Risk Planning in a High-Tech New Product Development Project

Abstract

Purpose- This paper explores the question of risk management in an NPD project of a high-tech company. It considers three bodies of knowledge: project management, risk management and Monte Carlo simulation to produce a more robust framework. The study presents the application of a modified PMI's project risk management framework to a case study, instrumental in providing insight to the issue of early project risk assessment. It uses Monte Carlo simulation to understand or confirm the impact of risks thought to have the greatest impact on key project's objectives. Based on similar NPD projects, the Company reduced the uncertainty of the project's duration and cost. Future directions for research could include case studies or empirical studies that could include the testing of hypotheses, and the integration of optimization procedure for improved NPD project's planning and execution.

Keywords-Project management, Risk management, Monte Carlo simulation, New product development
Paper type-Research paper

1. Introduction

Project management in new-product development (NPD) poses added challenges than those faced by other type of projects (Söderlund, 2004; Midler & Silberzahn, 2008). Complexities in a project arise due to uncertainties caused by unpredictable elements within each task, interdependencies among tasks, and counterintuitive configuration behaviors. NPD projects typically have long lifespans and relatively high costs, requiring a thorough risk management planning before their execution. On the market side, most new products that reach their marketplace have a rather short time-span left based on patent protection or anticipated competition from substitute products, creating additional pressures and other kind of risks.

During the last two decades, there has been an increase number of published research on complexities of high-tech projects and programs (Hobday, 2000.) In fact, NPD projects exhibited numerous complexities presented in multi-project programs, but at the lower task level (Fens, 1991; Pellegrinelli, 1997.) Companies have often underestimated these complexities and haven't been able to fully analyze and manage risks associated with such projects and the potential consequences on the organization's strategy. For example, setbacks caused by inappropriate dependencies' assumptions and lack of coordination between task's elements have motivated researchers and practitioners to further the understanding of the role of contracts, relationships and cooperation in these settings (Martinelli, Waddell & Rahschulte, 2014.) The result has been an increase in the number of improved risk management frameworks, structured linking a number of current best practices to tackle these and other project risk management issues.

This paper explores the question of risk management in an NPD project of a high-tech company. It considers the integration of three bodies of knowledge (project management, risk management and Monte Carlo simulation) to produce a modified analytical framework. In a nutshell, it expanded the risk management framework proposed by the Project Management Institute (PMI) and Monte Carlo simulation, focusing on issues related to task elements' uncertainties. The framework comprised core dimensions to analyzed NPD project's task elements uncertainties (Elmaallam & Kriouile, 2011; Project Management Institute, 2004). A case study of an NPD project conducted during 2012-14 was used for the purpose of illustration (for confidentiality, the name of the company is not revealed and will be referred as 'The Company'.) It contributes to the discussion introducing a framework that considers stochastics behaviors within the tasks' elements and among their dependencies. The presented study might also stimulate and smooth the progress of such cross-disciplinary best practices debates.

2. Theoretical background

2.1 Risks

In general, a risk refers to a possible future event that could impact the successful completion of at least one intended objectives. This definition applies to either project and process based initiatives. Although the terms "uncertainty" and "risk" are frequently used interchangeably, most authors in risk management recognized that there is a distinction between the terms, and have provided definitions of both based on the cause-and-effect thinking (Bellos, Leopoulos, Sfantsikopoulos & Politechniou, 2004.) In the academic literature, risks definitions are based on the stakeholders 'attitude toward risk or a suitable definition of the author's research (Turner & Müller, 2005; Chapman & Ward, 1996). Furthermore, professional associations have their own particular definitions that take into account the primary activities of their affiliates. Due to these discrepancies, there is no general accepted and used definition of the term "risk." In this study, it was useful to differentiate both terms and included two others (event and issue) to appropriate address different concerns during risk's assessment and dynamic, as have been done by other authors (Saunders, Gale & Sherry, 2015; Mousavi & Gigerenzer, 2014; Rasmussen, 2013.)

Considering risk as a part of a cause-and-effect process, the cause of a risk is grounded on an uncertainty on a distinctive task element as task duration, cost, quality inadequacy, resource availability or task dependency. In this process view, the risk is the concern that something won't be met or done [or something that could be a lost], and the effect is the consequence. For example, inadvertently a supplier over sighted the quality of a product (the cause); consequently, the production unit that received this product (e.g., parts, components or services) had to use defectives products (the risk), resulting in a shortfall in the production unit's productivity (the effect.) While in this example the discussion only considered one cause and one effect, in reality, a risk might be the product of various causes and produce many effects (see Figure 1.)

Figure 1. Cause-and-effect risk's process

The Project Management Institute's Guide to the Project Management Body of Knowledge (PMBOK® Guide, 2013) differentiated between a risk and an issue. The simple distinction is that former hasn't happened yet. The latter, has already happened and might be the result of an unidentified risk, thus should be addressed at once. In the author's experience, for all practical purposes, an identified high-impact risk is considered an "issue" if it has a high probability of occurrence. Whatever the case may be, to be a successful project manager, risks have to be proactively planned. This proactive approach embrace three key issues: (1) it's not feasible to respond to all identified risks, (2) it's impossible to account for all risks (also known as unknown-unknown risks), and (3) risks tend to decrease and impacts tend to increase as the project progresses (Yeo & Ren, 2009.)

2.2 Frameworks

Most risk management frameworks utilize serial processes for identifying, evaluating, and prioritizing risks. They also proposed generic risk response strategies based on the likelihood (probability) and severity of consequences (impact) of the risk. In general, risk management frameworks are intended to provide: 1) a set of guidelines to assist in the analysis of a project for risk elements, 2) a process by which these risk elements can be organized into groups of related risk factors and ultimately into risk perspectives that match stakeholder views, 3) a model representation that enables formal risk analysis to be performed using a quantitative approach while keeping the data requirements to a minimum, and 4) a process of analysis that assists in the identification of key risk factors, outcomes and reactions, and the creation of action plans to mitigate these risks, i.e. to target resources where the payoffs are expected to be the greatest (Guled, Dange & Chawan, 2012.)

During the last decade, most risk management frameworks have been developed based on ISO 31000:2009, risk management-principles and guidelines (Preda, 2013; Raydugin, 2012; D'Ignazio, Hallowell, & Molenaar, 2011; Wiboonra, *2011*). It was published as a generic framework to safeguards a consistent approach to risk management for processes and projects (see Figure 2.)

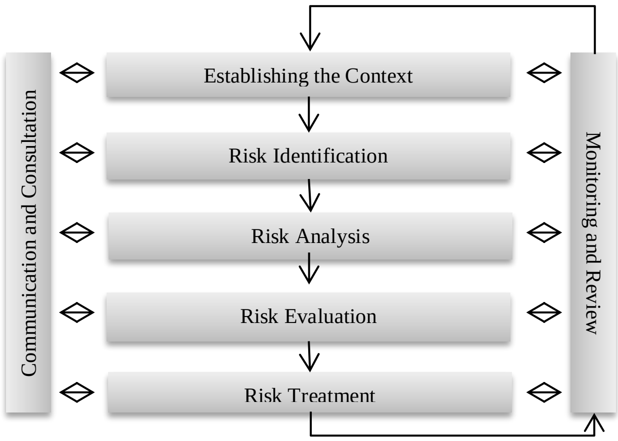

Figure 2. ISO 31000:2009 processes for managing risk
Source: ISO 31000:2009 Risk management principles and guidelines

Table 1 shows several studies that have used frameworks based on these processes in project risk management. As can be seen, some studies used all processes recommended by the guideline. They also confirm the lack of consensus regarding what processes should be employed in a project risk management framework: Only risk identification, risk analysis and risk response strategies were used in all studies. Most risks centered on durations, costs, and dependencies' issues.

Table 1. ISO 31000:2009 processes in project risk management

	ISO 31000:2009 Processes					
Sample Studies	Communication and Consultation	Establishing the context	Risk identification	Risk analysis	Risk response strategies	Monitoring and Review
Oehmen, Olechowski, Kenley & Ben-Daya (2014)	X	X	X	X	X	X
Gangadharan & Luttighuis (2010)			X	X	X	
Perano (2012)	X	X	X	X	X	X
Löhr & Khushnood, (2012)	X		X	X	X	X
Olechowski, Oehmen, Seering & Ben-Daya (2012)			X	X	X	X
Arnold (2013)	X	X	X	X	X	
Yashin & Semenov (2013)		X	X	X	X	X
Maria-Sanchez (2012)	X		X	X	X	

Risk management in projects has received a distinctive consideration by PMI. It is seen as an integrative embedded process that accompanies a project in its initiation, planning, execution and control phases, up to its completion and closure. Figure 3 shows the key six processes according to PMI. Pekkinen & Aaltonen (2015), Sanz & Bernad (2014), and Too & Weaver (2014) are some authors that discussed in detail its implementation. Many formal project risk management frameworks are extensions of this framework.

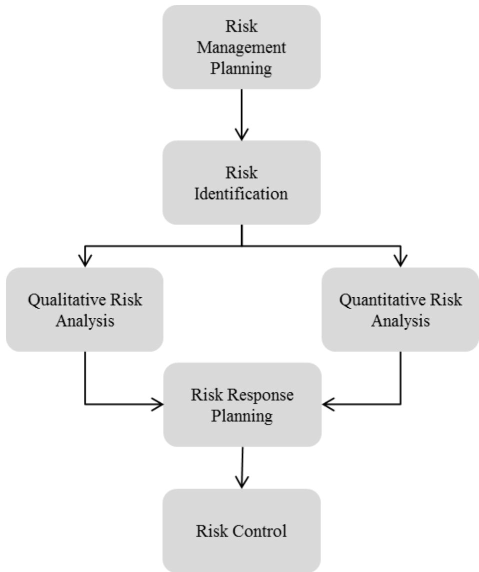

Figure 3. PMI's PMBOK® risk management area of knowledge

Other companies in the study used *ad-hoc* frameworks based on an array of standards, norms or references, including those shown on the following Table 2. Most of these frameworks were developed for business continuity management, supply chain risk management or enterprise risk management. Consequently, these frameworks focus attention on the organization's primary interest risk management coverage, i.e. the business domain and scope in which their operations are more vulnerable. They have been developed so can be readily applied to both small scale and quite large complex operations, with manageable levels of data requirements.

Table 2. Risk management standards, guidelines and frameworks

Code and Name	Publisher	Scope
ISO 28000:2007- Supply Chain Security Management System	International Organization for Standardization	Supply Chain
ISO 31000:2009 - Risk management (Principles and guidelines)	International Organization for Standardization	General (Non-specific)
ISO 22301:2012 – Societal security business continuity management system	International Organization for Standardization	Business continuity
BSI 259999 & 31100	British Standards Institution (BSI)	Business continuity
Supply Chain Management Framework	Association of Operations Management (APICS)	Supply chain
COSO	Committee of Sponsoring Organizations of the Treadway Commission	Enterprise
ASIS/BSI BCM.01:2010 Business Continuity Management Systems: Requirements with Guidance for Use	ASIS and BSI for North America	Business continuity

2.3 Risk Identification and Categorization

The risk identification process consists of identifying and describing the potential risky events of the project and their consequences. There is no unified definition or consensus on the issue of project risk categories. Projects face a wide variety of risks, hindered in very different ways, among different project levels (Zacharias, Panopoulos & Askounis, 2008). Some methods or sources used in the identification of risks are brainstorming, cause-and-effect (Ishikawa), risk registers of completed projects, and several forms of expert opinion studies. The final selection of a particular identification method will rest on stipulated standards-and-policies of the organization or the project member’s experiences and proficiencies’ selection criteria. Once a risk has been identified it is classified in a designated category for further consideration, accountability and prioritization.

The most basic risk categories are internal and external. Internal risks are mainly embedded within and between the project’s tasks, consequently affecting its objectives. There is a tendency to view risks in a hierarchical structure which describe sources of risks (Hillson, 2003.) PMI recommends using a Risk Breakdown Structure (RBS) as a categorization scheme. Other PMI’ categorizations are based on the work-breakdown-structure (WBS), while others combine the RBS with the WBS and the organizational breakdown structure (OBS.)

Some authors suggested the use of the following categories (Keizer & Vos, 2003): technology, market, finance, and organization. Financial risks are related to cash flow, commercial viability, inflation, foreign exchange, and insurable resources. Market risks are associated with consumer and potential actions of competitors. Those related to product design and development, intellectual property, completion time, quality and performance are technical risks, and those related to political instability, attitude of the government toward specific type of projects are organizational [or political] risks. Organization risks are related internal processes, the project team, co-development with external parties, and supply and distribution. Once a risk has been identified, it is classified in a predetermined category for further consideration, accountability and prioritization.

2.4 Risk Analysis

Most methods fall into two generic categories: quantitative or qualitative. Current practices use a mix of quantitative and qualitative methods and models, but at eh aggregate level subjective methods are preferred to estimate aggregate risks. Quantitative risk methods are predominantly used when,

- it's essential to have improve accuracy of the probability or impact of a risk,
- develop probability-based performance standards, as is the case when organizations must objectively show that a proposed activity can meet a specified performance standard,
- regulations, competitiveness goals, legal and compliance constraints, and internal issues require more rigorous measures.

Most quantitative methods (e.g., Monte Carlo simulation, cost risk analysis, decision analysis, value at risk method, earned value analysis, and network analysis) are grounded on proven scientific theories. Therefore, have been traditionally preferred over qualitative risk techniques (e.g., brainstorming, Delphi method and scenario analysis), when accurateness is imperative.

After risk analysis, through quantitative and qualitative techniques, risk are scaled based on the perceive impact and probability. This binomial is used for risk prioritizing, usually shown using a visual aid like heat-maps or impact-and-probability matrices.

2.5 Response strategies

Once risks have been assessed and prioritized, cost efficient response strategies are considered. Risk response strategies are expected to lessen negative risks effects or increase positive risks, in the most effective and practical way. Figure 4 shows the generic strategies suggested by PMI for positive (opportunities) and negative (threats) risks. The specific action requires for responding to a risk will depend upon its nature. Contingent response strategies are those developed to be used in a predefined situation on a particular event, and fallback plans, known as secondary plans, are those response actions that would only be delivered in case that the primary response strategy was ineffective.

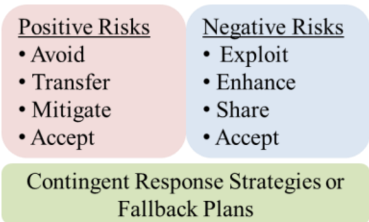

Figure 4. PMI's generic strategies

In most projects, the preferred generic strategy for high probability and high impact risks is avoidance. Risks with low probability and low impact are dealt with some kind of mitigation strategy or are not thoroughly planned for (acceptance strategy.) In the latter, if the risk occurs, administrative and budget reserves are often used to confront it. Furthermore, it is often the case to make trade-offs between the cost of implementing a risk response strategy's and the cost of living with it. As shown in Figure 5, response intensity (assigned resources, processes and budget) should be suitable for each risk, and any deviation from this adequacy could result in a disproportionate risk response.

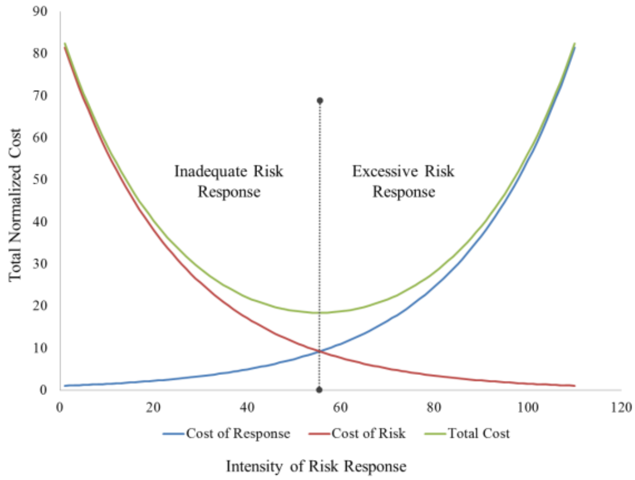

Figure 5. Cost of risk and cost of response's trade-off

To sum up, risk prioritization has to be done before a response strategy is chosen. Risk analysts may establish a function for determining a risk level. Traditionally, to determine risk level, risk analysts use two risk measures, including risk probability and risk impact, as shown below. The response level is an index presenting the intensity of risk response that should be used. Within a simple view, it can determine a response level as the following equation. It should be noted that a negative risk/response level refers to a threat, while a risk/response level of a positive value refers to an opportunity.

$$Risk\ level = Risk\ probability \times Risk\ impact = f(Risk\ measures; Risk\ classes\ weighted\ factors)$$

$$Total\ normalized\ cost = \frac{Response\ probability \times Response\ impact}{Intensity\ of\ Risk\ Response}$$

Once the total risk response strategy cost has been normalized, its prioritization might change, as illustrated in Figure 6.

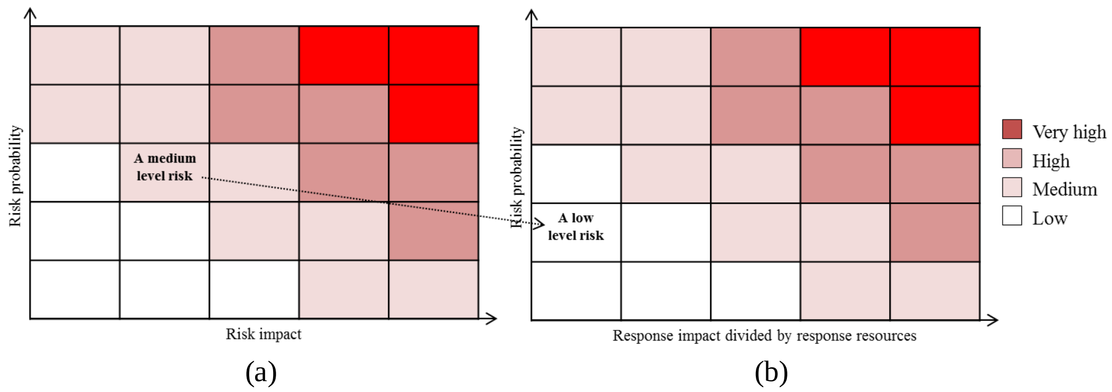

Figure 6. (a) Risk level and (b) Response level

3. Methodology

The study presents the application of a modified PMI's project risk management framework to a case study. The framework is instrumental in providing insight to the issue of early medium-high probability and impact risks assessments (see Figure 7.) Monte Carlo simulation was used to understand or confirm the impact of risks thought to have the greatest impact on key project's objectives.

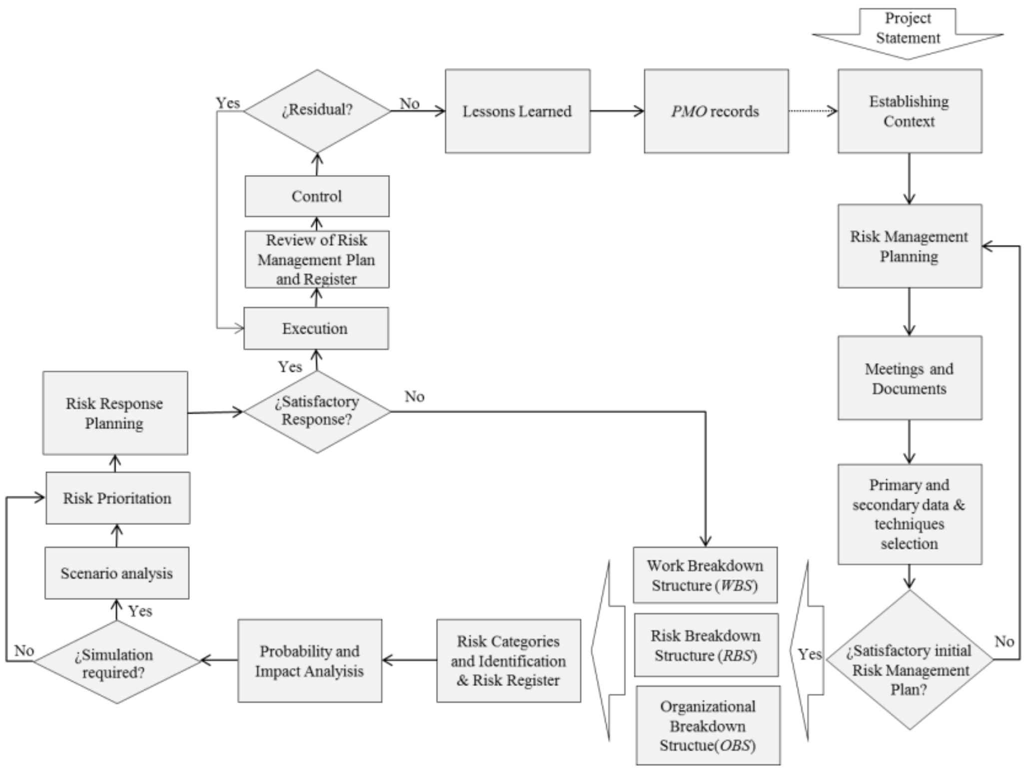

Figure 7. Framework for implementation project risk assessment

The attention was drawn to the case because of the complex nature of NPD projects that need initiative that can address issues of project risk management. The framework provided a useful tool used by project stakeholders to better understand the myriad of risks that can impact an NPD project. This framework uses both qualitative and quantitative techniques, providing a robust framework.

In the study, data was collected from several sources, in order to understand different aspects of the project at hand. Publicly available documents were reviewed for background information on the events leading up to the decision to venture in The Company's industry and its activities since its establishment. Supporting records provided includes historical data and records of similar project performances over the past decade: In-depth detailed data on nine projects including risk assessments, categorization, references, and recommendations. Finally, brief semi-structured interviews were conducted with some stakeholders seeking feedback on their experiences with the risk assessment process.

4. Case Study Analysis

4.1. Company setting

The case study concerns a company that needed to expand its production line to compete in a fast-growing high-tech market. Only two companies were servicing the market, with proprietary and patent protected products, and in 2011 both companies were serving 45% of the potential market. The Company had prior experience developing and marketing similar products, but with limited functionalities, which follows its low-cost niche strategy at the time. Each NPD's project was structured in four major dependent phases: Project administration, technical analysis, development stage, and commercialization. In most projects, The Company uses these phases as a natural risk category outline. The expectations and project objectives were (1) that the proposed new product would be able to compete one-on-one with the other companies' products, but at a lower price (using its experience producing low-cost products), (2) complete the project [including commercialization] in less than 1.5 years, (3) overrun costs could not be more than 20% of the assigned budget (prior projects had an average overrun of 7%), and (4) comply with project's metric baselines. Regarding the latter, these metrics measurements were selected to make some goals clearer, assigned actions and defined consequences. Some metrics were: percent of requirement deficiencies at qualification testing, number of in-process design changes/number of parts, number of design review deficiencies/number of parts, number of prototype iterations, percent R&D resources/investment (total of new products plus sustaining and administrative), task completion versus plan, and time-to-market/time-to-volume.

Prior to implementing of the framework, the risk management process was based on using a brainstormed list of risks in each project phase. Each risk was assessed for its impact and a response plan was generated to avoid the risk or take advantage of an identified opportunity. The process was not effective for risk response planning as there was no scoring method for risk prioritization. Fortunately, The Company had already initiated the risk identification and categorization process as a requirement for ISO22301 (Business continuity) certification a year earlier. Nevertheless, the project management knew that the scope of the certification focuses more on supply chain management issues (even that some would overlap several project tasks), and was prepared to start digging into risky events and its consequences to the NPD project.

4.1 Risk Identification and Categorization

The Company was aware of the endemic problem of cost, time-to-market, and tasks' duration escalation on its NPD projects. Cost and duration estimations were complex, and managing the capital development and commercialization of these projects requires the coordination of a multitude of organization, technical, human, and natural resources. Being acquainted with these issues, The Company decided to base the risk identification and categorization in the four major dependent phases mentioned previously.

In the identification process, thirty two risks were identified. Thirteen risks were classified as low-probability/low-impact, and a contingency budget was separated in case a risk materialized: Consequently, no specific strategy responses were selected. Eight risks were regular tasks within many of The Company' projects, which were considered "systematic insignificant exposures," and again; no specific strategy responses were selected. Eleven tasks have risks' elements constructs that became the focus of the risk management efforts, which are shown in the following table.

Table 3. Risk elements identification

Category	Task	Risk	Risk Elements Construct	Probability (1-5)	Impact (1-5)
Administration	Align and confirm marketing strategies	Changing market conditions	Resources	3	4
	Financial assessments	Inadequate metric measures gathering	Duration/Accuracy	2	3
Technical	Initial NPD plan	Inadequate documentation	Duration	2	5
	Initial S&OP	Lack of single point accountability	Duration	1	3
	Product prototype process	Product doesn't fit for purpose	Duration	3	5
	Verify operational capabilities	Inadequate third party performance	Resources/Productivity	1	3
	Customer product testing	Inadequate test procedure elements	Resources/Representativeness	2	4
Development	Selection of proper customer sample group	Lack of agreed-to user acceptance testing and criteria	Duration/Representativeness	2	3
	Redefine product requirements	Poor production system performance	Duration	2	4
Commercialization	Confirm product specification	Technical limitations of solution reached or exceeded	Duration/Accuracy	1	4
	Product capability against competitive response	Unreasonable project schedule and budget	Duration/Yield	2	5

4.2 Risk Analysis-Monte Carlo Simulation

Table 3 shows the impact on each of the eleven main risks selected by The Company's project team. These figures were obtained by Monte Carlo simulation performed on the project model using the program @Risk. Historical data was used to estimate the statistical distribution and correlations of all tasks. The observed project's output variables were the NPD project cost and duration. The variation of the output variable with changes in input parameters (the eleven tasks) helped both model validation and interpretation of results. The tornado graph in Figure 8 displays the input risk factors that have the greatest impact on the project's duration. Three other similar analyses were performed in the other output variables with their corresponding [and pertinent] input variables (accuracy, representativeness, productivity, etc.)

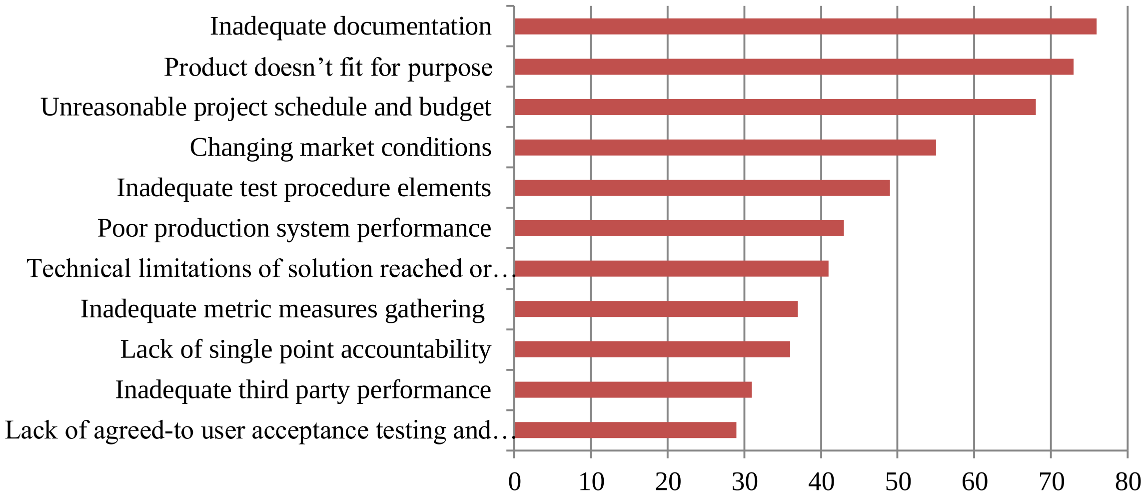

Figure 8. Risks with greatest impact on project’s duration

4.3 Risk Response Strategies

As shown in Figure 8, “Inadequate documentation,” “Product doesn’t fit for purpose,” and “Unreasonable project schedule and budget,” have the greatest impact on NPD’s project duration. On the former, once the causes of this risk were studied, the generic strategy Avoid was chosen. As it happened, this task was delegated mainly to an “ad-hoc” committee composed of personnel that works strictly at the PMO (there were budget and time control issues behind this decision), triggering a series of difficulties. Afterward, The Company decided to include this task into the project’s team responsibilities.

“Product doesn’t fit for purpose” risk elements were caused by assumptions made at the beginning of the project that were revised and changed throughout the project lifetime. If deviations arose, they were managed using administrative (including technical) reserves, established for this purpose. Suggestions based on changing task precedences were considered but finally rejected. The impact of “Unreasonable project schedule and budget” was convoluted: squatter actual project schedule could lead to an increase over the budget (mainly to fast-track several tasks), and vice versa. To prepare for this task, The Company relies on a number of procedures: for example, benchmark studies, actual operation's capabilities, and industry information. The main concern for The Company was tying up financial resources by overallocation. The response strategy for this task's elements was based upon a combination of transfer's risks, using prearranged excess capacity of third-party companies to buffer any operational excess required: The Company operates at the expected schedule level and budget. This strategy implies a contingency reserve in case that risk was triggered. Adequate response strategies were chosen for other risks elements. All responses costs were normalized, prior their selection and inclusion in the risk register.

5. Conclusion

Risk management using combined recognized generic frameworks, as PMI's project risk management, and Monte Carlo simulation provides an effective way for assessing complex project' objective outcomes. Such approach leads to an analysis system where scenarios based on variabilities in task's elements, could trace many possible consequences: the interaction between cost, schedule, and performance measures drives the analysis. This is crucial in NPD projects where risk is an inherent component of its scheme. These projects are based on a number of assumptions and estimates that reflect the organizations understanding of the current situation in the project formulation phase. However, events seldom go according to plan, so the project must adapt to an ever-changing environment.

The project risk management framework that includes Monte Carlo simulation provided a systematic process for identifying, analyzing, and responding to project risks. It was applied to a case study of an NPD project of a high-tech company, which showed the project management effectiveness of using the modified framework. The revised framework presented in this study builds upon the existing literature and takes a more analytic approach in risk assessment. Based on similar NPD projects, The Company reduced the uncertainty of the project's duration and cost. Future directions for research could include case studies or empirical studies that could include the testing of hypotheses, and the integration of optimization procedure for improved NPD project's planning and execution.

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