The Human Side of Managing Risks in High-Tech Product Developments

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ABSTRACT. A two-year field study into technology-based product developments examines risk management approaches. The findings show the critical importance of identifying and dealing with risks early in the development cycle. This requires sophisticated look-ahead simulation and rapid prototyping techniques, supported by modern information technology, as well as broad-scanning across all segments of the project organization. Managers must foster a work environment where people can deal with the uncertainties, ambiguities, and organizational imperfections. The critical importance of reducing complexity on all aspects of the product design and its organizational processes is discussed. To be effective as "risk managers," project team leaders must be capable of more than understanding the tools and techniques of enterprise risk management. They must also understand the infrastructure of their organization and deal with the complex social, technical and economic issues that determine the culture and value system of the enterprise.

INTRODUCTION

Few issues are more important to new product success than the ability to deal effectively with risks and uncertainties that are part of virtually every product development process. Looking at the *product development lifecycle,* each stage has specific inputs and outputs and success criteria, categorically shown in Figure 1, which eventually integrate into the final product with its ultimate set of success measures. However, defining product success in today's business environment is neither simple nor singular (Elliott 2001, Nellore & Balachandra 2001). Foreseeing and neutralizing the factors that impede success, is even more difficult (Pinney 2002). In many cases, the traditional measures, such as meeting budget, time and scope objectives, capture only part of the variables associated with product success or failure, and often represent a rather arbitrary snapshot in the product lifecycle. For example, the Sydney Opera House, by traditional measures of schedule and budget performance, had to be declared as an unsuccessful project, at the end of its construction. Today, few people would share such a judgment. Similar arguments can be made for new product developments that were completed on time and budget, but failed in the market because of problems with user friendliness, environmental concerns or competitive actions. It is clear, that measures of success and failure are much broader than those of traditional project metrics. Table 1 lists a small sample of typical risk factors that affect product success. While Management has long recognized the importance of identifying and dealing with risk during the early stages of a product development, to avoid problems at more mature phases of the development cycle or after rollout (Cooper and Edgett, 2001), predicting specific situations, their timing, root-cause and dysfunctional consequences in today's dynamic environment is a daunting undertaking. Most challenged seem to be managers responsible for complex, technology-intensive projects, involving intricate organizational processes with self-directed teams, rapidly changing technology, fluid requirements, resource limitations, and demands for flexibility and speedy implementation (Thamhain 2003). Traditional models, rules and methods of risk management that emphasized primarily contingency planning, mitigation and statistical analysis, are often not effective and are being augmented by method that connect more effectively across the enterprise, focusing on early risk recognition and prevention.

Today, managers have available an enormous array of tools and techniques to deal with risks (Dey 2002; Elliott 2001). These tools emerged under the umbrella of Integrated Product Development (IDP) and are the result of continuous process improvement efforts across industries. Contemporary risk management tools cover a wide spectrum, ranging from very simple to highly complex, from analytical to behavioral, and from quantitative to qualitative. Methods include interviews, brainstorming, focus groups, on-line databases for categorizing and sorting risks, and sophisticated Monte Carlo analysis for determining the probability of outcomes at specific project life-cycle points. There is little argument that all of these concepts

Table 1. **How Uncertainties Impact New Product Success**

A *computer disk drive needed to be reworked* at a cost of $2M at the roll-out stage, to incorporate new technologies *not foreseeable at earlier development stages.*

A *special instrument development*, although technically successful, *missed the NASA launch date, due to technical difficulties* during the assembly and test stage.

A new *ultra-portable CD-player failed* in the market, because of higher-than-expected *unit production cost.*

A *computer chip development* results in a marginally competitive product, because of *unpredictable changes in IC support technologies.*

A new *mutual fund product failed* in the market, because of *changing investor needs and economic conditions.*

A new *drug development was terminated* during the clinical trial stage, because *FDA approval became very unlikely.*

A *telecommunications satellite development* resulted in a large financial loss due to rework resulting from *regulatory changes.*

An *automobile industry supplier lost a production contract to a competitor*, after investing $5M into the product development.

A *supersonic passenger jet development was cancelled* after expenditures of $1B, because of *changing conditions* in the airline industry.

A *medical equipment development failed* to gain acceptance among MD users, because of *operational complexities and costly maintenance* procedures.

A *new chemical product development*, once announced as "critically important to the company's core business and long-range strategy," was *terminated because of changing corporate priorities.*

A *new web-based banking support system* received only 12% satisfaction rating from the bank's customers, resulting in a major overhaul of the system, *doubling its original development budget.*

An *application software development failed* in the market because of *interconnectability problems and user-unfriendliness.*

A *new computer operating system failed* at the system integration stage, requiring additional design work, resulting in *six months schedule delay and $2M budget overrun.*

A *new oil refinery was delayed by two years* at the pilot operation, because of newly discovered *environmental concerns.*

A *new TV consumer product failed* in the market, because of *reliability problems* that did not surface during the product development or rollout stages.

provide an important toolset for enterprise risk management (ERM). Yet, there is also a growing sense of disappointment and frustration, especially for technology-based projects, that not all techniques work equally well, nor are all equally applicable to all situations (cf. Iansiti & MacCormack, 1997; Piney 2002; Pappas 2002; Thamhain 1994, 2002). This frustration is especially strong among managers who realize the critical importance of early risk identification, but are unable to detect problems before they cause major disruptions, rework or changes in the development or deployment process, an important area of future research.

OBJECTIVE, METHOD AND SIGNIFICANCE

This paper presents the first set of findings of a two-year field study into the practices and business processes of enterprise risk management (ERM) looking at the *"fuzzy front end"* of *new product development projects. Particular focus* is *on the people issues* that affect the ability of the enterprise to identify and deal with risks in *high-technology product development situations.* As a by-product of the initial data collection, the risk management approaches available to product development managers will be identified and categorized. A focus on the front-end, or concept phase of new product developments is especially useful, because decision-making during this project phase has the greatest impact on the development outcome, with the least amount of resource commitment, as graphically shown in Figure 1. *The results* should help both management practitioners and scholars to better understand the complex issues, and organizational dynamics involved in enterprise risk management (ERM) at the early stages of new product development processes, and to establish the framework for further research into the effectiveness of specific risk management approaches.

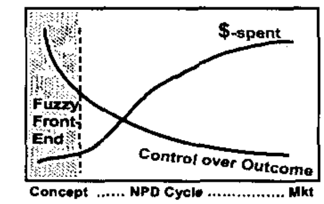
Method. All components of this investigation -- risk management, product development, team work and high-technology project management -- involve highly complex sets of intricately related variables. Researchers have consistently pointed at the non-linear, often random nature of these processes, that involve many facets of the organization, its members and environment (Danneels & Kleinschmidt, 2001; MacCormack, et al, 2001; Nellore & Balachandra, 2001). Investigating these organizational processes simultaneously is not a simple task, making it less likely to find simple models for researching these environments. Because of the complexities, and the absence of specific theories or constructs, an exploratory field research format has been chosen for the investigation, involving *questionnaires* and two qualitative methods: *participant observation* and *in-depth retrospective interviewing.* Specifically, data were captured between 2000 and 2003 from 27 technology organizations, as part of an ongoing research in the area of technology-oriented product development and team-based project management with regularly published results. The field study, ongoing since 2000, yielded so far data from 74 project teams with a total sample population of 435 professionals such as engineers, scientists, and technicians, plus their managers, including 18 supervisors, 22 project team leaders, 18 product managers, 10 directors of R&D, 8 directors of marketing, and 10 general management executives at the vice presidential level. Together, the data covered over 118 projects in 14 companies. The projects involved mostly high-technology product/service developments with budgets averaging $1,200,000 each. All project teams saw themselves working in a high-technology environment. The 14 host companies are large technology-based multinational companies of the "FORTUNE-1000" category. *Content Analysis* has been used in addition to standard statistical methods for evaluating the survey data.

RESULTS

The findings of this exploratory study are organized into three sections: First, the types of risks that emerge over the lifecycle of a new product development are identified and summarized. Second, the management approaches taken to deal with these risks are discussed. And third, the management practices for dealing with future risks during the conceptual stages are explored.

Types of Risks Affecting Product Success

For the purpose of definition, risks are defined as issues, incidents or situations which have the potential of affecting the product development adversely, and ultimately impact product performance, business performance and success. Using content analysis of the survey data, from the three sources (1) interviews, (2) questionnaires and (3) observations, managers in our study identified over 1000 unique risks situations which we grouped into twenty generic categories, separated in two classes, as shown below. Class-I contains *cause-related risks,* while Class-II contains *impact-related risks.* That is, Class-I defines risks categories that can *cause* problems, such as the possibility of changing markets or technology. These risks are manageable, at least in principle. *Impact related risks* of Class-II, such as schedule slips or budget overruns, have already affected project performance, and are beyond the point of manageability. Both risk categories and classes are overlapping in product development environments.



gure 1. Leveraging product value and uccess during conceptual phase

Class-I, Cause-Related Risks. These are incidents or risks that have a negative impact on project performance and ultimate affect product success negatively. Examples are:

Inability to determine market or customer needs
Inability to estimate resource requirements accurately
Inability to estimate timing requirements accurately
Changing management commitment or inability to sustain commitment
Changing organizational priorities
Inability to deal with regulatory requirements
Environmental quality problems
Inability to predict technology trends or changes
Technical product complexities too high
Intellectual property rights disputes
Inability to attract or hold quality team members
Changing contractor relations
Changing social or economic conditions

Cause-related risks are the pre-cursor of work problems that impact project performance only, if the "cause" is not managed appropriately.

Class-II, Impact-Related Risks. These risks affect the outcome of the project or its success directly. Examples are:

Budget overruns
Schedule delays
Product performance problems
Market or customer acceptance problems
License and permit problems
Logistic problems
Profitability or cash flow problems

Risks that impact product performance directly are often *caused by a multitude of problems* that were not predictable or could not be dealt with earlier in the product development cycle. An example might be the resignation of a key project team member that causes work flow disruptions, sub-optimal design, confusion, organizational conflict, sinking team spirit and fading commitment. All these factors contribute to schedule delays and system integration problems, causing time-to-market delays, missed sales opportunities and ultimately an unsatisfactory profit performance of the new product in the market.

It is interesting, that while project leaders understand the sources of risks (Class-I), they focus most of their attention on *monitoring* Class-II risks, such as schedules and budgets, trying to manage problems only after they started to impact project performance. On average, less than one-third of the project leaders interviewed, could trace performance problems back to specific changes that occurred earlier in the work environment. Only one-quarter of these managers felt that they could have foreseen or influenced the events that eventually impacted project performance adversely. It is further interesting to note that many of the organizational tools and techniques that support early risk detection and management readily exist in many organizations, embedded in the planning, tracking and reporting process of today's project management systems. However, they must be carefully cultivated. Understanding both (1) the potential risk factors and their organizational dynamics and (2) the project management process and its tools, is an important prerequisite for *identifying and managing risk factors in their early stages, before they impact project performance irreversibly.*

General Risk Categories. Because of the difficulties in clearly separating risks on the basis of cause and effect, many managers classify the risk areas into five general categories:

1. *Technical Risks* that affect product performance or its service in the field
2. *Financial Risks* that affect monetary aspects of the product life cycle, including budgets, cash flow and profitability
3. *Schedule Risks* that affect timing of the product, including work interfaces, critical path deliverables and time-to-market.
4. *Logistical Risks,* such as training, manufacturing setup, distribution, licenses and permits, that affect the work flow and ultimately schedules, budgets, deliverables and overall project performance.
5. *Organizational Risks,* such as changing priorities, reorganization and leadership changes, that might affect schedules, budgets and work processes directly as well as indirectly via weakened team spirit and commitment.

How Do Companies Manage Risks?

Driven by business pressures and advances in information technology, many companies have invested heavily in *risk management tools and techniques*, promising to rig the odds of project success by improving the ability to deal with contingencies more effectively. While analytical approaches are still a major component of the overall risk management toolset, they are predominately used for quantifying probabilities of risk, and for translating these probabilities into specific schedule or budget parameters. Yet, the ultimate usefulness of many analytical methods depends on the assumption that the as risks factors and their underlying parameters, such as economic, social, political and market factors can actually be quantified and reliably forecasted over the project life cycle. Therefore, many of the more contemporary approaches to *risk management* go beyond the identification and quantification of risk factor, but try to deal with the broader issue of *eliminating the cause of risk* by simplifying the product design and its processes, reducing development time, and testing product feasibility early in the development cycle. In our field study, we observed many approaches that aimed effectively at the reduction or even elimination of risks. Other methods focused on the predictability of product success or failure at the very early stages of development, before substantial resources have been spent and organizational commitments have been made.

Five Categories. To establish a framework for discussion and future research, we have grouped risk management approaches of new product developments into five categories.

1. ***Identifying and Managing Risk Factors.*** Examples are the anticipation of changing requirements, market conditions or technology. If the possibility of these changes is recognized, their probability and impact can be assessed, additional resources for mitigation can be set aside, and plans for dealing with the probable situation can be devised. This is similar to a fire drill or hurricane defense exercise, where specific risk scenarios are known and prevention measures, such as early warning systems, evacuation procedures, tool acquisitions and skill developments can be put in place, as a measure of readiness to minimize the impact, in case the risk situation actually occurs.
2. ***Simplify the Product and Product Design.*** Examples are the use of pre-fabricated components, subcontracting, snap-on assembly techniques, plastic vs. metal, microprocessor vs. e-components, and compilers vs. machine language. Any innovation that reduces complexity, development time, resource requirements, testing, production setup or assembly, also reduces the risk of contingencies to occur over the development cycle.
3. ***Simplify the Development Process.*** Examples are innovations in work process or project management, such as concurrent engineering, stage-gate and integrated product development processes. All of these systems are designed to make the product development team work together as an unified group, minimizing organizational barriers and increasing communication effectiveness within the product development team and its host organization, while at the same time minimizing reliance on team-external infrastructure.

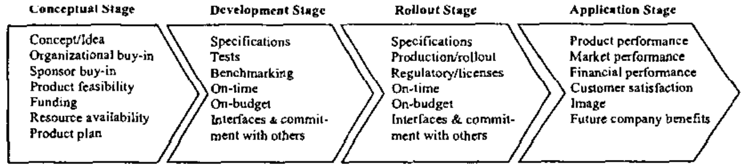


Figure 2. Gates and Checkpoints toward Product Success built into Project Life Cycle

4. ***Reduce Product Development Time.*** This can be accomplished through the combination of product and process simplification, but also via parallel development work, such as concurrent engineering or design-build processes. The logic for the resulting risk reduction is simple. The shorter the product development cycle, the less changes and contingencies can occur in the product development and its social, economical and technological subsystems.

5. ***Test Product Feasibility Early.*** Traditionally, the crucial product viability test, such as system integration, market acceptance, flight tests, automobile crash tests, were performed toward the end of the development cycle. However, with the help of modern computer and information technology, it is possible to advance these tests to the very early stages of a new product development. Examples are CAD/CDE/CAM-supported simulations, emulations and modeling of products in their final application environment. A simulated jet flight or automobile crash test is not only much less costly and time consuming than the real thing, but also yields valuable information for the improvement and optimization of the product design at its early stages, long before a lot of time and resources have been expanded. Technology offers also many other forms and methods of early testing and validation, ranging from stereo lithography for model-building to focus groups for early design usability testing. These technology-based methods also allow companies to test more new product ideas, and their underlying assumptions for success, in less time and with considerably less resources than with traditional "end-of-the-development" test methods.

INCREMENTAL PRODUCT DEVELOPMENTS

As an evolution of *multi-phased approaches* to project management, *incremental product developments*, such as *Phase-Gate Processes*, have gained wide acceptance for managing complex projects. These concepts are consistent with contemporary "look-ahead" project execution methods, such as *Rolling Wave Concepts, Phased-Developments, Phase-Reviews, Voice-of-the-Customer,* and other integrated product development (IPD) concepts. They all emphasize the need for incremental and iterative implementation of project plans and aim at the reduction of risks and uncertainties. As graphically shown in Figure 2, various gates and checkpoints are established throughout the new product development cycle, to guide the product developments, from idea to launch and beyond. One of the prime objectives for using *incremental* or *phase-gate processes* is to make the project cycle and its outcome more predictable, that is, to minimize downstream uncertainty, risk and complications. Each stage contains several *gates* specifying the criteria for the project to succeed in the next stage and beyond. If these gates are designed and managed properly, these checkpoints validate, via multifunctional reviews, all necessary "conditions for future success". As an example, the gates within the Concept Phase should be designed to verify that the work in progress can be transferred smoothly downstream. Thus the gates help to validate criteria such as producability, testability, repairability, quality, available licenses, and profit targets.

For simplicity, the phase-gate process is often presented as a serial, step-by-step method. However, its application is for both serial and parallel work processes, including *concurrent engineering, design-builds, fast tracking, rolling wave developments* and multi-organizational joint developments. To present such concurrent application graphically, one can envision each stage as a time line on a Gantt Chart. Time lines can be overlapping or running completely in parallel to each other. One of the critical elements of the incremental development concept is the *review process* associated with each *gate*. Not only must the gate metrics be designed to validate the correctness of the current project approach and its phase outputs, but equally important, the review process, its people, environment, and leadership must be conducive to a dynamic and candid assessment of the project and its performance against the final mission objectives and success parameters. Moreover, "downstream task leaders" must be willing and able to define the "upstream" gate criteria and to guide the "upstream" design process toward desired results on which they depend on as "customers."

DISCUSSION AND CONCLUSION

In spite of the complexities of new product development processes and the inevitable uncertainties throughout the development cycle, the risk of product failure is not random and can be managed. Based on our field observations, the *major influences for dealing with risks* in product developments are derived from three sources or subsystems of the enterprise: (!)work and its process, (2) analytical tools and methods, and (3) people. As shown in Figure 3 all three subsystems are interrelated as part of the organizational environment and its culture which is driven by its managerial leadership.

Reducing Risks within Work and Organizational Processes. Risk and uncertainties originate from the work itself. This is highlighted with the examples of Table 1. Our field study shows that the complexity of the product, its design and work process contribute especially heavily to the uncertainties and risks that affect product success. Whatever can be done to simplify the product, its design and work process, will make the project more manageable and increase its probability of success according to established plans. Many companies are focusing on the streamlining of their work processes by establishing new project management platforms, such as Concurrent Engineering or Stage-Gate processes. These organizational enhancements not only simplify the work process but often also reduce development time, which further reduces the potential for changes and contingencies. Yet another area of strong managerial focus is *early feasibility testing*. Modern computer and information technology makes it possible to test at an early stage of the product development, everything from functionality and interconnectability to environmental behavior and ultimate product

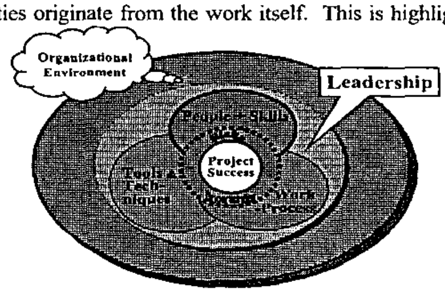


Figure 3. Organizational Influences on Risk Factors and Project Success

performance in its target application. Whether a company undertakes an airplane development, computer design or the rollout of a new insurance product, such rapid prototyping techniques provide a powerful *look-ahead ability* from concept to market, or any point in between, reduces uncertainties enormously. It also provides the ability to iterate designs at the click of a computer button, hence testing out alternate assumptions, options and applications.

Reducing Risks with Analytical Tools and Methods. Modern information technology provides the basis for many of today's analytical tools and methods for risk management. These tools cover a wide spectrum, ranging from very simple to highly complex, from highly quantitative to graphical and behavioral. Methods range from interviews, brainstorming and focus groups, to on-line databases for categorizing and sorting risks, to sophisticated Monte Carlo analysis for determining the probability of outcomes at specific project life-cycle points. These tools are especially helpful in processing complex arrays of data searching for risks, analyzing their impact or supporting risk management decisions. These tools and methods also provide the engines for electronic testing, rapid prototyping and other look-ahead techniques discussed in the previous paragraph.

Reducing Risks with People. People, though their work, behavior, organizational interaction and imperfections, are one of the greatest sources of uncertainty and risk in any product development process. They are also one of the most important resources for reducing risk. The quality of communications, level of trust, respect and credibility, conflict, job security and skill sets, all influence the collective ability of the organization to identify, process and deal with risk factors. Based on our exploratory study, many of the favorable influences on people to effectively deal with risk, are derived from the work itself, including personal interest, pride and satisfaction with the work, professional work challenge, accomplishments and recognition. Other important influences include effective communications among team members and support units across organizational lines; good team spirit, mutual trust, respect, low interpersonal conflict, personal pride and ownership, plus opportunities for career development, advancement and, to some degree, job security. All of these factors seem to help in building unified project team that focuses on cross-functional cooperation and desired results. In this mission-oriented process, the high-performing team also isolates and minimizes risk factors.

CONCLUSION

Effective risk management of new product developments involves a complex set of variables, related to task, tools, people and organizational environment. Managers point at the critical importance of identifying and dealing with risks early in the development cycle. The ability to inexpensively and quickly assessing feasibility at an early development stage, seems to be an important key to reducing uncertainties and costly iterations. To be effective as "risk managers," project team leaders must be capable of more than understanding the tools and techniques of enterprise risk management. They must also understand the infrastructure of their organization and deal with the complex social, technical and economic issues of the enterprise. One of the more striking findings is that many of the drivers toward effective risk management are derived from the human side. Organizational components that satisfy personal and professional needs, seem to have the strongest effect on the team members' perception of trust, respect and credibility. People who find their assignments professionally challenging, leading to accomplishments, recognition and professional growth, also seem to enjoy a climate of active participation, minimal dysfunctional conflict, and effective communication. They also seem to handle risks more effectively. To foster such a favorable work environment requires carefully developed skills in leadership, administration, organization, and technical expertise, and the ability to involve top management to ensure organizational visibility, resource availability and overall project support.

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