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COMPLEX RISK ASSESSMENT IN PROJECT MANAGEMENT

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Abstract

Despite of the fact that tools of project management have been developed and used for more than 35 years a gap seems to exist between project planning and execution which does not allow project managers to deliver objectives as they were set originally. While planning is a fairly rigorous exercise with sophisticated financial analysis and operations research techniques, execution proves to be ad-hoc, and non systematic due to unpredictable changes and disturbances. Complex risk assessment can be used to bridge this gap and prepare project managers for better control in the execution phase. The Project Management Body of Knowledge says: 'project risk *management* includes the process concerned with identifying, analysing and responding to uncertainty'. Risk threatens all three dimensions of projects; scope, delivery time and budgets. Corrective actions on one dimension have impact on others, and these relations can and should be utilized in complex risk minimization and recovery planning. The formal analysis goes through four major steps; defining and quantifying potential risk factors, preparing risk minimization plans, preparing contingency plans and identifying trigger points or flags. The framework is illustrated with a hypothetical product development project tested and analysed by more than 200 managers and engineers.

Keywords: project management, risk analysis, contingency planning.

1. Introduction

According to a recent survey of 150 project managers it was found that only 25% of projects are completed on time, within budget and to the client's satisfaction (LA PLANTE, 1995). The same survey has shown that 50% of those projects which are finished on time are over budget by 60 to 190% and contain 70% of originally promised functionality. The survey focused on information system projects in the North American environment. Although there is no empirical evidence, we believe the situation for other projects in different environments is similar in nature to the quoted one. This is an interesting finding, since the tools of project management have been developed and used for more than 35 years. A gap seems to exist between project planning and execution which does not allow project managers to deliver objectives as they were set originally. While planning is a fairly rigorous exercise with sophisticated financial analysis and operations research techniques, execution proves to be ad-hoc, and non systematic due to unpredictable changes and disturbances.

In this paper we describe the importance of complex risk assessment to bridge this gap and prepare project managers for better execution through proper risk management. According to the Project Management Institute's [PMI] Standards Committee, project risk management has been part of the Project Management Body of Knowledge (PMBOK, 1994), but its importance is not recognized yet in Modern Project Management (MPM). PMI is the leading professional organization of project management and PMBOK is the collection of theories and models applied in MPM. PMBOK defines risk management as follows: 'project risk management includes the process concerned with identifying, analysing and responding to uncertainty'. The more uncertain the environment where MPM is implemented the more attention should the project manager put on risk assessment. This is especially valid in transitional economies, where the rate and magnitude of change is much higher than in the North American economies where the PMBOK stems from.

The structure of the paper is organized into 5 main sections. After the introduction, the 2. section summarizes the general approaches to risk analysis in project management and points out the lack of integration between the different dimensions of projects such as scope, time and resources. Section 3 outlines the recommended process of complex or integrated risk analysis in order to address this issue. Section 4 provides an example using a product development case tested and analysed by more than 200 practising project managers and team members of a large multinational company. Finally Section 4 draws the conclusions from the complex risk assessment model and the presented example, and recommends to include it into the project management lifecycle between the planning and execution phase.

2. Project Risk Management

Project management is defined as the management process of delivering specified objectives on time and within the available resource constraints. Objectives are referred to as the project scope and also called as deliverables. Time constraints or deadlines are managed by scheduling and resource constraints are handled by allocation, levelling or smoothing. Usually resources are aggregated in project costing, and project budgeting focuses on the aggregated resource constraint that is the total available budget. These three dimensions are often described as the project triangle:

upper corner is scope, lower right is time or scheduling and lower left is resources or costs. When defining project risk, we should explore all the three dimensions.

According to the PMBOK, project risk management contains the following four processes:

Risk identification, determining which risk events are likely to affect the project.

Risk quantification, evaluating the range of possible outcomes and their likelihood of occurrence.

Response development, defining the enhancement steps for opportunities and mitigation steps for threats. This process is also called response planning or risk mitigation.

Risk control, responding to changes in risk over the course of the project.

The terminology of risk is used in a broad sense in this paper; both as uncertainty and threat. Risk identification and quantification is usually called risk analysis. Sometimes risk quantification and response development is treated as a single process and called risk assessment. By the same token, response development and risk control is sometimes combined under the phrase risk management.

Risk assessment and risk management traditionally focus on the schedule dimension of projects, that is to analyse and control the likelihood of project overruns (KRAJEWSKY, RITZMAN, 1990). The first attempt to extend the deterministic Critical Path Method (CPM) to perform stochastic calculations is the Program Evaluation Review Technique (PERT). A 'PERT critical path' is computed from the average activity durations rather than the single point or most likely estimations of CPM. In this way, PERT draws attention to that path (or paths) which has the potential to delay the project on average. PERT also computes the standard deviation, a measure of dispersion, which serves as a measure of the risk of overrunning the overall project schedule. The major problem with PERT is that it does not take into account the important build-up of risk at path convergence points. This method has fallen out of favor and has been replaced mainly by simulation approaches.

The most widely used simulation method in risk assessment is the Monte Carlo simulation (SCHUYLER, 1994a). Monte Carlo iterates the project many times, each time selecting one duration value at random from the user-specified distributions of each uncertain activity. When enough iterations have been completed the project duration results are presented in tables, bell curves and S-curves. Monte Carlo identifies the highest risk activities as those that appear on the critical path as the largest percentage of iterations during the simulation.

Besides the Monte Carlo simulation there are other techniques to assess uncertainty, like fuzzy logic (LORTERAPONG, 1994.) and the classic decision tree analysis (SCHUYLER, 1994b). As far as risk responsiveness and control goes, Hulett has summarized the major strategies in schedule risk management (HULETT, 1995). The implication of risk management actions should result in a 'straightened S curve' as he describes it.

Ultimately, the key to schedule risk assessment is its quantification. Quantitative information on the uncertainty in activity duration includes low and high ranges, and distributions.

The major problem of schedule risk assessment is that it only focuses on the time dimension of projects and does not take into account its relation to the other two dimensions; resources and scope. Complex risk management should expand the analysis to the time-resources-scope relationship.

Problems in estimating duration often stems from nuclear, not well defined objectives or project scope. The broader the scope the higher the uncertainty of activity durations and total project lead times. The purpose of scope management is to minimize 'scope risk', that is, to narrow the range of scope definition which in turn allows less uncertain estimation for activity duration.

In information system projects McFarlan identifies three components of scope risk: size, technology and problem structure (MCFARLAN, 1981). Generally, the greater the size, the less is the experience with technology, and the less we can structure the objectives, the higher the scope risk of projects. Based on several examples, McFarlan proves that formal project planning and control can only be used after the scope risk is reduced by applying external and internal integration methods. This is also called 'objectives driven project management'. External integration focuses on the customers or requestors of the project, and through intensive communication ensures that deliverables will provide acceptable quality, that they are quantified and measurable. At the same time internal integration ensures that the project team is aware of the quality demands, changes are communicated and responsibilities are understood.

Under the umbrella of Total Quality Management there are several methodological tools to minimize scope risk. From the Ishikawa diagram to the Quality Function Deployment (QFD), these methods belong to the wide range of problem and system analysis tools, usually carried out in a team environment.

If scope risk is very high, formal planning, risk assessment and mitigation will not provide acceptable results on the scheduling level, because the whole project structure – described by the Work Breakdown Structure (WBS) and the network diagram – is uncertain.

Activity duration is not dependent only on the deliverables but also on the type of resources used and budget available. If there are uncertainties in resource availability and efficiency then the delivery of even a very well defined project is uncertain. This is a common phenomenon in labour resource intensive projects versus automated, machine intensive projects.

There are two main approaches to resource constrained scheduling; the optimization's techniques and the heuristic techniques. The optimization's main limitation from a risk assessment point of view is that it assumes a static problem definition which means the scheduling variables are definitive (KURTULUS and DAVIS, 1982). Heuristic methods can account for only one scheduling objective at a time, e.g. the minimum slack rule is effective for providing minimal project delays (DAVIS and PATTERSON, 1975). Recently, Lortarepong has introduced a risk assessment method in this problem area (LORTAREPONG, 1994) using the concept of fuzzy heuristics. Unlike traditional resource allocation methods, the technique investigates the consequences of each allocation before any scheduling decision is made. In addition, it incorporates a more direct and natural approach for modeling uncertainties associated with temporal knowledge in the project network. Although this is a very big step involving the impact of resource constraints to assess project risk, it still does not address questions of substituting resources or non-linear resource allocations within activity durations

There are sophisticated risk assessment and mitigation methods used in cost and budget control. The United States Department of Defence has required the contractors management control systems to comply with the Cost/Schedule Control Systems Criteria (C/SCSC) since 1967 (CHRISTENSEN, 1994). A widely used part of C/SCSC is the earned value analysis, which provides ranges of estimates to budget overrun at a given time during the project. Periodically carried out earned value analysis gives input for trend analysis, which can further refine the estimate at completion values. The problem with earned value is twofold; a) it is mostly used in long-lead-time and large-size projects where accounting is able to track activities, b) estimates for budget at completion are given on the assumptions that input numbers are 100% exact (SIGURDSEN, 1994).

In order to meet the criteria of successful project management, which is delivering objectives for customer satisfaction on time and within budget, project managers have to analyse all the dimensions of risk introduced above. We recommend a complex formal risk assessment phase built in between the planning and execution phase of the project lifecycle which uses all the information generated in the planning phase and the risk analysis methods of the project triangle (scope, resources, time). The outputs of this phase are the contingencies, reserves and potential responses for controlling risk in the execution phase.

3. Complex Formal Risk Assessment and Analysis

The major assumption on which the risk assessment is based is that there is a strong relationship between the risk factors threatening the three dimensions of the scope–time–resource triangle. This not only means that they have to be identified and quantified in relationship, but also warns the project manager that risk mitigation always has the combination of three opportunities: exerting corrective measures in the scope, time, and budget dimensions. The proposed method consists of 4 distinctive steps preferably carried out by the whole project team and documented by the project manager at the end of the phase.

Step 1: Defining Potential Risk Factors

The objective of this step is to define and quantify the risk factors threatening successful project completion. As we described above, factors have to be organized into three groups: scope, time and resource factors. Recommended methods are brainstorming or Nominal Group Technique.

Input information for definition may come from three main sources:

a) experience of project team members with previous projects (historical data and knowledge),
b) information from the environment of the project (external information),
c) information generated during the planning phase (Work Breakdown Structure (WBS), activity network, Gantt diagram, resource assignments, resource histograms and cost budget).

Quantification is recommended along two dimensions: subjective probability of each factor, and estimated impact on the project. Quantification will result in a two dimensional grid, illustrated in *Fig. 1*, where factors with high impact and high probability of occurrence are situated above the main diagonal.

The output of this step is basically *Fig. 1*, indicating the factors which warrant risk mitigation and contingency planning, called critical risk factors.

It is important to emphasize that factors which should be treated as critical are not only the ones situating in the high probability – high impact grid but also those ones which are quantified as low probability –

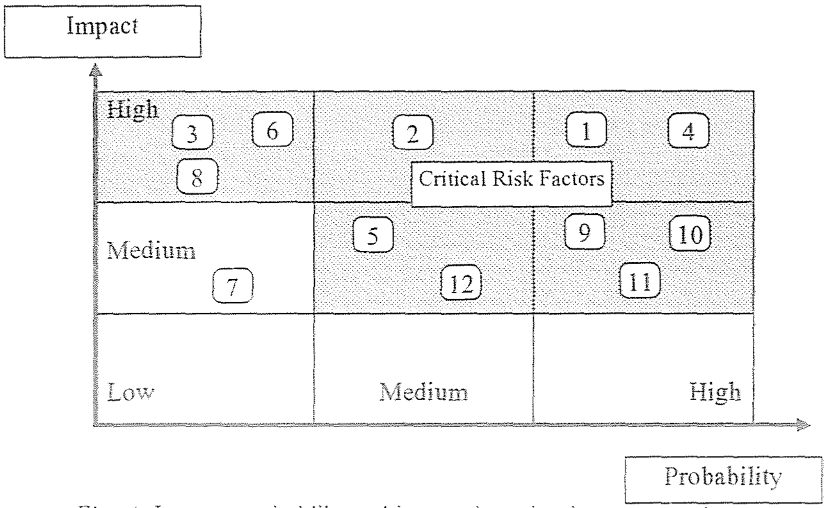


Fig. 1. Impact-probability grid – product development project

high impact (e.g.: 3, 6, 8). High impact factors jeopardise the outcome of the projects let they occurrence be probable or not, therefore in a highly unstable environment these factors need further investigations.

Step 2: Risk Minimization

As we defined earlier, risk mitigation is a series of proactive steps designed to minimize the probability of occurrence of the critical risk factors. Proactive steps may take two basic forms:

a) changing the project plan focusing on the critical risk factors,
b) defining such actions and responsibilities which were previously not included in the plan in order to prevent risk.

Revision of the project plan should examine all the information generated during the planning phase. Examinations in this context mean to further analyse the project WBS, network, schedule, resource plan and budget in order to search for potential risk factors. Some of these can be the following:

WBS: Definition of tasks, depth and desired output. Poorly defined tasks mean potential risk. Too many layers in the WBS could lead to coordination problems. Task should be assigned to one single primary responsible party otherwise quality and timeliness is threatened.

Network: A linear network, especially on the critical path produces high risk. Tasks with too many predecessors engender coordination problems.

Lack of milestones results in lack of control and fewer chances to correct deviations.

Schedule: The risk minimization schedule is the ASAP (As Soon As Possible) or left side schedule. This means that tasks start at their Early Start and finish at Early Finish. It is also desirable to crash the critical path so that the project's planned lead time is less than the desired deadline which means that the project's earliest finish is less than required latest finish. The difference might be used to absorb delays, just like contingency funds absorb over expenditure of costs.

Resources: Overloaded resources mean potential risk for low quality scope or time delay. Availability should be assessed by individual resources, especially in the case of human resources. Availability is determined by factors such as work conditions, experience, motivation, dependency on external information, rework, priorities of task and other responsibilities.

Budget: The major risk factor in project budgets is the short term financing of resources. Therefore, cost accruals should be compared to cash availability. Mismatches result in resource reallocation and/or rescheduling of tasks.

An important part of risk mitigation is the identification of reserves in resources, scope and time. Project managers should also clarify which are the effective constraints (the ones which cannot be negotiated with the client or requestor) and the non-effective constraints (which potentially can be redefined during the project if necessary).

The output of this step is a revised plan which minimizes the critical risk factors' probability of occurrence.

Step 3: Contingency Planning

Experience shows that not all critical factors can be mitigated by the project team. Also, some of them have such high impacts on the project that mitigation will not provide enough of a guarantee for proper project performance. This is the main reason why the project team should also prepare contingency plans for the critical risk factors.

Contingency plans are alternative courses of action to be executed in case the identified threat has actually occurred. Alternative plans can be as sophisticated as new mini-projects, started at the time of the occurrence of the event, or as simple as one or two new tasks to be carried out by previously identified responsible. Since commercial project management software tools cannot handle 'what-if' situations (the flow of tasks can not be altered), therefore contingency plans have to be stored separately from the original, mitigated plan.

Contingencies usually mean rescheduling, reallocating, preparing alternative budgets and determining bargaining strategies in order to negotiate project constraints (deliverables, deadline and costs).

A critical issue in contingency planning is the identification of the trigger points which warrant the use of the appropriate alternative corrective action.

Step 4: Defining Trigger Points

Definition of trigger points is the final part of contingency planning. Project management also calls them 'flags', which are connected to a decision about the further progress of the project. Triggers are usually connected to milestones, but they might also be incorporated in activities. They have to be well marked and located in the project network together with the necessary information to make effective decisions and corrective actions.

Decision, in this context, means how the project should be continued. There are some natural triggers in projects, such as contract signatures, tests or study results. Sometimes, though, the project manager or the project team has to define and append triggers which are not naturally part of the activity set. These triggers could be special team meetings, previously not defined data analysis or investigation of external information. Frequently, activities have to be broken into shorter phases, and the results of each phase have to be compared to a desired outcome.

Trigger points are the critical focus of project control, which is a main part of the execution phase. The better triggers are defined and placed, the easier project control will be later on.

4. Example for Complex Risk Analysis

This illustration for complex risk analysis is taken from product development. We have used it to practice the process of project risk analysis with more than 200 project team members and managers at one of the biggest multinational company (MNC) in Hungary. The example is hypothetical, product parameters are altered and the development process is significantly simplified. The project has been developed by the conceptual ideas of Dr. David Weil (WEIL, 1995) and with the contribution of experts of MNC. Regardless of this, MNC's experts have found it immensely useful not only in practising risk analysis, but also as a communication tool for product development. The concrete solution presented here is a synthesis and generalization of the numerous courses the author has conducted at MNC.

The input information to the planning phase is presented in *Table 1*.

		Respon.	2 DES	3 PRO	3 ME	1 PROD	1 QD	1 PM	1 FIN	1 ENH	1 SYST	1 SOUR	Elapsed Time
1.0	DEFINITION												
1.1	**Develop Basis Of Interest (BOI)** (Cust/appl. need, target market, etc.)	PM	4	6	6	1		2	2				3
1.2	**Conduct preliminary safety assessment** (Environmental concerns/benefits)	ENH	0.4	0.4						1			2
1.3	**Analyze preliminary financials** (lamp cost/volume to justify project)	FIN	0.4	0.6	1			1	1			0.2	2
1.4	**Review program feasibility** (Go/No go)	PM	0.2	0.2	0.2	0.2	0.2	0.2	0.2				1
2.0	TECHNOLOGY / MANUFACTURING ASSESSMENT												
2.1	**Conduct capacity analysis** (global look, cost analysis)	ME			0.6	0.2			1			0.2	2
2.2	**Conduct equipment feasibility** (process timing/speeds, etc.)	ME		6	6	2	2	2			1	0.4	2
2.3	**Issue trial engineering data** (design based on theoretical)	DES	4										3
2.4	**Make prototypes** (for feasibility testing)	DES	8	9	9	1	0.8						4
2.5	**Initiate testing of product** (lumens, watts, life)	DES	9										3
2.6	**Review poduct process** (understand major process issues)	PRO	1.6	2.4	0.2								1
2.7	**Review product design** (undestand major design issues)	DES	1.6	2.4									1
2.8	**Update product specs. and costs** (specs. based on testing)	DES	0.4	0.6		0.2	0.2	0.2	0.2			0.2	1
2.9	**Execute design validation** (product meets all specs?)	DES	2	2			1	1					4
2.10	**Develop temporary engineering data** (method to manufacture)	DES	0.2	0.2									1
2.11	**Review project with Manufacturing/Engineering** (formal design review)	ME	0.8	0.8	0.8	0.2	0.2	0.2	0.2				1
2.12	**Prepare formal approval** (product design feasible)	PM	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2			1
3.0	DESIGN												
3.1	**Finalize all plans** (timing, resources, volumes)	ME	1	1	1	0.8	0.8	0.8	0.8	0.8	0.8		3
3.2	**Prepare final AR and approvals** (O.K. to spend funds)	ME	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.2			4
4.0	FINAL DESIGN												
4.1	**Conduct des./proc./equip review** (develop process platforms)	ME	0.6	0.6	0.6	0.4	0.4	0.2		0.2			3
4.2	**Develop and issue equipm. design specs.** (equipment speeds, #heads, etc.)	ME	1	4	12	4	5					2	4
4.3	**Develop equipment concepts/layouts** (determine equipment details)	ME		1	1	1	0.4			0.4		1	3
4.4	**Vendor quotes** (vendor selected)	ME			0.6							0.6	1
4.5	**Issue contract** (equipment built)	ME			0.2		0.2		0.2	0.2		0.2	2
5.0	INSTALL AND DEBUG												
5.1	**Test equipment at vendor** (perform equipment validation)	ME		3	3	3	1					1	1
5.2	**Install and Debug** (testing, ramp up)	ME	2	12	12	8	4			1	1		6
5.3	**Perform test at manufacturing** (product validation test)	ME	2	3	3	1	1			1	0.2		1
5.4	**Provide training** (equipment safety, EHS, etc)	ALL	2	3	3	2	2			1	1		10
6.0	PRODUCTION AND DELIVERY												0

The basic assumptions of this project are that it is a new design not a product line extension, it needs new processes and equipment. *Table 1* is a summary of objectives and, more importantly, it is a task list indicating the WBS hierarchy, deliverables of each task, and assignment of resources. Resource assignment is defined in weeks/resource/task, that is, how many weeks does any given resource spend on a given task. These numbers are in the body of *Table 1*. The codes represent the following:

DES:	design
PRO:	process engineering
ME:	mechanical engineering
PROD:	production engineering
QD:	quality department
PM:	project manager
FIN:	finance
ENH:	environment and health
SYST:	information system
SOUR:	sourcing

Elapsed time is also specified in weeks, and this represents the duration of each task. Based on the data in *Table 1*, the following plans were prepared:

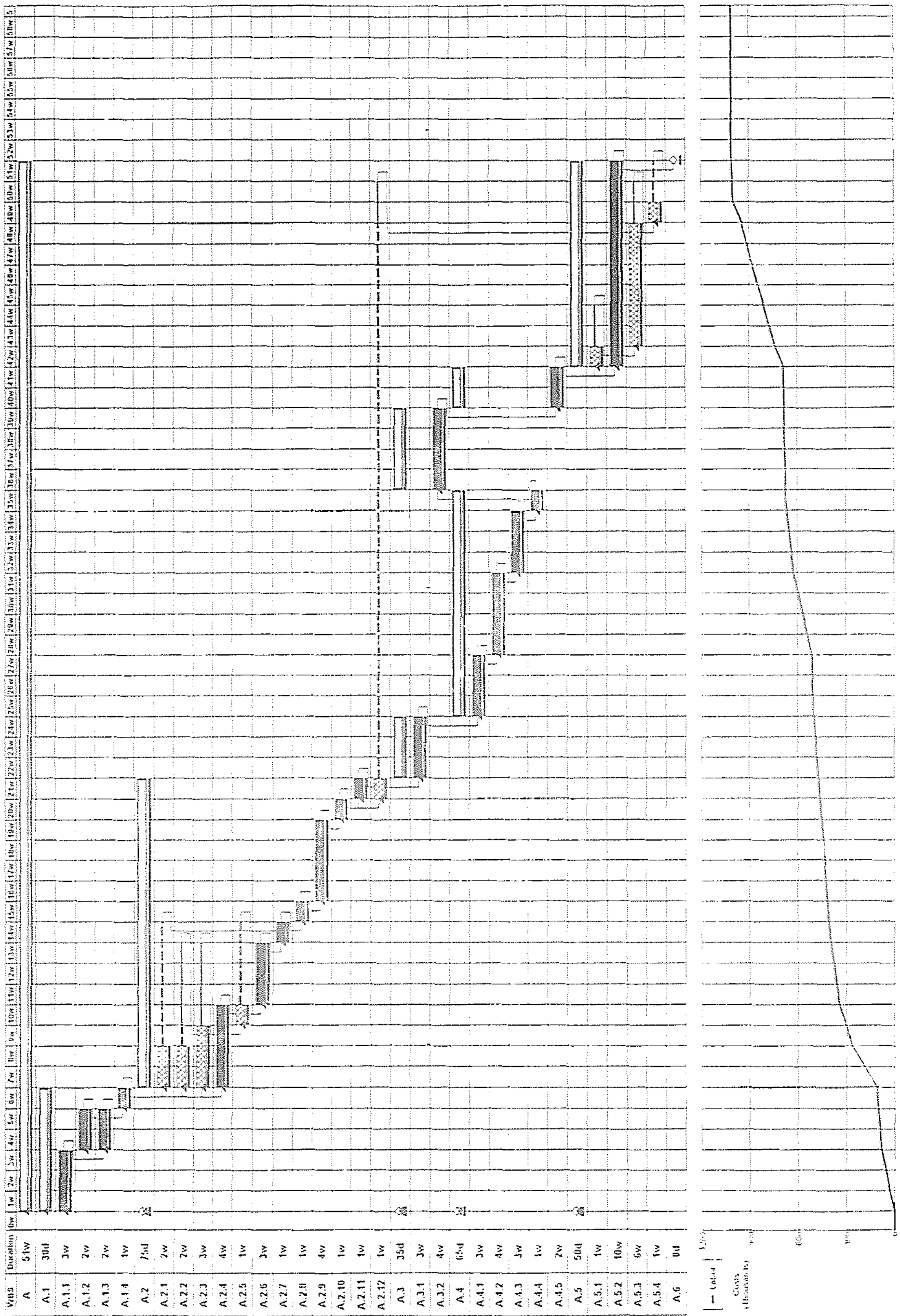
a) Gantt diagram and Project Network (*Fig. 2*). Black rectangles indicate critical activities, cross hash indicates activities with float. Dashed line symbolizes free float and thick lines are proportional with total float. The logical precedence of activities is described by the connecting lines and integrates the network information into the time diagram. *Fig. 2* is saved as a baseline plan, this is indicated by the underlining of each activities.

b) Resource Loading Histograms (*Fig. 3*). The availability of critical resources shows an uneven load with high peaks at the beginning and at the end of the project.

c) Cumulative Cost Curve as it is seen on the lower half of *Fig. 1* Costs had been calculated based on the assumption that the total cost of a resource, including allocated overhead, is $ 4.000/week.

Step 1: Defining the Potential Risk Factors

The most common risk factors are summarized in *Table 2* and *Fig. 1* illustrates them on the impact-probability grid. Teams have used brainstorming to define and quantify the items.



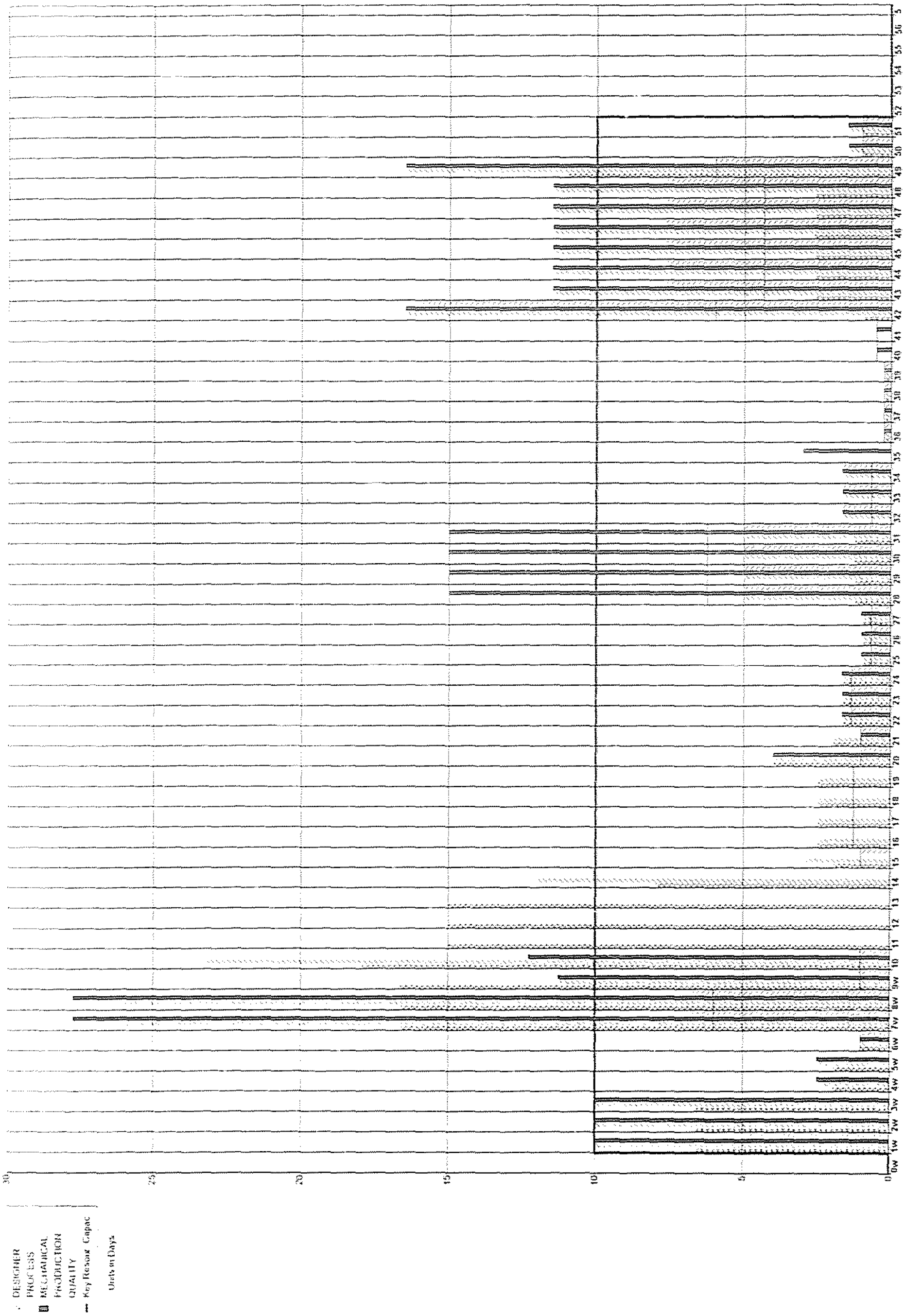

DESIGNER
PROCESS
MECHANICAL
PRODUCTION
QUALITY
Key Resour Capac
Units in Days
0
5
10
15
20
25
30

Table 2
List of risk factors

	Risk factors	Impact	Probability
1.	Project lead time is too long, decision is too short,	3	3
2.	Critical Path is too linear,	3	2
3.	Design requires change due to problems in manufacturing,	3	1
4.	Machine is not manufactured and delivered on time,	3	3
5.	Unpredictable problems in technology,	2	2
6.	Customer changes specification,	3	1
7.	Lamp is protected with a trade mark,	2	1
8.	Technology cannot produce the lamp,	3	1
9.	Financial plan is not accepted,	2	3
10.	Lack of resources	2	3
11.	Budget cuts along the project	2	3
12.	Variable cost increases due to external factors	2	2

Table 3
Risk minimization plans

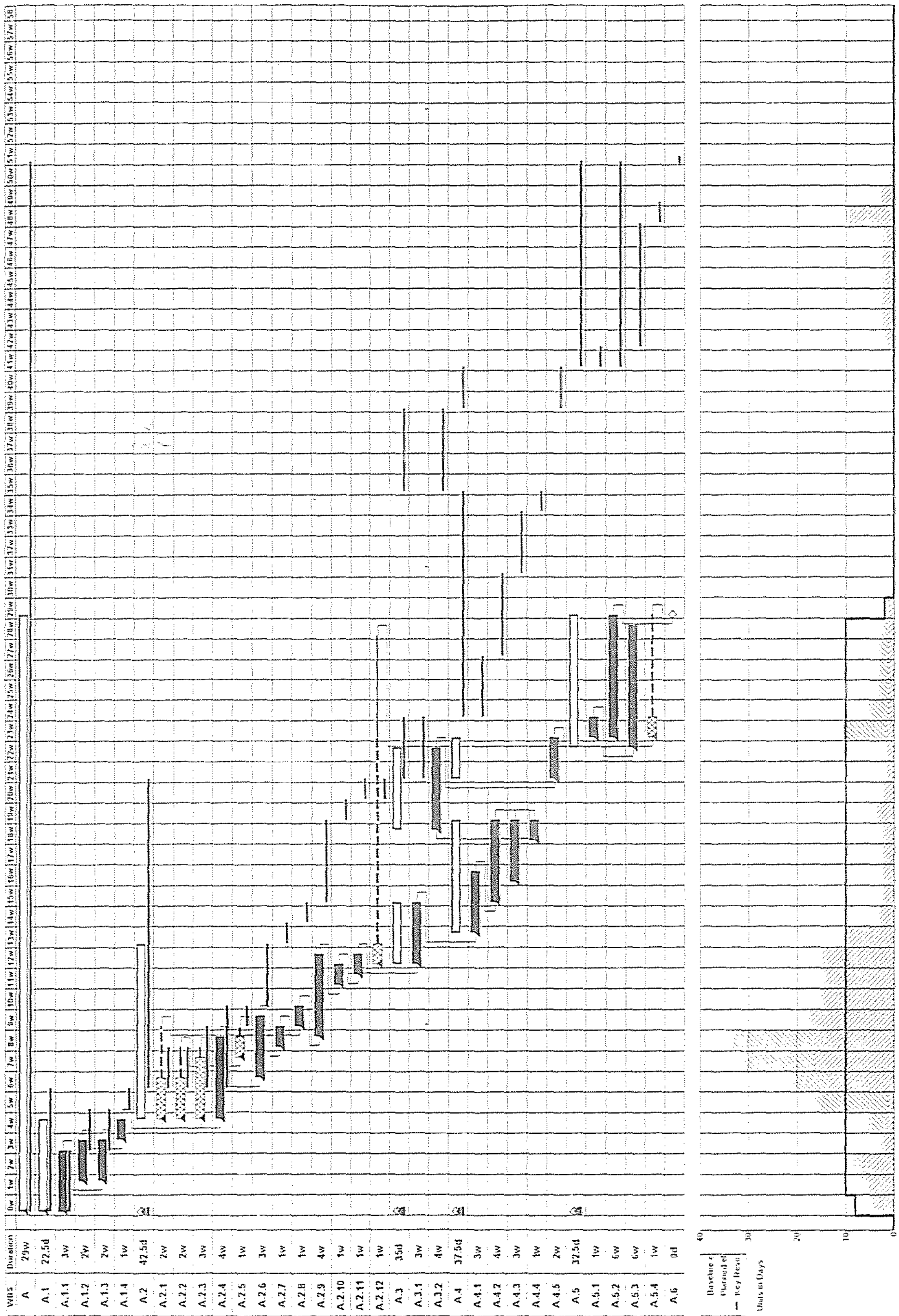
No.	Risk minimization plan	Risk Factors
1.	Refinement of financial analysis	9
2.	Resource levelling, regrouping and/or substitution	10
3.	Start everything which is possible in ASAP	11 , 10, 12
4.	Search for alternative markets	6
5.	Purchasing licence, and alternative suppliers	4, 7, 8, 3, 5
6.	Design and prototype for 5 different constructions	5, 3, 6
7.	Crashing the linear part of the critical path with overlapping	1, 4, 5.
8.	Special relationship and communication with equipment vendor	4

Step 2: Risk Minimization

Risk minimization plans are summarized in *Table 3*, where the last column indicates which critical risk factors are addressed by the given plans.

As a general principle cycle time reduction provides a cushion for meeting deadlines; *Fig. 4* illustrates the solution of MNC's experts.

MNC has traditionally encouraged media-rich, frequent, two-way communication between upstream and downstream phases of product development projects (WHEELWRIGHT and CLARK, 1992). This integrated problem solving model, which is illustrated in *Fig. 5*, makes it possible for downstream engineers not only to participate in a preliminary and continuous dialogue with upstream colleagues, but by using the information and insight it gives them to initiate an early start on their own work. The suc-



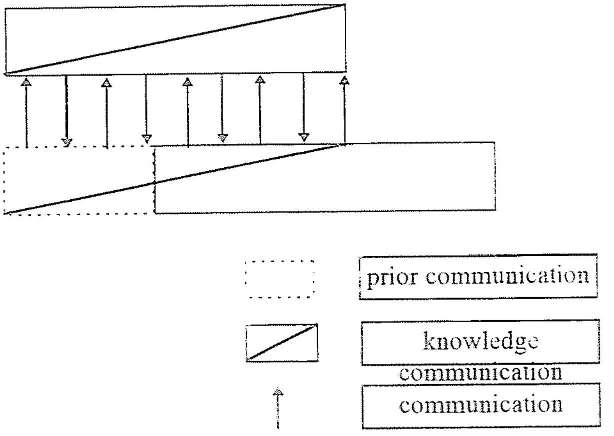


Fig. 5. Upstream and downstream integrated problem solving

cess of this model is dependent partly on communication techniques and partly on the special capabilities of upstream and downstream experts.

On the communication side MNC has encouraged the use of face-to-face discussions and the idea of virtual teams, communicating through E-Mail, tele- and videoconferencing. Conflicts are attempted to be resolved based on data, analyses and joint creative problem solving in a timely way, so that action can be taken to avoid costly mistakes downstream. The essence of mutual adjustment is real time coordination between upstream and downstream groups. In this way design engineers take into account the preliminary results of process engineering problem solving in order to make products easier and less expensive to manufacture.

As far as special capabilities are concerned, both parties have special responsibilities. Upstream capabilities consist of the following:

a) Providing downstream-friendly solutions, that is, upstream engineers have to be knowledgeable about downstream constraints and capabilities.
b) Providing error-free input to downstream. MNC experts use the most advanced design methods, such as Quality Function Deployment, Taguchi's experimental design and others to reduce error in the product design phase.
c) Quick problem solving. MNC trains its managers for the ability of problem solving and conflict management.

Downstream responsibilities are:

a) Forecasting from upstream information, that is, to start working in the absence of full information necessary to carry out the work. This is the case not only in internal processes but also when ordering long lead time materials from subcontractors.

b) Assessing trade off between the benefit of an early start and the risk of change.

c) Coping with unexpected change, that is, being able to be flexible and skilled at quick diagnosis and quick remedy. MNC machine division has procedures for managing engineering change, but there is always the matter of engineering talent.

Cycle time reduction is achieved by using task overlapping only between certain activities along the critical path. *Fig. 4* shows that technically this is done by keeping finish-start relationships and using negative lead/lag times for the overlap. The baseline plan illustrated by the lines had a lead time of 51 weeks, while the reduced lead time is only 29 weeks, that is, the original plan is shortened by 22 weeks (42% cycle time reduction). *Fig. 4*, on the other hand, demonstrates an unfavorable trade off, namely, the increased resource load along the project, mostly around the 5th–6th, and the 22nd–23rd weeks.

Steps 3. 4: Contingency plans and triggers

Table 4 contains the results of defining the basic courses of action in case the critical risk factors occur.

The last column of *Table 4* indicates the risk factors addressed by the contingencies, while the second column lists the alternatives experts recommend. There are two other columns: identification of trigger points in the activity network and information based on which alternatives have to be selected.

The case study does not contain the last step of the risk assessment phase, which is the assignment of responsible for recovery planning. Responsibilities should focus both on the monitoring of triggers and on executing contingencies if the situation calls for it.

5. Conclusions

The purpose of this paper was to draw attention to the importance of complex risk analysis in project management. Risk threatens all three dimensions of projects: scope, delivery time and budgets. Corrective actions on one dimension have impact on others, and these relations can and should be utilized in complex risk management.

The paper has demonstrated that several techniques exist and are practised for analysing the probabilistic nature of projects in each separate

Table 4
Contingency Plans and Triggers

No.	Contingency plans	Triggers	Information	Risk factors addressed
1.	Parallel with 4.1 to 4.5 use of float for repeated test Change equipment specifications (lowering scope) New engineering solutions/alternatives	Building in new task 4.6 (parallel with 4.1-4.5	Monitoring equipment manufacturing	4, 10
2.	Marketing negotiates with customer to respecify deadline and specs. Choosing simpler alternative Running shorter burning tests Reschedule tasks 2.1, 2.2 and 2.4 in their float times	Building in new milestone after 2.5	Decision on prototype performance	8, 5, 10
3.	Marketing starts exploring other markets with longer deadlines and with lower specs. Documenting project status and reschedule further progress. Selecting cheaper supplier and reassessing quality	Existing task 3.2	Decision on approvals	11, 12
4.	Assigning alternative resource for weeks 6–12 in design and process engineering Preparing substitutes possibly from outside suppliers Crashing the critical path after the 12. week. Enhance direct communication between design, process, equipment and manufacturing (E-mail, teleconferencing)	Regular meetings on labor capacity utilization and performance in 6–12 week	Decision based on status reports	10

dimension, and also terms of references provide guidelines for risk management (PMI's PMBOK). Still, managers need a practical framework to organize and implement these techniques and correctly integrate them into the project life cycle.

The author has outlined and illustrated a complex risk analysis phase, placed between the planning and execution phases of projects. The inputs of this analysis are information generated in the planning phase, previous experience with similar project and external factors. The processing of this information goes through four major steps; defining and quantifying potential risk factors, preparing risk minimization plans, preparing contingency plans and identifying trigger points or flags.

For all practical purposes risk factors have to be quantified according to their impact on the project and their probability of occurrence. High impact and probability factors are to be considered as critical and should be addressed by minimization and/or contingencies.

Risk minimization is a series of proactive steps to mitigate risk, by reducing the subjective probability of the factors' occurrence. Several techniques have been demonstrated, with special attention given to cycle time reduction and its principle assumption; the integrated problem solving between upstream and downstream activities in the project.

Contingency planning lists alternative courses of action in case a given risk factor actually occurs. Contingencies are generated by triggers, which measure information necessary for decision making and placed at places in the project network, allowing timely warning for firing the alternative plans.

The framework is illustrated with a hypothetical product development project tested and analysed by more than 200 managers and engineers. Risk analysis and contingency planning is a major contributor to MNC to deliver projects on time, within budget and according to specification in a changing, economical environment.

References

CHRISTENSEN, D. S. (1994): A Review of Cost/Schedule Control Systems Criteria Literature. *Project Management Journal*, Vol. XXV, No.3, pp. 32–39.

DAVIS, E.W. – PATTERSON, J.H.(1975): A Comparison of Heuristic and Optimum Solutions in Resource Constrained Project Scheduling. *Management Science*, Vol. 21, No. 8, pp. 944–955.

KRAJEWSKY, L. J.– RITZMAN, L. P. (1990): Operations Management — Strategy and Analysis. Addison-Wesley.

KURTULUS, I– DAVIS, E.W.(1982): Multi Project Scheduling: Categorization of Heuristic Rules Performance. *Management Science*, Vol. 28, pp. 161–172.

LA PLANTE, A. (1995): Scope Grope. *Computerworld*, March 20. pp. 81–84.

McFarlan, Warren F.(1981): Portfolio Approach to Information Systems. *Harvard Business Review*. Sep.-Oct., pp. 142–150.

Project Management Institute (1994): A Guide to the Project Management Body of Knowledge (PMBOK). Exposure Draft. Aug. pp. 45–49.

Schuyler. John R.(1994a): Decision Analysis in Projects: Monte Carlo Simulation. *PMNETwork*, Jan.. pp. 30–36.

Schuyler, J. R. (1994b): Decision Analysis in Projects: Other Probabilistic Techniques, *PMNETwork*, Apr., pp. 20–24.

Sigurdsen, Arild(1994): Method for Verifying Project Cost Performance. *Project Management Journal*, Vol. XXV, No. 4, pp. 26–31.

Tulett. D. T. (1995): Project Schedule Risk Assessment. *Project Management Journal*, Vol. XXVI, No. 1, pp. 21–31.

Weil. D. E. (1995): Project Management: Concepts, Principles and Applications', Training Manual.

Wheelwright, S. C. – Clark, K. B. (1992): Revolutionizing Product Development – Quantum Leaps in Speed, Efficiency and Quality. The Free Peress.