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INCREASING SECURITY OF FINANCIAL INVESTMENTS: A COMBINED RISK MANAGEMENT - PROJECT MANAGEMENT - OPERATIONS RESEARCH APPROACH

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Abstract

As every financial investment can be identified as a project, proper models should be identified and implemented to reduce risk and increase security. As a result, the practical and theoretical approaches for risk management in projects have received vast attention over the past few years. Yet, most solutions are still far from being effective and in most cases, risk management plans do not respond to the randomly generated risk events that actually occur during project execution. This paper presents a different approach for the risk management of projects, using a Linear Programming model. Accordingly, this paper includes a Linear Programming formulation for risk management that is part of the optimization model for managing the project. Moreover, the paper includes proof that a large group of risk events can be easily and better handled in this way.

Keywords: Risk management, project management, linear programming

1. INTRODUCTION

Every financial investment involves high level of risk. Reducing that level of risk can assist in improvement of such an investment. This paper uses project risk management and operations research models to reduce risk of financial investments. As a financial investment can be identified as a project, such a model can reduce risk and increase security.

The practical and theoretical approaches for risk management in projects have received vast attention over the past few years. Yet, most solutions are still far from being effective, not to mention optimized. Even project management software provides only partial solutions for this problem. Hence, most project managers improvise solutions when an unplanned event occurs

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during a project. This main drawback of this approach is that it provides a local solution to the problem and not a global one.

We were motivated to study the risk management challenge from a Project Management Simulation (PMSIM) game that enables training project managers to react to risk events (Zwikael & Gonen, 2007). The PMSIM was developed especially to challenge project managers with uncertainty and unplanned events. Originally, this game was designed to train project managers in applying their risk management plan. During the simulation game, the PMSIM generates some unplanned events that occur during the project, for example, a temporary absence of one of the project team members due to illness. Once a risk event occurs in the simulation, the project manager has three main options to choose from. He may: (1) issue his risk management plan, (2) let the project management software update its plan using a built-in heuristic, or (3) decide on a new solution to the problem.

While running the PMSIM, we found out that most of the randomly generated events were unexpected to the participants. In other words, the events that actually occurred in the project simulation were not part of the risk management plan. Hence, no ready response was available in the risk management plan and the project manager had to develop and update his project plan. This solution was not more than local optimization of solving the current problem, rarely looking at the whole solution. The phenomenon of inefficiently handling unexpected risk events led us to seek out the best decision that a project manager can make. We found that, for the most cases, risk events responses can be handled by optimization methods.

The following paper describes an optimization approach for handling risk events during the execution phase of a project. Since optimization techniques are common used during the planning phase of a project for scheduling, budgeting and resource allocation, we may use the same optimization system to include the unexpected events occur during the project execution. Hence, the objective of this paper is to present a model in which project risk events can be best handled using Operations Research's optimization models.

In order to better understand the suggested approach, we will first review the literature concerning risk management handling, formulate the project management planning optimization model and show how most events can be handled by updating the optimization formulation. The next section will introduce related literature in the areas of project management, risk management, and project management optimization.

2. LITERATURE REVIEW

The area of project management has recently received vast attention in the business discipline. A *project* is defined as *a temporary endeavor undertaken to create a unique product or service*. According to PMI's Project Management Body of Knowledge (PMBOK), a project has the following four phases: initiation, planning, execution and closure (PMI, 2008). *Initiation* is the phase of formally authorizing a new project. This phase links the project to the ongoing work of the performing organization. *Planning processes* define and refine objectives and select the best of the alternative courses of action to attain the objectives that the project was undertaken to address. *Executing processes* coordinate people and other resources to carry out the plan. Finally, *closing processes* formalize acceptance of the project and bring it to an orderly end.

Since a project manager has to deal with high uncertainty levels, the subject of risk management has received a lot of attention, being one of the nine knowledge areas of a project (PMI, 2008). The risk management knowledge area deals with identifying and reducing the project's risk level, including risk management planning, monitoring and control processes. The risk management planning processes includes risk identification, qualitative and quantitative risk analysis and risk response plan. Risk monitoring and control is the last risk management process, which is performed during the project's execution phase. Tools included in this knowledge area are: planning meetings, risk rating and risk control.

According to Wideman (1992) risks can be divided into five groups: (1) external, unpredictable and uncontrollable risks, (2) external, predictable and uncontrollable risks, (3) internal, non-technical and controllable risks, (4) internal, technical and controllable risks and (5) legal and controllable risks.

Some software and tools are available for project risk management, including @Risk, Risk+, Crystal Ball simulation tool and Predict. Zwikael and Globerson (2004) found that despite the high number of models and tools available, their frequency of use is very low. The reason for this may be their low impact on project success (Zwikael & Globerson, 2005). These results point to a specific need to improve project managers' handling of risk events.

Despite the existing models available for project planning and risk management, there is still a lack of optimization models. Software project management tools being used by project managers provide only heuristic solutions (i.e. resource and time management) or no solutions at all (i.e. risk management). However, some operational research models have been effectively implemented in project management, improving its management and increasing effectiveness. One of the well-known optimization models used in project management is the known "Resource Constraint Project Scheduling Problem" (RCPSP) for optimizing the duration of a project under a limitation of resources (Zwikael et al., 2006).

The RCPSP is known to be NP-hard in the strong sense (Demeulemeester & Herroelen, 2002; Kolisch et al., 1995; Leung, 2004; Kolisch et al., 1999 and others). Therefore, all exact optimal techniques have a non-polynomial complexity, and none of them are able to solve large projects in a timely manner. The classical resource-constrained problem is introduced in the next paragraph.

Consider a single project that is performed over a finite number of periods with T being the upper bound on the project make span and t=1,…,T is a period index. The project consists of J activities. R is the number of sets of renewable resource types and each resource type r, $0<r\leq R$ has limited availability of K_{rt} at any given time t. Each activity j has duration of d_j and a resource consumption of k_{jr}. The activities are partially ordered by precedence constraints where P_j is the set of immediate predecessors of activity j. The activities are numerically or alphabetically labeled, so that any predecessor of j has a smaller number than j. Using the traditional forward and backward

recursion, the earliest and latest start (ESj, LSj), and finish times (EFj, LFj) could be computed for each activity j. If we disregard resource constraints, these could be used as intervals for the start and end of activity j. However, due to resource constraints, these intervals could be infeasible. To enable these intervals to include at least one feasible schedule, the definition of LFj and LSj shall be changed as follows: Use any resource-leveling heuristic technique to generate a feasible solution and mark the activities' finish times by Fj. Take the maximum of {Fj, LFj} to be the new LFj and the new LSj becomes: LFj-dj. This definition ensures that there is at least one feasible schedule with the new set of intervals (ESj, LSj), (EFj, LFj) for all $j \in J$.

For modeling the problem as an Integer Programming (IP) problem, Pritsker, et al. (1969) defined binary variables Xj,t, j=1,…,J that are 1 for t={EFj, EFj+1,….,LFj} and 0 elsewhere. This Integer programming formulation requires J times T binary decision variables. Following this work, Kaplan (1988), Alvarez-Valdes and Tamarit (1989), Mingozzi (1998), Kolisch (1996) and Klein (2000) improved the mathematical programming formulation of this problem. The 'branch and bound' concept is also used in solving RCPSP problems (Agin, 1966; Demeulemeester et al., 2000). Demeulemeester and Herroelen (2002) introduced an efficient branch and bound approach allowing for delays in schedule.

3.THE LP FORMULATION

The project management scheduling problem is handled in the literature as a stochastic problem where the duration of each activity is distributed according to the Beta distribution. However, in most cases both project managers and Linear Programming models prefer to treat the project activities' durations as deterministic. Hence, when dealing with risk management, we can insert each possible delay in an activity as a risk in the Risk Management Plan (RMP). From now on the project management scheduling problem is a deterministic scheduling problem and the risk management problem includes all uncertainty.

The classical resource-constrained problem is formally stated as follows:

Time: Let T be the upper bound on the project make span, or duration. The project is performed over finite number of periods T and t=1,…,T is a period index.

Activities: project consists of J activities. The activities are partially ordered by precedence constraints where Pj is the set of immediate predecessors of activity j. In other words, let us denote by $i \prec j$ if activity *i* precede activity *j*. The set $A \subset (JxJ)$ is called the precedence constraint set when $(i,j) \in A$ Iff $i \prec j$ (A contains all the pairs (i, j) such that activity *i* precede activity *j*).

Assumption 1: The activities are numerically or alphabetically labeled, so that any predecessor of *j* has a smaller number than *j*.

Resources: Let us assume that there are R renewable resource types and each resource type r, r=1,…,R has limited availability of $K_{r,t}$ at any given time t.

Time duration and resources: Each activity j has a duration of d_j and a resource consumption of k_{jr} , r=1,…,R.

Cost: Each resource r, r=1,…,R has a cost per hour $C_{r,j}$ for each activity j=1,…,J. The set-up cost of activity j is $C_{0,j}$.

The traditional forward and backward recursion is used to compute the earliest and latest start (ES_j, LS_j), and finish times (EF_j, LFj) for each activity j.

It can also be derived by solving the following Linear Programming (LP) problem:

Min {ESJ}

s.t:.

ESi + di ≤ESj for all (i,j) ∈ A

EFi = ESi + di i=1,…,J

LFJ = EFJ

LFi ≤ EFj = LFj – dj for all (i,j) ∈ A (I)

If we disregard resource constraints, the above formulation can be used to calculate intervals for the start and end of activity j. However, due to resource constraints, these intervals could be infeasible. In order to enable resource constraints, we need the following notations:

For each activity j, *j*=1,…,*J* and time index t, 1≤t≤T defined binary variables X*j,t*, such that X*j,t.*=1 for t∈ {EFj, EFj+1,….,LFj} and 0 elsewhere.

The resource constraints are:

r=1, $\sum_{j=1}^{J} X_{j,t} \cdot k_{j,r} \leq K_{r,t}$ (II)

The formulation of (I) and (II) together enables us to solve the Resource Constraints Project Management.

The cost of the project can be calculated as follows:

$$C = \sum_{j=1}^{J} C_j \quad \text{(III)}$$

where: Cj is the cost of activity j

There might be some budget constraints like

$$C_j = C_{0,j} + \sum_{t=1}^{T} X_{j,t} \sum_{r=1}^{R} k_{j,r} C_{r,j}$$

a limited total project budget:

C≤ Cmax (IV)

or where the budget of a certain set of activities is limited:

$$\sum_{j \in \bar{J} \subseteq J} C_j \leq Const \quad \text{(V)}$$

etc.

This model can be easily formulated and developed during the planning phase of a project in order to optimize the project duration, budget and resources allocation. Since most of project management software do not optimize the planning, this is the first benefit for the project manager. Moreover, this project formulation plan should serve the project manager as an infrastructure for handling unexpected events during the execution phase of a project.This part will be introduced in the next section.

4. HANDLING RISK MANAGEMENT EVENTS

Risk management literature provides a list of potential risks that should be handled by the project manger. Such a list includes a convenient grouping of risks generally classified according to the risk's source. During a project's execution phase, some risk events occur. In this section, we show how to integrate risks into the optimization formulation presented in the previous section.

Definition 1: The definition of a *risk even*t is: "*Project risk is an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality*" (PMI, 2008). A risk event occurs at a specific time and may influence future project objectives.

Widemand (1992) provides a list of typical project risks. After analyzing the possible risks we could find that all the risks can fall into one (or more) of the following risk categories:

1. A risk event that affects the project time (cause delay)
2. A risk event that affects the project cost (increase the budget)
3. A risk event that affects the project scope (cause a change in the activities)
4. A risk event that affects the project quality
5. A risk event that affects the project resources

We state that any unexpected event that occurs during the execution phase of a project belongs to one (or more) of these five groups, for examples:

1. Market risks like changes in the cost of raw material or competition can be fit to the family of cost risks. The same applies to risks of currency changes, inflation or taxation.
2. Internal risks of management control incapacity, lack of coordination usually end by delays, change of scope or resource changes.
3. Technical risks like changes of technology, performance or inadequate design usually end by changing the scope, adding budget or causing a delay.
4. Legal risks like patent rights, licenses, and contractual difficulties are also solved by changes in the scope, time or budget.

It can be seen that all the possible risk examples that were tested can be diverted into any combination of the five risk categories stated above. The next section will introduce proofs for formulating LP problems while changes occur in all five of the above-mentioned project risk families: time, cost, scope, quality and resources.

The first claim is that every risk event that affects the time (cause delay) can be reformulated into the LP model. In order to prove it, we assume that the risk event occurs at time t_0 and, without losing generality, we assume it starts its affect on the project at time t_0. Please note that we are interested only in the time it starts to affect the project. This affect changes the time – either in the duration or starting time or any constraint on the finish time.

First, we define all the variables that are related to time before t_0 as constants. For example, all the ES_j, EF_j… that are less than t_0 have already been executed and they are no longer variables.

The event may change some of the durations of activities and in this case we update the dj accordingly. If the event limits the starting or the finish time of an activity, it can be added as a linear constraint according to the following format:

$\alpha \leq E\Sigma\varphi \leq \beta$ or $\alpha \leq E\Phi\varphi \leq \beta$ or $\alpha \leq \Lambda\Sigma\varphi \leq \beta$ or $\alpha \leq \Lambda\Phi\varphi \leq \beta$

or it can be any combination of the above.

Since setting dj to a new entry and the above constraint do not change the linearity, the LP problem can be enhanced to include changes in the timing caused by events.

Other types of events that affect the time indirectly are lack of resources. There are many cases where a resource is either not available or only partially available during a certain time frame. In that case, the resource capacity Kr,t is changed. In other cases, when the requirements of resources for activity j are changed, the $k_{j,r}$ are updated accordingly.

Example:

1. ***Risk event***: Activity j needs an additional five days to reach execution.

Risk handling: Define dj as previous dj+5

The second claim is that every risk event that affects project cost (increase the cost) can be handled by adding it into the LP model.

The proof of the claim is that a risk event that affects the budget can be either changes in currency, taxes or other rules that influence all the rates from t_0 or specific changes in a group of activities like changes in the price of oil, changes in components' price, and changes in the rates of resources.

The changes should be added to the budget as follows:

For each resource r, r=1,…,R there might be a change in the cost rate per hour to $\overline{C}_{r,j}$ for each activity j=1,…,J. The set-up cost of activity j is $\overline{C}_{0,j}$. The new cost from time t_0 can be defined as

$$C = \sum_{j=1}^{J} C_j$$

where:

$$C_j = C_{0,j} + \sum_{t=1}^{t_0} X_{j,t} \sum_{r=1}^{R} k_{j,r} C_{r,j} + \\ + \sum_{t=t_0+1}^{T} X_{j,t} \sum_{r=1}^{R} k_{j,r} \overline{C}_{r,j}$$

The constraint that should be added is:

$C \le Cmax$

In addition, the variables of the optimization problem are only for activities j such that $EF_j > t_0$. If $ES_j \le t_0 \le EF_j$ than ES_j is not a variable anymore but EF_j is still a variable.

Example:

1. ***Risk event***: The setup cost of activity j is increased by a

Risk handling: Define $C_{0,j}$ as $C_{0,j}$ + a. Compute the new C (It affects constraints like (IV) or (V))

2. ***Risk event***: The taxes on working hours are going to increase by 1.5% starting at time t_0.

Risk handling

Define $C_j = C_{0,j} + \sum_{t=1}^{t_0} X_{j,t} \sum_{r=1}^{R} k_{j,r} C_{r,j} +$

$$+ \sum_{t=t_0+1}^{T} X_{j,t} \sum_{r=1}^{R} k_{j,r} C_{r,j} \cdot 1.015$$

for all activities j.

The third claim is about risks that might affect the project scope. That means, every risk event that affects the scope can be handled by adding it into the LP model.

We assume that an event that affects the project scope can be any change, addition or deletion of some part of the project. These changes are managed by changing, adding or deleting tasks. Adding a task with all its precedence and resources will create a need to reformulate the LP in accordance with the new problem. Assume we add a task number J+1 (we need to renumber the task such that assumption 1 is satisfied). The amounts of resources needed for this task are $(k_{1,J+1},\dots,k_{R,J+1})$. The immediate preceding activities are added to A such that $(i,J+1) \in A$ if i should immediately precede J+1. The formulation remains almost the same as in the previous section:

Min {ESJ}

s.t.

$ESi + di \le ESj$ for all $(i,j) \in A$

$EFi = ESi + di$ i=1,…,J+1

$LFJ = EFJ$

$LFi \le EFj = LFj - dj$ for all $(i,j) \in A$ (VI)

$$\sum_{j=1}^{J+1} X_{j,t} \cdot k_{j,r} \le K_{r,t}$$

r=1,…,R t=1,…,T (VII)

In addition, the variables of the optimization problem are only for activities j, such that $EF_j > t_0$. If $ES_j \leq t_0 \leq EF_j$, then ES_j is not a variable anymore but EF_j is still a variable.

Example:

1. ***Risk event***: The customer wants to add another three-day review after activity j has been completed.

Risk handling: Adding a new activity entitled "added review" that lasts three days and should be executed after activity j. The process of adding an activity was described above in problem (VI) and the additional constraints (VII).

The fourth claim is that every risk event that affects the quality can be handled by adding it into the LP model.

A risk event that affects the quality is usually a failure on a test or a review. The failure causes an additional correction task and probably another test. Handling these additional tasks was demonstrated in the previous claim.

Therefore, quality risks are translated into change in scope as was proved in the third claim.

Example:

1. ***Risk event***: Failure on the Factory Acceptance Test (FAT)

Risk handling: Adding a corrective task (or, if it was planned, updating its duration), adding a new FAT, updating the budget if it includes a penalty. All these were discussed in claims 2 and 3.

2. ***Risk even***t: The customer rejected the analysis document.

Risk handling: Adding a corrective analysis task, updating the budget if it includes a penalty. All these were discussed in claims 2 and 3.

The fifth claim is that every risk event that affects the resources of a project can be handled by adding it to the LP model.

A risk event that affects the resources means that a resource is either not available or only partially available during a certain timeframe. In this case, the resource capacity $K_{r,t}$ is changed, but the LP formulation is not changed. In other cases, when the resources requirements of activity *j* are changed, the $k_{j,r}$ are updated accordingly. Again the LP formulation is not changed.

Example:

Risk event: One of the resources in resource group r will not be available from t_1 to t_2

Risk handling: Define $K_{r,t}$ as $K_{r,t-1}$ for all t, $t1 \leq t \leq t2$

Summarizing all the above claims, we can state the main result of this section:

Theorem 1: Every risk event that affects time, cost, scope, quality or resources can be handled by adding it to the LP problem.

Proof: According to the above claims, all five types of risk events can be handled by adding them to the LP problem formulation.

A risk event can also include several affects. In such a case, the handling can be done step by step by adding one affect at a time. Since in each part, a linear constraint is added, (or some coefficients are changed without changing the LP formulation), the order in which the constraints are added is not important.

In the previous section, we covered all the examples of risk events mentioned in the definition of risk event in the PMBOK (PMI, 2008). We showed that all risk events can be handled by the LP formulation. However, since there is no proof that we did not miss an event, we summarized our findings in Theorem 1, which covers all risk events that affect time, cost, scope, quality or resources.

5. CONCLUSIONS

Risk events can be handled in different ways as they occur. Usually, when a risk event occurs, the project manager examines whether a planned response appears in his risk management plan. If he cannot find such a response, he should test different responses and choose the best of them. This process of choosing the best response for a risk event was analyzed in this paper showing that it can be solved by an optimization procedure. We showed that risk events that occur during project execution can be handled by the original LP formulation. This means that if a project manager maintains the LP program during the whole life cycle of the project, he can use it for every risk event that occurs, without using any heuristics or common sense responses.

The main difficulty is the size of the problem and its computational complexity. However, it might take a reasonable time using multiple processing technologies, but this is outside the scope of the current study.

Finally, we summarize the risk handling as follows:

1. Identifying and Quantifying risks stays the same as in the PMBOK (PMI, 2008)
2. In Preparing the response plan, the contingency plan for risks should include reference to the LP formulation and explanation about required changes in the LP plan.
3. The Monitoring and Control plan should include the maintenance of the LP model, running it for each occurrence of risk and implementing its result.

Project managers in organizations should implement these optimization techniques in order to improve project efficiency. In this paper, we showed that once the LP had been developed at the beginning of the project, all changes became possible and only minimal effort was required to include them in the optimization model.

In this paper, we covered all the risk events mentioned in the definition and examples of risk events. We believe that all risk events can be handled by the LP formulation. However, since there is no proof that we did not miss an event, we summarized our findings in Theorem 1, which covers all risk events that affect time, cost, scope, quality or resources. Actually, we did not find any risks that cannot be formulated, directly or indirectly, as affecting time, cost, scope, quality or resources. Practically, Theorem 1, ensures that handling risk events can be done using the LP formulation.

ПОВЕЋАНА БЕЗБЕДНОСТ ФИНАНСИЈСКИХ ИНВЕСТИЦИЈА: КОМБИНОВАНИ ПРИСТУП УПРАВЉАЊА РИЗИКОМ - УПРАВЉАЊА ПРОЈЕКТИМА И ОПЕРАЦИОНИХ ИСТРАЖИВАЊА

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Извод

Како се свака финансијска инвестиција може идентификовати као пројекат, потребно је пронаћи и применити адекватне моделе којим се смањује ризик и повећава безбедност. Као резултат, практични и теоријски приступ за управљање ризиком пројекта добио је на значају током претходних година. Ипак, већина решења су још увек далеко од максималне ефикасности, планови менаџмента ризиком не одговарају случајно генерисаним ризичним догађајима који се заиста јављају током реализавије пројекта. Овај рад представља различит приступ управљању ризика пројекта, употребом модела линеарног програмирања. Према томе, овај рад укључује формулацију управљања ризиком коришћењем линеарног програмирања, као део модела оптимизације пројеката. Такође, овај рад потврђује да се велика група ризичних догађаја може лакше управљати на овај начин.

Кључне речи: Управљање ризиком, управљање пројектом, линеарно програмирање

References

Agin, N. (1966) Optimum seeking with branch and bound. Management Science, 13(4): 176-185.

Alvarez-Valdes, R., & Tamarit, J. M. (1989). Heuristic algorithms for resource constrained project scheduling. Pp 134-143 in Slowinsky R. & Weglarz J. (Eds.), Advances in Project Scheduling, Elsevier, Amsterdam.

Demeulemeester, E. D., & Herroelen, W. S. (2002). Project scheduling – a research handbook. Kluwer International.

Demeulemeester, E., De-Reyck, B., & Herroelen, W. (2000) The discrete time/resource trade-off problem in project networks: a branch and bound approach. IIE Transactions, 32: 1059-1069.

Kaplan, L. A. (1988). Resource constrained project scheduling with preemption of jobs, Unpublished PhD Thesis. University of Michigan.

Klein, R. (2000). Scheduling of resource constrained projects, Kluwer, Academic publishers, Boston.

Kolisch, R. (1996) Series of parallel Resource-constrained project scheduling methods Revisited: Theory and Computation. European Journal of

Operational Research, 90: 320-333.

Kolisch, R., & Hartman S. (1999) Heuristic algorithms for solving the resource constrained project scheduling problem: classification and computational analysis. Pp. 147-178 in Weglarz, J. (Ed.), Handbook of recent advances in Project scheduling, Kluwer academic publishers, .

Kolisch, R., Sprecher, A., & Drexl, A. (1995) Characterization and Generation of a general class of resource-constrained project scheduling problems. Management Science, 41: 1693-1703.

Leung, J. Y-T. (2004). Handbook of scheduling. CRC press/Chapman & Hall.

Mingozzi, A., Maniezzo V., Ricciardelli S., & Bianco L. (1998) An exact algorithm for resource constrained projects scheduling problem based on a new mathematical formulation. Management Science, 44: 715-729.

PMI Standards Committee (2008). A Guide to the Project Management Body of Knowledge. Newtown Square, PA: Project Management Institute.

Pritsker, A. A. B., Watters, L. J., & Wolfe P. M. (1969) Multi project scheduling with limited resources: a zero-one programming approach. Management Science, 16: 93-108.

Shtub, A. (2005). Project management game. Proceedings of the PMI Asia Pacific conference, February, Singapore.

Sprecher, A., Kolish, R., & Drexl, A. (1995) Semi-Active, Active, and Non-Delay schedules for the resource constrained project scheduling problem. European Journal of Operational Research, 80: 94-102.

Wallace, S. W. (2000) Decision making under uncertainty: Is sensitivity analysis of any use?. Operations Research, 48 (1): 20-25.

Wideman, R.M. (1992). Project and program Risk Management: A guide to managing project risks and opportunities. Project management Institute.

Zwikael, O., & Globerson, S. (2004) Evaluating the Quality of Project Planning: A Model and Field Results. International Journal of Production Research, 42 (8): 1545-1556.

Zwikael, O., Cohen, Y., & Sadeh, A. (2006). Non-delay scheduling as a managerial approach for managing projects. International Journal of Project Management, 24 (4): 330-336.

Zwikael, O., & Globerson, S. (2005) Critical Planning Processes for Project Success, PMI Asia Pacific, February, Singapore.

Zwikael, O., & Gonen, A. (2007) Project execution game (PEG): training towards managing unexpected events. Journal of European Industrial Training, 31 (6): 495-512.