LS due to its latest pushing time characteristic, may provide a better managerial flexibility.

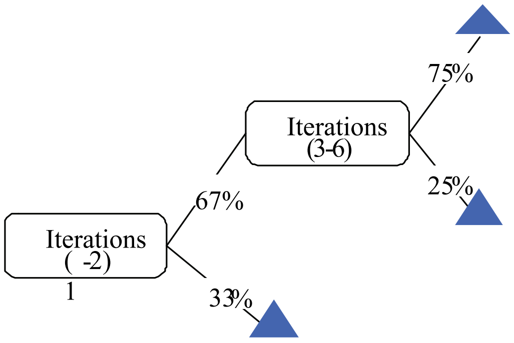


Figure 5: Options for CPM LS.

Table 4: Cash Flows for the Project under the CPM LS schedule.

Iteration Number	0	1	2	2	3	4	5	6
Initial Outlay	10.000			20.000				
Cash flow		10.000	12.000		15.000	12.000	11.000	10.000
Terminal Value								110.000
Net Cash Flow	-10.000	10.000	12.000	-20.000	15.000	12.000	11.000	120.000
Discounted Rate	0%	12,61%	12,61%	0%	12,61%	12,61%	12,61%	12,61%
Present Value	-10.000	8.880,2	9.463,7	-20.000	10.504,2	7.462,6	6.077,3	58.852,3

Table 5: Cash Flows for the Project under the CPM WD schedule.

Iteration Number	0	1	2	2	3	4	5	6
Initial Outlay	10.000			20.000				
Cash flow		10.000	13.000		16.000	14.000	13.000	11.000
Terminal Value								110.000
Net Cash Flow	-10.000	10.000	13.000	-20.000	16.000	14.000	13.000	121.000
Discounted Rate	0%	12,61%	12,61%	0%	12,61%	12,61%	12,61%	12,61%
Present Value	-10.000	8.880,2	10.252,3	-20.000	11.204,4	8.706,4	7.182,3	59.342,8

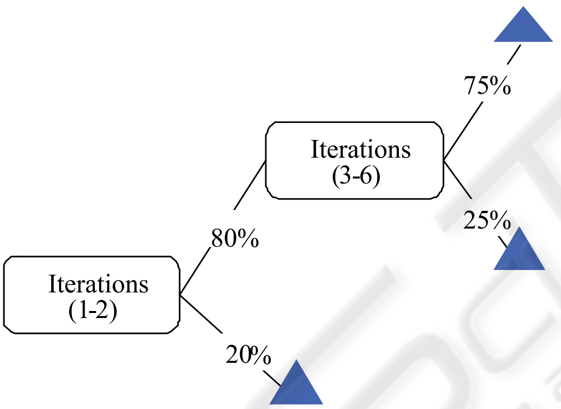


Figure 6: Options for CPM WD.

Pushing stages to their LS times transfers coordination (work discontinuity) from the last iteration stages to those in the beginning of the project. Consider, for example, that in both schedules the work discontinuities have been transferred from the final iteration stages (stages D, E and F) to those in the beginning (stages A, B and C). However, the total work discontinuity time for stages A, B and C in CPM LS is equal to 48 weeks, while the same stages in CPM WD present a total work-discontinuity time equal to 26 weeks. Thus, the R&D management has more time to review risky situations upon unexpected changes and coordination delays earlier in the project (e.g., remove defects and consider requirements changes).

Furthermore, the objective of minimizing work discontinuities may negatively affect the coordination time between project stages. On one hand, this may improve the smooth flow of development work, on the other, the risk of having a low defect removal efficiency in early iteration stages is increasing (and consequently in later stages). In general, establishing the right coordination policy is a difficult and high risky task (Mookerjee and Chiang, 2002). Coordination is affected by dynamic factors that cannot be easily predicted due to the differences in the intensity of coordination needed at different project stages. Moreover, coordination is highly dependent on the development team's learning curve. Since, in general, the development teams' knowledge of the system improves with time, a lot of coordination may be needed early in the project.

6 CONCLUSIONS

In this study, we extended the results of previous work on multi objective analysis of scheduling iterative/incremental software projects which follow timeboxing disciplines. By applying Real Options, we moved forward the optimization decision of the release planning process to perform the cost valuation of different scheduling decisions. We argued for the proposed approach by examining the risk of two options, the option to stall (abandon) an incremental delivery plan at a pre-defined iteration and the option to continue iterations (expand development) and deliver the full system functionality.

To demonstrate the usefulness of the approach, we calculated the static discounted Net Present Values of selected schedules in a project case study, and then we compared these values with those resulting from the Real Options application. The analysis results highlighted how Real Options can provide increased managerial flexibility as they force management to consider investment risks associated with the alternative project scheduling decisions, as unexpected events in one stage or iteration may affect not only the iteration completion/delivery times but also the work continuity in project resources. Furthermore, this study discussed that applying Real Options can be useful to discover knowledge concerning the value of candidate schedules to be adopted in iterative/incremental projects in a retrospective manner and, thus to enable decision makers/ project managers to better manage the scheduling alternatives.

For future work, we are interested in moving the approach one step forward by considering Real Options as a possible tool to be applied in the selection and prioritization of features to be delivered in each software iteration/increment. It is also our intent to experiment and apply the approach into real scale incremental/iterative projects, exploiting the full scope of Real Options methodology, tools and techniques. Such exploration will demonstrate the required input data and how they can be collected to realize the approach in complex software projects.

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