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Risk Management of New Product Development Process

By

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Abstract

Winners in today´s global changing environment, are those who continuously pursuit innovations in order to guarantee their sustainability. If in the presence of a certain environment many enterprises makes enormous mistakes, in an uncertain environment as the development of innovations, these mistakes will be multiplied. Moreover, since little effort has been made in developing empirical models, metrics and tools to manage risks in product development, this work aspires to satisfy the necessity of high-tech enterprises with a useful and pragmatic approach to manage the risks of their new product development (NPD) process. Besides it provides for enterprise´s innovation life cycle, a NPD risk management methodology with efficient techniques to manage risks in advance and during the development of new products, it will provide a new conceptualization of enterprises' innovation and NPD process, for supporting future research in the innovation field.

This master thesis will explore the innovation field, revealing that radical and incremental innovations are complementary during the innovation life cycle and accomplished through distinct process of developing new products. Through this new perspective, this work succeed in providing a NPD risk management model for both type of innovations aiming a universal best practice to identify, analyze, and manage risks in the NPD process.

Resumo

Os vencedores deste meio ambiente global e de constante mudança, são aqueles que procuram inovar para garantir a sua sustentabilidade. Se na presença de um determinado ambiente muitas empresas cometem erros, num ambiente incerto como é o de desenvolvimento de inovações, estes erros serão multiplicados. Dado que pouco esforço tem sido feito no desenvolvimento de modelos empíricos, métricas e ferramentas para gerir os riscos no desenvolvimento de novos produtos, este trabalho tenciona satisfazer esta necessidade das empresas High-Tech, através do desenvolvimento de um modelo útil e pragmático para gerir os riscos no desenvolvimento de novos produtos. Este modelo além de proporcionar durante o ciclo de vida da inovação de uma empresa um processo com eficientes técnicas de gestão dos riscos antes e durante do desenvolvimento de novos produtos, irá desenvolver uma conceptualização sobre a inovação das empresas e o processo de desenvolvimento de novos produtos, suportando futuras pesquisas no campo da inovação.

Esta tese de mestrado irá explorar o campo da inovação, revelando que as inovações radicais e incrementais são complementares durante o ciclo de vida da inovação e obtidas através de um processo distinto de desenvolvimento de novos produtos. Através desta nova perspectiva, este trabalho faculta com sucesso um modelo de gestão de risco do desenvolvimento de novos produtos para cada tipo de inovações, pretendendo fornecer uma metodologia universal de melhores práticas para identificar, analisar e gerir os riscos do desenvolvimento de novos produtos.

Contents

List of Figures

List of tables

1. INTRODUCTION

a. Context of the research

Due to the constantly challenges in today's global, intense, and competitive market, enterprises are forced to match their core business into the market necessities. Winners in this permanent changing environment, are those who pursuit continuously new methods to generate competitive advantages (Hung et al., 2007). Almost all high-tech companies recognize their need to innovate (Knight, 1967) in order to guarantee their sustainability (Qin and Wang, 2006).

As high-tech enterprises are subjected to an extremely dynamic environment (Teece et al., 1997; Cormican and O'Sullivan, 2004), they must invest all their efforts in aligning a perfect strategy to the development of an effective, efficient, and profitable new products (Hung et al., 2007; Knight, 1967; Qin and Wang, 2006). High-tech companies have to demonstrate timely responsiveness and rapid and flexible product innovation (Teece et al., 1997; Eisenhardt and Martin, 2000), because waiting for the new product to become available will entail high lost profits (Gardner and Buzacott, 1999). Therefore, it´s completely clear that the only way to create, sustain, and safeguard company´s competitive advantage, is to actively manage the innovation process to efficiently deploy innovations (Teece et al., 1997; Cormican and O'Sullivan, 2004; Baccarini et al., 2004).

However, uncertainty is a given factor whenever companies intent to develop innovations. If in the presence of a certain environment many enterprises makes enormous management mistakes, in an uncertain environment as the development of innovations, these mistakes can be amplified. In fact, besides innovations entail a high level of uncertain, as any project its success will be influenced through a large number of factors. In future, for these risks not to result in errors or failures that will be translated into high costs for the organization, it´s imperative to realize its analysis and posteriorly the management of all risks. The difficulty is patented in any type of management, especially when companies are facing risky projects. However, it is not an excuse for the resignation of managers, since innovation is a key business factor for high-tech enterprises (Song et al., 1996; Dong and Yan, 2006; McDonough, 2000; Chen, 2007; Jassawalla and Sashittal, 1998).

There are several knowledge areas where the project management actuates. Within the risk management, the project manager intent to identify, analyze, and respond to the risks that occur in a project. The risk management will deliver the inputs, to be further complemented with the proper measures and knowledge areas of project management. The risk is the possibility of a threat or an advantage occurring within a project when a certain event takes place. Its study will allow the comprehension of the risk´s impacts and its causes during the development of new products, ensuring the concentration of enterprises' resources on the specific risk to enhance opportunities and reduce threats.

Risk management will contribute to the quality control within the NPD process, aiming the control of the three major variables within a project: cost, time and scope. The costs of implementing a risk management process during the NPD comparably to the risks taken in such kind of projects are in fact insignificant. It can be argued that the cost incurred is an investment that will have an amazing return (Simon et al., 1997).

Even though high-tech enterprises recognize high risks in developing new products, little effort has been made to develop empirical validation models, metrics and tools to identify, evaluate and manage risks in product development, remaining far from clear which methodology NPD managers should adopt (Boer, 2002; Keizer and Halman, 2007; Keizer and Vos, 2003). Since, it is extremely important for High-Tech enterprises to carefully manage the risks of new product development, and in general it is achieved intuitively, this work will provide a vanguard methodology to manage risks previously and during the new product development process.

The application of a risk management process within the development process of innovations will stimulate the formulations of more realistic NPD models, to identify, evaluate, and manage its risks. The new product development process is a standard procedure required from ISO 9000 and adopted by the European Community members and many other countries to provide quality to the new product and consistently in meeting customer requirements (Tedaldi, 1997). Besides, it’s the best way to identify in the complete NPD process which items generate risk to the process success, it is a tool to verify where they came from. Moreover, many companies believe that these processes already incorporate risk management because they have built into it procedures of worker´s awareness of project risks. Unfortunately, this risk deliverables by itself does nothing to prevent the risks, and companies seldom move beyond this, move to manage their project risks (Smith, 2002). Therefore, the NPD process is insufficient to guarantee the success of developing new products. But together with risk management process, will provide a major tool to manage the development of innovative products, so necessary in high-tech companies. Through the monitoring of the cooperation of each functional elements from the new product development team during the new product development process, it will be verified which items will generate risks and from which functional areas they are from, providing a real data base to manage new product´s risks.

Contrarily of some researcher’s opinions, that new products have to fit company´s competences, this work perspective goes beyond of such restrictive thinking. It is enterprises who have to adjust their strategies and competences to develop new products for its continued prosperity.

The actual process of product development still is considered among innumerous researchers as a “black box”. Many investigators view the NPD process within different perspectives (Kagioglou et al., 1998; Cooper, 1990; Ulrich and Eppinger, 2004; Schroeder, 2003), nevertheless they all based their perspectives on staging the NPD process accordingly to the state of the product during its development.

Since each process varies according to company´s particularities and product´s innovation, there isn´t a NPD standard process for all existing products (Boer, 1999; Ulrich and Eppinger, 2004; Miller et al., 2005). Consequently, many researchers in the innovation field proposed to investigate different innovation categorizations to better address an appropriate development process. These investigations had some level of ambiguity due to the abundance of different innovation characteristics and its categorization aim.

The risky path of developing new products will influence or even limit the success of innovative high-tech enterprises. Therefore, any methodology that aims to manage this process will have to be supported with all the domains that influence the development of the innovation process. These domains go from the nature of innovation, to the activities of developing new products, until the type of management. Due to these reasons, the NPD risk management will be difficult to interpret without a lucid and extensive literature review of high-tech industry, new product development, innovation, and risk management. The literature review had the purpose to provide a rich and solid foundation of the development process theory of new products, with the aim to guarantee the best risk assessment of this process.

b. Scope and objectives of the research

This work was proposed to accomplish the graduate program of master in industrial management engineering at Universidade Nova de Lisboa, Faculdade de Ciências e Tecnologia and to satisfy the real necessities of a R&D department in the Photovoltaic Energy Industry. The work developed, ambitious to serve high-tech enterprises with a simple and most of all a practical methodology to manage the development of their innovative products.

It is recognized among innumerous researchers that implementing risk management early in the new product development process is in general much more useful as it is difficult, since the results of managing risk in advance, are substantial superior than manage the risks in the instant of occurrence. However, in most of the cases, since projects rarely proceed exactly according to plan, enterprises manage the risks on new product development process only once they are in its presence. This real enterprise´s necessity, and the lack of existent methodologies to face it, generates the market necessity in providing a universal model to manage risks in advance and during the development of new products. Certainly the risk assessment may be imprecise before the product is developed, but complemented with an effective risk control during the development process, it will cover the ambiguities of managing the project while is less defined and respond to the appearance of any new risks, provoked by the uncertain environment of NPD process. Thus, this work proposes for enterprise´s innovation life cycle, a universal NPD risk management model with several recognized techniques to manage risks in advance, and a specific risk control methodology during the development of new products. Besides, focused on a technical improvement model, this work goes beyond of such restrictive aim. It seeks in providing a new conceptualization of enterprises' innovation and NPD process, to future research in the innovation field be based on reliable theory.

c. Research methodology

This research work was conducted through a literature review of more than one hundredth papers and ten books. The literature review was examined disregarding the years of publication, to capture a unique interpretation of all domains in study. The review intents to analyze the previous documents of the literature in question, for not being influenced with other researcher´s interpretations.

In this perspective and with a six month NPD monitoring in a high-tech company, it was developed an empirical model to control the development of new products in high-tech industry, through risk management. The methodology adopted to achieve the greatest potential of the risk management integration in the NPD process is illustrated in the figure bellow.

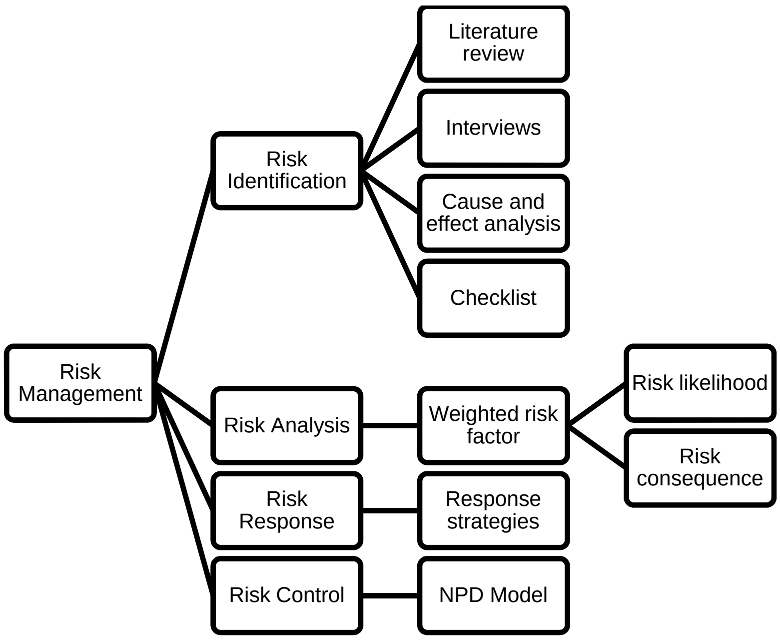


Figure 1 – Proposed risk management methodology

For the development of the proposes, it was used data from the literature review and a six month NPD monitoring.

It was also conducted a field study using interviews, brainstorming, forms, and checklists about two different new product developments in a high-tech photovoltaic tracking systems company. The interviewees were drawn from multiple functional areas and from various organizational levels. Commonly they lasted from 20 to 40 minutes and were scheduled through e-mail. The choice of each project was based on the innovation life cycle criteria.

d. Thesis structure

This thesis is structured by five chapters. The present chapter has an introductory nature which answers to “What” is Risk Management of New Product Development Process, “Why” is interesting in developing a dissertation on this subject, and “How” the objectives of this thesis are going to be accomplished.

The second chapter aims to deepen the theory needed to develop a risk management model of NPD process, which was based upon an analysis of Innovation in High-Tech industry and of Risk Management. Relatively to the Innovation theory, is described within five main thematic: High-Tech Industry, New Product Development, Radical versus Incremental Innovation, Cross-functional and New Product Development Team. The Risk Management concept is explained through the characterization of a process.

In the third chapter is defined the proposed Risk Management model of NPD process based on two sub-chapters, on Innovation under Enterprises´ Life Cycle and on NPD process.

In the fourth chapter, the model developed earlier will be applied to a radical and an incremental innovation of a High-Tech enterprise of photovoltaic tracking systems. In this chapter it will be implemented the proposed techniques to manage NPD risks, and it will be explained how these techniques should be applied.

The last chapter presents the main conclusions and contributions of this work, and will also suggest future research to continue the work developed and interest applications of the approach produced in this dissertation.

2. RISK MANAGEMENT IN NEW PRODUCT DEVELOPMENT PROCESS

a. Innovation

i. High-tech industry

In high-tech competitive industry, companies are forced to seek new methods to generate competitive advantages (Hung et al., 2007). Almost all industries recognize their need to innovate (Knight, 1967) in order to guarantee their sustainability (Qin and Wang, 2006).

According to Jassawalla and Sashittal (1998), Jenkins et al. (2006), and Miyazaki (2009) high technology firms are a unique segment of organizations because in comparison to others:

(a) Employ proportionately more scientists, engineers, and technically (and often terminally) qualified people;
(b) Face considerably higher rates of product obsolescence because of rapid advances in new technology coupled with intensive competitive pressures;
(c) Invest proportionately larger sums in R&D, and focus considerably on developing new products technology;
(d) Rely inordinately on rapid, efficient new product introductions to meet revenue and profit objectives, and to remain competitive;

With theoretical intuitions and qualitative empirical work, Coad and Rao (2008) studied the role of innovation in the growth of high-tech firms. Their quantile regression analysis showed that innovations have a positive influence on company profits, truly believing that no firm can survive without at least some degree of innovation. This is in agreement with Knight´s (1967) statement "*An organization represents an adaptive system that must continually improve its performance to keep alive in modern society*".

Strategically, as Miyazaki (2009) distinguish, or high-tech companies adapt an internal growth with research and development (R&D) investment, or they choose external growth strategy through mergers and acquisitions (M&A). Nevertheless, either one will have an internal growth company-based which develops innovations.

The continuum searching of innovations in high-tech industries, makes them more regular and routine (Knight, 1967). The growth of innovations provided by high-tech industry was confirmed by Barto´s (2007) research, revealing that high-tech manufacturing has been dominating the manufacturing sector with respect to innovation and productivity rates. Such companies are concern about research and development, advance or state-of-the-art techniques, producing sophisticated products, and employing a large share of scientific, technical and engineering personnel (Jenkins et al., 2006).

In Bartos´ (2007) perspective, high-tech industries can be distinguished according to their technical sophistication of the final product or according to their level of research and development (R&D). With the aim to provide better understanding of which main sectors are within high-tech industry, it was elaborated the following figure.

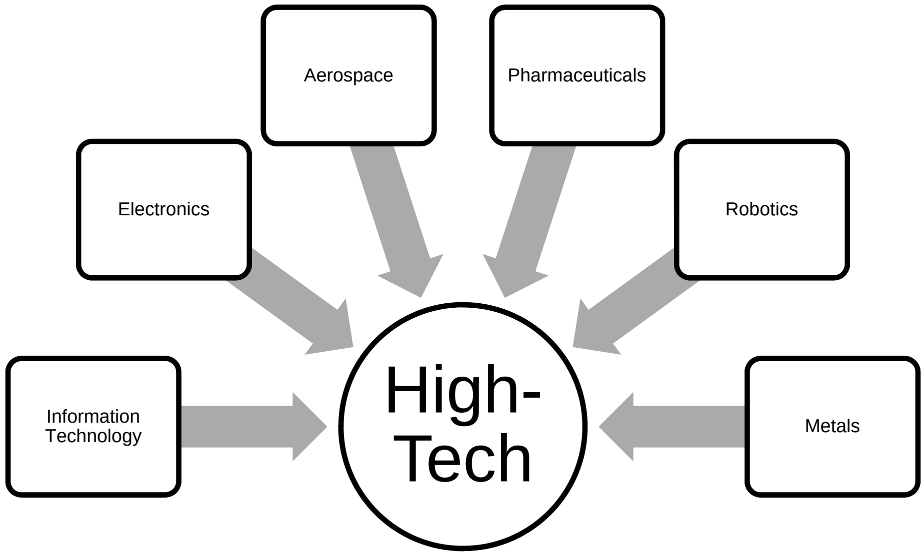


Figure 2 - Industrial main sectors of high-tech industry
Fonte: Based on Bartos (2007) and Hagedoorn (2002)

As we can verify in the Figure 2, there are six main sectors within high-tech industry. They are information technology, electronics, aerospace, pharmaceuticals, robotics, and metals. According to Bartos´ (2007) investigation, Information Technology stands up from all the technologies represented, in terms of productivity advances.

Thus, high-tech firms have been playing an important role on the development of new technology and on building national innovation systems of various countries (Qin and Wang, 2006).

Teece et al. (1997) investigation, points out managerial and organizational process as the essence for sustaining and safeguarding company´s competitive advantage. In environments of rapid technological change, like in high-tech industries, companies have to be aware to the strategy of developing new products or innovations (Knight, 1967; Qin and Wang, 2006).

Throughout a questionnaire survey, Hung et al. (2007) examined successfully the importance of organizational process alignment in managing core high-tech process and the potential to generate superior performance using dynamic capability approach.

In order to companies sustain competitive advantages being innovative and consequently one step forward then others, all their organizational structure must be align to the contingencies of their environment, strategy, and technology (Hung et al., 2007). Especially when the success of high-tech companies are intrinsically connected to the uncertain of NPD process (Song and Montoya-Weiss, 2001; Song et al., 2007).

Gresov´s (1989) empirical work emphasized the importance of organizational process alignment, reveling that a positive alignment affects the organization performance. The organizational processes are designed to align and react to the contingencies of all constituent areas of the company with the aim to pursue common organizational goals (Hung et al., 2007; Gresov, 1989). Being the developing of innovations the main organizational goals in high-tech industry (Knight, 1967; Qin and Wang, 2006; Hauptman and Hirji, 1996; Denison et al., 1996), organization process as Song et al. (1997), Teece et al. (1997), and Henderson and Venkatraman (1999) investigations points out, have to be focus in providing the ways, as throughout cross-functional integration, to accomplish these goals. Besides a perfect organizational structure configuration to a timely responsive and flexible product innovation, it´s necessary to integrate company´s capabilities for the accomplish of this objectives (Teece et al., 1997; Eisenhardt and Martin, 2000; Cormican and O'Sullivan, 2004).

In this context, Henderson and Venkatraman (1999) argue that the strategic alignment isn´t a single event but a continuous process of adaptation and change accordingly to the industry environment. For this reason, the organization strategy will be inherently dynamic. Although organizational process alignment positively influences organizational performance, Hung´s et al. (2007) investigation showed that its influence is done mediate dynamic capabilities. Thus, according to them, dynamic capability is a crucial factor within organization process alignment to improve organization performance.

High-tech companies can never be certain of how they will perform in the future (Coad and Rao, 2008) and much less when their new technologies emerge (Sarin and Mohr, 2008). Either the innovation succeeds spectacularly or the company wastes a large amount of resources (Coad and Rao, 2008). Such companies have to be prepared/preventive for the eventuality of losing its market to its rivals (Easingwood et al., 2006).

In order to safeguarding their business, or may even say, in order to survive in the competitive high-tech market, almost all innovative companies patented their innovation (Fosfuri, 2000). Notwithstanding, some companies consider the process of patenting expensive or too slow, preferring other alternatives to protect their innovations, such as secrecy or copyright (Coad and Rao, 2008).

ii. New product development

The utilization of a formal process in the development of new products is the decision factor of the success or failure of the product (Griffin, 1997).

The International Organization of Standardization, ISO, is an international body which promulgates industrial and commercial standards (Schroeder, 2003). The ISO 9000 is one of it´s families of standards with the aim to ensure company´s quality. ISO 9000 doesn´t guarantee the quality of new products, rather, it describes the organizational process to achieve this goal (Tedaldi, 1997; Cooper and Kleinschmidt, 1986; Schroeder, 2003). In the context of new product development (NPD), this standard recommends the elaboration of a NPD process to promote quality in meeting customer´s requirements (Schroeder, 2003). This NPD process shall include documented procedures, process flowcharts, operator instructions, inspection and testing methods, measures of customer satisfaction, and job descriptions (Tedaldi, 1997; Schroeder, 2003).

New product development process is a conceptual and an operational model to drive new products from idea to commercialization (Cooper, 1990). Its creation will allow a better estimation of time to project completion, develop optimal schedules, and will track all development activities (Boer, 1999). This process is a set of activities from distinct functional areas in an organization, with the aim to identify the needs of customers and quickly create products that meet these needs (Ulrich and Eppinger, 2004). The ISO 9000 is aware of cross-functional importance on the development of new products, establishing the necessity of defining a new product development team and document their communication flow (Tedaldi, 1997).

High performance along product quality and cost dimension, and development time, cost, and capability dimension, according to Ulrich and Eppinger (2004), should guarantee the profitability of the product in question.

Cooper and Kleinschmidt (1986) conducted an extensive and detailed study of 252 new product histories at 123 firms. For each firm, they interviewed the most responsible managers for the development of new products questioning them about which of the 13 activities presented by Cooper and Kleinschmidt (1986) were included in their new product development process. More than one third of the total NPD processes were constituted for about 8 and 9 activities. The activities most frequently within the NPD process were the initial screening, preliminary market assessment, preliminary technical assessment, business/financial analysis, product development, in house product testing, customer tests of product, production start-up, and market launch.

Staging the NPD process is widely accepted and useful practice in high-tech industry (Boer, 1999; Garcia and Calantone, 2002; Griffin, 1997; Cormican and O'Sullivan, 2004; Schroeder, 2003; Cooper and Kleinschmidt, 1986). Due to its clearly importance on most organizations, innumerous investigations on NPD process were made in order to characterize the development of new products. Since many researchers view the NPD process within different perspectives this paper will map five NPD process, based on a technology perspective (table 1). Nevertheless, most of them based their process on staging the NPD process accordingly to the state of the product during its development.

Table 1 - Main NPD process characterization

Author (year)	NPD process	NPD stages
Kagioglou, Cooper, Aouad, Sexton, Hinks, and Sheath [18] (1998)	4 main stage-gate® system containing 10 phases	Pre-project Pre-construction Construction Post-completion
Boer [24] (1999)	5 stages	Raw ideas Conceptual project Feasibility Development Early commercialization
Cooper [17] (2001)	6 stage-gate® system	Discovery Scoping Business case Development Testing and validation Launch
Schroeder [23] (2003)	3 stages	Concept development Product design Pilot production/testing
Ulrich and Eppinger [22] (2004)	5 stages	Concept development System level design Detail design Testing and refinement Production ramp-up

Schroeder (2003) indicates three typical development phases: Concept Development, Product design, and Pilot production/testing. For Schroeder (2003), concept development consists in generate the idea that most meet the market needs through an evaluated process of various alternative ideas. The design phase is concerned with product specifications and engineering drawings. At the end of the product design phase, it will be delivery to production all the documentation needed to begin its manufacture. During pilot production/testing phase, the process for mass production is finalized throughout prototype tests.

A product design focus was presented by Ulrich and Eppinger (2004). Primarily, they introduce the *"project planning"* as one of the NPD stages, *"phase zero"*. Then, they identified five more stages for putting the new product in the market:

1. Concept development
2. System-level design
3. Detail design
4. Testing and refinement
5. Production ramp-up

In the “*concept development”* phase, is described the form, the functions, and features of the product, accordingly to an economic, market, and production analysis. The second Ulrich and Eppinger´s phase, layouts the final product assembly for production. The “*detail design”* corresponds to the elaboration of the control documentation of the product. The fourth NPD phase will test and evaluate multiple pre-productions and the final stage will improve the remaining production problems to launch the product in the market.

While Ulrich and Eppinger (2004) propose a NPD process focus on the product design, Boer (1999) approaches the NPD process through the influence of R&D organizational department. According to Boer (1999), the NPD will differentiate five R&D stages during its development: The first stage, or as Boer (1999) defined “*the phase zero*”, is “*Raw ideas*”. The second is the “*Conceptual project stage*” previous to the “*Feasibility stage*” and “*Development stage*”. Finally the last stage of R&D influences during the development of new products is the “Early commercialization stage”.

Cooper (1990) proposes six stage-gate® systems, allowing in each stage, separated by gates, the involvement of multiple functional departments to provide an in-depth review and consequently a control checking points. Each gate is a control checkpoint or a go-no-go decision maker which according to a specific criterion, transforms the outputs from the previously stage into the inputs of the next stage (Cooper, 1990). Cooper drives new products through “Discovery”, “*Scoping”*, “*Business case*”, “D*evelopment*”, “*Testing and validation*”, until “*Launch*” stage (Karlstrom and Runeson, 2005).

Kagioglou et al. (1998) design and construct a NPD process based on four stage-gate® systems in the manufacturing industry. They incorporate in each stage their phases and distinguish “*hard gates*” from “*soft gates*” according to the level of concurrency applied in the decisions of each gate. As other investigators, they recognize four pre-project stage phases, “*Demonstrating the need*”, “*Conception of need*”, “*Outline feasibility*”, and “*Substantive feasibility study & outline financial authority*”. These phases aim to determine the market needs for a design project solution, and verify its feasibility to proceed to the pre-construction stages through “*soft gates*”. The “*Outline conceptual design*”, “*Full conceptual design*”, and “*Coordinated design, procurement and full financial authority*” pre-construction phases, will develop the appropriate product design solution, in order to provide the necessary information for its production. The gates between these three phases add the potential of concurrent coordination. The following construction phases are the “Construction information” and the “Construction”. To Kagioglou et al. (1998) the post-construction stage, the “*Operation & maintenance*” will monitor and manage the maintenance of the final construction.

The stage-gate® system was adopted by innumerous companies, such as the General Motors, Northern Telecom, and the 3M (Cooper, 1990). While General Motors wanted to drastically reduce the product life cycle time, 3M adopt stage-gate to enable an optimum innovation process management (Cooper, 1990).

The mainly difference between their models is the conceptualization perspective. In other words, the difference of the models presented by these NPD researchers and many other investigators (O'Connor and Ayers, 2005; Kagioglou et al., 1998; Cooper, 1990; Schroeder, 2003) depends on the aim and on the detail that each one requires for efficiently characterize the development of new products towards their perspective. Although, it is possible to verify that the main activities and competences to develop new products are present within almost every NPD process (Kagioglou et al., 1998; Cooper, 1990; Ulrich and Eppinger, 2004; Schroeder, 2003; Boer, 1999).

Regard these methods, the staging of NPD process, has to be aware of all innovation perspectives and specially, depending of which company are controlling the NPD, has to look out to the companies characteristics of risk, level of spending, and to a large degree, to the skills of the personal conducting the R&D, because each stage could differ accordingly to these companies particularities (Boer, 1999; Ulrich and Eppinger, 2004).

The early stages of new product development process will critically influence the success or failure of the new product or innovation (Bacon et al., 1994). These stages will guide the development phase of the product, describing the product parameters, features, and functions to reach the target market. They may even inform which technologies the product will rely, but not its technical specifications (Bacon et al., 1994).

The reality of the product development environments, according to Bacon et al. (1994) is against the common notion that after the initiation of the product development, the idea generation stage will be frozen. Due to the market uncertainty, there could be the necessity of changing the primordial specifications of the product. NPDT must monitor this possibility, and decide if it´s viable to adjust the product development within this changes.

Through an empirical literature review on product development, Brown and Eisenhardt (1995) synthesized their research findings into a model of factors that influence the success of product development. They realize that while the new product development team, senior management, and suppliers’ affect NPD process performance, the project leader, customers, and senior management affects product effectiveness. In addition, the factors which affect the NPD process performance were analyzed in detail by the American Productivity and Quality Center benchmark study. The study found that the major forces of each three Brown and Eisennhardt´s factors, i.e. the new product development team, senior management, and suppliers’, were respectively the integration of cross-functional, management strategy and commitment, and technology (Cooper, 1999). The conjugation of NPD process performance and product effectiveness, will consequently achieve the success of the product developed (Brown and Eisenhardt, 1995).

iii. Radical versus incremental innovation

There are many definitions for innovation. According to Knight (1967) innovation can be successful or unsuccessful but still is an innovation. It´s impact depends on the society acceptance and economic advantage. Thus, Knight (1967) defines innovation as ”*the adoption of a change which is new to an organization and to the relevant environment”*.

In order to capture the essence of innovation from an overall point of view, Garcia and Calantone (2002) reviewed the 1991 OECD study quoting that "*innovation is an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention*".

For many researchers cited by Dewar and Dutton (1986), such as Downs and Mohr 1976, Damanpour 1984, Kimberly and Evanako 1981, and Moch and Morse 1977; the organizational application of an universal innovation theory might be inappropriate due to the differences across all the innovation types. Therefore Dewar and Dutton (1986) proposed to test the efficacy of developing two universal types of innovation under a technical perspective. They supported their theory with other similar investigations arguing that the differences across innovations need to be acknowledged and measured.

The categorization of different types of innovations raise their success (Miller et al., 2005).This categorization can provide a better identification of all their organizational and environmental influences allowing an optimum innovation management (Miller et al., 2005; Ettlie et al., 1984; Dewar and Dutton, 1986; Knight, 1967; Garcia and Calantone, 2002; Gray, 1997). Thus, according to the type of change in an organization, it is possible and useful to theorized innovation in multiple types (Ettlie et al., 1984; Dewar and Dutton, 1986; Knight, 1967). However, this abundance of innovation´s typologies could generate countless conceptualizations with the same meaning (Garcia and Calantone, 2002; Dewar and Dutton, 1986).

Further bellow, it will be showed three distinct theoretical hypotheses to characterize all existent types of innovation.

1. Knight (1967) presented four general inter-related innovation categories through a structure organization perspective: Product or service innovation, which the organization sells, produce, or gives away; Production-process innovation, which includes incorporate innovation in organization´s tasks, decisions, information technology, information systems, and services operations; Organizational-structure innovation, this includes new formal interactions and authority relations among participants in the organization; and people innovation, this includes dismissing or hiring personnel and academic educate workers.

2. Upon extensive literature, Garcia and Calantone (2002) proposed three types of innovations based on a marketing, a technological, a macro-level, and a micro-level perspective. They proposed radical innovation, when it is created a new technology that results in a new market, *really new innovation* to define the development of new technologies to existing markets or for existing technologies the exploration of new markets, and incremental innovation to conceptualize the improvements of the existing technology in the existing markets.

3. While previous researchers investigated administrative and technological innovation, technical and administrative, and compatible and incompatible innovations Dewar and Dutton (1986) proposed radical and incremental innovations under a technical/product innovation approach. These two types of innovation were essentially distinguished through their incorporate level of new knowledge, opposing to focusing simply on an organizational functional area.

The focus of this dissertation is essentially about innovation management perspective. As Dewar and Dutton (1986) propose, innovation´s management varies according to the type of innovation. Despite of some researchers' characterizations of innovations according to the level of new technology, in a management approach they should be distinguished according to the level of knowledge, to the type of change in the organization, and to the innovation development complexity. Nevertheless, radical and incremental innovations are those who best characterize the different innovation characteristics regarding the functional areas that they change (Koberg et al., 2003). In addition, adopting two innovation typologies for innovation characterization will provide a simple and an understandable conceptualization to manage efficiently the development of the innovation (Dewar and Dutton, 1986; Garcia and Calantone, 2002).

One possibility was to include Garcia and Calantone´s (2002) third moderate innovative categorization, the "*really new innovation*", in between radical and incremental innovation. However in a management point of view, it is only interested in classifying completely different typologies, due to the fact that only different innovation characteristics will real vary their NPD process. If the characteristics are very similar, the management focus will be dispersed.

Incremental innovation refers to a progressive, continuous, and cumulative innovation without a new scientific component for the improvement of the present technology (Qin and Wang, 2006). In a High-tech product perspective, incremental innovation, as the name indicates, is the incremental/improvement of the existing technology/product in the existing market (Garcia and Calantone, 2002; Gray, 1997). And it involves the next version of an existing product or process (Gray, 1997; Diedericks and Hoonhout, 2007). Besides improving existing technology, incremental innovation as Garcia and Calantone´s (2002) work indicates, can actuate accordingly to the markets: a borrowed technology from a certain industry may be new to a different market. This type of innovation, is a quick and effective competitive weapon in the short-term growth of the organization, protecting or increasing the company´s position on market (Garcia and Calantone, 2002; Ettlie et al., 1984; Gray, 1997).

Diedericks and Hoonhout (2007) points out the relation of innovation with consumers. They explained that while incremental innovation is often built on knowledge collected around consumer´s experiences with the existing product, radical innovation is built upon the needs of those costumers. Radical innovations do not address a recognized demand, but instead have the ability to emerge and create entire industries, products, and markets, making the concurrent obsolete (Koberg et al., 2003; Garcia and Calantone, 2002).

Miller´s et al., (2005) literature investigation, indicates some historical examples of radical innovations such as Pasteur´s breakthroughs in the microbiology of disease, Thomas Edison´s lamp, the cotton gin, the automobile, the airplane, television, cellular mobile telecommunications, and the internet.

Through the analysis of the regression equations of Dewar and Dutton´s (1986) work, we verified that the size of the organizations in general, are an important matter for adopting radical innovations. The higher are the resources of organizations to innovate, the greater will be the risk taken of the organization. More resources, means that more experiments and trials will be made (Dewar and Dutton, 1986). However, nowadays there are specific small-sized organizations characterized by a core business of innovations (i.e., it doesn´t matter if the organization is small or medium sized, what matters is the capital invested in the innovation and their available resources). These organizations are more prepared for innovation process and have a specific organizational structure to this aim (Ettlie et al., 1984; Gray, 1997).

Based on Edison´s point of view, Gray (1997) considers that outsourcing radical innovation will increase the success of organizations. Gray´s work revealed that in order to innovate radically, it’s preferably for companies to outsource innovation through universities collaboration or in acquiring proven products, process, or companies. The main reason for this option is because while these organizations are completely focus on developing innovations, the ordinary organizations neither have the resources to carry out innovations. Contrarily, incremental innovations are unquestionably done best internally (Ettlie et al., 1984; Gray, 1997). Principally due to its quickly process requirement (Garcia and Calantone, 2002; Ettlie et al., 1984; Gray, 1997) and its necessity of excellent knowledge on existing products to understand in what areas can be improved (Garcia and Calantone, 2002; Gray, 1997).

However, as Ettlie et al. (1984) suggested, what really influence innovation is the strategy-structure of the organization. According to their questionnaire and e-mail survey of 90 management, marketing, and technical or production personnel, they verified that an aggressive technology policy and unique structural arrangements appears to be necessary to support radical process adoption. An aggressive technology policy is generally considered among many researchers, the way to promote the concentration of technical specialists, increasing innovative efforts. While the incremental process adoption is dependent on more traditional structure arrangements and market oriented strategies. Ettlie et al. (1984) quotes "*organizations match their structure for the innovation situation*".

The importance of the organization structure in the development of radical or incremental innovations was emphasized by Koberg et al. (2003), identifying the environmental, organizational, process, and the managerial factors the ones that most favor the frequency of incremental and radical innovations. These factors will be examined in detail afterwards in this work.

In resume, while incremental innovation exhibits low levels of uncertainty, and usually follows a well-defined development organized process, radical innovation exhibits much higher levels of uncertainty, and is often transformative and disruptive of the existing organizational development process (Miller et al., 2005). Their main characteristics will be distinguished in the table 2.

Table 2 - Radical versus Incremental innovation

Domains	Radical Innovation	Incremental Innovation
Organization alignment	Centralization Agressive Technology policy	Decentralization Traditional technology policy
Organization Environment	High Uncertainty	Moderate Uncertainty
Reason of development	Market needs	Costumer´s needs
Development process	Low level of knowledge High complexity	Moderate level of knowledge Moderate complexity
Technology	New	Existent
Duration	Long-term	Short-term
Risk	High Risk	Moderate Risk
Financial Resources	High	Limited

iv. Cross-functional

Due to the globalization of markets and continually changing technologies, firms necessarily had to change their business strategy into develop new products. To have a quickly, effective and efficient response for these competitive pressures, business identities had to gather all their efforts to optimize the process of the new product development. This means that they have to focus all their functional departments on NPD in order to enable its success within a dynamic capability (Song et al., 1997; Teece et al., 1997).

Raz and Michael (1998) distributed a questionnaire to a random sample of 400 project managers from software and high-tech sectors. There mainly objective was to identify the Project Risk Management (PRM) tools that most contribute in general, to the success of NPD. According to them, almost 50% of the tools that reported a better project management performance belongs to a group named "*Background group*". This group includes Simulation and processes, Subcontractor Management, Quality Management, Training, Customer Satisfaction Surveys, and an effective and efficient environment for managing projects. This finding suggests that the project success is achieved throughout many distinct organizational departments' tools. Their research told us that creating and developing new products requires a multidisciplinary and a cross-functional process, involving all the departments of the organization. This was emphasized by McDonough (2000), through a questionnaire of 112 new product development professionals with the aim to determine which were the primary reasons to implement cross-functional teams. They found that cross-functional teams improve the process of developing new products and allows the flux of information between the respective functional areas. These were the main reasons according to McDonough´s work, why companies wanted to adopt Cross-Functional approach. The most frequently performance outcome indicated by the interviewed for implementing cross-functional teams, was the need to improve time-to-market. Applying a multiple regression, McDonough (2000) found that cross-functional teams really have a positive impact on project performance. Therefore the hopes of top managers to achieve cross-functional outcomes within implementing cross-functional teams are granted.

The importance of cross-functional is highlighted by Jassawalla and Sashittal´s (1998) work. Their research emphasizes the importance of cross-functional outcomes on an organization, demonstrating that it improves product quality, reduces costs and engineering hours for product development, reduces production start-up problems, improves manufacture, and that cross functional leads to faster time-to-market and commercial success. These outcomes have made cross-functional the method of choice by which high technology organizations generate and deploy new products (Hauptman and Hirji, 1996; Denison et al., 1996).

Having a higher level of perceived importance of R&D-Marketing cooperation on NPD doesn´t assure a better project performance. There has to be an effective cooperation between them provided and controlled by the top manager (Sherman et al., 2005). Notwithstanding, some researchers extends the relationship of organizational functional areas within the NPD beyond R&D and marketing. According to Song et al. (1997), there will be other functional units involved on the development of new products, such as production and finance. They hypothesize that in spite of the divergent functional goals all four functions recognize the fundamental need for cross-functional cooperation for successful NPD. For Ulrich and Eppinger (2004), marketing, design, and manufacturing are the most common functional areas on product development project. But in fact, R&D–Marketing cooperation still plays a major role in the success of an NPD. As we can verify in the linear regression analysis of Lu and Yang (2004), the cooperation between R&D and Marketing are strongly supported in all stages of the achievement of the new product. The awareness of firms about the importance of cooperation between these two departments leads to a better NPD performance. Because of personal different educational and professional backgrounds from R&D and Marketing, managers have to think how to design an organizational structure to enhance cross-functional cooperation (Sherman et al., 2005).

Through the use of path analysis, Pinto et al. (1993) examined the impact of both organizational and project team rules and procedures on cooperation during the NPD. They found that only the project team rules and procedures had a significant impact on cooperation. However, organization and project team rules and procedures are complementary; one is the support of the other. This was exposed in Pinto´s et al., (1993) hospital case study, revealing that new product development teams (NPDT) faced numerous difficulties because most of the hospitals structure do not support innovative projects and had very limited experience.

Based on 141 cross-functional product development teams, Sethi et al. (2001) indicates that NPD is positively related to the level of superordinate identity in the team, encouragement to take risk, customer´s influence, and monitoring of the project by senior management. According to their research, if a company wants unique products, NPDT have to be encouraged for taking risks during the new product development process. This could be encouraged by managers to afford teams the comfortably in deviate approaches from routine and motivate them to take risks for pursuing unique and untried ideas. Even though, Cyert and March 1963 and Van de Ven 1986, cited by Sethi´s et al., (2001) investigation, revealed that organizations structure tend to avoid risk which consequently reduces the margin for new ideas and approaches.

The importance of organizations internal infrastructure in the integration of cross-functional tool is emphasize by McDonough´s (2000) study. His research evidence the implementation of cross-functional as an extremely complicated task even in those companies that acknowledged the importance of cross-function. The organizational structures characteristics were explored by Song et al. (1996) study because they often contribute to the formation of barriers between functional areas. Company's structures have to be prepared to provide an effective Cross-functional team.

Recent studies of cross-functional in NPD and the ones mentioned previously, demonstrate that this concept is essential for the improvement of New Product Development process. Therefore, is extremely important for companies who develop new products, to employ the best methods for integrate all functional departments involved in the development process. Many methods, such as hierarchies, rules, goal setting and plan, task forces, integrative roles, matrix organization, concurrent engineering, and formal interface management process such as phase review process, stage gate process, QFD, and PAGE were investigate for this aim (Jassawalla and Sashittal, 1998).

Collaboration, in the view of Jassawalla and Sashittal (1998), is lower when the NPD activities are defensive, i.e., when R&D initiatives are only focus to respond the competitor activities or to save costs and reduce time to market. When top manager´s interests extends to creative and make product innovation a central, focal component of the organizational mission, they found higher level of collaboration. Being renewable energy a High-Tech creative companies, collaboration is one of the principal’s concepts to be integrated in the organization.

Most important as Chapman (1998) quotes the CCTA publication Management of Program Risk, “people are the biggest risk of all, since it is people that undertake the project tasks to achieve the end result”. This view is reinforced by Rodriguez et al. (2008), revealing the important role played by cooperation, collaboration, and communication between all the organizational departments for the R&D project success.

v. New Product Development Team

While cross-functional increase the level of integration, managers and functional organization participants elevate integrative process into collaborative process (Jassawalla and Sashittal, 1998). The motivation of all functional groups to collaborate in the NPD process is often emerged intrinsically by one important element, trust. In Jassawalla and Sashittal´s (1998) work, they found that with a high level of trust, NPD participants are more vulnerable to the actions of other participants, more eager to share information, more likely to take the risk of voicing new ideas, and when facing doubts and uncertainties more willing to ask for assistance. However, manager´s initiatives and directives towards collaboration still plays a major role.

Management takes an active role in ensuring integration by controlling and directing the subjects involved in the NPD process towards a common goal. They must generate work environmental, formalize personnel roles assigning their responsibilities, and create a new product development team (NPDT). This task teams, are formed by representative members of each multiple organizational functions, to integrate their expertise and decentralize the decision-making authority (Ayers et al., 1997; Denison et al., 1996). The individuals within this NPDT often have specific knowledge in areas such as market research, mechanical engineering, electrical engineering, materials science, or manufacturing operations (Ulrich and Eppinger, 2004). All tasks, including product concept, feasibility, development, validation and commercialization are held by the new product development team (Dong and Yan, 2006).

Through in-depth interviews with 71 team members from 18 companies in a variety of technology-based industries, Barczak and Wilemon (2003) identifies team individual skills, knowledge, commitment to the project, cooperation and the support of senior management, the factors for a good NPDT experience. While these competences in several innovative enterprises are internally created, Ancona and Caldwell´s (1992) investigation revealed that occasionally the development of new products will require the rupture of traditional organizational boundaries, through external competences.

Being the NPD team characteristics, the principal contributors towards a positive NPD experience, elements effectiveness have to be assured. Members, who have strong work ethic, are disciplined, determined, resourceful, and motivated, and who are cooperative, are considered effective team members (Barczak and Wilemon, 2003).

Once New Product Development Team is constituted by effective functional expert members, senior managers have to put all their efforts in manage this team in order to be successful. Managers have to be supportive promoting the collaboration between team elements and have to define clear goals (Barczak and Wilemon, 2003; Akgun and Lynn, 2002; Ayers et al., 1997; Jassawalla and Sashittal, 1998; Dong and Yan, 2006). The greater is the number of functional areas in the new product development team during idea generation more difficult is the performance to achieve their goals (Sethi et al., 2001). When functional diversity goes beyond a moderate level, managers have to be more supportive in controlling and formalization member`s roles to incentive a team common goal (Sethi et al., 2001; Jassawalla and Sashittal, 2000). In this perspective, Ulrich and Eppinger (2004) characterized the NPDT within a *"core team"* which remains in almost all NPD stages, and an *"extended team"* who delivery sporadically expertise, i.e. only when it is needed.

The need to decentralize NPD decisions is emphasized by Jassawalla and Sashittal´s (1998) work showing in their research that putting the decision-making authority in a project team level leads to accentuate the collaboration between organization function elements. In addition, Ayers et al., (1997) revealed a limited motivation of NPDT participants to modify their interactions in meeting the need of others elements with a centralize decision maker.

According to Pinto´s et al. (1993) investigation, the decision-making decentralization is accomplished by role formalization of each NPDT members. When these functional elements are familiarized with role formalization, they will recognize their mutual dependences and develop responsible sense. Formalizing roles in NPDT is a group of measures in which rules and procedures are integrate. This concept reduces confusion over roles, defining precisely which goals have to be accomplished, fosters commitment and productive relationships, and reduces the time to make decisions, solve problems and actions (Ayers et al., 1997, Pinto et al., 1993, McDonough, 2000).

However, the use of high formalization during the NPD process is likely to impede the spontaneity and flexibility needed for internal innovation. Nevertheless, there is a difference between using role formalization in NPD and in NPDT members. The outcomes are completely different and role formalization in team elements will not impede their creativity, will just serve for guidance (Pinto et al., 1993, McDonough, 2000, Chen, 2007).

Being NPDT members from different areas of the organization, is possible that their work path will flow against each other while having a good performance. McDonough (2000) concluded that establishing goals for the new product development team will provide a common focal point for the functional team´s work, and constrain their efforts within boundaries. Moreover, formalization in Pinto´s et al., (1993) perspective, will consequently provide to managers a better way of regulate a specific interdependent work group. Through this perspective, the development of new products is viewed as an interlinked sequence of information processing tasks, where knowledge of market needs and technological opportunities is translated into information assets for production. This means that each stage of product development, from product planning to actual production, which represents the physical embodiment of the product concept, involves abundant fluxes of information. Such communication strongly contributes to the problem-solving activities of engineers (Hauptman and Hirji, 1996).

Dong and Yan´s, (2006) work revealed that new product development teams have to be adjusted accordingly to the new product characteristics. They choose to investigate the selection of the development team organization patterns by a trained fuzzy neural network model as a decision support system. Due to the complexity factors that affect the choice of organization patterns, they simplify the problem selecting only a few product characters, proposing three co-relations:

- If the product is complex, more intense the cooperation between developers should be.
- If the innovate level is high, the communication has to be increased.
- The more emergent the development of the product is, the fewer the accepted revisions are.

Akgun and Lynn (2002), focus their research on the importance of stability in the NPDT. Team member´s stability is viewed as a critical factor for an effectively functioning and performing group. Since the team personnel are from completely different functional areas, losing one or more participants means losing a specific knowledge needed to the development of a new product. Consequently, Akgun and Lynn´s (2002) investigation revealed that this occurrence once the new product project started, will affect negatively the product development causing information loss, increasing the time to launch new products, decrease team learning, and impede the success.

Towards the stability of NPDT members, Barczak and Wilemon (2003) suggested that members should understand how they are evaluated and rewarded. Their evaluation should be according to their individual´s and team´s performance, and not just their individual efforts. This specific knowledge will motivate them to improve their performance. However, according to Akgun and Lynn´s (2002) investigation, when a project isn´t going well managers consider that a change in leadership or member may impact the learning positively, when brought a different learned experience. In order to reduce the consequences of losing a NPDT element, managers have to assign the new participant to work with that individual before he or she leaves. The person assigned is responsible for capturing the ex-member´s knowledge.

b. Risk management

Developing new products has such a low success rates that many researchers estimate that only 14% of new product ideas are commercially successful (Keizer and Vos, 2003). The uncertainty path of developing new products will influence or even limit the success of NPD. This uncertainty is not just a question of how long a NPD project will take, or how much it will cost, it's the difference between the amount of information require to complete a project and the amount of information possessed by the project team at the time of the project initiation (Chapman et al., 2004; Sherman et al., 2005). Even with the information of past product development projects, uncertainty will still be highly present during the development of other new products (Sherman et al., 2005; Ulrich and Eppinger, 2004; Boer, 1999; Jassawalla and Sashittal, 2000; Pinto et al., 1993).

Failures during the NPD process are frequently attributed to organizational type of problems, particularly to the coordination of NPD functional areas and to the assignment of the roles associated to each NPDT element. However as it was referred earlier, failures are so high in NPD that errors are originated from all over.

Being uncertainty an immeasurable probability and a given factor in developing new products, high-tech enterprises need to take measures to constraint its influence on NPD. One way to effectively respond to this threat will be to assess uncertainty's impacts on NPD process through its risk. The risk management necessity, as Song´s et al. (1996) investigation revealed, will encourage manufactures, managers, and researchers to examine ways to optimize the process of developing innovations across the spectrum of risk. Like other management perspective, risk management is commonly executed through a sequence of steps, and should be addressed proactively and consistently throughout the project. The association for project management provides a practical framework, the Project Risk Analysis and Management (PRAM). This framework enables the analysis and management of the risks associated with a project. PRAM is based on the principal that risk exists as a consequence of uncertainty. This process is design to prevent and deal with the project´s risks, and is defined into two major stages and respective sub-stages (Simon et al., 1997).

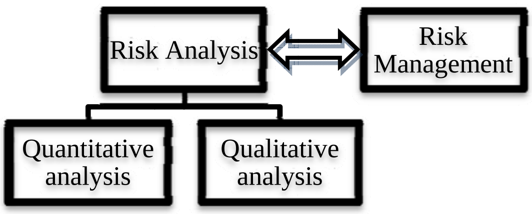


Figure 3 - PRAM

Notwithstanding, the same association for project management through a working party named specific interest group, detailed a nine-phase risk management process with the aim to explicit the importance of the capital roles within the risk management process

(Chapman, 1997). Their process is based on a large number of organizations which have used risk management process successfully for several years. Each nine-phase´s proceed in a parallel way initiating by the define phase. After this phase, it is taken the focus, identify, structure, ownership, estimate, evaluate, plan, and manage phases.

The Project Management Institute (PMI) is specially concerned in "*maximizing the results of positive events and minimizing the consequences of adverse events*". They synthesize the risk management process in their Project Management Body of Knowledge (PMBOK®) accordingly to the following figure (PMI, 2008).

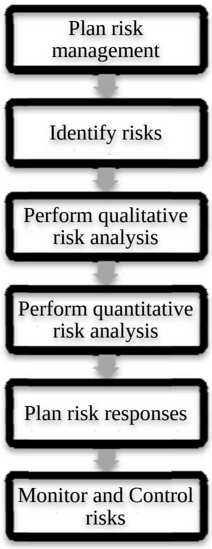


Figure 4 - PMBOK®

However, the risk management process structure could alter according to the different application areas (Project Management Institute [PMI], 2008). A research group at the Eindhoven University of Technology has been working on developing a systematic procedure to identify, evaluate and manage risks in product development area (Keizer and Vos, 2003). They design the following Risk Diagnosing Method (RDM):

Figure 5 - RDM

In the same application area, Smith and Merrit proposed a five-step process for managing project risks. Beginning with identifying risks, analyze risks, prioritize and map risks, resolve risks, until monitoring risks (Smith, 2002).

Reviewing these risk management literature, it is evident that there is general agreement regarding the majority of the processes described in almost all risk management process. Actually, the risk management processes contrarily to their activities aren´t more than the formalization of the common sense that project managers have applied for centuries (Chapman, 1997). Since their distinction depends essentially upon variations in the level of detail and on the assignment of activities within the correspondent process´s stages, it was selected the follow risk management process.

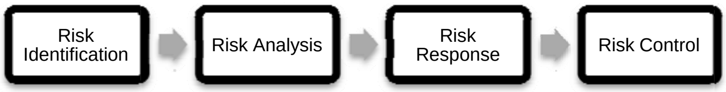


Figure 6 - Risk management process

Relatively to the designs of the risk management processes, the PRAM´s risk analysis incorporate PMI´s risk identification and risk quantification stage through the sub-phases named qualitative and quantitative analysis. Besides PRAM´s qualitative analysis incorporate a part of quantitative focus which will confound managers to undertake the correct activities within these two analysis, in accordance with PMBOK® Guide and RDM, risk identification should be integrated into the major stages of the risk management process due to its unquestionable importance to the risk management. It´s possible to verify too, that while PMBOK® distinguish risk response development and risk response control, some risk management processes combine these stages into a single process.

Without disregarding the design of the risk management process, in fact the methodologies and techniques adopted to identify and evaluate any risk which has the potential to jeopardize the development project, as well as the ones to select the most appropriate measure to minimize risk´s financial damage, are without a doubt what will define the success of risk management (Artikis et al., 1997; PMI, 2008; Keizer and Vos, 2003; Smith, 2002). These methodologies and techniques will be addressed within following steps of the risk management process (Figure 6).

i. Risk identification

As it was referred earlier, the development of innovative products is a high risk process involving numerous risks to be identified. The risk identification consists of identifying which internal and external risks are likely to affect in a positive or a negative way the project (PMI, 2008). This phase is therefore recognized as the most important phase of the risk management process since it will have a massive impact on the performance of the following risk management phases.

Despite of brainstorming being identified as the method more used to discover risks in NPD, these group sessions could restraint the opinions of each NPDT members and influence their decisions to label factors as risky or not risky. Thus, to minimize and possibly avoid the social influence on individuals when confronted with colleagues from different functional areas, individual interviews should be taken with the aim to potentiate individual knowledge in perceiving risks (Keizer and Vos, 2003; Raz et al., 1999). The checklist is other technique often used in identifying risks (Simon et al., 1997; PMI, 2008; Kasap and Kaymak, 2007). It provides useful risk guidelines within the organization, but consequently will constraint the identification of risks that go beyond to those in the list. Essentially this technique is preferably applicable to routine activities or standard projects, and it will be preponderant to the risk identification of future NPD projects. In addition, enterprises frequently add historical information of previous projects to their risk identification techniques. For example, usually the formulation of checklists is based on experience of early projects. In a literature resume, the most common techniques for risk identification are documentation reviews, brainstorming, checklist analysis, diagram process, Delphi technique, interviews, surveys, root cause identification, force field analysis, and the nominal group technique (Kasap and Kaymak, 2007; Simon et al., 1997; PMI, 2008).

During the new product development process, almost all activities which create value to the product can provoke positives or negatives risks. Those activities should be considered risky if they affect the success of the NPD for better or worst. The determination of project risks should be aware to the planning propositions like aggressive estimates of cost and time, and limitations of NPD resources. In addition, NPD risks commonly occur due to changes in requirements, design errors or misunderstandings, poorly defined or understood roles and responsibilities, poor estimates, and insufficiently skilled staff (Keizer and Vos, 2003; PMI, 2008).

The risk identification is a never ending stage, being performed on a regular basis throughout the project development.

ii. Risk analysis

After gathering the data of each risk provided by the NPDT members and project managers, it will be taken a specialized assessment of risks. This analysis can be qualitative, semi-quantitative, and quantitative. Generally, almost all risk management process adopt a qualitative analysis for prioritizing risks combining their probability of occurrence and impact, with either semi-quantitative or quantitative analysis or even with both. Their main difference is that for quantitative analysis its required specific numerical estimates of probabilities and distributions of risk´s impact (Cooper, 2005). The bigger is the level of estimation the greater will be its uncertain. Therefore, due to the uncertainties of the estimations, the ambiguity of the quantitative results could be significant (Aven, 2008). Thus, it will be interest to address a quantitative analysis with a qualitative approach, such as the semi-quantitative analysis. Further, the risk analysis should be complemented if possible with a specific quantitative analysis.

In an initial assessment, it is taken the qualitative analysis estimating the probability of risk occurrence and their impact on the project. Due to the dependency of these estimates upon the accuracy of estimators, project managers should guarantee that the estimators had sufficient capacities to perform an excellent estimation. Often this analysis is done through addressing point values within defined levels of probability and impact to each risk reducing the influence of bias (PMI, 2008). PRAM labels each risk in terms of high/low probability of occurrence and major/minor impact on the project (Simon et al., 1997). RDM categorize each risk through a consensus between their scores of risk probability of occurrence and risk impact addressing for each risk a three evaluation scale from 1 to 5, very low to very high respectively. Each risk will be scored according to the ability of the team to influence the risk, its level of uncertainty, and according its relative importance on the project performance (Keizer and Halman, 2007; Keizer et al., 2002). The Project Management Institute through it´s PMBOK® Guide provides decimal value quantification for the estimation of the probability of risk occurrence and the same quantification is addressed to characterize the risk consequence into the project within technical, schedule, and cost domain (PMI, 2008). In other perspective, Smith and Merrit´s model of risk define the magnitude of risk´s impact in expected project losses, yielding the probability of risk occurrence and their impact on the project (Smith, 2002).

These qualitative assessments will be used for further semi-quantitative and quantitative analysis with the aim to analyze the effect of identified risks on overall project objectives (PMI, 2008; Taylor, 2009). However, when an enterprise is pressured in time and resources, and the risks identified require urgent attention, it is often advisable to skip this assessment and prepare initial responses to each identified risk (Simon et al., 1997). Notwithstanding, either in semi-quantitative, and quantitative analysis several methods have been developed for analyzing the impact of risks and determining the most serious risks on the NPD process:

Table 3 - Methodologies of semi-quantitative and quantitative analysis

Risk analysis	Reference (Year)	Methodology	Description
Semi-quantitative analysis	*Taylor, M.* *(2009)*	Weighted Risk Factor (WRF)	Determines the magnitude of the risk on the project
	PMBOK® Guide *(2008)*	Probability and impact matrix	Through a look-up table, combine the risk probability and impact to rating the risks as low, moderate, or high priority
Quantitative analysis	*Kayis, B., Arndt, G., Zhou, M., Amornsawadwatana, S.* *(2006)*	IRMAS™	Provide a systematic approach to quantify potential risks at the project life cycle
	Project Management Institute *(2008)*	Sensitivity analysis	Determine the effect on the whole NPD process of a change on a determined risk
	Simon, P., Hillson, D., Newland, K., *(1997)*	Probabilistic analysis	Determine the effect of risks in combination by specifying a probability distribution for each risk. The most common technique to address this analysis is the Monte Carlo simulation
	Wang, Q., Chai, K., Brombacher, A., Halman, J. *(2004)*	Scenario analysis	Develop different alternative states of the future
	Project Management Institute *(2008)*	Expected monetary value analysis (EMV)	Statistical concept that calculates the average outcome

iii. Risk response

Concluded the risk analysis, management responses will take place in order to face risks. This might involve preventive measures to avoid risk, project plan alterations, contingency plans to deal with risks, and risk allocation in contracts and insurers (Simon et al., 1997; PMI, 2008). PMBOK® Guide categorizes risk response into avoidance, mitigation, and acceptance. PRAM gives the perspective of immediate response and contingency response. However both associations agree with four main categories of risk response: Avoidance, acceptance, transference, and mitigation.

Smith (1999) highlight risk avoidance from other techniques. He believes that whenever it's possible, enterprises should be proactive in avoiding risks usually by eliminating the causes. His work gives the example of the Black & Decker battery-powered screwdriver. Black & Decker was confronted to a market risk issue about the size and shape of the battery: Either the battery was slim for a more comfortable handle but with a reduce power, or was somewhat fatter with great power. Facing this decision Black & Decker decided to design both sets while doing more market research (Smith, 1999).

When other parties are better able to deal with risks, managers could transfer the responsibility for its management to them. However, transferring the risk per se will not manage the risks (Simon, 1997).

Mitigation seeks to reduce the risk probability of occurrence and its impact maintaining contact with costumers, reusing proven components, clarifying procedures and designs, and buying insurances. Moreover mitigating risks may lead into its elimination through, for example, by testing at a low level. In the case of facing a technical risk, enterprises could concentrate their efforts in developing that technical issue until through testing procedures they realize the causes of risk (Smith, 1999).

Enterprises often accept risks equating their benefits and penalties. Managers could leave new product development teams dealing with risks as they occur during the project or developing contingency plans to reduce the impact of the risk. The contingency plans involve the application of pre-defined procedures after the identified risks occur (PMI, 2008; Simon et al., 1997). Accepting the risk besides is adopted when is decided that no action will be done to deal with a risk, it can be a strategy to take advantage of an opportunity without actively pursuing it. Other strategies such as exploit, share, and enhance can be too, excellent approaches to take advantage of opportunities: Exploit seeks to ensure the risk likelihood. Share allocates opportunity ownership with a partner who can increase the potential benefits. And enhance strategy, intents to increase the probability and/or the impact of opportunities. Thus, whenever a risk occurs it can bring negative effects on a project as it could generate unexpected positive effects. In this perspective, the risk response strategies have to maximize the effects of positive events and minimize the probability and consequences of negative effects to the project objectives (PMI, 2008; Hillson, 2001b).

It is possible to verify a lot of similarities between the response strategies of threats and opportunities. Comparing them, there will be one response strategy of threats that will have the same strategy than one of the opportunities response strategies. This principle was generalized by Hillson (2001a) according to the following table.

Table 4 - Threats and opportunities response strategies

Threat response	Generic strategy	Opportunity response
Avoid	Eliminate uncertainty	**Exploit**
Transfer	Allocate ownership	**Share**
Mitigate	Modify exposure	**Enhance**
Accept	Include in baseline	**Accept**

This acknowledgement will enable project managers to potentiate the upside impact of risks within the NPD project. Since "*failing to implement proactive opportunity management strategies will guarantee that only half of the benefits of risk management can be achieved*" (Hillson, 2001a).

In special cases, where there will be major uncertainties of which risk response strategy should be adopted, a decision tree analysis can be used to choose the most appropriate responses (PMI, 2008). Possibly during the risk response phase, project managers can have innumerous strategies to mitigate risks. To support the project manager´s decisions in selecting the best mitigation plan, it will be interesting in adopting heuristic algorithms based on the available mitigation budget and project objectives (Kayis et al., 2006).

iv. Risk control

Even the most accurate risk identification, analysis, and response cannot identify and manage all risks and probabilities correctly. Moreover, the uncertain environment of NPD process could provoke new risks according to NPD changes or misjudgments during the process. For the reasons mentioned early, managers evaluate the effectiveness in reducing risks through the measures applied during the risk response stage, and when facing new risks they repeat the cycle of risk identification, analysis, and response. Possibly during the NPD process the effect of a certain risk could be greater than expected and maybe the risk event was not anticipated. Thus, it´s advise in this stage to repeat the risk response and perhaps the risk quantification or even adopt other strategies of risk response plans on those conditions. This risk control stage takes essentially corrective actions, keeping track of the identified risks and its response plans. These actions might be accomplished through regular risk reviews for continuously control (PMI, 2008).

These phases of risk management process will interact with each other, and with other knowledge areas of project management.

c. Main chapter remarks

Regarding the innovation thematic, emerges the necessity of choosing the appropriate innovation for the specific state of the enterprise´s life cycle. While incremental innovation keeps companies competitive, radical innovation creates competitiveness. Their complementary relationship will ensure a competitive advantage over a long-term. Thus, especially high-tech companies focus enormous resources in developing innovations. As the development of innovations requires distinct capabilities from different functional areas, enterprises should integrate cross-function in the development process according to the competences needed during the development of new products. Thus, for a better New Product Development (NPD) management, this work attends to detail the functional areas which influence the NPD process during each NPD stage without falling into redundancy, and institute stage-gates to assured the quality of the product and of the NPD process. This will be showed in this work, in the chapter 3. a. Further, this improved NPD process will evolve with the innovation life cycle approach, leading to the elaboration of a New Product Development model for innovation life cycle (see chapter 3. b.). The better will be the organization of NPD data and its ability to transparency reality, superior will be its risk management.

In fact, innovative high-tech companies may either succeed spectacularly, waste a large amount of resources, or may even declare bankruptcy (Jassawalla and Sashittal, 2000). On the one hand high-tech enterprises must innovate consistently to remain competitive, but on the other hand innovation is risky and expensive. Thus, in accordance with the literature review, it is unquestionably important to carefully manage the risks of developing innovations and not strangle enterprises growth avoiding them.

In general, all the different risk management process approach risks through a similar management perspective. Since their distinction depends essentially upon variations in the level of detail and on the assignment of activities within the correspondent process´s stages, for the NPD area it was selected a risk management process which gathers the risk identification phase, risk analysis, risk response, and risk control phase. This process has just small differences from the Risk Diagnosing Method (RDM). While the RDM gather in one stage the risk response and risk control, this process separates them since their main activities are considerably different. The risk control stage is particularly designed to assured the risk management during the NPD process.

Further in the chapter 3, besides it will be developed a new product development model for innovation life cycle, it will be applied a risk management methodology to this NPD model. In this methodology it will be adopted to each step of the risk management process, the most appropriate techniques found in the risk management literature review.

3. RISK MANAGEMENT IN NEW PRODUCT DEVELOPMENT MODEL

a. NPD process

According to the NPD literature review conducted in the state-of-the-art of this work, it´s possible to conclude that many researchers agree in at least three fundamental stages on developing new products: The product concept, development, and commercialization (O'Connor and Ayers, 2005; Boer, 1999; Garcia and Calantone, 2002; Griffin, 1997; Cormican and O'Sullivan, 2004; Karlstrom and Runeson, 2005; Kagioglou et al., 1998; Cooper, 1990; Bacon et al., 1994; Schroeder, 2003; Ulrich and Eppinger 2004; Cooper and Kleinschmidt, 1986). Complementing the NPD literature review with a six month NPD process analysis within a high-tech enterprise of photovoltaic tracking systems, it was verified that for efficiently manage the NPD process, two more stages should be added to the main three: Feasibility and Validation (Aleixo and Tenera, 2009).

Almost every best performing business, had instituted formal gates between stages, as an opportunity for multifunctional teams to review status, ensure consensus on objectives, and approve plans for the next NPD stage (Boer, 1999; Kagioglou et al., 1998; Cooper, 1990). The stage-gate process, will assured the quality of the product and of the NPD process. This is emphasized by the requirements of ISO 9000, proposing at each NPD stage a well documented design reviews to resolve any ambiguities, errors, or conflicts and not to allow that the next stage be badly influenced (Tedaldi, 1997).

Thus, this work proposes an improvement of the Cooper´s NPD stage-gate® process, within a five stages and four gates. During this NPD process, each stage represented in the Figure 6 will entail internal and external organizational resources, skills, and functional competences and through a determined criterion each gate will control and evaluate the procedures taken in the previous stage to decide whether the project should move forward (Teece et al., 1997; Boer, 1999; Kagioglou et al., 1998; Cooper and Kleinschmidt, 1986; Cooper, 1990).

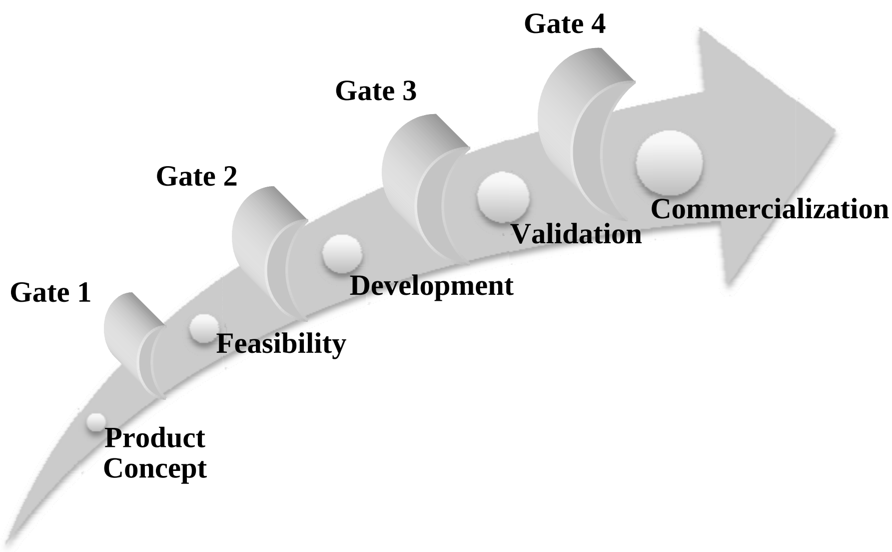


Figure 7 - NPD process

Product concept – According to Cooper and Kleinschmidt (1986), the major factor of differentiation on NPD process is the capacity of meeting customer needs. Since the assessment of customer needs are incorporated in this phase, most of the NPD failures can be later associated with this phase (Boer, 1999; Song et al., 2007; Bacon et al., 1994; Ulrich and Eppinger, 2004). Specially during this stage, decisions are often made with inadequate knowledge and information about technologies, resources, capabilities, and inadequate interactions among all NPD involved parties (Song et al., 2007). This stage will integrate tremendous multi-functional competences (Ulrich and Eppinger, 2004) to create, recognize, formulate, and select the market opportunities (O'Connor and Ayers, 2005) in accordance with company´s strategies and capabilities (Boer, 1999). It is establish a set of specifications which measure in detail the customer pretentions to the product (Ulrich and Eppinger, 2004). Usually, this process is performed informally, through discussions among scientists with industrial experience and marketers (Boer, 1999). Before selecting the concept, the ideas are taken into conceptualization through its technology shaping (O'Connor and Ayers, 2005; Boer, 1999; Diedericks and Hoonhout, 2007; Ulrich and Eppinger, 2004) and then it is taken a viable analysis to verify each economic potential, by comparing the strengths and weaknesses of the concepts (Ulrich and Eppinger, 2004). Thereby, the product concept stage is accomplished through marketing and R&D cross-functional integration (Ulrich and Eppinger, 2004; Boer, 1999).

The reality of the product development environment is against the common notion that after the initiation of the product development, the idea generation stage will be frozen (Knight, 1967). In an interesting three-year longitudinal study of 12 innovative enterprises, O'Connor and Ayers (2005) verified that in the life of these enterprises, marketers continuously develop proposals for potential new business, making this product concept stage a never-ending stage. Due to the market uncertainty, there could be the necessity of changing the primordial specifications of the product (Aleixo and Tenera, 2009).

Feasibility - As Boer (1999) states, "*the main tasks of this stage are to resolve the known issues and generate the cost and performance data that engineers and marketers need to undertake development*". Initially, this stage will verify if the technology of the product concept satisfies all customer needs (Ulrich and Eppinger, 2004) and then it will be addressed a set of product architectures, such as performance procedures, designs, materials, manufacturing cost estimation, and component standardizations to generate the data required to the next stage (Boer, 1999; Ulrich and Eppinger, 2004). After accomplish the feasibility stage, the costs of failures during the NPD process increase exponential (Boer, 1999), because the errors in the previous stages will be magnified. The decisions made during these stages will have significant implications into the following stages, in terms of viability, and especially in terms of expenditures (Bacon et al., 1994; Boer, 1999). Not only the investment on the previous product will be converted into costs but the time spent will be lost (Bacon et al., 1994). Thus, the feasibility stage, will confirm the NPD success before committing additional funds and to safeguard their business they should patented their innovation (Fosfuri, 2000).

In comparison with other stages, these two early stages have relatively low rates of expenditure, and for any product or process´ change it will incur lower cost penalties (Bacon et al., 1994).

Development - Once the gate 2 opens the development stage, i.e. after being assured the data needed for the development stage, R&D department takes the product concept into manufacturing. This stage will comport time and extraordinary expenditures prototypes (O'Connor and Ayers, 2005; Boer, 1999; Diedericks and Hoonhout, 2007; Ulrich and Eppinger, 2004; Kagioglou et al., 1998; Cooper and Kleinschmidt, 1986; Cooper, 1990).

Validation - After the development of the prototypes, the personnel responsible for its validation can actually interact with them in a realistic context transforming ambiguity into concrete issues (Diedericks and Hoonhout, 2007). Early in the validation stage, quality specialists review the product specifications through in house prototype tests, and field tests with customers, to insure that all product requirements, such as environmental and regulatory considerations, or even ISO standards, are achieved (Cooper, 1990; Tedaldi, 1997). After the product is in conformity, NPDT should provide all product´s documentation, including user manuals, production procedures, and installation instructions to be further used within the organization (Tedaldi, 1997).

Commercialization - Most of the times, a new technology doesn´t itself create industry disruption (Sarin and Mohr, 2008), but together with its application on the market does. Therefore, before the product is taken into full production, it´s distribution channels should be defined.

As it can be verified, this new product development process involves high-performance routines (Teece et al., 1997) and incorporates all the activities that according to Cooper and Kleinschmidt (1986) are more frequent on the NPD process. The activities of each stage in this NPD process and at many others, are from distinct organizational function areas (Kagioglou et al., 1998; Cooper, 1990; Ulrich and Eppinger, 2004; Schroeder, 2003; Boer, 1999). Thus, each NPD stage will potentiate the integration of cross-functional towards the achievement of each stage objectives (Eisenhardt and Martin, 2000).

Through the literature review exposed earlier, it was verified that there isn´t a consensus model to characterize which functional areas influence the NPD (Jassawalla and Sashittal, 2000; Ulrich and Eppinger, 2004; Song et al., 1997; Bacon et al., 1994; Sherman et al., 2005; Lu and Yang, 2004). Essentially, it depends on company´s based-strategy (Griffin, 1997), the level of innovation and uncertainty (Huang and Lin, 2006); Boer, 1999), and according to the particular characteristics of the product (Ulrich and Eppinger, 2004). Almost every NPD studies focus their research on the cooperation of marketing and R&D to develop new products. Notwithstanding, recent studies recommended a more complex, real and numerous cooperation. Ulrich and Eppinger (2004) suggest marketing, design, and manufacturing as the most central functions on NPD. Song et al. (1997) adds to marketing and R&D, the production and finance. Bacon´s et al. (1994) research, gave us a good example of the functional influences during the idea generation stage. They revealed that the creation of an idea requires a flux of information between a numerous corporate or divisional functions, including engineering, research, marketing, and manufacturing.

Through many cross-function investigations on NPD (Ulrich and Eppinger, 2004; Song et al., 1997; Bacon et al., 1994; Sherman et al., 2005; Lu and Yang, 2004) the main functional areas that influence the development of new products are marketing, R&D, production, and finance. Acknowledging these functions involvement with the work developed on each NPD stage (Song et al., 1997; Boer, 1999; Lu and Yang, 2004), and a six month NPD monitorization of a high-tech enterprise, the NPD process will be defined as follows in Figure 8.

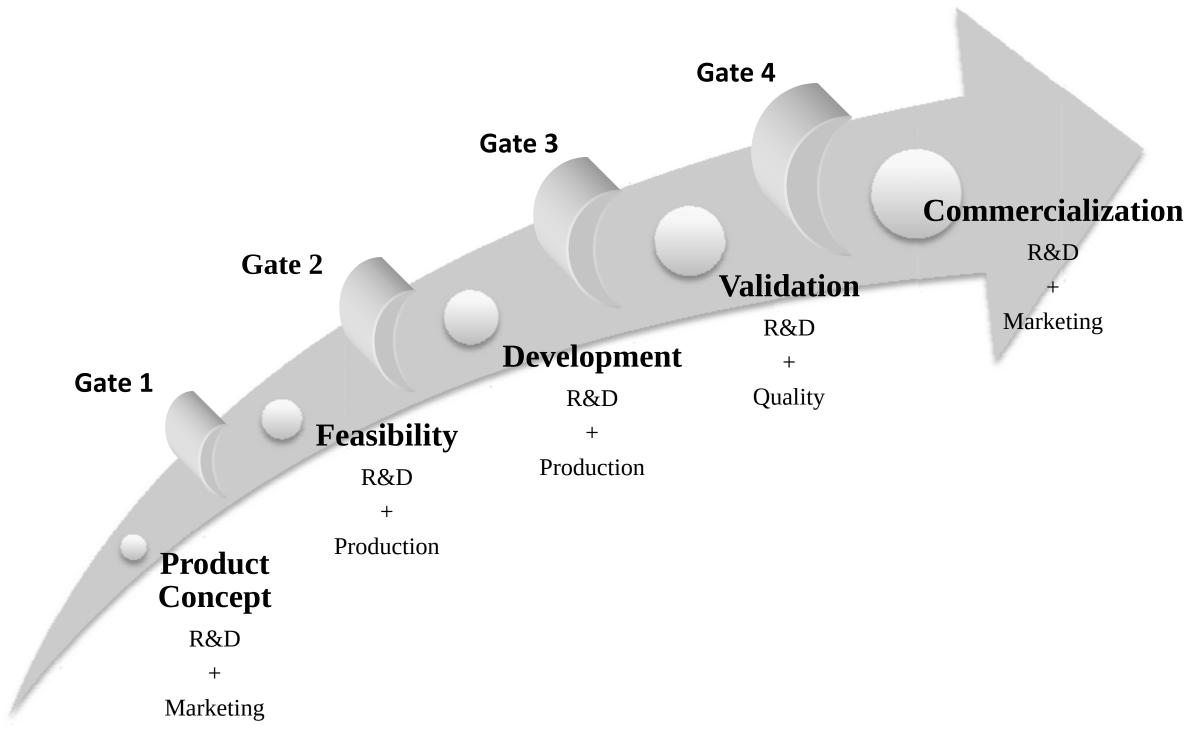


Figure 8 - Cross-function integration in NPD process

This NPD process was defined in terms of the state of the product during its development (Ulrich and Eppinger, 2004; Miller et al., 2005) and was characterized regarding the organizational function areas that most influences the product at that time. This design is essentially made to better detect and face the high-risks on the development of new products, since the higher is the level of distinction between different NPD functional areas within each stage, the better will be the detection of risks and its assessment.

Through a six month NPD monitorization of a high-tech enterprise, it was verified in the validation stage, that the quality department will perform almost all validation procedures. Therefore this work proposes its integration on the set of the functional areas that influence the development of new products (Aleixo and Tenera, 2009).

As we can verify in the Figure 8, the R&D department is represented in all new product development process from the beginning to the end. Even in the “commercialization” stage, R&D will interpret a small role. In case of the appearance of any issue associated to the product, the R&D personnel are the best experts to resolve it (Boer, 1999). Therefore, the R&D will be responsible to control this stage, incrementing performance advances and to support customer needs. This occurrence is in agreement with Boer´s, (1999) perspective and with an exploratory study of technology transfer and human interaction issues in Hi-Tech industrial organizations conducted by Jassawalla and Sashittal (2000). In their 46 R&D managers interviewed, they concluded that while R&D emerges in comparison with other functional areas in influencing the NPD, marketing is the other function that most participate in the NPD process, as can we verify in the product concept stage and at the commercial stage. Notwithstanding, each functional area will have a fundamental role in the life cycle process of NPD. While production functional area is concerned with effiency in production and cost minimization, R&D and Marketing have in general interesting in creating change through new products and new technologies (Song et al., 1997).

b. NPD model

In the high-tech´s growth process for maintaining competitive advantage, emerges the necessity of choosing the appropriate innovation, whereas radical or incremental innovation in a dynamic and never-ending activity (Hung et al., 2007; Qin and Wang, 2006). Many researchers are in agreement with defining the *product life cycle* according to its influence on market during the new product´s evolution (Werker, 2003). They acknowledge that a product during its life, pass through the introduction on the market, growth, maturity, saturation, and decline stages.

Qin and Wang (2006) researched the theories of enterprise´s life cycle. With this knowledge, they proposed four stages to characterize the growth process of high-tech firms: Start-up, Growth, Maturity, and Revival stage. They suggested that at the Start-up and Revival stages of high-tech enterprises, they should pursuit radical innovation, and at Growth and Maturity stages firms should adopt incremental innovations. Combining enterprise´s life cycle and product life cycle, Garcia and Calantone (2002) confirmed on their work that radical innovations are adequate for the early and final stages and incremental innovations for the intermediate stages (see Figure 9).

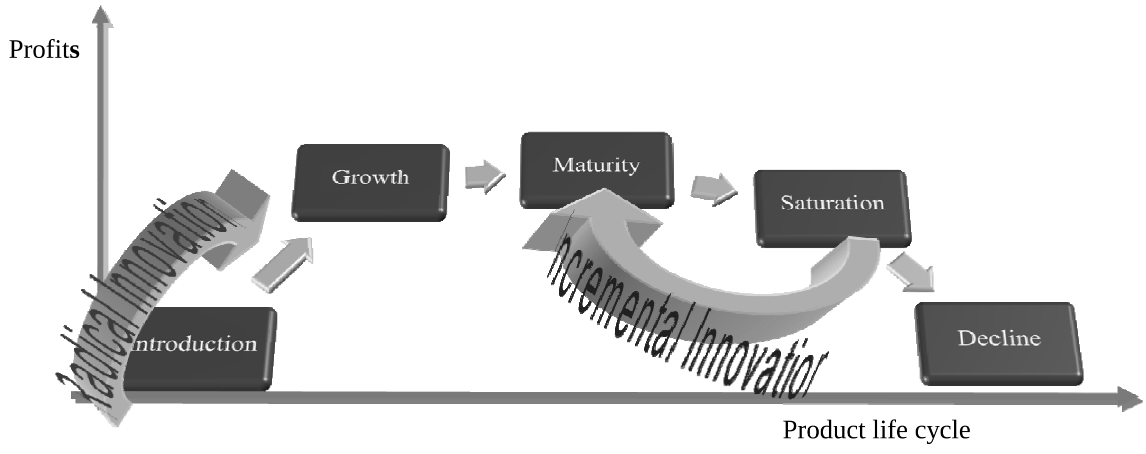


Figure 9 - Product life cycle under innovation

Therefore, during the *product life cycle*, the product´s introduction on the market could be better achieved with radical innovation, and to maintain the product on its level of maturity on the market, it should be subjected to incremental innovation. After the product reaches its decline in market, enterprises should again develop a new radical innovation approach (Aleixo and Tenera, 2009). This process represented in Figure 9, is in accordance with many researchers that consider radical and incremental innovations complementary (Qin and Wang, 2006, Garcia and Calantone, 2002; Salomo et al., 2007). While incremental innovation keeps companies competitive, radical innovation creates competitiveness (Salomo et al., 2007). Their relationship will ensure a competitive advantage over a long-term. The best product´s management will have to cover all its life cycle (Kagioglou et al., 1998) including the development process of radical and incremental innovations.

Due to the radical and incremental complementarities during the product life cycle, this work proposes a model of Innovation Life Cycle, through a continuous and cyclic process of radical and incremental innovation, as exposed in Figure 10.

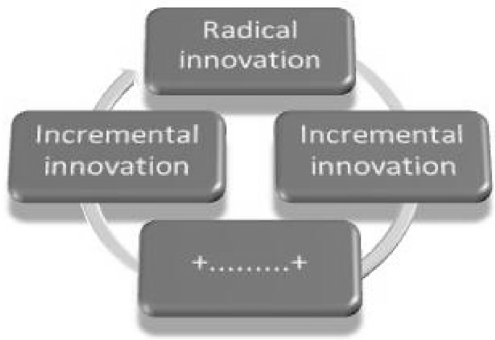


Figure 10 - Innovation under Product Life Cycle

The idea generation arises from the conjugation between a market necessity and the company´s capabilities (Danneels, 2002; Griffin, 1997; Koberg et al., 2003; Garcia and

Calantone, 2002; Diedericks and Hoonhout, 2007; Green et al., 1995). While incremental ideas are created to assure customer´s needs, usually around consumer´s experiences with the existing product (Diedericks and Hoonhout, 2007), radical ideas intents to create entire industries, products, and markets (Koberg et al., 2003; Garcia and Calantone, 2002). Due to its distinct impact level, incremental innovation in comparison with radical innovation uses less functional work. Since radical or an incremental discovery to be considered an innovation, have to pass through the laboratory into production, and add economic value to the firm (Garcia and Calantone, 2002), i.e. each innovation is the concept to classify the outcomes of the new product development process, the NPD process will vary according to the innovation nature (Garcia and Calantone, 2002) and as Green et al. (1995) states "*The better we understand this construct, the better we will understand other aspects of innovation management*". In addition, a survey conducted by Ettlie and Elsenbach (2007) of 72 automotive engineering managers involved in supervision of the NPD process, found that about a third of the managers, modified their NPD process to optimize the development process according to the different types of innovation.

The differences could be so distinctive that enterprises, according to Griffin (1997) could bring the incremental product forward to the feasibility stage on the new product development process. According to his five years research of NPD best practices, incremental innovation uses less collaboration of marketing, quality, and finance functional areas than radical innovation. This perspective is in accordance with Boer´s (1999) statement: "*when a new market is identified and most of the technology is all ready in hand, the project could skip the earliest stages and move rapidly to commercialization*".

For this reasons, and more specifically as Garcia and Calantone (2002) work reveal, due to R&D department may only need to improve existing technology to respond to consumer´s needs with the existing product, incremental innovations allows quick competitive advantage and a low project cost reducing the functional collaboration and NPD duration. Paradoxically, the decision to innovate radically promotes greater changes to the organization´s operations (Green et al., 1995), incorporating a complex fusion of ideas and knowledge from different organizational domains (Diedericks and Hoonhout, 2007).

Each innovation´s NPD process will only differ regarding the amount of functional competences needed to accomplish its development (Danneeels, 2002; Griffin, 1997; Koberg et al., 2003; Garcia and Calantone, 2002; Diedericks and Hoonhout, 2007). In this perspective, the expertise marked in a broken box in the Figure 11, i.e. quality, at the product concept stage marketing personnel, and at the feasibility production, will really be insignificant during incremental development, since it is only need an overall knowledge of these areas which can be, and should be provided by the project team leader.

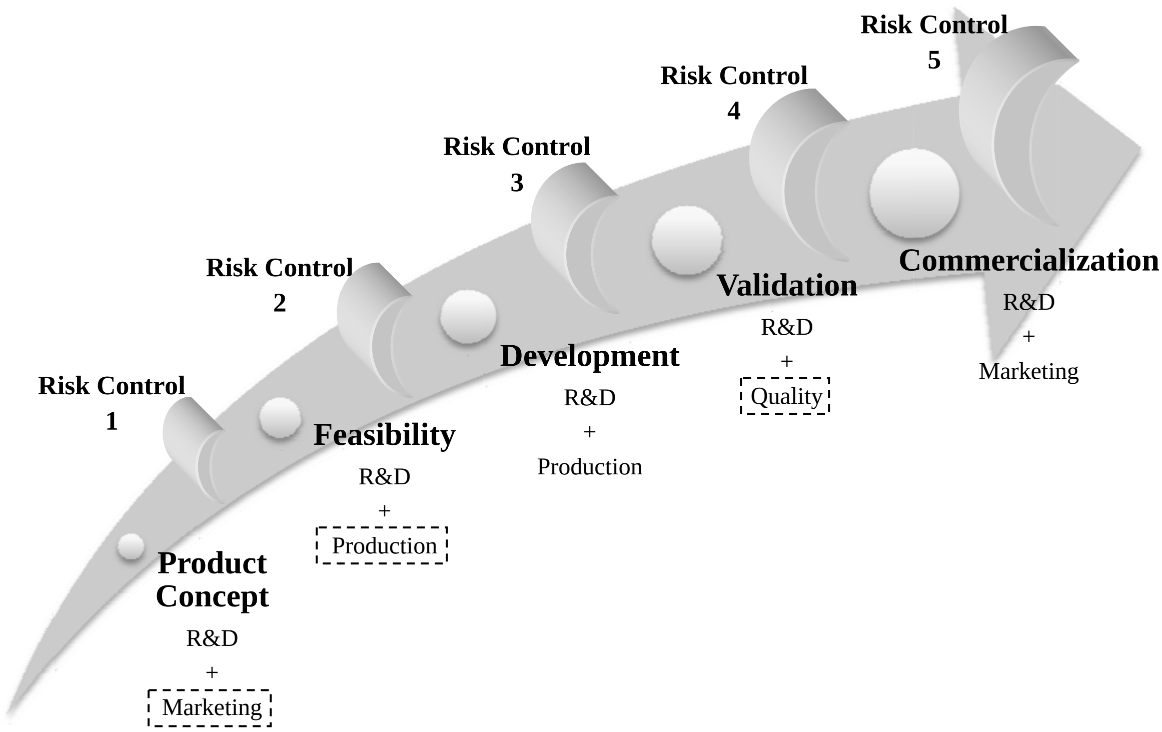


Figure 11 – The NPD Model

This NPD process is defined in terms of the state of the product during its development and is characterized according to the organizational function areas that most influences the product at that time. This design is essentially made to better detect and face the high-risks on the development of new products, since the higher is the level of distinction between different NPD functional areas within each stage, the better will be the detection of risks and its assessment. Since the NPD gates will contribute to control the risks of each NPD stage, it was incremented another gate in the final stage to control the risks of the commercialization stage.

Thus, it´s easy to verify, that the risk assessment of each innovation will also be different. The nature of the new product implies different competences for its development which consequently implies different risks (Danneels, 2002; Griffin, 1997; Koberg et al., 2003; Garcia and Calantone, 2002; Diedericks and Hoonhout, 2007; Green et al., 1995).

This NPD model (Figure 11) should potentiate a universal risk management model of developing innovative products in advance and during the NPD process. For a risk management of excellence, it´s essential to perfectly define the development process of innovative products in order to identify and assess precisely the key activities and responsibilities that could create risks.

c. Risk management methodology applied in NPD model

Without disregarding that risk management should be planned in advance to the NPD process, it is recognized by innumerous researchers that the excellence of risk management is only accomplished if the risk management planned in advance is complemented with a management during the development of the new product (Smith, 2002; PMI, 2008). In this perspective besides manage the risk in advance, this work proposes a risk control during the four NPD stage-gates®. This risk control will review the progress of the risks over the course of the NPD stages, as will review the effectiveness of the risk treatment actions made during the risk response phase, commonly in the form of surveys or audits. Such reviews, i.e. surveys or audits, will be undertaken in each gate ensuring that most of the critical problems are addressed and resolved in the precise time before the risk had made its consequence within the next stage. Each gate will decide if the project should move forward, and if the deliverables resulted from the NPD activities performed by functional experts meet a specific criterion (Cooper, 1990). Besides the common gate procedures of NPD, this work proposes that the risk control should be added to the specific criterion of each gate. Managing the NPD risks within each gate will allow mechanic and continuous corrections during the process in response to technical adaptations and changing environmental conditions (Song and Montoya-Weiss, 2001). The specific risk control scheme in this model will also provide a platform for project managers not getting caught off guard about the risks that can occur within each NPD stage (Taylor, 2009).

Through this technique, probably it will be verified, that some of the low risks during the NPD process will evolve into a higher level of severity to the project becoming important enough to be addressed preventive risk measures (Cooper, 2005). Moreover during the NPD process, the NPD team (NPDT) can face new risks while the team is developing the product. The risk list should be updated wherever these new risks appear. However, the NPD model based intents to reduce or even eliminate the implementation of those *workarounds*.

Following, it will be described and illustrated the NPD Risk Management model for enterprises´ innovation life cycle. This model will provide the best techniques to universally manage the risks of all types of technological innovations developments in advance and during the NPD process. Each type of innovation is inherent to the NPD process of adoption (see Figure 11). Before the NPD process the risk management will be divided into risk identification, risk analysis, and risk response.

i. Risk identification

Risk management is really a process of learning once failures on past projects provide extreme valuable information for future projects. This stage will be accomplished with an appropriate combination of risk identification techniques (Kasap and Kaymak, 2007; Simon et al., 1997), which together with historical information of previous NPD projects, will able to efficiently identify the risks of developing new products (PMI, 2008).

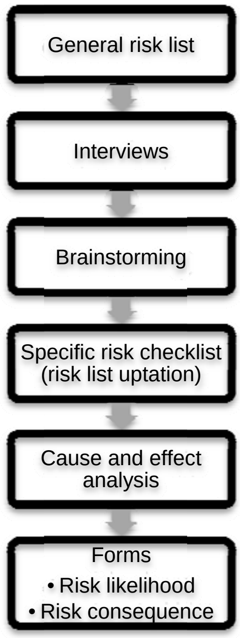
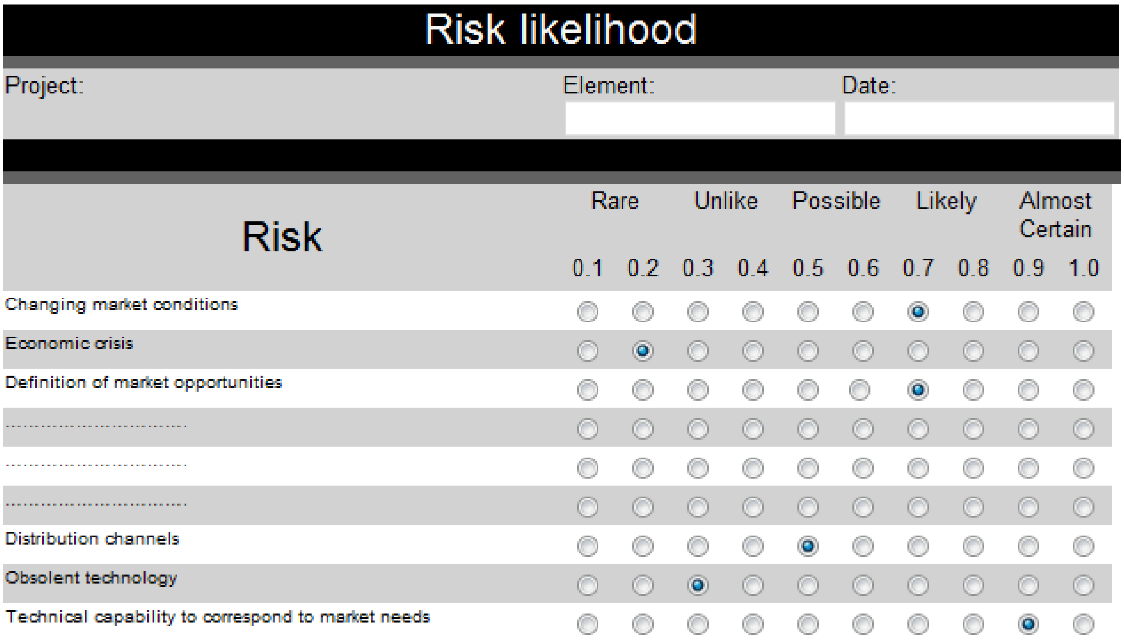


Figure 12 - Risk identification flowchart

Initially, it should be done a general risk list through the literature review to gather historical information from different NPD projects (Baccarini et al., 2004; Keizer and Halman, 2007; Cooper et al., 2005; Kasap and Kaymak, 2007). Then, individual interviews will be applied in this risk identification step to permit that each NPDT elements, from different functional areas, perceive risks without any influence (Keizer and Halman, 2007). Contrarily to the risk diagnosing method, these interviews will be performed informally to either core or extended NPD teams, and according to the NPD functional areas which generate the risk identified. According to the NPD process developed, the domains or sources to address risks in the interview will be marketing, R&D, quality, and production. However, as all processes have a management level; the management domain will be added to these risk sources.

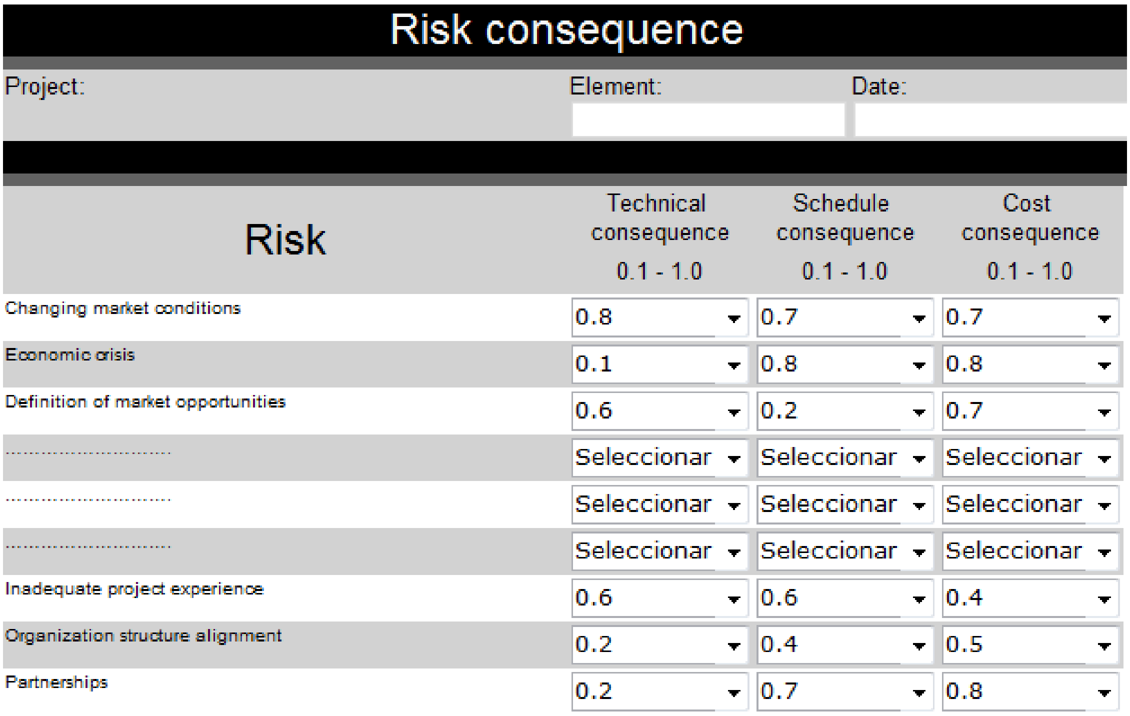
Posteriorly through a consensus between the NPDT it should be done a final risk checklist with all the risks identified. The combination of the general risk checklist with interviews will update the general risk list with the specific risks of the product in question, filling the risk list handicap for non-standard projects. This method will be crucial for the assessment of risks, since general risk list could have different causes with completely distinct consequences in the project.

After identifying all risks in the development process, it will be sent to each NPDT member specific forms created by InfoPath software to address risk´s qualitative analysis. The risks in these documents will not be separated within their functional area, for not provoke influence judgments. Each NPDT members will estimate the likelihood of risk occurrence during the project (see example in Figure 13), and address their impact through decimal value quantification from 0 to 1 (see example in Figure 14).



Risk likelihood										
Project:	Element:					Date:				
Risk	Rare		Unlike		Possible		Likely		Almost Certain	
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Changing market conditions	○	○	○	○	○	○	●	○	○	○
Economic crisis	○	●	○	○	○	○	○	○	○	○
Definition of market opportunities	○	○	○	○	○	○	●	○	○	○
....	○	○	○	○	○	○	○	○	○	○
....	○	○	○	○	○	○	○	○	○	○
....	○	○	○	○	○	○	○	○	○	○
Distribution channels	○	○	○	○	●	○	○	○	○	○
Obsolent technology	○	○	●	○	○	○	○	○	○	○
Technical capability to correspond to market needs	○	○	○	○	○	○	○	○	●	○

Figure 13 - Template for the risk likelihood assessment



Risk consequence			
Project:	Element:	Date:	
Risk	Technical consequence 0.1 - 1.0	Schedule consequence 0.1 - 1.0	Cost consequence 0.1 - 1.0
Changing market conditions	0.8	0.7	0.7
Economic crisis	0.1	0.8	0.8
Definition of market opportunities	0.6	0.2	0.7
....	Seleccionar	Seleccionar	Seleccionar
....	Seleccionar	Seleccionar	Seleccionar
....	Seleccionar	Seleccionar	Seleccionar
Inadequate project experience	0.6	0.6	0.4
Organization structure alignment	0.2	0.4	0.5
Partnerships	0.2	0.7	0.8

Figure 14 - Template for the risk consequence assessment

The quantification was divided into 5 categories, respectively according to the tables for risk likelihood and risk consequence assessments bellow (Taylor, 2009; Cooper et al., 2005):

Table 5 - Risk likelihood assessment

Likelihood (P)	Point Values
Rare	0.1 to 0.2
Unlikely	0.3 to 0.4
Possible	0.5 to 0.6
Likely	0.7 to 0.8
Almost certain	0.9 to 1.0

Each likelihood risk addressed will have the following effect on the technical, schedule, and cost domain bellow (Taylor, 2009).

Table 6 - Risk consequence assessment

Consequence (C)	Technical Consequence (Ct)	Schedule Consequence (Cs)	Cost Consequence (Cc)
Low (0.1 to 0.2)	Minimal impact to product performance	No impact to end date	Within budget
Minor (0.3 to 0.4)	Small reduction in product performance	End date will slip less than 10% of the project lifecycle	Less than a 10% cost overrun
Moderate (0.5 to 0.6)	Moderate reduction in product performance	End date will slip between 10% to 15% of the project lifecycle	10% - 20% overrun
Significant (0.7 to 0.8)	Significant reduction in product performance	End date will slip between 15% to 25% of the project lifecycle	20 – 50% overrun
High (0.9 to 1.0)	Product will not meet customer/user critical needs	End date renders the product useless to the customer	Overrun cannot be funded

This qualitative analysis prioritizes risks according to their likelihood of occurrence and potential impact on the technical, schedule, and cost of the project (Taylor, 2009; Cooper et al., 2005). However, depending on the NPD aim and development field, other factors can be included besides technical, schedule, and cost factors.

ii. Risk Analysis

Once all the NPD risks are identified and their qualitative analysis made, the estimates can be examined into a detailed semi-quantitative risk analysis.

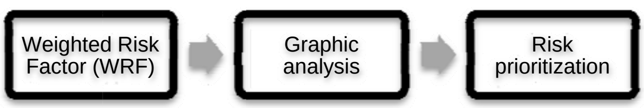


Figure 15 - Risk analysis flowchart

To determine the overall magnitude of risks and consequently prioritize them, it will be calculate the risk factor. The risk factor will reflect the magnitude of the likelihood of risk occurrence and its impact on the NPD process. Mathematically, it derives from the probability calculation for disjunctive events (Cooper, 2005):

$$prob\ (A \cup B) = prob\ (A) + prob\ (B) - prob(A) \times prob\ (B) \qquad (1)$$

Thus, the risk factor will be calculated as follows:

$$Risk\ factor = RF = P + C - (P \times C) \qquad (2)$$

Where:

1. P stands for risk likelihood
2. C stands for risk consequence

The equation (2) was based on Taylor (2009) and Cooper´s (2005) work, where the general disjunctives rule prevails. Taylor (2009) revealed that the conjunctive rule tends to be too optimistic.

The estimates of the risk consequence on schedule, technical and cost domain have a high level of ambiguity. Besides schedule risks are evaluate in time and cost risks in capital, the importance level of each other within the NPD process might be and most probably is very different (Kayis et al., 2006). To counteract this ambiguity, it will be applied the following weighted risk factor equation (3). This method will weight the percentage of each domain within the project, providing the real risk magnitude on the process according to the manager´s schedule, technical, or cost priorities of the project (Kayis et al., 2006; Taylor, 2009):

$$WRF = Wt \times RFt + Ws \times RFs + Wc \times RFc \qquad (3)$$

Where:

1. W stands for the value of technical (Wt), schedule (Ws), and cost (Wc) weight in the NPD process.
2. RF stands for the technical (RFt), schedule (RFs), and cost (RFc) risk factor.

To provide quick visual indications of risk priorities and severity, the WRF will be plotted with 3 iso-risk contours. These lines of equal WRF values will constitute the interval of three distinct risk response actions as showed in the Table 7 (Taylor, 2009).

Table 7 - Risk severity limits

Weighted Risk Factor (WRF)	Risk Level	Risk Response
0.0 to 0.4	Low	None
0.4 to 0.7	Moderate	Judgment call
0.7 to 1.0	High	Develop abatement plans

Each plot is addressed to the respective functional area that generates the risks, allowing managers facing risks with the appropriate actions. Allying this cross-functional integration, with cause and effect analysis and the WRF, managers are able to effectively define the risk owners, and which strategy response should be applied to the correspondent risk.

iii. Risk response

Figure 16 - Risk response flowchart

This stage provides appropriate responses to enhance opportunities and to reduce threats to project objectives, through its exploit, share, and enhance as well as avoidance, acceptance, transference, and mitigation, respectively (PMI, 2008). The assessment of the most appropriate risk response actions will be based in the probability of the risk occurrence, its consequences within three enterprise´s domains, and its WRF. Combining this data with risk´s causes and effects, it´s possible to describe the majority of the best´s risk response actions of each response strategy and the risk ownership as follows.

Table 8 - Template of risk response actions

Risk:	…………..		
Functional area:	…………..		
Threat response:			
Avoidance	**Mitigating**	**Transference**	**Acceptance**
…………..	…………..	…………..	…………..
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
…………..	…………..	…………..	…………..

After describing the response actions of each strategy, the project managers will have the essential data to select the most appropriate response strategy to each risk. This selection should be accomplished according to the judgment of the decision maker. To make the best decision, he or she will have the necessary data provided by the probability of the risk occurrence, its consequences within three enterprise´s domains, and its WRF. Most likely, to have for each risk an effective treatment, more than one kind of response should be addressed. Moreover, in special cases where there will be major uncertainties of which risk response strategy should be adopted, the decision maker should adopt specific tools to select the appropriate strategy. However, this response strategy selection goes beyond the aim of this dissertation, and so it will not be included in this model.

Usually these response strategies are design only if certain events occur. But possibly, there will be some risks that only occur under certain predefined conditions. In this case, contingent response strategies should be implemented for not caught managers of guard (PMI, 2008).

After taking the best actions to deal with risks, the project management plan should be updated, especially in terms of schedule, cost, and quality (PMI, 2008). Moreover, it is imperative to define some degree of margin in the project assumptions, since not all potential risks are identified, some are really unpredictable (Taylor, 2009).

iv. Risk control

Once the NPD process starts, it will be executed the risk control phase to track risks symptoms and consequently apply risk response plans. This control phase is illustrated in the risk control scheme, Figure 17. The general risks illustrated in the NPD gates of the risk control scheme which are in accordance with the state of the product development and their functional areas sources, were obtained through an extended literature review and through a six month NPD monitoring in a high-tech photovoltaic company. This general risk list according to the model proposed will be updated with specific risks of each development in question, being the project managers responsible to aggregate them in a conscientious and professional way. Managers may even eliminate some general risks, in order to allocate specific ones. In this perspective, it could happen that specific NPD processes could be influenced by different functional areas or even entail more functional areas than the proposed ones. Therefore it will only be necessary to adapt the functional areas of the NPD model to the specific nature of the NPD, maintaining the methodology of this NPD Risk Management process intact.

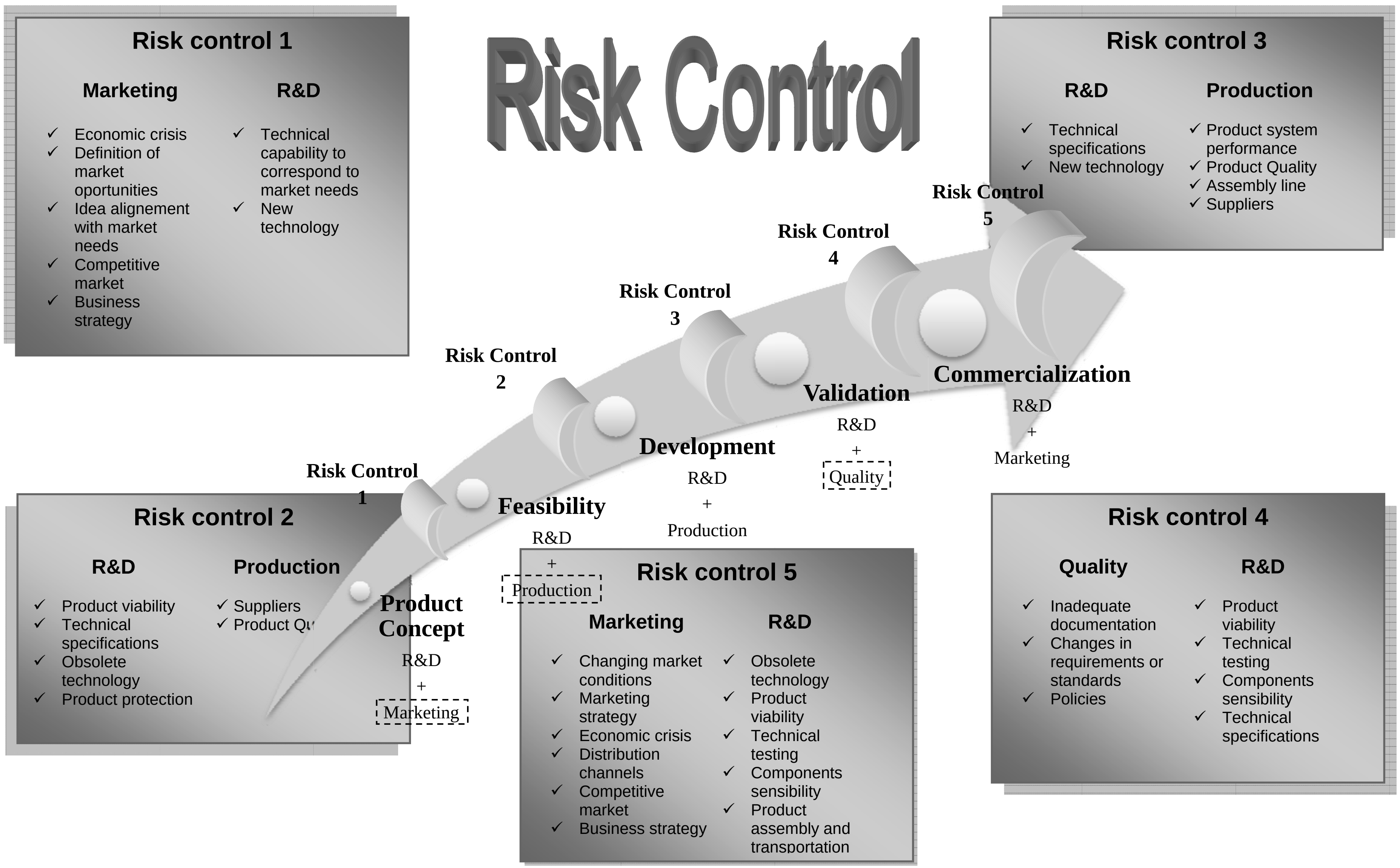


Figure 17 - Risk control scheme

After accomplish the risk control during each stage, the respective gate will overview if there is an uncontrolled risk and decide if the project should move forward or if it is need to take more or better risk response plans. One approach to monitoring the overall status of risk in the project is to reassess the risks incorporating on this risk management phase the techniques of risk analysis and if it´s needed, effective risk response adjustments or alternative plans will be applied.

As in any project, and NPD process is not an exception, management *per se* will entail major risks to the project. Therefore, even not being a functional area of developing new products, management risks will accompany the NPD risk along the risk management process. Thus, as in the other phases of risk management, management risks should be included in the risk control phase during the NPD process at all NPD gates, adding one more risk control list (Figure 18).

Risk control

Management

- ✓ Schedule expectations
- ✓ Availability of skilled staff
- ✓ Team work
- ✓ Changes in team members
- ✓ Enterprise´s resources
- ✓ Inadequate Project experience
- ✓ Capital investment
- ✓ Organization structure alignment
- ✓ Partnerships

Figure 18 - Control of management risks

It´s also possible to verify in the risk control scheme that some risks could occur more than once. For example, technical specifications risk could occur either in the feasibility stage, as in development or validation stages. Since it will be caused by distinct NPD activities, will consequently need different risk response strategies. Therefore, it´s imperative to distinguish them according to their occurrence causes.

The NPD model is extremely flexible, which will emphasize the idea of being a universal model to every NPD process, potentiating the integration of a risk management methodology.

After developing the integration of the risk management methodology to the NPD model, this work will apply it in the next chapter in a radical and incremental innovation in photovoltaic high-tech industry.

4. CASE STUDIES – NPD RISK MANAGEMENT IN PHOTOVOLTAIC INDUSTRY

The focus of this thesis is to develop and deliver a risk management model of enterprises´ NPD process. In order to verify the applicability and test the performance of the model, it will be carry out a case study in a photovoltaic tracking system´s company.

The WS Energia Lda. is a Portuguese company that develops, produces and sells products and services, and conducts research and development in solar photovoltaic industry. The company has already around twenty highly qualified staff, 90% graduates, including four PhD. The firm's business is divided into industrial research and development, commercial, industrial manufacturing, and installation and maintenance, with a turnover of about 1.1 M€ in 2008. The lines of business currently extend to the export of products to Italy, Spain and Switzerland, and to the creation of WS Energia manufacturing units in the United States.

The company was established in September 2006 after eight months of incubation in the start-up system of the Instituto Superior Técnico. Where two partners PhD João Wemans and PhD Gianfranco Sorasio worked for several years as a researcher and doctoral student in the Group of Lasers and Plasmas Department of Physics. They were challenged by an Italian company in renewable energy (Centro Ricerche ISCAT s.r.l.) to create a solution to increase the profitability of traditional photovoltaic systems.

The technology developed DoubleSun®, concentrate the incident solar radiation on the photovoltaic (pv) modules by a factor of 1.85 through reflective elements (Figure 19). This technology allows the concentration of direct solar radiation and reflective radiation on conventional pv modules by optical components.

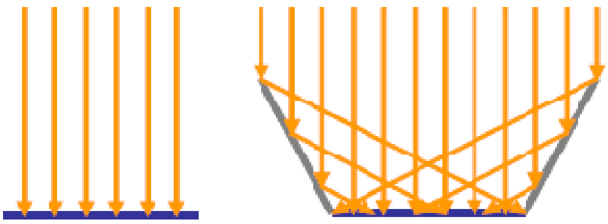


Figure 19 - Technology DoubleSun®

After conceptualize the idea, it was made the protection of industrial property at the end of 2005, registering the brand (trademark: 005606011) and patenting it (National Utility Model 10180, ES1065532UU pending in Spain and Italy).

In June 2006, the laboratory of solar concentration tracking systems goes into operation. Here was developed the first prototype of DoubleSun®, containing one axis of rotation and controlled by an internal clock that measure the position in relation to the Sun at intervals of 10 minutes. This technology was awarded with "BES Innovation Award 2006" as the best innovation in Portugal in the renewable energy sector in 2006.

Essentially, the possibility of implementing the DoubleSun® technology in standard photovoltaic modules allowed advancing with the creation of WS Energia Lda. At the end of 2006, several industrial prototypes were created in order to develop solutions to guarantee a long life product. At this stage, it was used the three-dimensional drawing of all the constituent parts of DoubleSun® and it was applied standard solutions already used in the market for other aims through the contribution of several suppliers.

The constant requests of the market that WS Energia received in the first semester of 2007, confirmed the product´s potential and led her to bet on incorporating new solutions and techniques on DoubleSun®. Thus, it was implemented a new phase of development, which led to the addition of one actuator in each DoubleSun® and to the optimization of the solar tracking system using inclinometers and data of longitude and latitude. The product included reflective elements, a tracking structure, two linear actuators and an electronic control system (Figure 20).

Figure 20 - DoubleSun®

Through advanced calculations, the electronic control system tracks Sun's apparent movement during every minute of the year, setting in motion the two linear actuators which place the structure with the same sun angle, in order to maximize the production of energy in every instant. At this stage of increasing specialization, the challenges were overcome with abroad advanced training courses and with partnerships of Research and Development groups and national companies.

In 2008, with the implementation of the decree-law of micro-generation (DL 363/2007), the WS Energia adapted to this new reality, developing a marketing plan, to define the best technical option for each client.

More than an innovative product, the DoubleSun® technology is a technical platform in constant evolution which will continually offer to its customers, higher profitability than the conventional solutions. In the final of 2008, WS Energia increment to DoubleSun® an electronic innovation, SunGravity Control®. In association with Global Tronics, they improved the electronic tracking system with the aim to raise its technical performance and to allow non-local monitoring through Wireless, CAN, I2C, and Bluetooth communications.

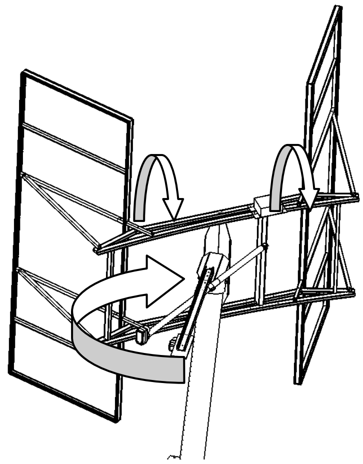


Figure 21 - DoubleSun® tracking system

The constant demand of DoubleSun´s® improvements will generate more reliable trackers, efficient optics, and an electronic tracking system with more functionalities.

Through the NPD risk management model constructed earlier, this work aims to manage the risks of WS Energia´s incremental and radical innovation.

Since the proposed NPD process (see Figure 11) varies according to the nature of each type of innovation, it´s necessary to first of all classify the type of innovation that enterprises´ want to be risk managed. In this management perspective, which is the scope of this thesis, the choice of selecting the appropriate type of innovation should be made according to the complexity and level of knowledge of the NPD activities (Dewar and Dutton, 1986). According to the literature review, the categorization of innovations will vary according to the aim of this categorization. This assumption could inherently generate ambiguity in choosing the appropriate type of innovation, but in fact what truly influences management is the complexity of the activities to develop innovations, which if high, will probably increase the generation of uncontrollable risks. The higher are the complexity and consequently the resources needed to innovate, the greater will be the risk taken of the organization. In order to clarify readers, complexity it´s different than the dimension of the activities needed to develop innovations. Essentially, it is the degree of difficulty to manage those activities. Acknowledging the characteristics of radical and incremental innovation present in the table 2, it´s possible to verify that the radical innovation in study will be the DoubleSun®, and the incremental innovation will be the SunGravity Control®. It is not required that the product developed had to have all the characteristics of the specific innovation to be considered that type of innovation. It could be very utopian in meeting all the characteristics, since each category will gather innumerous innovations with different specificities, but with similar level of change. Thus, it is possible to be present with a radical innovation which was developed through existing technology. Even without a new scientific component, such as the DoubleSun®, some products can entail such uncertain and most of all a complex development that will provoke extreme change in the organization and in the market. Moreover, the DoubleSun® was developed according to market needs and through a low level of knowledge about the real performance of a product when gather with different existing high technologies. In relation to the SunGravity Control®, the product was developed from consumers´ experiences in order to improve the Double sun´s® tracking systems. Being so classified as an incremental innovation.

The NPD model will organize all the actions taken during the development of the DoubleSun® and the SunGravity Control®, according to the state of the product development and the functional areas which influence the product at that time. Besides provide a great tool for the understanding of all aspects of the development process of the DoubleSun® and the SunGravity Control® enabling a better judgment to identify and assess the key activities and responsibilities that could create risks, it will be an excellent model to control the risks during the new product development.

Since many risks will be cross-functional, the NPD cross-functional team is more likely to find them (Smith, 1999). If only the scientists identify risks, they will probably miss many market risks. The new product development team (NPDT) or the new product development cross-functional team is characterized by a “core team” which remains in almost all NPD stages, and an “extended team” who delivery sporadically expertise (Ulrich and Eppinger, 2004). It´s possible to verify in the Figure 11, that either in the DoubleSun® as the SunGravity Control® development, the core team will be constituted by the R&D personnel which are present in all NPD stages. These elements often have specific disciplinary training in areas such as physics, mechanical and electrical engineering, market research, materials science, or manufacturing operations (Ulrich and Eppinger, 2004). Due to their high capabilities, most of the core team elements can be responsible of other functional areas than R&D in the development of the new product, as it happens in the case of WS Energia.

After conducting an extended literature review about risk management, this work will apply the risk management methodology developed in this work in both radical and incremental development process, i.e. in the NPD model of WS Energia. Further, for each innovation it will be addressed the same risk management methodologies based on the respective NPD model which will be illustrated in the beginning of each innovation study. Thus, in the incremental innovation study it will not be described the methods applied since they are explained during the radical innovation case study.

a. Radical innovation case

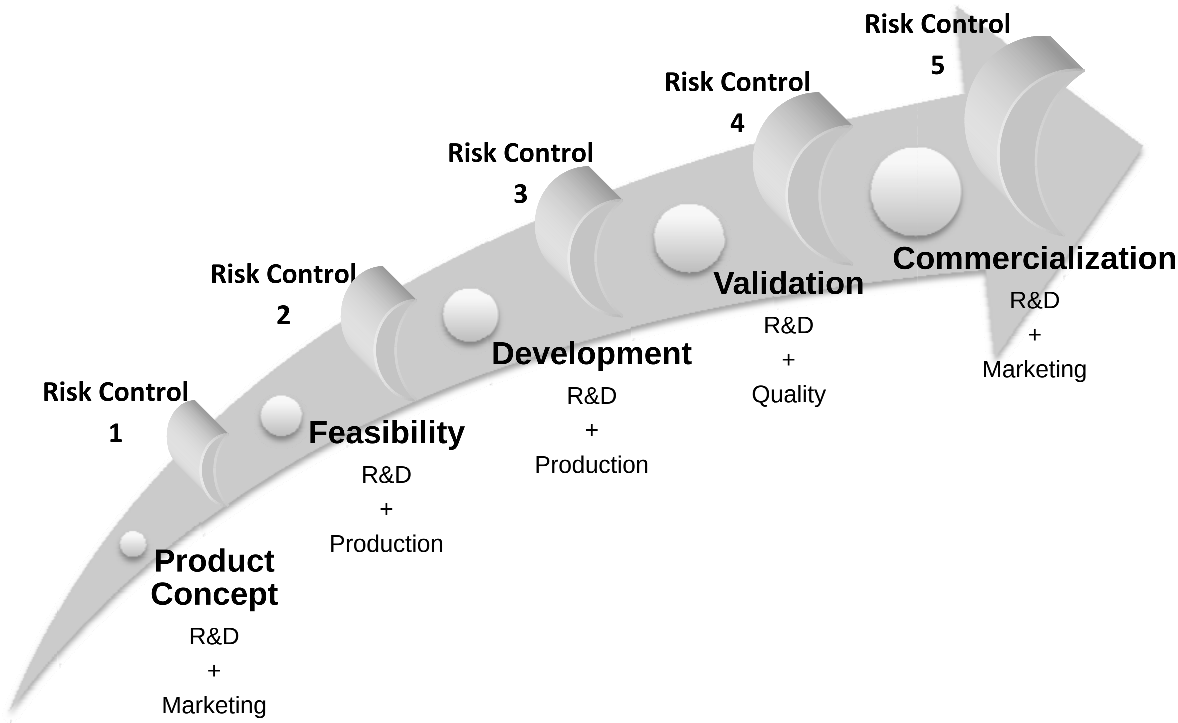


Figure 22 - DoubleSun® develeopment process

i. Risk identification

Initially, it was developed a general risk list (Annex 1). Combining this list with interviews conducted to an overall number of 4 NPDT members (Annex 2, 3, 4, 5), it was done a final risk checklist with all the risks identified (Annex 6).

After DoubleSun´s® risk identification, it will be assess by each NPDT elements the risk´s likelihood and consequences to the project by the form constructed through Infopath software.

However, during the interviews with each NPDT members to assess the risks, it was verified that not all members understood the real impact, being positive or negative, of each risk on the project. Many questions were made from the interviewed, asking what the consequences of each risk are. Therefore, before the semi-quantitative analysis taking place, this work proves the necessity of specify or characterize the causes and effects of each risk before any extended analysis. To address these risk characteristics, this work will include in the risk checklist, the description of the causes and consequences of each risk (table 9).

Table 9 - Risk checklist

Risk causes	Risk	Risk consequences
New decree-laws	Changing market conditions	Missing market oportunities
Exchange rate fluctuations affecting the credit	Economic crisis	Drop of sales
Errors in market analysis Discover of new markets	Definition of market opportunities	Poor market acceptance Market leader
Misunderstanding of the best techniques of marketing for the specific case or client	Marketing strategy	Unable to reach costumers
Inexistence of technology to meet market needs	Idea alignment with market needs	Concept doesn´t satisfy market needs
Development of innovations from the competitors Market competitive prices	Competitive market	Few costumers
Price too high Definition of price disregarding the all the costs	Price establishment of the product	Few margin of profits Few costumers Elitist image
Limited diversity of business Decision to commercialize with final clients or dealers	Business strategy	Losses of market opportunities Specialization in the business
Product with large dimensions	Product dimensions	Poor market acceptance High costs in transportation High resources to installation
Deficient assessment of the product´s requirements to meet costumer´s needs	Product specification require to meet costumer´s need	Product performance does not meet costumer´s need
Poor product logistics Transportations characteristics	Distribution channels	Goods losses Logistic expenditures
Technology already existent in the market	Obsolete technology	Inexistence of competitive advantage
Technology new to the world	Technical capability to correspond to market needs	Uncertain technology performance
New technologies in the market are expensive	Product viability	Costs bigger than benefits
Limited alternatives Inexperience of working with suppliers	Suppliers	Production delays High costs and delivery times Not respect its engagements
Limited budget	Enterprise's resources	Poor quality tests Poor work profitability Lack of maintenance
Absence of documentation	Technical specifications	Suppliers mistakes
Existent technology limitations Low cost of materials	Application with existent technology	System malfunction Less expenditures in manufacture

Table 9 - Risk checklist (Continued)

Risk causes	Risk	Risk consequences
Few resources Few quality procedures	Technical testing	System malfunction Product guarantee inexistence Bad image
Components without quality Work activities	Components sensibility	Misalignment of systems during installation
Uncertain and complex technology	New technology	Market leader Innovative image
Choice of components	Product system performance	Competitive advantage Product malfunction
Product doesn´t meet with the requirements Certifications	Product quality	Product´s unsatisfactory performance High cost of product materials Product guarantee
Incorrect manufacture Well defined manufacture procedures	Assembly line	Poor product quality High productivity
Imitations Product patent and copyright	Product protection	Loss of competitive advantage Competitive advantage
Inexistence of process and procedures	Inadequate documentation	Poor professionalization and competent work
Market changes Technology limitations	Changes in requirements or standards	Slippage of the schedule Poor knowledge
Legal and bureaucratic obstructions Fiscal inspections	Policies	Fines
Misjudgments of capacity of work Interruption of the work Limited resources Projects more urgent	Schedule expectations	Work overload High pressures Schedule slippage in dependent activities
Unknown work flow	Capital investment	Limited resources
Few multidisciplinary personnel Absence of qualified personnel	Availability of skilled staff	Poor quality of work Few capabilities in certain technical domains Personnel shortfalls
Inadequate communication Unconsciousness of responsibility Centralization Too much pressure in meeting the schedule planned	Team work	Poor quality of work Poor work profitability
Changes in team members	Inadequate project experience	Inadequate tests Poor confidence in the team Slippage of the schedule
Top management support Existence of an R&D department Enterprise´s organizational structure	Organization structure alignment	Poor work profitability
Poor quality of partners work Capital investment	Partnerships	Unconsciousness of responsibility Raise of resources Disagreements Loyalty

Once more, the documents to NPDT members assess risks, will not be organized according to their functional areas sources, for not motivate misjudgments. The use of the Ishikawa diagrams in this case is not so interesting, since we are in the presence of a high number of risks identified. Thus, besides this checklist will complement and will accompany the risk analysis documents deliver to the NPDT members, for being based on, it will be a major background to scrutinize which risks can generate positive effects to the project. As commonly NPDT members focus on negative issues when they are facing with risk identification and assessment (Hillson, 2001b), during each interview and assessment NPDT members were briefly informed of the possibility that some of the consequences of each risks could generate positive risks to the NPD process.

The next tables (Tables 10 and 11) will gather all the information from each NPDT members, to address the overall risk likelihood and overall risk consequence, respectively.

Table 10 - Overall risk likelihood

Risk	NPDT member 1	NPDT member 2	NPDT member 3	NPDT member 4	Average
Changing market conditions	0.6	0.7	0.5	0.6	0.60
Economic crisis	0.3	0.3	0.3	0.2	0.28
Definition of market opportunities	0.6	0.5	0.8	0.4	0.58
Marketing strategy	0.7	0.7	0.7	0.8	0.73
Idea alignment with market needs	0.8	0.7	0.6	0.6	0.68
Competitive market	0.5	0.7	0.5	0.6	0.58
Price establishment of the product	0.6	0.4	0.6	0.5	0.53
Business strategy	0.7	0.5	0.4	0.6	0.55
Product dimensions	0.6	0.3	0.7	0.8	0.60
Product specification require to meet costumer´s need	0.6	0.9	0.6	0.6	0.68
Distribution channels	0.8	0.6	0.8	0.5	0.68
Obsolete technology	0.1	0.3	0.1	0.2	0.18
Technical capability to correspond to market needs	0.5	0.6	0.4	0.3	0.45
Product viability	0.3	0.4	0.9	0.2	0.45
Suppliers	0.8	0.7	1.0	0.8	0.83
Enterprise’s resources	0.8	0.8	0.5	0.7	0.70
Technical specifications	0.9	0.6	1.0	0.6	0.78

Table 10 - Overall risk likelihood (Continued)

Risk	NPDT member 1	NPDT member 2	NPDT member 2	NPDT member 2	Average
Application with existent technology	0.6	0.3	0.5	0.3	0.43
Technical testing	0.6	0.3	1.0	0.8	0.68
Components sensibility	0.9	0.4	0.6	0.8	0.68
New technology	0.9	0.9	0.6	0.6	0.75
Production system performance	0.9	0.9	0.8	0.7	0.83
Product quality	0.5	0.6	0.9	0.8	0.70
Assembly line	0.2	0.4	0.2	0.2	0.25
Product protection	0.5	0.3	0.6	0.2	0.40
Inadequate documentation	0.9	0.6	0.5	0.8	0.70
Changes in requirements or standards	0.3	0.4	0.7	0.5	0.48
Policies	0.4	0.9	0.6	0.9	0.70
Schedule expectations	0.9	0.3	1.0	0.8	0.75
Capital investment	0.5	0.3	0.8	0.3	0.48
Availability of skilled staff	0.6	0.6	0.7	0.9	0.70
Team work	0.3	0.6	0.8	0.6	0.58
Inadequate project experience	0.8	0.7	0.7	0.6	0.70
Organization structure alignment	0.2	0.3	0.2	0.6	0.33
Partnerships	0.9	0.5	0.7	0.7	0.70

The average results of each item are in both tables 10 and 11 with two decimal numbers. Since the sample selection procedure is limited to the NPDT members, it will not be done a rounding for not losing the significance of the 4 samples.

Table 11 - Overall risk consequence

Risk	Technical Consequence					Schedule consequence					Cost consequence				
	1	2	3	4	Average	1	2	3	4	Average	1	2	3	4	Average
Changing market conditions	0.2	0.1	0.1	0.2	0.15	0.8	0.9	0.7	0.6	0.75	0.5	0.7	0.7	0.3	0.55
Economic crisis	0.1	0.1	0.1	0.2	0.13	1.0	0.9	0.9	0.7	0.88	0.7	0.7	0.8	0.5	0.68
Definition of market opportunities	0.4	0.3	0.3	0.2	0.30	0.6	0.7	0.8	0.6	0.68	0.8	0.8	1.0	0.7	0.83
Marketing strategy	0.2	0.4	0.3	0.2	0.28	0.8	0.9	0.8	0.8	0.83	0.6	0.8	1.0	0.8	0.80
Idea alignment with market needs	0.6	0.4	1.0	0.7	0.68	0.1	0.8	0.2	0.1	0.30	0.5	0.7	0.7	0.5	0.60
Competitive market	0.6	0.3	0.7	0.6	0.55	0.2	0.8	0.2	0.1	0.33	0.5	0.8	0.7	0.3	0.58
Price establishment of the product	0.3	0.2	0.3	0.2	0.23	0.3	0.7	0.2	0.4	0.40	0.9	1.0	1.0	0.7	0.90
Business strategy	0.1	0.2	0.5	0.4	0.30	0.2	0.7	0.4	0.3	0.30	0.3	0.8	0.8	0.5	0.60
Product dimensions	0.7	0.7	1.0	0.7	0.78	0.2	0.4	0.3	0.3	0.30	0.6	0.5	0.6	0.4	0.53
Product specification require to meet costumer´s need	0.8	0.8	0.7	0.6	0.73	0.3	0.4	0.1	0.2	0.25	0.3	0.7	0.8	0.4	0.55
Distribution channels	0.1	0.3	0.1	0.3	0.17	0.5	0.7	0.3	0.4	0.48	0.5	0.7	0.9	0.5	0.65
Obsolete technology	0.9	0.7	1.0	0.8	0.85	0.8	0.8	1.0	0.8	0.85	0.6	0.4	1.0	0.7	0.68
Technical capability to correspond to market needs	0.9	0.2	1.0	0.8	0.73	0.5	0.7	0.3	0.5	0.50	0.5	0.2	0.8	0.3	0.45
Product viability	0.7	0.4	0.8	0.9	0.70	0.3	0.8	0.9	0.6	0.65	0.8	0.8	0.9	0.6	0.78
Suppliers	0.7	0.7	0.8	0.8	0.75	0.7	0.8	0.8	0.7	0.75	1.0	0.9	0.8	0.6	0.83
Enterprise’s resources	0.5	0.3	0.5	0.7	0.50	0.5	0.7	0.8	0.8	0.70	0.1	0.6	0.2	0.5	0.35
Technical specifications	0.5	0.8	0.3	0.7	0.58	0.5	0.4	0.6	0.7	0.55	0.5	0.4	0.4	0.9	0.55

Table 11 - Overall risk consequence (Continued)

Risk	Technical Consequence					Schedule consequence					Cost consequence				
	1	2	3	4	Average	1	2	3	4	Average	1	2	3	4	Average
Application with existent technology	0.8	0.8	1.0	0.7	0.83	0.2	0.8	0.8	0.1	0.48	0.8	0.5	0.9	0.9	0.78
Technical testing	1.0	0.9	0.4	0.9	0.80	0.5	0.4	0.1	0.6	0.33	0.6	0.2	0.5	0.9	0.55
Components sensibility	0.7	0.8	0.8	0.5	0.67	0.3	0.3	0.3	0.2	0.28	0.3	0.2	0.3	0.4	0.30
New technology	0.8	0.7	1.0	0.7	0.80	0.4	0.5	0.3	0.7	0.48	0.4	0.5	0.1	0.3	0.33
Product system performance	1.0	0.8	1.0	0.9	0.93	0.2	0.7	0.1	0.1	0.28	0.7	0.3	0.6	0.4	0.50
Product quality	0.9	0.8	0.8	0.8	0.83	0.2	0.5	0.1	0.4	0.30	0.6	0.7	0.6	0.9	0.70
Assembly line	0.3	0.7	0.3	0.3	0.40	0.5	0.5	0.5	0.8	0.58	0.6	0.8	0.8	0.7	0.73
Product protection	0.2	0.7	0.9	0.4	0.55	0.1	0.2	0.1	0.7	0.28	0.3	0.3	0.9	0.8	0.58
Inadequate documentation	0.3	0.4	0.7	0.2	0.40	0.7	0.3	0.3	0.6	0.48	0.4	0.3	0.5	0.4	0.40
Changes in requirements or standards	0.9	0.8	1.0	0.8	0.88	0.4	0.8	1.0	0.6	0.70	0.4	0.4	0.7	0.4	0.48
Policies	0.1	0.4	0.1	0.3	0.23	0.5	0.9	0.1	0.5	0.50	0.1	0.7	0.3	0.3	0.35
Schedule expectations	0.4	0.6	0.3	0.2	0.38	0.8	1.0	1.0	0.7	0.88	0.3	0.5	0.1	0.4	0.33
Capital investment	0.3	0.4	0.4	0.3	0.35	0.4	0.7	1.0	0.4	0.63	0.1	0.3	0.2	0.5	0.28
Availability of skilled staff	0.6	0.3	1.0	0.7	0.65	0.6	0.8	0.7	0.6	0.68	0.6	0.3	0.2	0.4	0.38
Team work	0.6	0.3	1.0	0.8	0.68	0.6	0.8	1.0	0.3	0.68	0.6	0.3	0.2	0.3	0.35
Inadequate project experience	0.6	0.3	0.6	0.7	0.55	0.8	0.8	1.0	0.7	0.83	0.8	0.6	0.4	0.5	0.58
Organization structure alignment	0.5	0.3	0.9	0.2	0.48	0.5	0.6	0.9	0.5	0.63	0.5	0.5	0.3	0.4	0.43
Partnerships	0.8	0.9	0.3	0.7	0.68	0.8	0.9	0.8	0.7	0.80	0.8	0.9	0.6	0.8	0.78

ii. Risk analysis

Once all the qualitative analysis is made, the estimates can be examined into a detailed semi-quantitative analysis. The results of WRF are express in the following table 12 (Taylor, 2009). The risks in the table 12 are gathered in descendent way according to their severity to the project, in order to project managers prioritize the risks with more urgent risk response plans.

Table 12 - DoubleSun® WRF

Marketing risk	Technical consequence			Schedule consequence			Cost consequence			Total WRF
	P	Ct	WRF	P	Cs	WRF	P	Cc	WRF	
Marketing strategy	0.73	0.3	0.32	0.73	0.8	0.19	0.73	0.8	0.38	0.89
Idea alignment with market needs	0.68	0.7	0.36	0.68	0.3	0.15	0.68	0.6	0.35	0.86
Product specification require to meet costumer´s need	0.68	0.7	0.36	0.68	0.3	0.15	0.68	0.6	0.34	0.86
Definition of market opportunities	0.58	0.3	0.28	0.58	0.7	0.17	0.58	0.8	0.37	0.82
Distribution channels	0.68	0.2	0.29	0.68	0.5	0.17	0.68	0.7	0.35	0.81
Competitive market	0.58	0.6	0.32	0.58	0.3	0.14	0.58	0.6	0.33	0.79
Price establishment of the product	0.53	0.2	0.25	0.53	0.4	0.14	0.53	0.9	0.38	0.78
Changing market conditions	0.60	0.2	0.26	0.60	0.8	0.18	0.60	0.6	0.33	0.77
Business strategy	0.55	0.3	0.27	0.55	0.3	0.14	0.55	0.6	0.33	0.74
Economic crisis	0.28	0.1	0.15	0.28	0.9	0.18	0.28	0.7	0.31	0.63
Production risk	**Technical consequence**			**Schedule consequence**			**Cost consequence**			**Total WRF**
	P	**Ct**	**WRF**	**P**	**Cs**	**WRF**	**P**	**Cc**	**WRF**	
Suppliers	0.83	0.8	0.38	0.83	0.8	0.19	0.83	0.8	0.39	0.96
Product system performance	0.83	0.9	0.39	0.83	0.3	0.17	0.83	0.5	0.37	0.93
Product quality	0.70	0.8	0.38	0.70	0.3	0.16	0.70	0.7	0.36	0.90
Assembly line	0.25	0.4	0.22	0.25	0.6	0.14	0.25	0.7	0.32	0.67
Quality risk	**Technical consequence**			**Schedule consequence**			**Cost consequence**			**Total WRF**
	P	**Ct**	**WRF**	**P**	**Cs**	**WRF**	**P**	**Cc**	**WRF**	
Changes in requirements or standards	0.48	0.9	0.37	0.48	0.7	0.17	0.48	0.5	0.29	0.83
Inadequate documentation	0.70	0.4	0.33	0.70	0.5	0.17	0.70	0.4	0.33	0.82
Policies	0.70	0.2	0.31	0.70	0.5	0.17	0.70	0.4	0.32	0.80

Table 12 - DoubleSun® WRF (Continued)

R&D risk	Technical consequence			Schedule consequence			Cost consequence			Total WRF
	P	Ct	WRF	P	Cs	WRF	P	Cc	WRF	
Technical specifications	0.78	0.6	0.36	0.78	0.6	0.18	0.78	0.6	0.36	0.90
New technology	0.75	0.8	0.38	0.75	0.5	0.17	0.75	0.3	0.33	0.89
Technical testing	0.68	0.8	0.37	0.68	0.3	0.16	0.68	0.6	0.34	0.87
Product viability	0.45	0.7	0.33	0.45	0.7	0.16	0.45	0.8	0.35	0.85
Application with existent technology	0.43	0.8	0.36	0.43	0.5	0.14	0.43	0.8	0.35	0.85
Enterprise´s resources	0.70	0.5	0.34	0.70	0.7	0.18	0.70	0.4	0.32	0.84
Product dimensions	0.60	0.8	0.36	0.60	0.3	0.14	0.60	0.5	0.32	0.83
Obsolete technology	0.18	0.9	0.35	0.18	0.9	0.18	0.18	0.7	0.29	0.82
Components sensibility	0.68	0.7	0.36	0.68	0.3	0.15	0.68	0.3	0.31	0.82
Technical capability to correspond to market needs	0.45	0.7	0.34	0.45	0.5	0.15	0.45	0.5	0.28	0.76
Product protection	0.40	0.6	0.29	0.40	0.3	0.11	0.40	0.6	0.30	0.70
Management risk	**Technical consequence**			**Schedule consequence**			**Cost consequence**			**Total WRF**
	P	**Ct**	**WRF**	**P**	**Cs**	**WRF**	**P**	**Cc**	**WRF**	
Partnerships	0.70	0.7	0.36	0.70	0.8	0.19	0.70	0.8	0.37	0.92
Capital investment	0.70	0.6	0.35	0.70	0.8	0.19	0.70	0.6	0.35	0.88
Schedule expectations	0.75	0.4	0.34	0.75	0.9	0.19	0.75	0.3	0.33	0.86
Team work	0.70	0.7	0.36	0.70	0.7	0.18	0.70	0.4	0.33	0.86
Inadequate project experience	0.58	0.7	0.34	0.58	0.7	0.17	0.58	0.4	0.29	0.81
Availability of skilled staff	0.48	0.4	0.26	0.48	0.6	0.16	0.48	0.3	0.25	0.67
Organization structure alignment	0.48	0.3	0.22	0.33	0.6	0.15	0.33	0.4	0.24	0.61

Table 13 - Domain´s weight on NPD

	Technical weight (Wt)	Schedule weight (Ws)	Cost weight (Wc)	Total
Weight on NPD	0.4	0.2	0.4	1.0

After calculating the WRF for each NPD risks, it will be carried out the following graphics of each NPD functional area for further analysis. The yellow vertical line corresponds to the moderate level of risk severity and the red vertical line to the high level of risk severity to the project.

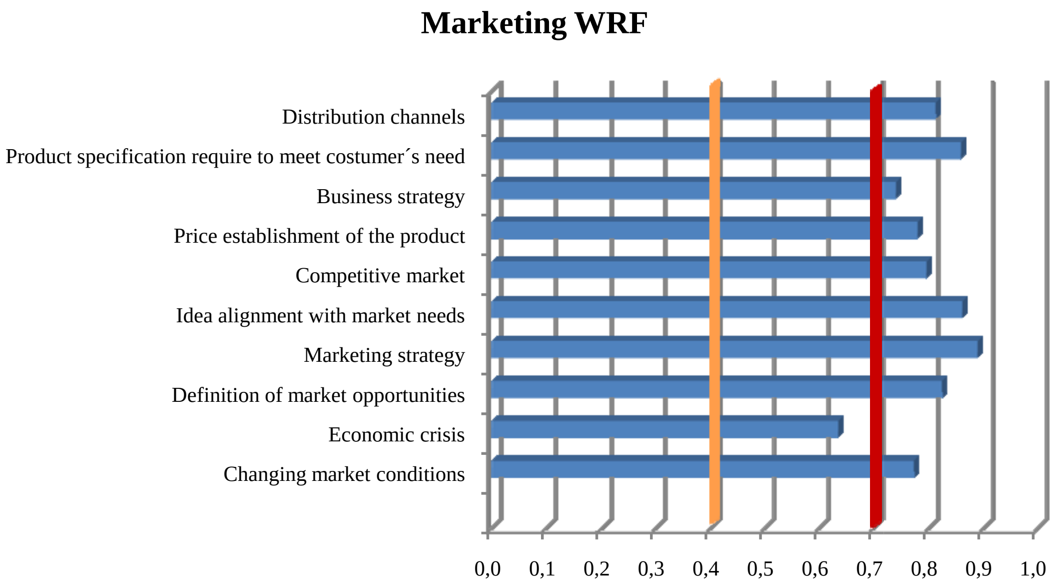


Figure 23 - Marketing WRF

In the Figure 23, it´s possible to verify that contrarily to the other risk indicators in the marketing functional area, economic crises is a moderate risk. In relation to the other indicators, an appropriate risk response strategy should be applied, especially to the marketing strategy, idea alignment with market needs, and product specification require to meet costumer´s need, that have a WRF far above 0.8.

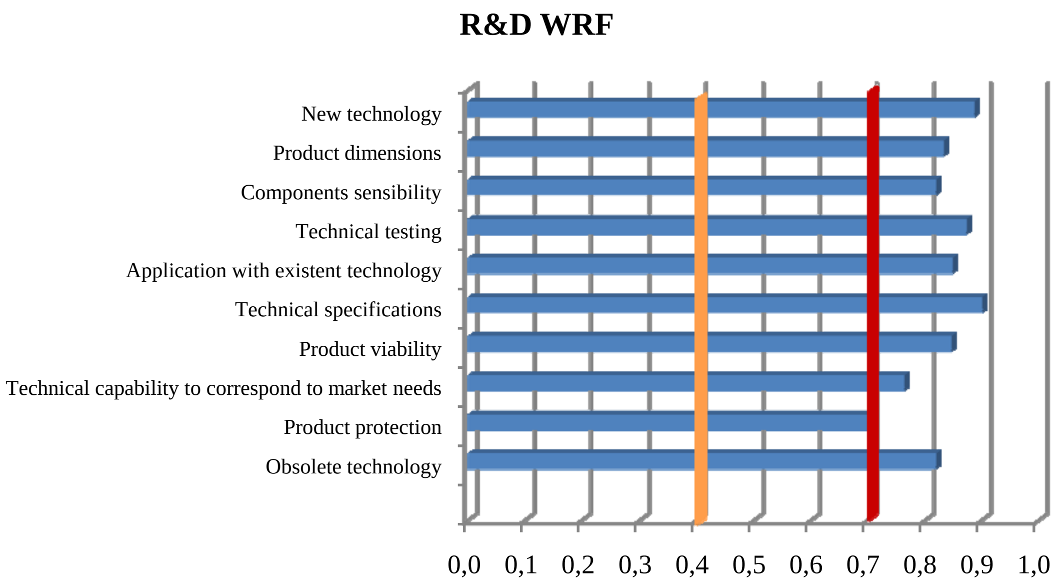


Figure 24 - R&D WRF

In relation to the R&D risks, almost all indicators have a WRF superior than 0.8. This is in accordance with the importance of the activities developed from the R&D functional area to the NPD process. In relation to the product protection indicator, top managers should decide if it´s worth to develop abatement plans, such as patenting the product. To the other high risks, appropriate management knowledge areas should be adopted to effectively respond to risks. Relatively to the new technology indicator, as other risk identified, it could be transformed into an opportunity to the enterprise. Entailing high uncertain, the new technology indicator can lead to a competitive advantage. Thus, it´s essentially to address the appropriate methodologies to either mitigate risks or even stimulate opportunities. The assessment of the appropriate methodologies will be achieved in the risk response phase.

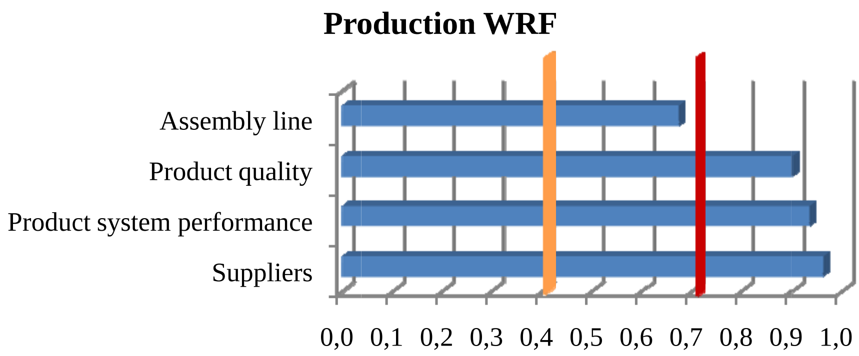


Figure 25 - Production WRF

The product quality, suppliers and the product system performance are major risks to the NPD process. Moreover, the suppliers risk indicator is the highest identified risk to the NPD process. This implies that the DoubleSun® development is extremely influenced with the supplier´s conditions and for that is particularly important to propose procedures in order to eliminate the causes of this risk. Thus, in the risk response phase measures should be taken to manage these risks. During the development of the DoubleSun® the assembly line is a moderate risk since maybe the manufacture in WS Energia will be simple and quick for this product. Allying the results of the assembly line risk with supplier´s risk, it´s possible to conclude that the major part of DoubleSun´s® production is made through outsourcing, since the high risks to the development process are gather within the suppliers. This reinforces the idea, that extraordinary risk response plans should be adopted to reduce supplier´s risks.

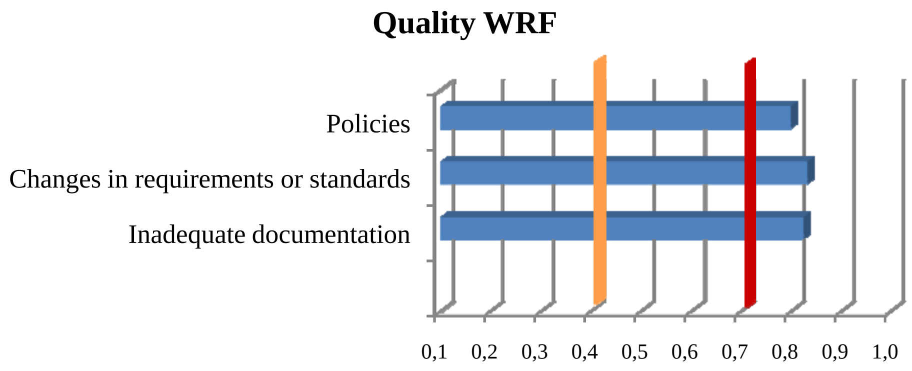


Figure 26 - Quality WRF

In the quality functional area, there are three high risks that need to be treated but none is above 0.8. In a management perspective, the quality risks would be the easiest to be managed, since their causes (see Table 9) have a low level of uncertainty. All of the treatment to address to these three quality risks will be done through a specific risk response strategy.

Figure 27 - Management WRF

In the Figure 27, it´s possible to analyze that the availability of skilled staff and organization structure alignment are moderate risks generated from the management functional area. Analyzing in detail (see table 12), both probability of occurrence is very low, which can indicate that WS Energia have all the requirements needed to face these risks during the NPD process, without needing any risk response strategy. Relatively to the other management risks, especially risk response concerned should be focus into partnerships, capital investment, and schedule expectations. However, also the remaining risks have to be managed. The partnerships´ high level of WRF is in accordance with the earlier analysis that the DoubleSun® development will be accomplished with a major interaction with suppliers or even partners.

After prioritizing the risks that need urgently to be managed, it will be necessary to address the appropriate risk response strategy for consequently apply other project management knowledge areas.

iii. Risk response

Combining the analysis of the Figures 23, 24, 25, 26, 27 with the information data of the tables 9 and 12, for each risk it will be addressed the appropriate risk response actions for each response strategy. The risk response will be prioritized according to its severity to the project showed in the Figures 23, 24, 25, 26, 27, and its actions will be defined to face its causes and consequences revealed in the table 9.

Since in this phase it will be fulfilled the template of risk response actions (see table 8) for every identified risk with high severity to the project, it will be only revealed in the body of this work one risk, the marketing strategy risk. In the annex 7 the reader will find the others risk´s response actions.

Table 14 - Marketing strategy response actions

Risk:	Marketing strategy		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implementation of multiple strategies to ensure that one succeeds	Flowcharting the process	Outsourcing	
Preparing simulation models	Periodic measure the customer satisfaction		
Past project knowledge			
Perform a marketing plan			
Evaluate the best distribution marketing channels that match the marketing strategy			
Implement Marketing-mix			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Develop innovative marketing strategy	Differentiation		

However, for low risks and some moderate ones it will not be addressed any response strategy as it was concluded in the risk analysis phase. But it´s wised according to their nature and severity, to develop contingency plans. Therefore, in accordance with the perspective above, it will be showed in the body of this work the actions of a contingent plan for one risk, the Economic crisis risk.

Table 15 – Economic crisis contigency plan

Risk:	Economic crisis
Functional area:	Marketing
Contingent response strategy:	Economic prevision analysis
	Postpone commercialization

These proposed risk response actions were generated from past NPD projects, a six month NPD monitoring, and from literature review.

iv. Risk control

After defining the measures to be taken, managers should provide continuous monitoring and risk status evaluation over the course of the NPD process. The project leader will maintain a list of the major risks that have been identified in the risk analysis stage, and will update the risk control scheme as it is showed in the Figure 28.

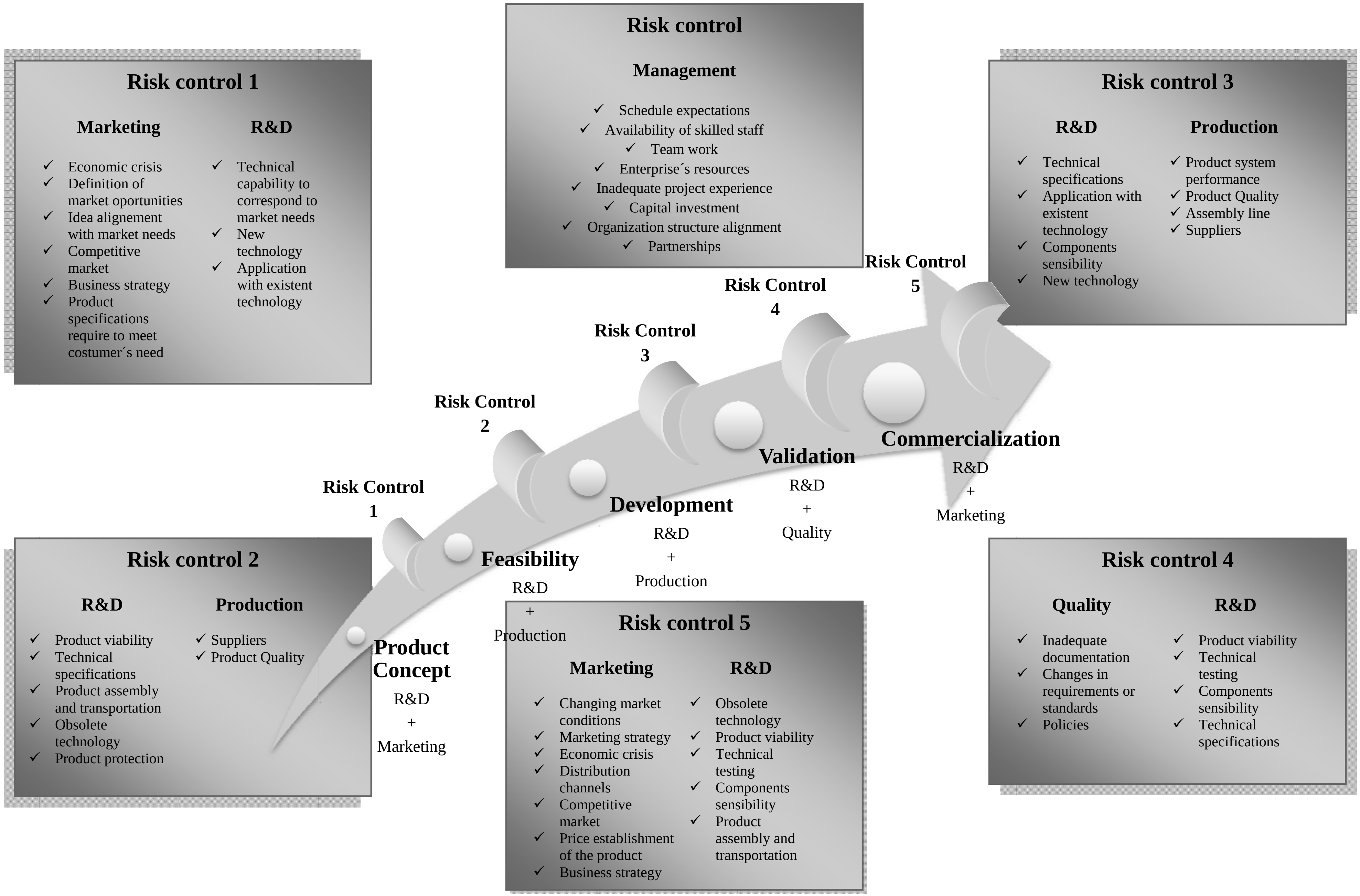


Figure 28 - DoubleSun® risk control

Then, if the project manager is facing any of the risks identified in risk control gates, he should return to the risk analysis phase and if needed, he or she should complement the risk response strategies already implemented before the NPD or even apply alternative effective risk response strategies.

b. Incremental innovation case

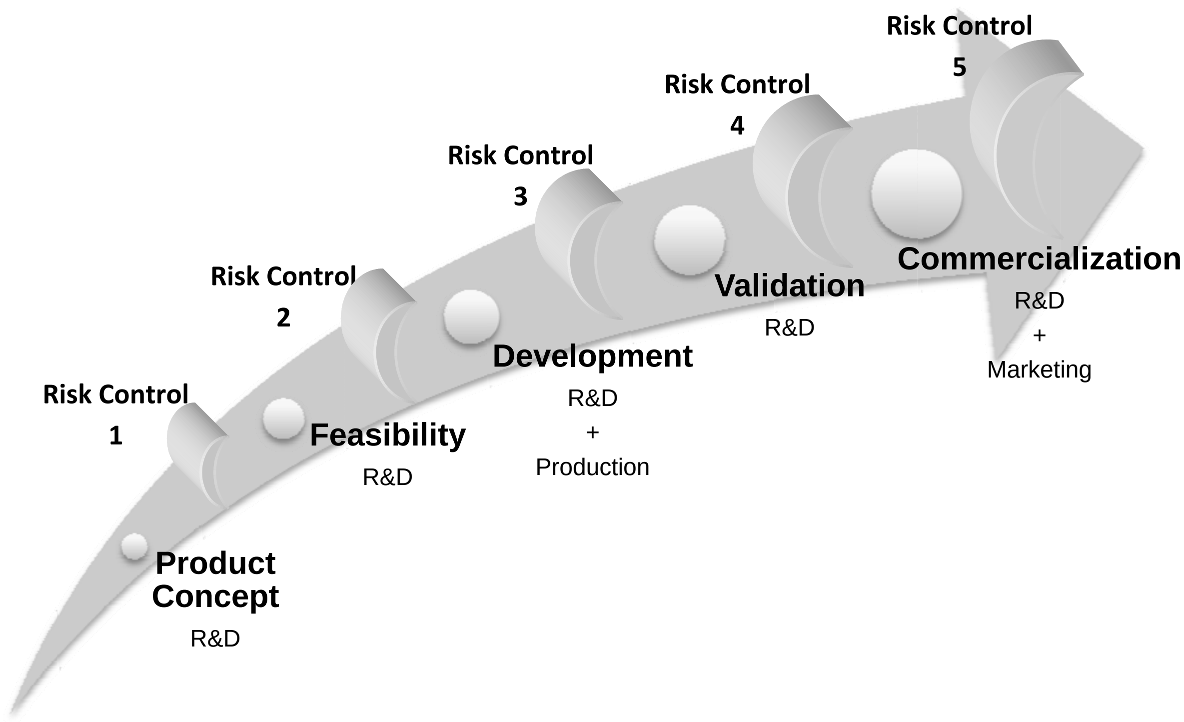


Figure 29 - SunGravity Control® development process

All the risk management process in the incremental innovation will be equal to the radical innovation, with exception of the members that will identify and assess the risks. In the SunGravity Control® development, only some members from R&D and production will influence its development.

i. Risk identification

For the risk list with risk´s causes and effects of SunGravity Control® development, it was realized a brainstorming session with the personnel responsible for its development. The brainstorming session was based on the risk checklist of the radical innovation disregarding the application of the interview technique, since most of the risks were carried to the incremental innovation checklist. As we can confirmed in the following incremental risk checklist, it was added 4 specific risks of SunGravity Control® development and eliminated some of the risks correspondents to a radical innovation development, being the causes and effects different due to the nature of this product in study.

Table 16 - Risk checklist

Risk causes	Risk	Risk consequences
Misunderstanding of the best techniques of marketing for the specific case Price establishment	Marketing strategy	Unable to reach costumers
Inexistence of technology to meet market needs Deficient assessment of the product´s requirements to meet costumer´s needs	Technology alignment with market needs	Concept doesn´t satisfy market needs Product performance does not meet costumer´s need
Development of innovations from the competitors Market prices	Competitive market	Few costumers
Technology already existent in the market	Obsolete technology	Inexistence of competitive advantage
New technologies in the market are expensive Value added to the main product	Product viability	Costs bigger than benefits
Limited alternatives Inexperience of working with suppliers	Suppliers	Production delays High costs and delivery times Not respect its engagements
Limited budget	Enterprise’s resources	Poor quality tests Poor work profitability Lack of maintenance
Absence of documentation	Technical specifications	Suppliers mistakes
Few resources Few quality procedures	Technical testing	System malfunction Product guarantee inexistence Bad image
Technology inadequacy with main product	Product assembly with main product	Product performance limitations Unadoptable technology
Components without quality Work activities	Components sensibility	Misalignment of systems during installation
Creation of new market Technology uncertain	New technology	Market leader Innovative image
Choice of components	Production system performance	Competitive advantage Product malfunction
Product doesn´t meet with the requirements Certifications	Product quality	Product´s unsatisfactory performance High cost of product materials Product guarantee
Imitations Product patent and copyright	Product protection	Loss of competitive advantage Competitive advantage
Inexistence of process and procedures	Inadequate documentation	Poor professionalization and competent work
Market changes Technology limitations	Changes in requirements or standards	Slippage of the schedule Poor knowledge

Table 16 - Risk checklist (Continued)

Risk causes	Risk	Risk consequences
Misjudgments of capacity of work Interruption of the work Limited resources Projects more urgent	Schedule expectations	Work overload High pressures Schedule slippage in dependent activities
Few multidisciplinary personnel Absence of qualified personnel	Availability of skilled staff	Poor quality of work Few capabilities in certain technical domains Personnel shortfalls
Inadequate communication Unconsciousness of responsibility Centralization Too much pressure in meeting the schedule planned	Team work	Poor quality of work Poor work profitability
Changes in team members	Inadequate project experience	Inadequate tests Poor confidence in the team Slippage of the schedule
Poor quality of partners work Capital investment	Development partners	Unconsciousness of responsibility Raise of resources Disagreements Loyalty
Components sensibility Poor product quality	Resources needed after installation	Uncontrollable costs Stock rupture

Afterwards it was analyzed the risk likelihood and consequence from each NPDT members through the standard forms, in order to obtain the average results of each assessment (table 17 and 18) and to begin with the risk analysis phase.

Table 17 - Overall risk likelihood

Risk	NPDT member 1	NPDT member 2	NPDT member 3	Average
Marketing strategy	0.5	0.9	0.6	0.67
Idea alignment with market needs	0.3	0.7	0.4	0.47
Competitive market	0.3	0.7	0.7	0.57
Obsolete technology	0.3	0.4	0.2	0.30
Product viability	0.4	0.5	0.9	0.60
Suppliers	0.9	0.9	1.0	0.93
Enterprise's resources	0.5	0.3	0.2	0.33
Technical specifications	0.7	0.3	0.7	0.57
Technical testing	0.7	0.8	0.9	0.80
Product assembly with main product	0.7	0.2	0.5	0.47
New technology	0.4	0.4	0.6	0.47
Product system performance	0.5	0.1	0.2	0.27

Table 17 - Overall risk likelihood (Continued)

Risk	NPDT member 1	NPDT member 2	NPDT member 3	Average
Product quality	0.5	0.3	0.6	0.47
Product protection	0.4	0.5	0.4	0.43
Inadequate documentation	0.7	0.6	0.6	0.63
Changes in requirements or standards	0.4	0.6	0.7	0.57
Schedule expectations	0.9	0.9	1.0	0.93
Availability of skilled staff	0.9	0.4	0.4	0.57
Team work	0.6	0.3	0.6	0.50
Inadequate project experience	1.0	0.2	0.4	0.53
Development partners	0.7	0.3	0.8	0.60
Resources needed after installation	0.5	0.8	0.9	0.73

Table 18 - Overall risk consequence

Risk	Technical Consequence				Schedule consequence				Cost consequence			
	1	2	3	Average Ct	1	2	3	Average Cs	1	2	3	Average Cc
Marketing strategy	0.2	0.1	0.1	0.13	0.4	0.2	0.2	0.27	0.6	0.7	0.7	0.67
Idea alignment with market needs	0.7	0.9	0.9	0.83	0.5	0.7	0.3	0.50	0.3	0.5	0.8	0.53
Competitive market	0.2	0.2	0.2	0.20	0.2	0.1	0.2	0.17	0.7	0.6	0.9	0.73
Obsolete technology	0.2	1.0	0.9	0.70	0.7	1.0	0.2	0.63	0.7	1.0	0.7	0.80
Product viability	0.4	0.5	0.5	0.47	0.1	0.2	0.1	0.13	0.6	0.7	0.7	0.67
Suppliers	0.5	0.2	0.8	0.50	0.5	0.4	0.8	0.57	0.8	0.4	0.9	0.70
Enterprise's resources	0.5	0.6	0.7	0.60	0.5	0.8	0.6	0.63	0.3	0.2	0.5	0.33
Technical specifications	0.8	0.8	0.8	0.80	0.4	0.5	0.3	0.40	0.7	0.3	0.7	0.57
Technical testing	1.0	0.4	0.9	0.77	0.5	0.5	0.3	0.43	1.0	0.2	0.7	0.63
Product assembly with main product	0.7	0.8	0.9	0.80	0.3	0.2	0.2	0.23	0.2	0.2	0.5	0.30
New technology	0.2	0.2	0.8	0.40	0.5	0.2	0.1	0.27	0.5	0.8	0.5	0.60
Production system performance	1.0	0.3	0.9	0.73	0.7	0.4	0.7	0.60	0.5	0.4	0.7	0.53
Product quality	0.8	0.5	0.7	0.67	0.3	0.4	0.2	0.30	0.5	0.5	0.7	0.57
Product protection	0.1	0.1	0.1	0.10	0.1	0.1	0.3	0.17	0.2	0.3	0.7	0.40
Inadequate documentation	0.7	0.3	0.3	0.43	0.2	0.2	0.4	0.27	0.2	0.2	0.6	0.33
Changes in requirements or standards	0.6	0.8	0.8	0.73	0.3	0.9	0.3	0.50	0.3	0.6	0.5	0.47
Schedule expectations	0.1	0.5	0.3	0.30	0.9	1.0	1.0	0.97	0.3	0.4	0.6	0.43
Availability of skilled staff	1.0	0.9	0.8	0.90	0.5	0.9	0.4	0.60	0.5	0.3	0.6	0.47
Team work	0.4	0.8	0.6	0.60	0.5	0.8	0.3	0.53	0.3	0.4	0.2	0.30
Inadequate project experience	0.2	0.6	0.1	0.30	0.9	0.8	0.3	0.67	0.3	0.8	0.6	0.57
Development partners	0.8	0.8	1.0	0.87	0.8	0.4	1.0	0.73	0.7	0.3	0.9	0.63
Resources needed after installation	0.3	0.2	0.6	0.37	0.5	0.3	0.3	0.37	0.7	0.9	0.7	0.77

ii. Risk analysis

The next table will show the WRF of each risk, in descendent way according to risk´s severity to the project.

Table 19 - SunGravity Control® WRF

Marketing risk	Technical consequence			Schedule consequence			Cost consequence			Total WRF
	P	Ct	WRF	P	Cs	WRF	P	Cc	WRF	
Marketing strategy	0.67	0.13	0.28	0.67	0.27	0.15	0.67	0.67	0.36	0.79
R&D risk	**Technical consequence**			**Schedule consequence**			**Cost consequence**			**Total WRF**
	P	**Ct**	**WRF**	**P**	**Cs**	**WRF**	**P**	**Cc**	**WRF**	
Technical testing	0.80	0.77	0.38	0.80	0.43	0.18	0.80	0.63	0.37	0.93
Resources needed after installation	0.73	0.37	0.33	0.73	0.37	0.17	0.73	0.77	0.38	0.87
Technical specifications	0.57	0.80	0.37	0.57	0.40	0.15	0.57	0.57	0.32	0.84
Changes in requirements or standards	0.57	0.73	0.35	0.57	0.50	0.16	0.57	0.47	0.31	0.82
Idea alignment with market needs	0.47	0.83	0.36	0.47	0.50	0.15	0.47	0.53	0.30	0.81
Obsolete technology	0.30	0.70	0.32	0.30	0.63	0.15	0.30	0.80	0.34	0.81
Product viability	0.60	0.47	0.31	0.60	0.13	0.13	0.60	0.67	0.35	0.79
Inadequate documentation	0.63	0.43	0.32	0.63	0.27	0.15	0.63	0.33	0.30	0.77
Product quality	0.47	0.67	0.33	0.47	0.30	0.13	0.47	0.57	0.31	0.76
Competitive market	0.57	0.20	0.26	0.57	0.17	0.13	0.57	0.73	0.35	0.74
Product assembly with main product	0.47	0.80	0.36	0.47	0.23	0.12	0.47	0.30	0.25	0.73
New technology	0.47	0.40	0.27	0.47	0.27	0.12	0.47	0.60	0.31	0.71
Product protection	0.43	0.10	0.20	0.43	0.17	0.11	0.43	0.40	0.26	0.57
Production risk	**Technical consequence**			**Schedule consequence**			**Cost consequence**			**Total WRF**
	P	**Ct**	**WRF**	**P**	**Cs**	**WRF**	**P**	**Cc**	**WRF**	
Suppliers	0.93	0.50	0.39	0.93	0.57	0.19	0.93	0.70	0.39	0.97
Product system performance	0.27	0.73	0.32	0.27	0.60	0.14	0.27	0.53	0.26	0.73

Table 19 - SunGravity Control® WRF (Continued)

Management risk	Technical consequence			Schedule consequence			Cost consequence			Total WRF
	P	Ct	WRF	P	Cs	WRF	P	Cc	WRF	
Schedule expectations	0.93	0.30	0.38	0.93	0.97	0.20	0.93	0.43	0.38	0.97
Development partners	0.60	0.87	0.38	0.60	0.73	0.18	0.60	0.63	0.34	0.90
Availability of skilled staff	0.57	0.90	0.38	0.57	0.60	0.17	0.57	0.47	0.31	0.86
Inadequate project experience	0.53	0.30	0.27	0.53	0.67	0.17	0.53	0.57	0.32	0.76
Team work	0.50	0.60	0.32	0.50	0.53	0.15	0.50	0.30	0.26	0.73
Enterprise´s resources	0.33	0.60	0.29	0.33	0.63	0.15	0.33	0.33	0.22	0.67

For a better analysis of the risk´s priority in terms of severity to the project it will be made the following bar charts according to the correspondent functional area. Relatively to marketing functional area it won´t be interest in doing a bar chart since in this incremental innovation there only be one risk indicator, the marketing strategy. As we can verify in the table 19, marketing strategy has a WRF of 0.79, being consider according to the table 13 a high risk to the project. Therefore, it´s necessary to execute a risk response plan to face this risk.

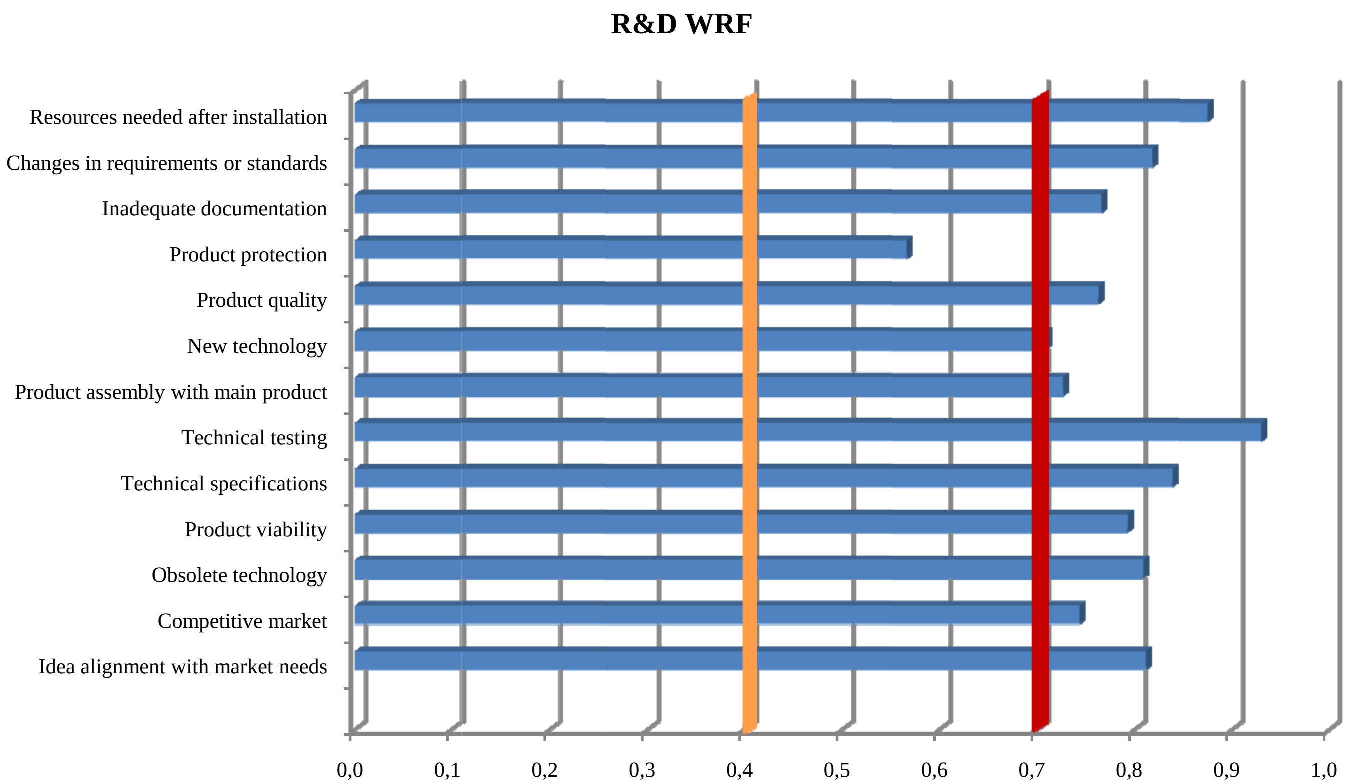


Figure 30 - R&D WRF

Regarding to the R&D risks, only one of thirteen risks is moderate, the product protection. The risk response plans for this risk will be selected according to the will of top managers. Almost all decisions, but not all, when facing moderate risks to the development projects stay in stand-by waiting for the development of the product. During the development, if the risk enhances more severity it will be taken appropriate procedures to manage it. Relatively to the other risks in R&D, it will be selected according to their priority the appropriate risk response strategies.

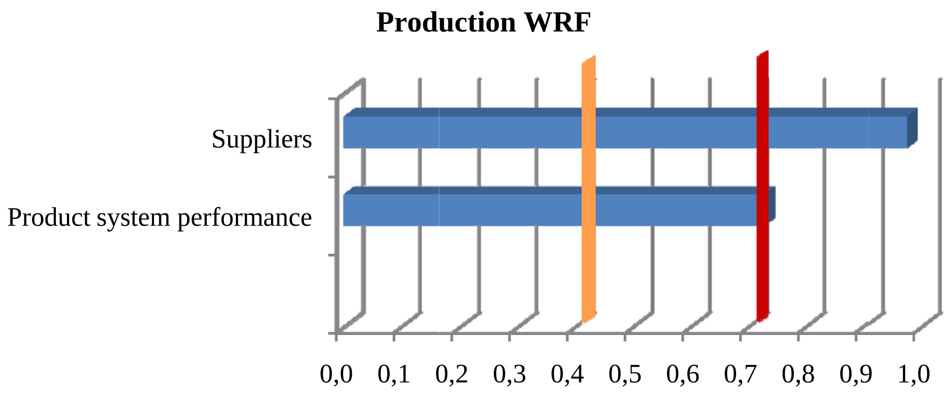


Figure 31 - Production WRF

The two production risks of the SunGravity Control® development have both high severities to the project. However, the supplier´s indicator call attention to risk response phase since with other risk has the highest score of WRF. It is possible to conclude that this incremental innovation development is extremely influenced with the supplier´s conditions. Therefore all of these two risks need a suitable risk response strategy, supplier´s indicator in special.

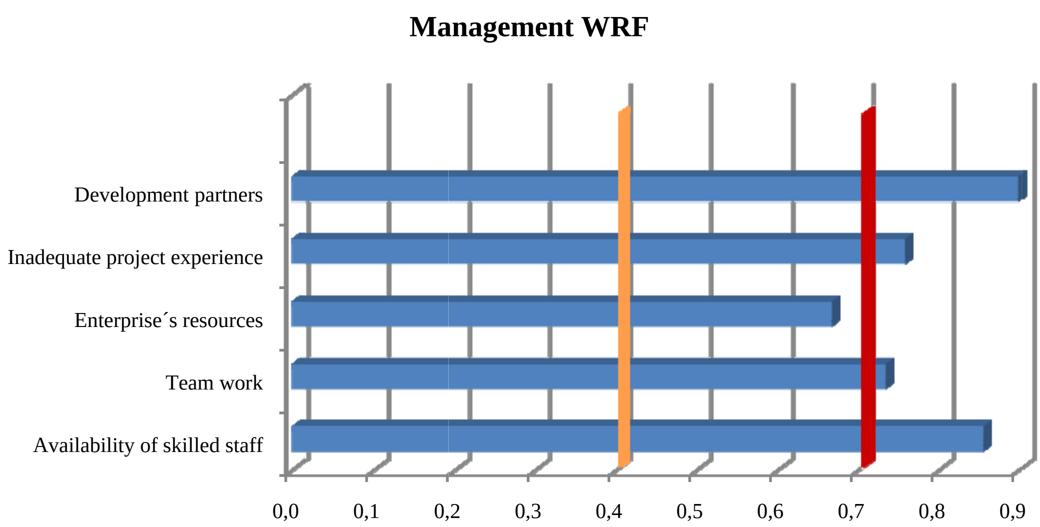


Figure 32 - Management WRF

Relatively to management risks, all of them pass the red limit line of 0.7 with the exception of enterprise´s resources indicator which entails a moderate risk. This implies that the others four are high risks to the project but with different severity rankings. Being the schedule expectations indicator the highest risk with a WRF of 0.97, the strategy to face this risk should be exceptionally examined to not let happen the risk´s consequences. To the other high risks it should be addressed in advance the appropriate risk response strategies. The low level of WRF of enterprise´s resource could be explained due to WS Energia already have all the resources required to develop this product. However, managers should control these risk and if needed apply the appropriate treatment.

Since in development process of this incremental innovation, only 4 functional areas influence the development, from which Marketing only have one risk and production three, it won´t be interesting in analyze through a 3D chart which functional areas project manager have to focus their efforts.

iii. Risk response

Like it was executed in radical innovation, during the risk response phase of the incremental innovation it will be described the response actions within each response strategies, for project managers decide which actions they should apply to the SunGravity Control® identified risks. The risk´s treatment can be achieved through avoidance, mitigation, transference, acceptance, enhance, share, and exploit. For more detailed information about the methodology to apply in this phase please go to the chapter 3.c. iii. The risk response actions of this chapter will be showed in the annex 8.

iv. Risk control

As referred earlier, each phase of the risk management process of the incremental innovation will be accomplished through the same methods of the radical innovation risk management. However, since we are in presence of different innovation, the risks to be controlled during each NPD gate will be different as it is revealed in the following Figure. This Figure will properly provide the risks that managers have to be worried when NPD is taking in place. For more detailed information about the methodology to apply in this phase please go to the topic 3. c. iv.

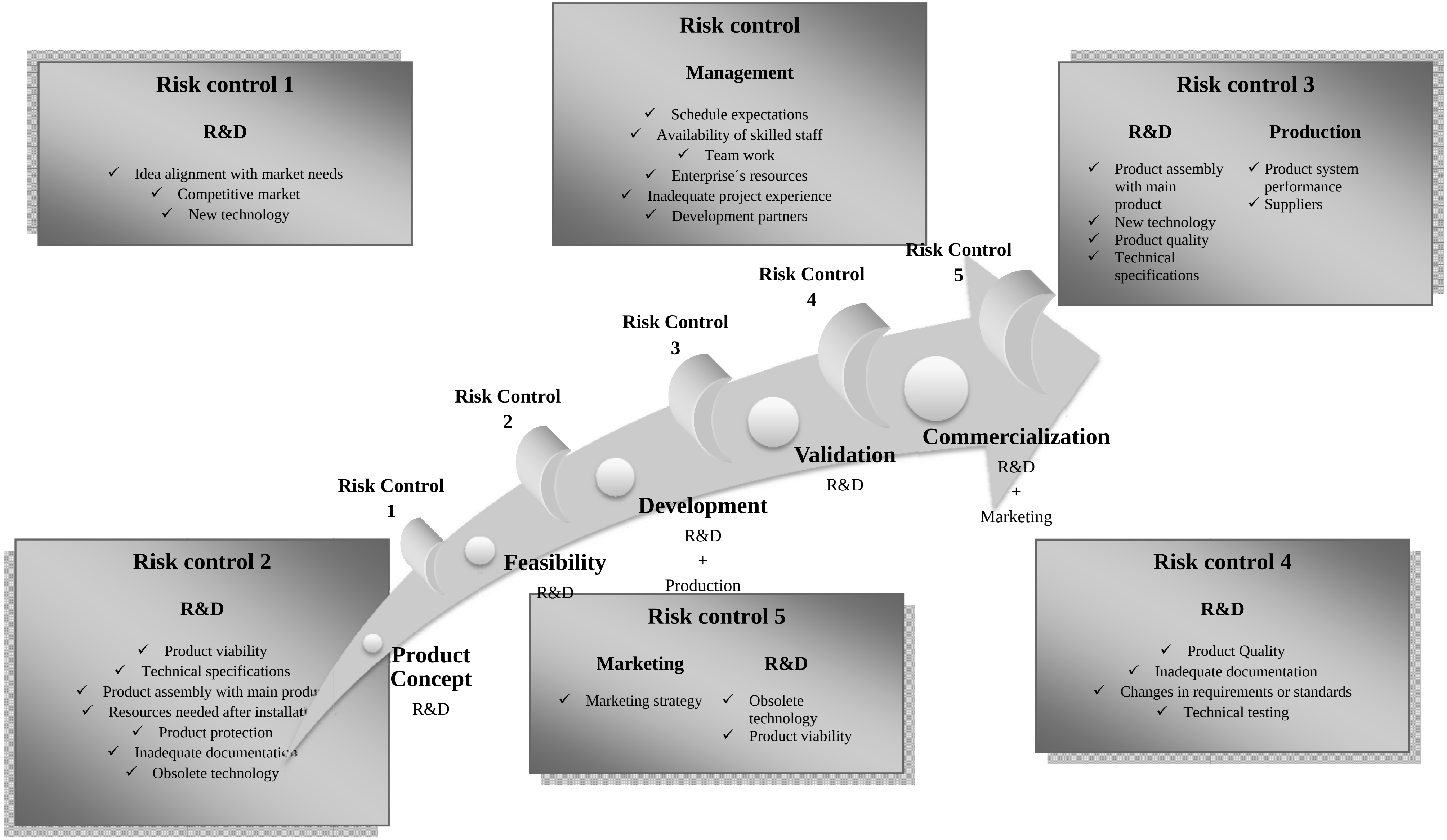


Figure 33 - SunGravityControl® risk control

5. MAIN CONCLUSIONS AND FUTURE RESEARCH

a. Main conclusions

For the application of an efficient and effective risk management methodology on new product development process it is essentially to elaborate a precise process. Actually, as the risk management methodology developed in this work is based on the NPD process, any failure in characterizing this process will influence its risk management in terms of identifying the risk causes, sources, and consequences, as in controlling the NPD risks during the development process.

According to the requirement described above, this work goes beyond of only develop a practical risk management best practice for NPD process. Since there still exists some level of ambiguity regarding the NPD process thematic, this thesis aims on developing an approach of NPD process. Based on organizational theory, empirical research, and a six month NPD monitoring, it was verified that the NPD process is influenced by the state of product development, the functional areas which are needed to develop the product, and the nature of innovation. This work improved the common NPD process, proposing a universal NPD process for the innovation life cycle of enterprises for both radical and incremental innovations.

The innovation life cycle gather complementarily radical and incremental innovation in a continuous way, to ensure a competitive advantage for enterprises over a long-term. According to their necessity at that time, enterprises adopt radical innovation to create competitiveness and incremental innovation to keep companies competitive. The choice of distinguishing innovations in these two categories was made only for a management perspective. In fact, what truly influences management is the complexity and level of knowledge of the activities to develop innovations, which if high, will probably increase the generation of uncontrollable risks. While incremental innovation should allow quick competitive advantage and a low project cost, the decision to innovate radically promotes greater changes to the organization´s operations incorporating a complex fusion of ideas and knowledge from different organizational domains. Thus, to propose a universal risk management methodology for all types of new product development processes, the conceptual NPD process was constructed according to the nature of the innovation, either radical or incremental innovation. Since incremental innovation incorporates less functional collaboration to be commercialized, and as for develop SunGravity Control® it was only needed a multidisciplinary R&D personnel with comprehensive knowledge in all functional areas, this universality was accomplished through incorporating a reasonable level of flexibility on the NPD process. Curiously, the enterprise´s resources risk have different severity to the two innovation development process. While in radical innovation this risk is considered a high risk to the project with a WRF of 0.84, in the incremental innovation it only had 0.67. Besides indicating that for SunGravity Control®, WS Energia have all the resources needed to develop it, it implies that the development of incremental innovation have less complexity and functional collaboration.

For DoubleSun´s® development process, the functional area which entailed the most severe risks to the project was the R&D with almost all risks above 0.8 of WRF. This is in accordance with common knowledge that the risks in developing new products are usually generated from a technical nature. However, it was verified that more than 60% of the risks identified in DoubleSun´s® development process were generated from different functional areas. Thus, it was shown that NPD risks are not only generated from a technical nature, but from all activities in developing new products executed by different functional areas. This complexity stimulates the integration of the functional areas in the NPD process to enable a better judgment to identify and assess the key activities and responsibilities that could create risks. Inclusive, it was verified that many risks were produced from the management domain, which was incorporated with the functional areas which generate risks to NPD. The assemblage of risks within the functional areas together with WRF plots improved the management effectiveness enabling the focalization of enterprise´s resources on the most severe functional areas addressing the risks to the parties that better deal with them.

The NPD process is therefore a major tool to identify, assess, and control the risks originated from that process. Since the risk management model for NPD process developed in this work aims to most of all satisfy enterprises´ necessities of identifying the NPD risks, properly select the best risk response strategies in advance, and continuum control risks during the new product development process, this work recommends the construction of a NPD process for an effective application of a risk management methodology. The consistent application of the NPD process over the innovation life cycle will provide great risk identification and consequently, its ideal evaluation through its data organization in stages and in the respective functional areas. It will also allow the application of a risk control methodology on the stage-gates of the NPD process.

The majority of enterprises manage the risks on new product development process only once they occur. Certainly this will happen during the development process, but in today´s competitive environment the idea of being expectant to what can happen seems clearly retrograde. Thus, the proposed risk management methodology composed by risk management techniques found in the literature review, suggests a risk management in advance and during NPD process, which if not done with diligence, could let major risks occur.

For the case studies conducted during this research on two distinct development processes in a photovoltaic company, before applying the risk management methodology it should be selected the appropriate type of innovation to characterize the nature of each development process. To make such selection, this work proposed to distinguish radical from incremental innovation, showing the characteristics that each type of innovation might have, contrarily to must have. Acknowledging that for the same type of innovation there will be innovations with distinct specificities and characteristics, the innovation could gather characteristics from both types of innovation. However, in overall the appropriate type of innovation will cover most of its characteristics, which will mainly gather the similar level of change, knowledge, and complexity.

The proposed risk management methodology was developed for NPD process in general. For each type of process, it must be integrated specific parameters allowing a precise management for distinct NPD process, which became innovations. During the risk identification, it was verified that there is a natural resistance or reluctance to identify and assess risks on anything other than in their negative issues. Before any approach with NPDT members, this work recommends the existence of a risk facilitator or a project manager who should brief team members about, besides other aspects, the possibility that some of the consequences of each risk could generate positive risks to the NPD process for potentiate opportunities. Also, during the interviews with each NPDT members to assess risks, it was verified that not all members understood the real impact, being positive or negative, of each risk on the project. Many questions were made from the interviewed, asking what the consequences of each risk are. Therefore, before the semi-quantitative analysis taking place, this work proves the necessity of specify or characterize the causes and effects of each risk before any extended analysis, as well as the necessity of respondents being prepared for the interview. The application of individual interviews, stimulate NPDT members in bringing forward their interpretation of risks, disregarding the opinion of others.

Since the inputs of this risk management model are obtained from the personnel involved in the product development process, the project manager for the application of this methodology should be effective in acquire information reducing any ambiguity and time during the collection of the data needed.

It is recognized among innumerous researchers that the results of managing risks in advance are substantial superior than manage the risks in the instant of occurrence. But since projects rarely proceed exactly according to plan and the risk assessment may be imprecise before the product is developed, the differentiation of the risk management application into during and before the NPD process satisfies the real enterprise´s necessity. Moreover, the risk management methodology is differently applied on these two domains. Before the NPD process it is applied the risk identification, risk analysis, and risk response. During the NPD process it is taken a risk control within each gate, assessing the risk of each stage and evaluating if the new product should pass to the next stage. In case of uncontrolled risks, project manager should apply the risk analysis phase and the risk response phase. The risk management during the NPD process could even be controlled by top managers allowing them to view the risk exposure associated with the project and check if all possible steps to reduce or manage the risks have been taken. For many top managers, this issue will be extremely important since nearly all managers feel the necessity to overview and specially to know what is being done in this context. This model is a best practice risk management for the development of new products.

The techniques used in the risk management model, responded to the management necessity of WS Energia NPD process. Citing WS Energia´s administrators "*this Risk Management model for NPD process is not interesting, it is a necessity*". They believe that the adoption of the Risk Management methodology for NPD process will reduce the critical risks, raise the level of industrial competitiveness to commercialize new products and reduces the new products development time and costs, improving company´s sustainability.

b. Future research

After developing this work, it is recommended future research in the proposed New Product Development model (NPD model), and in the risk response and risk analysis phases of the risk management process.

NPD model - The universality of the proposed NPD model allows between other applications, the modulation of the best techniques to manage the risks of all types of new products that enterprises want to develop. The application on only two types of NPD proccessses do not confirm the aim of this work in developing an universal NPD model. Diferent analysis on this model should be taken in place in order to verify its universal validity through an appropriate sample of NPD processes.

Risk response - The risk response actions described in the respective risk management phase of radical and incremental innovation were essentially executed to provide a general but efficient data for project managers decide which response strategy is more appropriate to deal with the specific risk. Basically, they were generated from past NPD projects, a six month NPD monitoring, and from literature review. However, for such description and posterior strategy selection, extensive knowledge of all project management knowledge areas, such as integration management, scope, time, cost, quality, human resource, communications, and procurement management should also be applied. Thus, the selection of the risk response actions goes beyond of the aim of this dissertation which is about of only one of the project management knowledge areas, the risk management. However, since the model developed aims to satisfy all management necessities of NPD process, it was executed a comprehensive and brief research to determine the best techniques for selecting the appropriate risk response strategy. According to this research, this work recommends that the selection should be accomplished comparing the data provided by the probability of the risk occurrence, its consequences within three enterprise´s domains, and its WRF provided by the risk management model developed in this work. However, is most likely to have for each risk, more than one kind of appropriate responses. In these special cases where there will be major uncertainties of which risk response strategies should be adopted and more strategies could equal be selected to the specific risk, the decision maker should adopt auxiliar tools to select the appropriate strategy. This work recommends for future research the study of a Fuzzy Logic model to select the appropriate strategy in these cases. When the decision maker is facing this doubt, only the variables of the resources needed to implement that strategy, the cost and time in meeting the challenge, and its impact are needed to dissipate his or her doubt.

Risk analysis - For future research, it will be interesting in integrating quantitative analysis in this risk management model in order to reduce the bias of risk analysis. While through sensitivity analysis it´s possible to determine which risks have the most potential impact on the project, the Expected Monetary Value (EMV) statistical analysis can calculate the average outcomes under uncertainty. The transformation of the inputs into probability distributions can be used extensively in modeling and simulating specific detailed uncertainties, typically performed using the Monte Carlo technique. In fact, these tools can provide very interesting analysis, however in order to successfully apply Monte Carlo in the risk management of NPD process, this work also recommends that it should be taken future researches in measuring and controlling the bias of transforming deterministic data into probabilistic. It will be interesting too, in employing variance analysis to compare the planned results to the actual results: The Earned value analysis indicates the potential deviation of the project from cost and schedule targets, and the technical performance measurement compares technical accomplishments to the plan´s schedule of technical achievement. These techniques can help to forecast the degree of success in achieving the project´s scope.

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Annex 1

Table based on literature review, which contain a risk list of NPD process within 5 functional areas

Literature risk list				
Marketing	**R&D**	**Production**	**Quality**	**Management**
Changing market conditions	Obsolete technology	Product system performance	Inadequate documentation	Schedule expectations
Economic crisis	Technical capability to correspond to market needs	Product quality	Changes in requirements or standards	Unrealistic budget
Definition of market opportunities	New technology	Incomplete requirements		Availability of skilled staff
Idea alignment with market needs	Product viability	Suppliers		Team work
Competitive market	Technical specifications			Change in team members
	Technical testing			Inadequate project experience
	Product protection			Capital investment
				Organization structure alignment
				Partnerships
				Enterprise´s resources

Annex 2

Risk list of DoubleSun´s® development process, full fielded by PhD Eng Gianfranco Sorasio

Project:	DoubleSun®			Reference:
Element:	PhD Eng Gianfranco Sorasio			
Marketing	**R&D**	**Production**	**Quality**	**Management**
Marketing acceptance	Feasibility of the product in application with existent technology (Inverters, modules PV)	Suppliers limitations (1 supplier)	Product guarantee	Schedule expectations
Product´s image	Technical testing (performance of a central)		Inadequate documentation	Budget
Uncertain technology (Cost/benefits ratio)	Existence of complementary products (performance of existent components)			Logistics (transportation)
	Complex installation of the product (weight danger)			Capital market
	Few resources			

Annex 3

Risk list of DoubleSun´s® development process, full fielded by Msc Eng João Wemans

Project:	DoubleSun®			Reference:
Element:	Msc Eng João Wemans			
Marketing	**R&D**	**Production**	**Quality**	**Management**
Existent market technologies	Poor technology performance (product resistance, deficient tracking)	Suppliers relation (1 supplier)	Policies	Team capabilities (mechanic and electric knowledge)
Business strategy (Final client)	Product tests (product life and quality)		Inadequate documentation	Logistics (transportation)
Shadows on the system due to trees or other objects	Performance of the standard PV modules under concentration			Team work
				Partnerships

Annex 4

Risk list of DoubleSun´s® development process, full fielded by PhD Eng Luís Pina

Project:	DoubleSun®			Reference:
Element:	PhD Eng Luís Pina			
Marketing	**R&D**	**Production**	**Quality**	**Management**
Marketing strategy	Few resources for tests (Product quality, image, reparation)	Product performance	Product specifications (wrong product specifications)	Personnel capabilities
Product´s alignment with market needs	Suppliers quality	Components fabrication (How far it´s interesting to produce x material)	Standard PV modules are not certificated for low concentration applications	Logistic (Lead time)
Strategy ambit of the product (product based only in ROI disregarding maintenance)	Technical characteristics			Distribution channels
Strong competitive market	Relation of high-technology and expenditures			Interruption of work (urgencies)
	Misalignment of systems during installation			Organizational structure alignment

Annex 5

Risk list of DoubleSun´s® development process, full fielded by Eng Rodrigo Rodrigues

Project:	DoubleSun®			Reference:
Element:	Eng Rodrigo Rodrigues			
Marketing	**R&D**	**Production**	**Quality**	**Management**
Market conditions	Product performance	Quality of suppliers	Documentation	Partnerships and outsourcing
Competitiveness	Application in standard components	Assembly line	Technical tests	Team competences
Real specifications of product requirements to satisfy customer´s needs	Assembly and transportation limitations		Quality control	Schedule
Product viability				Logistics and transportation

Annex 6

Risk checklist of DoubleSun´s® development process

Risk checklist				
Marketing	**R&D**	**Production**	**Quality**	**Management**
Changing market conditions	Obsolete technology	Product system performance	Inadequate documentation	Schedule expectations
Economic crisis	Technical capability to correspond to market needs	Product quality	Changes in requirements or standards	Availability of skilled staff
Definition of market opportunities	Product viability	Assembly line	Policies	Team work
Marketing strategy	Technical specifications	Suppliers		Inadequate project experience
Idea alignment with market needs	Application with existent technology			Capital investment
Competitive market	Technical testing			Organization structure alignment
Price establishment of the product	Product assembly and transportation			Partnerships
Business strategy	Components sensibility			Enterprise´s resources
Product specification require to meet costumer´s need	New technology			
Distribution channels	Product protection			
	Product dimensions			

Annex 7

Risk response actions for DoubleSun´s® risks

Risk:	Idea alignment with market needs		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Market research Concurrent analysis Surveys	Implement feedback systems	Outsourcing	
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Create new markets			

Risk:	Product specification require to meet costumer´s need		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Concept testing using renderings or user-interface prototypes	Implement feedback systems		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Definition of market opportunities		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Market research Implement Marketing-mix			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Realization of ANSOFF matrix Implementation of powders-sales service	Periodic realization of market analysis		

Risk:	Distribution channels		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Partner´s Competitor´s analysis Carry out a logistic analysis	Periodic evaluation of the distribution channels		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Differentiation		

Risk:	Competitive market		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implement Porter´s five forces model Perform a SWOT analyze	Realize periodically SWOT analysis		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Competitive advantage		

Risk:	Price establishment of the product		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Benchmarking Sales forecasting			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Quality/price ratio		

Risk:	Changing market conditions		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implement prevision techniques Implement marketing-mix	Periodic market research		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
New market opportunities			

Risk:	Business strategy		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Realize business plan			
Develop balance scorecard			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Differentiation		

Risk:	Technical specifications		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Strong documentation	Implement feedback systems		
Standard conceptualizations			
	Potentiate communication between stakeholders		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	New technology		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Combining proven technology	Analysis of performance		
Realization of specific tests	Raise resources		
Consult expert professionals			
Create multiple solutions			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Level of innovation		

Risk:	Technical testing		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Defining requirements and procedures Incorporate time testing in project schedule Infrastructure managers of resources	Periodic feedback meetings		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Material certifications			

Risk:	Product viability		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Definition of the cost and price target	Replace components Implement new components		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Quality and performance differentiation			

Risk:	Application with existent technology		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Utilization of proven technologies Realization of specific tests Material certifications			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Utilization of technologies which are commercialized for an interesting number of companies	Utilization of proven technologies		

Risk:	Enterprise´s resources		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Quantify the resources needed for the WBS Raise resource´s budget	Periodic evaluate resource´s performance Periodic realize market analysis	Create partnerships	Accept limitations
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Forming and training personnel		

Risk:	Product dimensions		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Analysis of all product applications 3D documentation	Potentiate communication between R&D and Marketing		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Several possibilities of application	Product´s image		

Risk:	Obsolete technology		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Market analysis Raise speed-to-market process Change technology	Implement new components		Accept market uncertain environment
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Components sensibility		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Replace components	Field tests Implement adequate work equipment	Restrict company´s responsibilities in contracts	Implementation of a maintenance plan
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Technical capability to correspond to market needs		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Recruit expert professionals Raise company´s resources	Forming and training professionals	Outsourcing	
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Technical level of innovation		

Risk:	Product protection		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Copyright and patenting			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Competitive advantage		

Risk:	Suppliers		
Functional area:	Production		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implementation of quality assurance task forces Application of penalties Multiple suppliers	Identify dependent activities Periodically measure the partner´s productivity and efficacy Organization of meetings	Definition of the responsibilities in a contract	
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Supplier´s condition		

Risk:	Product system performance		
Functional area:	Production		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Identify dependent activities Utilization of proven technology	Replace defaulting components Implement quality procedures Realization of specific tests		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	High product performance		

Risk:	Product quality		
Functional area:	Production		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Use components with quality certifications Implement procedures Auditioning	Measure customer satisfaction Realization of specific tests		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Quality certification	Enterprise´s image		

Risk:	Assembly line
Functional area:	Production
Contingent response strategy:	Realize a production plan Specify production procedures

Risk:	Changes in requirements or standards		
Functional area:	Quality		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Restrict changes after the feasibility stage	Periodic product performance analysis		Change as faster as possible
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Inadequate documentation		
Functional area:	Quality		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Develop document templates	Document all activities		
Documentation done by experts	Flowcharting the process		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Policies		
Functional area:	Quality		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Issue identification	Forming personnel	Consultation of experts	
Policy quantitative and qualitative analysis			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Partnerships		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implementation of quality assurance task forces Strong standard procedures	Periodically measure the partner´s productivity and efficacy Organization of meetings or conferences	Definition of the responsibilities in a contract	
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Future partner´s relationship	Communication Enterprise´s image		

Risk:	Capital investment		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Partnerships Candidate to financial programs	Research potential investors		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Enterprise´s image Press releases Participate in meetings and conferences		

Risk:	Schedule expectations		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Reinforce the NPDT with new members Organization of meetings Implementing milestones	Reassigning the focus of work Prioritize work objectives	Found outside expertise	
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Implementation of procedures		

Risk:	Team work		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Provide high level of support	Organizing meetings		
Recruit senior and junior professionals	Quality evaluation of members		
Organizing team buildings	Decentralization structure		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Communication		
	Good working environment		

Risk:	Inadequate project experience		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Recruit senior professionals			
Realize benchmarking analysis			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Effective work		

Annex 8

Risk response actions for DoubleSun´s® risks

Risk:	Marketing strategy		
Functional area:	Marketing		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implementation of multiple strategies	Flowcharting the process		
Past project knowledge	Periodic measure the customer satisfaction		
Realize a marketing plan			
Evaluate the best distribution marketing channels that match the marketing strategy			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Develop innovative marketing strategy	Differentiation		

Risk:	Technical testing		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Defining requirements and procedures	Periodic feedback meetings		
Incorporate time testing in project schedule			
Infrastructure managers of resources			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Utilization of quality certificate materials			

Risk:	Resources needed after installation		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Testing the product using renderings or user-interface prototypes Laboratory tests Specify technical requirements	Plan product maintenance	Maintenance contracts	
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Technical specifications		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Strong documentation Standard conceptualizations	Implement feedback systems Potentiate communication between stakeholders		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Changes in requirements or standards		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Restrict changes after the feasibility stage	Periodic product performance analysis		Change as faster as possible
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Idea alignment with market needs		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Market research Concurrent analysis	Implement costumer´s feedback systems	Outsourcing	
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Create new markets			

Risk:	Obsolete technology		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Market analysis Raise speed-to-market process Change technology	Implement new components		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Product viability		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Definition of the cost and price target	Replace components Implement new components		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Quality and performance differentiation			

Risk:	Inadequate documentation		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Develop document templates Documentation done by experts	Document all activities Flowcharting the process		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Product quality		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Use components with quality certifications Implement procedures Auditioning	Measure customer satisfaction Realization of specific tests		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Quality certification	Enterprise´s image		

Risk:	Competitive market		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implement Porter´s five forces model Realize SWOT analyze	Realize periodically SWOT analysis		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Competitive advantage		

Risk:	Product assembly with main product		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Specific technical tests with main product	Assembly performance analysis in laboratory and field		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Product performance		

Risk:	New technology		
Functional area:	R&D		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Combining proven technology	Analysis of performance		
Realization of specific tests	Raise resources		
Consult expert professionals			
Create multiple solutions			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Level of innovation		

Risk:	Suppliers		
Functional area:	Production		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implementation of quality assurance task forces	Identify dependent activities	Definition of the responsibilities in a contract	
Application of penalties	Periodically measure the partner´s productivity and efficacy		
Multiple suppliers			
	Organization of meetings		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Special supplier´s condition		

Risk:	Product system performance		
Functional area:	Production		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Identify dependent activities	Replace defaulting components		
Utilization of proven technology	Implement quality procedures		
	Realization of specific tests		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Product performance		

Risk:	Schedule expectations		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Reinforce the NPDT with new members	Reassigning the focus of work	Found outside expertise	
Organization of meetings	Prioritize work objectives		
Implementing milestones			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Implementation of procedures		

Risk:	Development partners		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Implementation of quality assurance task forces	Periodically measure the partner´s productivity and efficacy	Definition of the responsibilities in a contract	
Strong standard procedures			
Define milestones	Organization of meetings or conferences		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**

Risk:	Availability of skilled staff		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Recruit expert personnel	Potentiate communication	Consulting experts	
Define NPDT members roles	Evaluate personnel performance		
Management support			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
Resources	Work environment		

Risk:	Inadequate project experience		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Recruit senior professionals			Redefining schedule
Realize benchmarking analysis			
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Effective work		

Risk:	Team work		
Functional area:	Management		
Threat response:			
Avoidance	**Mitigation**	**Transference**	**Acceptance**
Provide high level of support	Organizing meetings		
Recruit senior and junior professionals	Quality evaluation of members		
Organizing team buildings	Decentralization structure		
Opportunity response:			
Exploit	**Enhance**	**Share**	**Acceptance**
	Communication		
	Good working environment		