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UNCERTAINTY MANAGEMENT IN SOFTWARE PROJECTS

Ph.D. Thesis

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The future is uncertain... but this uncertainty is at the very heart of human creativity.

—ILYA PRIGOGINE

Resumo

Vários tipos de projetos são propostos, com diferentes objetivos, em que é preciso gerenciá-los estrategicamente de acordo com metas organizacionais. Projetos bem sucedidos aumentam as vendas, reduzem os custos, melhoram a qualidade, a satisfação do cliente, o ambiente de trabalho, entre outros benefícios. Assim, um número crescente de empresas utilizam o gerenciamento de projetos como uma estratégia fundamental para manter a competitividade, aumentando a possibilidade de valor aos seus negócios. No entanto, muitos projetos com todos os ingredientes para o sucesso, falham. Um dos motivos porque isso acontece relaciona-se com a não avaliação das incertezas pelos executivos, gerentes e equipe do projeto. Em um ambiente de desenvolvimento de software típico não é diferente. Baseado nisso, o objetivo geral deste trabalho é propor uma abordagem para gerenciar as incertezas em projetos de software, contribuindo assim para um melhor desempenho dos projetos de software e influenciando no seu sucesso. O método de pesquisa adotado neste trabalho está fundamentado nos princípios da Engenharia de Software baseado em evidências. Foi realizada uma pesquisa exploratória da literatura sobre gerenciamento das incertezas em projetos de software. Em seguida, de forma mais estruturada, foi realizada uma revisão sistemática da literatura sobre o estado da arte do tema juntamente com uma pesquisa-ação, conduzida em um projeto de desenvolvimento de software. Além disso, entrevistas semi-estruturadas foram realizadas com especialistas da indústria de software e pesquisadores na área a fim de avaliar as evidências encontradas e adicionar insumos para a abordagem. Na fase de avaliação foi realizado um grupo focal com especialistas que avaliaram a abordagem proposta. Os resultados da revisão da literatura exploratória serviu para caracterizar a diferença entre riscos e incertezas e foram mapeadas as fontes de incertezas. Da revisão sistemática da literatura encontramos 5 formas de gerenciar as incertezas nos projetos e 18 práticas para o gerenciamento de projetos focando na redução das incertezas. Foi realizada uma confirmação das fontes de incertezas mapeadas nos estudos primários e avaliada a relação entre incertezas e projetos inovadores. Na pesquisa-ação pôde-se aplicar técnicas e estratégias em projetos e investigar se essas contribuíram para gestão da incerteza. Nas entrevistas semi-estruturadas foi avaliado e adicionado o ponto de vista prático para a abordagem. Finalmente, um grupo focal foi realizado para avaliar a abordagem elaborada. Os resultados desta pesquisa contribuem para a gestão de projetos de software por definir uma abordagem para o gerenciamento de incerteza, bem como descrevendo as estratégias e orientações para os membros da equipe.

Palavras-chave: Incerteza. Gerenciamento de Projetos de Software. Projetos de Software. Incertezas em gerenciamento de projetos. Incertezas em Projetos de Software.

Abstract

Various projects types are proposed with different objectives; it is necessary to manage strategically, according to organizational goals. Successful projects increase sales, reduce costs, improve quality, customer satisfaction, the work environment; among other benefits. An increasing number of companies use project management as a key strategy for maintaining competitiveness, increasing the value possibility to their business. However, many projects with all the ingredients for success fail. One reason for this is related to failure in assessing the uncertainties by executives, managers and project team. In a typical software development environment it is not different. Thus, the aim of this work is to propose an approach to manage uncertainties in software projects to contribute to their better performance and influence their success. The research method used in this work is based on the principles of Evidence-Based Software Engineering. During the guide conception stage an exploratory literature research on managing uncertainty in software projects and a systematic literature review on the state of the art theme in a more structured way along with an action research conducted in a software development project were conducted. In addition, semi-structured interviews with software industry experts and researchers in the field were carried out in order to obtain improvement to the approach. In the evaluation phase a focus group was conducted to evaluate the proposed approach. The results showed that an exploratory literature review helped to characterize the difference between risk and uncertainty and mapped the uncertainty sources. The systematic literature review found 5 ways to manage uncertainties in projects; 18 practices for project management focusing on reducing uncertainties; a confirmation of the uncertainty sources mapped in primary studies and the relationship between uncertainty and innovative projects was assessed. In the action research there was an application of techniques and strategies in projects and investigation on whether those contributed to uncertainty; in semi-structured interviews the addition of the practical point of view for the approach was evaluated and added. Finally, the focus group was performed to assess the elaborated approach. The results of this research contribute to software project management by defining an approach to uncertainty management, as well as describing strategies and guidelines for team members.

Keywords: Uncertainty. Software Project Management. Software Projects. Uncertainties in Project Management. Uncertainty in Software Projects.

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List of Acronyms

PRINCE2 - *Projects In Controlled Environments*.

PMBOK - *Project Management Body of Knowledge*.

RPM - *Rethinking Project Management*.

SPF - *Software Project Framework*.

WBS - *Work Breakdown Structure*.

PMI - *Project Management Institute*.

IT - *Information Technology*.

HROs - *High Reliability Organization*.

EBSE - *Evidence-based software engineering*.

EBM - *Evidence-based Medicine*.

HPCIn - *High Performance in Informatics Center*.

PCs - *Personal computers*.

Petrobras - *Brazilian multinational energy corporation*.

FPGA - *Field-Programmable Gate Array*.

GPUs - *Graphics Processing Unit*.

CPUs - *Central Processing Units*.

UFPE - *Federal University of Pernambuco*.

PMO - *Project Management Office*.

MBA - *Master's in Business Administration*.

FG - *Focus Group*.

Contents

1

Introduction

"It is the uncertainty that charms one. A mist makes things wonderful"
Oscar Wilde

This introductory chapter presents the work's context and the main motivations for performing it. The following sections describe the objectives and the approach used to develop it, as well as its major contributions. Finally, the framework in which this document is organized is presented.

1.1 Contextualization

In recent decades, the world has gone through profound and rapid social, economic and cultural transformation. Some of the main contributing factors in this have been economic globalization and geopolitical redefinition, along with the scientific and technological evolution. One of the legacies of this transformation is the intensification of competition in the business environment (MARINHO; SAMPAIO; MOURA, 2014a).

This socio-economic environment of constant change poses enormous challenges to organizations. The search for competitive advantage makes the business environment increasingly complex with the centralization of corporate activities on core competencies, creating new employment relationships, such as outsourced workers; risky investments to reach niche markets, collaboration growth between companies, including competitors through alliances, among other factors (DIMAGGIO, 2009).

In this highly competitive environment, the property of agility, the ability to adapt and implement strategies, and the capability to continually offer new products and services have become major advantages, sometimes even requirements, for business survival. For any new product, process or service it is indispensable that innovation and innovation development projects are on the executive agenda, as well as developing understanding of changes in the business environment and the planned actions for responding to these changes or even influence them.

One of the way to respond to the above challenges is to strengthen management practices within projects, whether single or multi-functional. Project management leads to a more formal and centralized control which facilitates the progress of the firm towards becoming an organization of the future, in an ordered, delivered and non-chaotic way.

Project management has been discussed by executives and by academics as one of the possibilities of organizations to integrate complex efforts and reduce bureaucracy. Manage projects effectively is presented as a solution and at the same time, a major challenge of the business world. That is why projects and project management have an increasingly important role in society and are used as scientific research objects (KERZNER, 2009).

Many studies have associated the success and productivity of software projects with proper management, such as:

- Boehm (BOEHM, 1984) warned that poor management can increase the cost of software faster than any other factor;
- Scacchi (SCACCHI, 1984) affirmed that low productivity is directly related to bad project management;
- In the words of Brooks (BROOKS JR, 1964) “when coordination stops the work stops”;
- According to Simmons (SIMMONS, 1991), the main cause of large software project failure is often “poor management". The author also claims that good project managers help team members to remain motivated, committed and focused on project objectives.

Over the past 20 years there has been an improvement in the quality and rigor of project management research. There are an increasing number of citations, implying that the research is soundly based on recent theory development. Works are appearing in a much wider range of journals outside the field, suggesting that project management is contributing to a wider range of other disciplines. And the methodologies are becoming more rigorous, implying that the research is much sounder and can itself contribute to theory development (TURNER, 2010).

However, according to THE STANDISH GROUP (2013), 39% of projects are realized as successful, finished on time and complied with requirements and budget defined; 43% are delivered with time, cost and requisites settings modified in relation to agreed; and, finally, 18% are canceled on delivery and never used.

According Shenhar and Dvir (SHENHAR; DVIR, 2007) many projects with all the ingredients of success still fail. The reason for this is that executives, project managers and the project team are not accustomed to assess and analyze uncertainties, and so fail to adapt their management style to the situation.

Nowadays it is noticed that many projects fail; software projects are notoriously disaster prone, not necessarily because of technological failure, but more often due to uncertainties.

Various project management approaches do not consider the impact that uncertainty has in software project management.

The uncertainty level is co-related with the existing quantity of information about the subject involved (WIDEMAN, 1992). In figure 1.1 it is shown an uncertainty spectrum in which **knowns** when there is complete and enough information about what may happen and its impact on the project objectives, the certainty is total; **known unknowns**, if the information is partial, it is known that there is any probability for the event to happen and it is possible to evaluate the probable impact on the project objectives so it is risks; **unknown unknowns**, when there is a complete lack of knowledge of what is going to happen it is the uncertainty.

Figure 1.1: Spectrum Uncertainty
Source: Adapted from WIDEMAN (1992)

The methodologies for project management, as PRINCE2 - *Projects In Controlled Environments* (OGC, 2009) and best practices such as PMBOK Guide - *Project Management Body of Knowledge Guide* (PMI, 2013) suggest processes, techniques and tools to be followed and used to successfully achieve the project objectives, managing events that can impact them negatively or positively. Thus, the first two uncertainty levels (*knowns and known unknowns*) are included in these methodologies and practices (RUSSO, 2012).

The PMBOK indicates that "certain unknown risks can not be managed proactively, for which it suggests that projects shoud have a contingency plan". However, to generate a contingency plan it is necessary knowledge of the risk, so the PMBOK does not check the uncertainties' type *unknown unknowns*.

Relating to uncertainties, some studies (WEICK; SUTCLIFFE, 2001; SHENHAR; DVIR, 2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; CLEDEN, 2009; WYSOCKI, 2010; LOCH; DEMEYER; PICH, 2011; WEICK; SUTCLIFFE, 2011; O'CONNOR; RICE, 2013; MARINHO et al., 2013) criticize the current project management practices based on advance planning. They suggest the use of different approaches according to the uncertainty and complexity combination.

In addition, several authors (PENDER, 2001; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; MURRAY-WEBSTER; PELLEGRINELLI, 2010; LOCH; DEMEYER; PICH, 2011) say that risk management based on planning is not enough to manage uncertainties generated by restrictions and project areas which are not clearly defined.

A research network called *Project Management Rethinking* (RPM), highlighted the need for a project management research fundamental reassessment. The network developed some studies based on collaboration between academic researchers and practitioners (CICMIL et al., 2006; ATKINSON; CRAWFORD; WARD, 2006; WINTER et al., 2006), and identified five directions for the research advancement. One of them involved uncertainty in projects.

The interest in this research topic came from the evolution of thinking in project management study, in which a project management framework was proposed. The *Software Project Framework* (SPF) is presented by defining its elements. A set of new dimensions to software project management is set. The uncertainty in projects is one of SPF's new definitions (MOURA, 2011). Figure 1.2 is a representation of the proposed SPF.

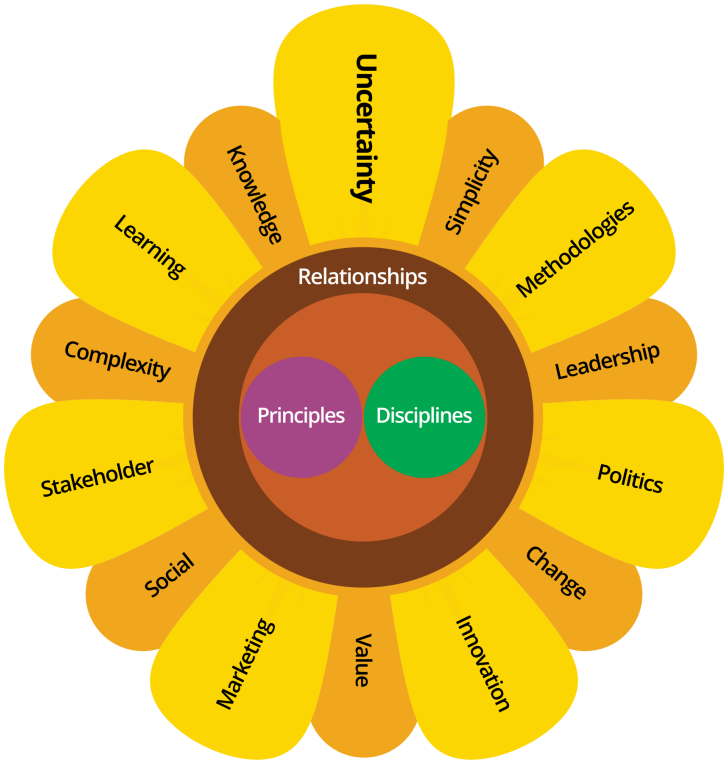


Figure 1.2: Software Projects Framework.
Source: MOURA (2011)

MOURA (2011) through his studies, reports uncertainty as a dimension which software project managers must observe for improving projects' implementation. According to him, uncertainty has a relation with these projects' innovation level, ie there is a natural relation between software projects that have an innovation degree and uncertainties. This work is co-related with SPF as the phenomenon of uncertainty in software projects is going to be deepened; but the relationship between uncertainty and risk is also going to be explored. Furthermore, an approach to manage uncertainties in software projects is going to be explained.

1.2 Motivation

There is a great commercial competition that companies have to face nowadays, which demand fast decisions, optimum resource allocations and a clear focus definition. In a software development environment it is basically the same. Many types of project are proposed with different objectives in which need strategic management according to organizational goals (MARINHO et al., 2015a).

Projects are fundamental for any company's success as well as activities which lead them to new products, services and business development. Successful projects lead to sales increase, costs reduction, quality improvement, client satisfaction, work environment, and other benefits. As a consequence, a large number of companies use project management as a key strategy to maintain competition and add value to their business (MARINHO et al., 2015a).

The project management's standard and formal approach is grounded in a predictable, fixed, relatively simple and right model. It is not coupled to changes in the environment or business needs; once the project plan is created, it outlines the objectives for the project and the project manager should run it as planned (SHENHAR; DVIR, 2007).

SHENHAR (2001) claim that "the same size does not fit all", which means that each project is unique and that one needs to understand how they differ and take appropriate measures according to the organization and the project's specific needs. So, if the projects are unique and never repeated with the same set of circumstances, one may wonder why it is common for businesses to follow a single specific approach to manage them.

This research focuses on the following point: if everyone can blindly follow a recipe to manage a project and projects are unique, it is likely that the manager will not have a chance to succeed. But if the manager is able to create a so called "adjusted recipe" to the conditions and to the moment uncertainty, they will have planted the "seeds of success".

Change is constant and unpredictable. In fact, change itself is changing at a rapid pace. This should come as no surprise to anyone. Yesterday's practice belongs to yesterday. Today is a new day with new challenges. All project managers either more or less experienced are challenged to think about how to effectively adapt their approaches to project management, instead of following a routine or recipe (WYSOCKI, 2010).

If managers simply rely on the use of routine methods, failure is very likely. The major motivation of this work is to help project managers manage their projects properly and enable them to deal with everyday uncertainties. Stretching their thoughts on how to effectively manage projects and thus, add value to the expected business.

The uncertainty and risk management should be considered complementary approaches, while risk management keeps on being an important strategy, the project manager also needs strategies to manage uncertainties, or else, to deal with risk management areas that are unknown.

Uncertainty can arise from deficiencies in a range of knowledge areas, such as the contextual information on a project, our comprehension of underlying processes, explanations of

past events and the velocity of change (or time). According to CLEDEN (2009) uncertainty is much less susceptible to analysis; it is what is left behind when all the risks have been identified. Uncertainty represents a threat, but we cannot be sure what form it will take. If it was otherwise we would identify it as a risk. We may be able to see that there is a gap in our understanding but, unlike a risk, we do not perceive what we do not know, not until uncertainty manifests itself into a specific problem it is the nature of the threat revealed and by then it may be too late to deal effectively with the consequences.

For conducting uncertainty studies in software projects, the concept of qualitative research according to BOGDAN; BIKLEN (1998) is going to be used. Qualitative researchers analyze their data inductively. They do not set out to find data to prove or disprove hypotheses that they had prior to their study. Their theories come from the "bottom up" rather than the "top down". For CRESWELL (2013) a qualitative study inquirers state research questions, not hypotheses. Thus, the next section presents the thesis assumptions followed by the research questions and the objective of this work.

1.3 Thesis Assumptions

Whereas, as shown in the previous sections:

- Projects are essential to the success of any company, combining activities that lead to new products, services and business development. Successful projects increase sales, reduce costs, improve quality, customer satisfaction, work environment, among other benefits. Thus, an increasing number of companies use project management as a key strategy for maintaining competitiveness, increasing the value possibility to their business.
- Despite the existing practices and methodologies in the market, research indicates that many projects are not delivered properly. One of the reasons why this happens is related not to evaluate uncertainties.
- Furthermore, in the risk management literature in projects, there is not a common understanding of what uncertain is.

It is assumed that:

The use of a approach to orient managers and staff about managing uncertainty and that supports software projects may be a determining factor in project success.

1.4 Research Question and Goals

Aligned with the assumption above, the research questions that are going to guide this work are the following: **RQ1:How to manage uncertainties in software projects?** To help

answer the fundamental question of this research, other related questions were elaborated:

- RQ1.1 How do software project managers manage uncertainties?
- RQ1.2 What strategies, practices and techniques do software project managers use to reduce uncertainties in their projects?
- RQ1.3 What are the recommendations for managers who seek to manage uncertainties?
- RQ1.4 How is the concept of uncertainty management in software projects understood by managers?
- RQ1.5 How can uncertainty management help the risk management process in software projects?

These represent some of the initial concerns that motivated this work; once nothing has been found in the literature that could offer satisfactory answers.

Aligned to defined research question, the aim of this work is to propose an approach to manage uncertainties in software projects.

In order to achieve the overall objective of this thesis the following specific objectives are defined:

- Determining the uncertainties' state of the art in the software project management context;
- Conducting an action research to implement actions in order to reduce uncertainty in a software project;
- Exploring practices and strategies adopted by project managers to manage uncertainty in order to identify critical issues that can influence the software projects success;
- Developing an approach to project managers with strategies that aim to manage uncertainties;
- Evaluating the theoretical approach built in order to ensure that the acquired knowledge is accurately the software project managers' vision and perspective.

1.5 Thesis Summary

In this introductory chapter the general ideas were presented describing their application context, the motivation for development, their assumption and objectives. Besides the introduction, the research is composed of eight chapters and an appendix, as follows: Chapter 2 presents

the theoretical framework which highlights the work related to the theme. Chapter 3 presents the methodological approach selected for this research. Chapter 4 presents a systematic review of literature. Chapter 5 explores actions taken in a software project. Chapter 6 presents the interviews' results and focus group conducted with project managers and project management researchers. Chapter 7 presents an approach to manage uncertainties in software projects. Chapter 8 presents the closing remarks. Appendix A presents the systematic review protocol. Appendix B presents the interviews' protocol. Appendix C presents a structured view of the approach. Appendix D presents an illustration of the approach application.

2

Theoretical Background

"Science is founded on uncertainty. Each time we learn something new and surprising, the astonishment comes with the realization that we were wrong before."
Lewis Thomas

This chapter aims to present concepts related to the work, there are going to be presented risks, a discussion about risks and uncertainties, uncertainties and uncertainty sources identified in an exploratory literature review. Some studies related to this work are also described in this chapter; they are: Early Signs and Sensemaking. Furthermore, some of the related works that has supported this work development is going to be tackled.

2.1 Risks

Projects are often subject to risks and the possibility of their manifestation depends on their nature. Risk is an event, condition or interaction with negative consequences on the project's objectives and hence, the project's success. DINSMORE (1999) says that project risk management is aimed to maximize the events' positive results and minimize the negative events'consequences.

There have been a number of different approaches to risk management in projects since the discipline's emergence. Project risk management is understood as the systematic process of identification, analysis, responses, monitoring and control to project risks in order to maximize positive events' probability and results and minimize adverse events' probability and consequences to project objectives (PMI, 2013).

According to VARGAS (2003), risk management provides the opportunity to better understand the project nature, involving team members in order to identify and respond to potential forces. PMI (2013) presents a traditional view of risk management in projects, defining project risk as an "uncertain event or condition that, if it occurs, it will cause a positive or negative effect on one or more project objectives, such as time, cost, scope or quality".

Risk Management can be defined as skills and expertise use, combined with the knowledge gained through the processes use with techniques and methods use for the iden-

tification, analysis and control of risks (GUSMÃO; MOURA, 2009). In general, project risks literature defines this process in an analogous manner eg, (ARTTO, 1997; CHAPMAN; WARD, 2004; BARBER, 2005). Some researchers reduce or increase the number of process' steps or phases (BOEHM, 1991; CHAPMAN; WARD, 2002; TURNER, 2009). However, there is a general understanding among researchers about what is included in these risk management process phases. It is a continuous and present process in all project development phases. Hereinafter, risk
management process is presented in PMI (2013):

- **Plan Risk Management:** This process has the purpose of defining how to conduct a project's risk management, the necessary resources for implementation and execution of the actions considered necessary in the Risk Management Plan. It is about planning all actions related to project risk management. A careful and explicit planning enhances the success possibility of the five other risk processes;
- **Identify Risks:** In this process, risks which may affect the project are raised. The most important aspect of the risk identification activity is composing a documentation formalizing the data collected;
- **Perform Qualitative Risk Analysis:** It is the prioritizing risks process for further analysis or action by assessing and combining their occurrence and impact probability. It assesses the identified risks priority using their relative probability of occurrence and the corresponding impact on project objectives if the risks occur, as well as other factors such as the time frame for response and tolerance to risks of associated organization.;
- **Perform Quantitative Risk Analysis:** Its purpose is to numerically analyze the effect of identified risks on overall project objectives;
- **Planning for Risk Response:** It is the process responsible for developing options and actions to enhance opportunities and reduce threats to project objectives. Each risk response requires an understanding of the mechanism by which the risk will be addressed. This mechanism is used to analyze if the risks' response plan is having the desired effect. It includes the identification and designation of a person responsible for risk response and establishment of its execution cost;
- **Risk Control:** The risk control process implements the risk response plans, the identified risk monitoring, risk monitoring, new risk identification and evaluation of the risk process effectiveness during the project.

PMBOK's previous editions describe risk through the uncertainty notion. SHENHAR (2001) argues that successful project management is much more than merely risk management. Thus, a comparison of risks and uncertainties is going to be discussed in the next section.

2.2 Risk and Uncertainty

In common usage, words such as doubt, uncertainty, risk and ambiguity are often used interchangeably; but to develop a detailed understanding of why uncertainty emergence and how it can be controlled, one needs clearer definitions. Essentially, there is an important distinction between risk and uncertainty. It's easy to get misunderstood; to think that through risk management, uncertainty is also managed: the two are not the same thing (MARINHO; SAMPAIO; MOURA, 2014a).

The traditional view of project risk management stresses the importance of planning as a major routine, supporting other activities such as risk identification, analysis, monitoring and control. Risk itself is traditionally described as an uncertain event (PMI, 2013), which provides grounds for some scholars to argue that risk management should be referred to as uncertainty management in projects (GREEN, 2001; JAAFARI, 2001).

Other studies present uncertainty management as being derived from strategic management and represent a critical view of the role and influence of strategic planning on the organization's performance (DVIR; LECHLER, 2004). The main assumption is that project activity planning is necessary from an early stage but it is not a guaranteed criterion for project success. Considering projects as complex endeavors with constraints of time, costs, resources and precise product specifications, planning seems to be a difficult task. However, there are restrictions in gray areas, that neither the client nor the project organization are able to recognize at an early stage (ANDERSEN, 1996). These "gray areas" can be considered as project uncertainties and should be treated before, during and after the project. The following are definitions of risk and uncertainty:

According to the dictionary RODITI et al. (2005) :

- Risk: (sec. XVI) "danger, inconvenience more or less predictable, failure probability, the failure of something, as a function of a possible event, uncertain, whose occurrence does not depend exclusively on the stakeholders' willingness".

- Uncertainty: "lack of certainty, doubt, hesitation, indecision, inaccuracy, ambiguity, difficult to understand, to clarify, that has (or can have) different interpretations, ambiguous, vague, dubious, obscure".

According to CLEDEN (2009) uncertainty is much less susceptible to analysis; it is what is left behind when all the risks have been identified. Uncertainty represents a threat, but we cannot be sure what form it will take. If it was otherwise we would identify it as a risk. We may be able to see that there is a gap in our understanding but, unlike a risk, we do not perceive what it is that we do not know. Not until uncertainty manifests itself into a specific problem is the nature of the threat revealed and by then it may be too late to deal effectively with the consequences.

According to JAUCH; KRAFT (1986), adept of organization theory depict uncertainty as "emanating from some set of objective (but largely unmeasured) environmental characteristics". In technical terms, risk can be defined as a "state of knowledge in which each alternative leads to a set of results and where the probability of occurrence is known by the decision maker". And uncertainty is "the state of knowledge in which each alternative leads to a set of results but the probability of occurrence of each outcome is unknown to the decision maker" (JAUCH; KRAFT, 1986).

For CHANG; TIEN (2006), several uncertainty factors may influence project management, such as: activities features; activities interdependence; environmental factors; information acquired from activities; and technological factor changes, among others.

Describing uncertainty in terms of probability is not new to project uncertainty management scholars. The classic distinction between risk and uncertainty comes from economics, particularly from the seminal work of Frank Knight in his book *Risk, Uncertainty and Profit*. Knight states that risks are events subject to known or knowable probability, whereas uncertainty refers to events for which it is impossible to specify numerical probabilities (KNIGHT, 2002).

Keynes suggests a distinction between risk and uncertainty in a similar vein. For him, uncertainty is a state in which individuals find it impossible to attribute a reasonably definite probability to the expected outcome of their choice (KEYNES, 2006). Keynes perceived uncertainty as inherent in economic life-like a rule of the game. If the rules are known, we are able to calculate possible outcomes and risks associated with that. If rules are not known, we are in the situation of uncertainty. Hence, uncertainty is the situation when it is not possible to calculate risk. Consequently, risk is perceived as less threatening as compared to uncertainty.

In the decision-making process knowledge area (DEQUECH, 2001) presents risk as situations in which individuals could be based on probabilities logically deductible or statistically inferred through experiments. DEQUECH (2001) states that uncertainty is about the probability subjectivation that occurs in the subjective expected utility theory [1]. From beliefs or accurate personal confidence levels, you could assign probabilities individually built to any uncertain events in the future, or else; it is not possible to eliminate uncertainty from the reality of one's problem.

Another definition of uncertainty comes from psychology: it is described as a state of mind characterized by a conscious lack of knowledge about the outcomes of an event. This description, in contrast with the Knight's definition presented above, allows us to assume that the external environment is not the only source of uncertainty (HEAD, 1967; STANFORD ENCYCLOPEDIA OF PHILOSOPHY, 2012).

Because each project is unique and is, by definition, being done for the first time; it involves a certain degree of risk. Note that although risk and uncertainty are related, they are not the same thing. As stated in this section, uncertainty is the unknown, whereas risk is what can

[1] The utility is the value subjectively assigned to an event (DEQUECH, 2001)

knowingly go wrong. Clearly, a large part of project risk depends on uncertainty; however there are other factors that contribute to project risk, including time, resource scarcity and inadequate skills. Table 2.1 gives a brief summary comparing uncertainties and risks from the perspective of various knowledge strands.

Table 2.1: Comparison Between Risks and Uncertainties from Various Knowledge Strands

Source	Risks	Uncertainties
Dictionary	Danger, failure probability (RODITI et al., 2005)	Lack of certainty, doubt, hesitation, indecision (RODITI et al., 2005)
Project Management	Risk itself is traditionally described as an uncertain event (PMI, 2013)	Uncertainty is an event or a situation which was not expected to happen, regardless of whether it could have been possible to consider it in advance (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)
Org. Theory	State of knowledge in which each alternative leads to a set of results and where the probability of occurrence is known by the decision maker (JAUCH; KRAFT, 1986)	State of knowledge in which each alternative leads to a set of results, but the probability of occurrence of each outcome is unknown to the decision maker (JAUCH; KRAFT, 1986)
Economics	Events subject to known or knowable probability (KNIGHT, 2002)	Events for which it is impossible to specify numerical probabilities (KNIGHT, 2002)
Decision making Processes	Situations in which individuals could be based on probabilities logically deductible or inferred statistically through experiments (DEQUECH, 2001)	Deals with the subjectivity of probability that occurs in the theory of subjective expected utility. From beliefs or accurate personal confidence levels, you could assign probabilities individually built to any uncertain events in the future (DEQUECH, 2001)

Psychology	The decision is made under conditions of known probabilities (STANFORD ENCYCLOPEDIA OF PHILOSOPHY, 2012)	A state of mind characterized by a conscious lack of an event (HEAD, 1967)

Based on the information shown in Table 2.1, it is possible to conclude the following: The concept of uncertainty is different from the concept of risk in the science field presented. In the project management field, some researchers (CHAPMAN; WARD, 2002; LOCH; SOLT; BAILEY, 2008) define uncertainty as the risk source, such as the one used in this work. Thus, one can derive the relation shown in Figure 2.1.

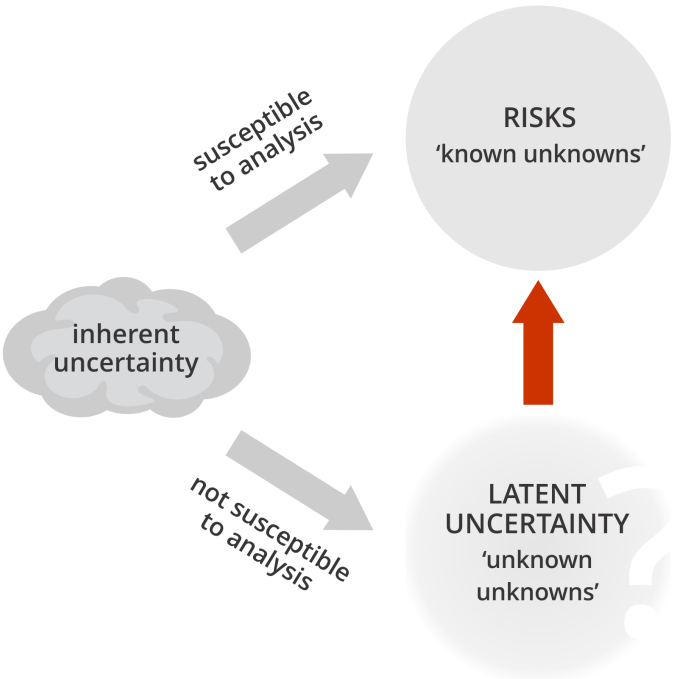


Figure 2.1: Risk and Uncertainty.
Source: the author

Figure 2.1 presents two types of uncertainty: **inherent uncertainty:** in which all project members have, before making any attempt to analyze the risks; and **latent uncertainty:** which remains once all risks have been identified. This means that the risk analysis process (ie the measures taken to identify and quantify project risks) transforms some, but not all, the uncertainty inherent in risks. What remains is the latent uncertainty.

Risk management is an essential tool for reducing the general uncertainty level associated with the project. Currently, there are many risk management well-established techniques which, if properly applied, can manage the inherent threats to risks successfully, however, risk management alone is not enough and is limited for some reasons:

- In complex projects, risk management quickly becomes a project with intensive use of resources;
- Opinion errors in prioritizing risks can introduce vulnerability;
- One can not control unforeseen situations.

A project manager who relies solely on risk management can work under a false impression that all the unknown is being treated. But as shown in Figure 2.1, some uncertainty is not susceptible to risk analysis. Thus, the latent uncertainty can manifest itself as a problem, later in the project, often without notice. Since it does not appear in the project risk register and the project team may be badly equipped to deal with it. In the next section, the definition of uncertainty used in this work is going to be presented.

2.3 Uncertainty

The term uncertainty may be applied broadly as the "lack of certainty", which means absence of information. Therefore, it covers not only probabilistic or indefinite results, but also an ambiguity and lack of clarity concerning various factors (HOWELL; WINDAHL; SEIDEL, 2010). In (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008) "Uncertainty is an event or a situation which was not expected to happen, regardless of whether it could have been possible to consider it in advance".

Many project management approaches do not consider the sources of project uncertainties (ATKINSON; CRAWFORD; WARD, 2006). The use of uncertainty management within project management can be a determining factor for project success. One needs to clarify what can be done, decide what should be done, and ensure that management is carried out based on the prior identified uncertainties. For example, best practices in planning, coordination, milestone definition, and procedural changes, in some way seek to manage uncertainties in projects. However, it is necessary to understand the uncertainty sources in a project to be able to contribute to its success.

Nowadays organizational survival is achieved through successful projects, and they are the driving force of innovation and change (SHENHAR; DVIR, 2007). It is through projects that organizations become better and more efficient, and yet, project management has been largely neglected in the business strategy field. The fact remains is that many projects fail and the literature suggests that conventional project management needs to be improved in order to meet current business needs.

Each project has different features, so uncertainty levels vary. High-risk projects, typically innovation projects, which usually pursue ambitious goals and where the failure probability is high, contain a high degree of uncertainty (CLEDEN, 2009). Low uncertainty projects often create limited opportunities, whereas high uncertainty projects will be evaluated primarily on their business effect and long-term effect, rather than on measures of time and budget (SHENHAR; DVIR, 2007).

CHAPMAN; WARD (2002) say that every management decision should consider the degree of uncertainty, since it may trigger project risk and affect organizational performance. The management of the organization needs to understand the nature of threats in order to identify, access and manage risks.

The uncertainty arises naturally from complex situations, being simply an inevitable factor of most projects. Uncertainty is simply an expression of ambiguity and project indeterminacy in the same way that the color yellow is an attribute of daffodils, but is not a discrete flower or a separable part (CLEDEN, 2009).

That suggests that our defense mechanisms against uncertainty should be based on a better understanding of how the constituent parts of the project function. It is necessary to understand in what way projects are different from each other in order to suit the right situation to the particular project. Plans to minimize uncertainties can be executed before beginning a project, but with the understanding that they will not be eliminated. During the course of the project, certain measures, such as re-planning, can be performed to continually minimize the uncertainties, but new uncertainties may appear. The best way to manage is to accept things as they are (SHENHAR; DVIR, 2007). This does not mean to abandon the plans and schedules, but that it is necessary to adapt traditional management to an approach that assists achieving the project's success.

In order to consolidate the subject as a topic of study and research aiming to build greater clarity on the concept and align the main definitions found on uncertainties in the project management area, shown in 2.2, this work proposes a definition of uncertainty that will standardize future approaches on the subject. Therefore:

Uncertainty in projects is the resulting phenomenon of limitations in seeing signs that may affect a project success. Thus, it is something that can not obtain an occurrence probability, even if subjective. This difficulty may be generated by lack of experience, sufficient information, perceptive ability or even because of mindset of the people involved in the project. At this point, the organizational culture can have a strong influence.

In other words, it is believed that uncertainty in projects arises from individual experience (eg manager's, team members') such as: either lack of knowledge, understanding and/or awareness of the project's important elements, its environment and their interrelationship; so that one can not obtain the probability that might impact on the project success.

Table 2.2: Project Uncertainty Definitions

Author	Uncertainty Definition
WEICK (1995)	Uncertainty is ignorance of any interpretations.
CHAPMAN; WARD (2002)	"Uncertainty is lack of certainty in the simple common language sense..."
DE MEYER; LOCH; PICH (2002)	Uncertainty can not be identified during project planning. The team either is unaware of the event's possibility or considers it unlikely and does not bother creating contingencies. "Unknown unknowns", or "unk-unks", as they are sometimes called, make people uncomfortable because existing decision tools do not address them.
ATKINSON; CRAWFORD; WARD (2006)	Uncertainty is a perceptual phenomenon. They conclude that "uncertainty results from vagueness, ambiguity and contradictions associated with lack of clarity because of lack of data, incomplete and inaccurate detail, lack of structure to consider issues, the working and framing assumptions being used to consider the issues, known and unknown sources of bias, limited control of relevant project players, and ignorance about how much effort it is worth expending to clarify the situation" .
SHENHAR; DVIR (2007)	Uncertainty is about our information state on the project goals, its job and its environment
LOCH; SOLT; BAILEY (2008); LOCH; DEMEYER; PICH (2011)	Uncertainty as the lack of knowledge on the introduced innovations
PERMINOVA; GUSTAFSSON; WIKSTRÖM (2008)	Uncertainty is an event or a situation which was not expected to happen, regardless of whether it could have been possible to consider it in advance
CLEDEN (2009)	Uncertainty represents a threat, but we can not be sure what form it takes, otherwise we would identify it as a risk. We may be able to see that there is a gap in our understanding but unlike a risk, we do not known what is not know
MARINHO et al. (2013)	Uncertainty in projects is defined as the lack of information and an inability to define the probability of an event to happen.

This work establishes that uncertainty can arise from deficiencies in different sources of expertise, such as: not understanding a particular technology to be used in implementing

the project; the consumer's lack of knowledge about a particular product; and product rejection based on cultural issues. This section is based on several uncertainty studies. Uncertainty for many authors is perceived as isolated within a particular knowledge area. However, the aim here is to show that, based on exploratory research and studies on the subject, project uncertainties be classified into four interconnected areas: market uncertainty, technological uncertainty, environmental uncertainty and socio-human uncertainty.

The next subsection presents the uncertainty sources that have been mapped as a result of exploratory studies.

2.3.1 Uncertainty Sources

It is not always possible to be aware of a certain uncertainty, but one can be alert to factors that can influence the success or not of the project; it is important to understand the uncertainty sources (MARINHO et al., 2013).

From the beginning, project managers and their teams should be focused on project objectives. If organizations are planning to achieve project objectives, then project managers should incorporate the investigation of uncertainties in order to ensure strategic benefits for the organization.

Since uncertainty may be related to one or more sources, note that the four sources presented are purposefully interconnected. Project uncertainty can not be managed in the same way as risks or certainties. Indeed, traditional project risk management tools such as planning, monitoring and control are effective for avoiding risks (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008). However, effective project management is possible if the solution of project uncertainties is focused on. This means understanding where the project uncertainties can be elicited from among the many areas of knowledge, analyzing and documenting the uncertainties based on the four uncertainty sources, and then monitoring and making the necessary changes as the project evolves.

2.3.1.1 Technological Uncertainty

The technological uncertainty source was defined based on research such as (CHANG; TIEN, 2006; SHENHAR; DVIR, 2007; CLARK, 1985; DOWNEY; HELLRIEGEL; SLOCUM JR, 1975; KOUFTEROS; VONDEREMBSE; DOLL, 2002; SHENHAR, 1993). Technological uncertainty depends on the extent to which the project uses new technology or mature technology. The level of project technological uncertainty is not universal, but subjective, and depends not only on what technology exists *technological know-how* but also what is accessible to the organization (SHENHAR, 1993). It is therefore a measure of the amount of existing new technology compared to mature technology available for use in the project.

Among other things, technological uncertainty impacts on the project, communication, the time needed to freeze the plan, and the number of planning cycles. It can also affect the

technical expertise needed by the project manager and team members. A good classification for technological uncertainty is presented in (SHENHAR; DVIR, 2007):

- **Projects Low-Tech:** it involves existing technology implementation, that means well-established and mature technologies in which all industry participants have equal access;
- **Average-Technology Projects:** projects that are based on existing and mature technologies, however they may involve a small amount of new technology;
- **Design of High-Technology:** uses new technologies, although existing;
- **Design of Super-High-Technology:** new technologies development that do not exist at project initiation time, and its development is part of the project.

Superior technology produces more advanced end products, with increased performance and functionality. However, they obviously create an increased technology risk. At a very high technology level, customers expect a leap in performance and benefits, but due to the technologies that need to be developed during the project, these projects are much riskier than those that adopt known technologies (MARINHO et al., 2013).

One example of technologic uncertainty was the Denver Airport Project. A huge, industry standard and problem-free construction project was expected. Although without any visible problem, it became a nightmare to its stakeholders. It resulted in long delays and excessive costs. One of the project items was the design and development of a modern luggage management system. The system was supposed to accelerate the luggage administration and handling, which takes a lot of time to deal with manually. With the desired system in place planes would be able to take off within 30 minutes. However, the lack of attention to technologic uncertainties lead to the airport opening being delayed and excessive costs (SHENHAR; DVIR, 2007). Although the airport had a standard design, the luggage system was the first of its kind, and needed more attention.

2.3.1.2 Market Uncertainty

This source was defined based on research such as: (JAAFARI, 2001; DVIR; LECHLER, 2004; JAUCH; KRAFT, 1986; CHANG; TIEN, 2006). Market uncertainty indicates how new the product is to the market, to consumers and to potential users. It represents the extent to which buyers and users are familiar with this type of product, its benefits and how they can use it. The level of market uncertainty indicates the external uncertainty and also reflects the uncertainty of the project goal. It also indicates the easiness of knowing what to do or what to build and how to introduce consumers to the product (MARINHO et al., 2013).

Different consumers and markets behave and think differently. Therefore, project teams should know how their customers think, what the main problems are, how customer organizations function, and what their customer type is (i.e. government, business, or individual consumer) in order to reduce market uncertainties.

Projects at different levels possess their own unique elements that stand out and help to define them. Project extensions and existing product projects include activities such as cost reduction activities, improvements and modifications. Although these projects contain cost estimations, as well as other specifications, they are generally fairly accurate, and there is no need for market experimentation.

Projects involving new generations of existing product lines typically create new product families, replacing previous products in an already well-established market sector. Although some products in these projects may include new technologies, consumer product usage is foreseeable.

However, products that represent radical market innovations are usually developed in projects that create and transform a new concept or idea into a product that consumers have never seen or experienced, and know nothing about or how to use.

As an example of market uncertainty, there is the Los Angeles subway project. The project faced several technical and administrative challenges: soil gas, abandoned oil wells, contaminated groundwater and high seismic activity. But the biggest challenge of all was to change citizen's attitudes. Even though the project had met its desired goals and had been chosen "project of the year" by *Project Management Institute (PMI)*, the remaining phases of the project were abandoned a few years later, when the city realized that the train usage was significantly lower than expected (SHENHAR; DVIR, 2007).

In this source of uncertainty, organizations need to carefully analyze the market of the product in production, and should determine the managerial implications during the planning phase and throughout the project.

2.3.1.3 Environment Uncertainty

This source is based on research such as: (BURNS; STALKER, 2009; CAPON et al., 1992; ZIRGER; MAIDIQUE, 1990; DUNCAN, 1972a; JAUCH; KRAFT, 1986; MILLIKEN, 1987; CHANG; TIEN, 2006; DUNCAN, 1972b). This area indicates the degree of uncertainty of the external and internal organizational environment. Organizational theories emphasize that organizations must adapt to their environment if they are to remain viable (DUNCAN, 1972b). A lack of understanding of how environmental components may change can affect the project management in a negative manner, as shown below:

- An inability to predict the future behavior of a key competitor;
- Inability to predict changes in the political arena;

- Uncertainty about whether a key union will call for a national strike;
- Uncertainty about environmental factors;
- Lack of experience in managing/ execution of activities;
- Lack of integration with the organizational goal;

Environmental components as well as their specific dimensions must first be identified. It is only by making a study of the environmental characteristics of a project that the environmental uncertainties can be reduced. Such study facilitates the identification of the types of environment that contribute to different degrees of uncertainty, as perceived by the individuals involved in the decision making (DUNCAN, 1972b).

Environmental uncertainty can arise from the actions of different organizations (suppliers, competitors, consumers, government, shareholders, etc.) and this may affect the project. Doubts about the probability or nature of changes in the environment (socio-cultural trends, demographic changes) can lead to a number of environmental uncertainties (MARINHO et al., 2013).

It should be emphasized that environmental uncertainty and its dimensions are defined here in terms of the perception of the individual member of an organization. Research has indicated that differences exist between individuals concerning their perceptions and tolerance for uncertainty (DUNCAN, 1972b).

The "Chunnel" Project, envisaged as a link between Britain and the European Continent, is an example of a project with environment uncertainties. The project required a treaty between Britain and France, which was signed by both countries, and it involved cultural differences, political complications, conflicts of interest, and lack of leadership at the highest level. Two companies led the project, Eurotunnel and Transmanche Link Company, but they had different priorities. Eurotunnel thought that the tunnel should reflect the latest technology of the current generation. On the other hand, Transmanche thought that their only role was to provide a tunnel that fulfilled the contract. Disagreements between the two organizations increased during the project's course. Both companies lost 1 billion dollars during the project, and an additional loss of 3.2 billion dollars was accumulated during the first three years, and yet, despite all the problems, the construction was concluded. Most problems encountered during the project execution occurred because of the conflicting needs of governments, two different cultures, and a consortium of companies with different missions. In such cases environmental uncertainty should be carefully analyzed to reduce the impact on the project (FAIRWEATHER, 1994; ANBARI et al., 2005).

2.3.1.4 Socio-human Uncertainty

Although modern organizations have technological tools that can meet most needs and structural deficiencies, it alone is not enough to ensure the acquisition of individual and group

knowledge. This is due to cognitive factors intrinsically related to how people perceive, learn, remember and think about information (STERNBERG; OSÓRIO, 2000). Projects can be a unique way of helping organizational processes to change, innovate and adapt to competitive market reality.

Project management can not be left to only one person, it must become an issue for everyone (SHENHAR; DVIR, 2007). The relationships between several parties may be complex, and may not involve formal contracts. This area is based on research such as: CLEDEN (2009); STERNBERG; OSÓRIO (2000); WEICK (1977); ALDERMAN et al. (2005); WEICK (1979).

Human relations are often viewed as fuzzy in the management process. When misunderstood, they can lead to conflicts that can threat project development, especially in technological innovation projects that present a high degree of complexity and uncertainty. This kind of challenge requires creativity and flexibility in project teams.

2.3.1.5 Uncertainty Source X Universal Risk Areas

The final report on universal risks in project (HALL; HULETT, 2002) created after extensive discussion with experts, a typology of risks, including three areas of risk, they are: in managing risks, external risks and technological risks. Paralleling of which sources of uncertainty (presented in Section 2.3.1) may result in risks, Table presents the sources of uncertainty (unknows unknow) that give rise to areas of risks (unknows know).

Table 2.3: Relationship between Source of Uncertainty and Universal Risk Area

Source of Uncertainty	Universal Risk Area
Technological Uncertainty	technological (requirements, adequacies, applications)
Market Uncertainty	external (economic)
Environment Uncertainty	management (corporate, stakeholders); external (natural)
Socio-Human Uncertainty	external (cutural)

2.4 Early Signs

In the mid 1970*s* Igor Ansoff introduced the first version of his theory of weak signals (ANSOFF, 1975). Ansoff sought improvement to the strategic planning method, which does not work well when there are sudden changes or unforeseen discontinuities in business development. Ansoff states that strategic surprises can provide information before they happen, there are signs

or symptoms of surprises to come. This information is initially inaccurate, the signs are vague, distorted and of difficult interpretation, but they gradually become more distinct and easier to decipher.

Ansoff refers to the information level as having two extreme stages: strong signals and weak signals. According to Ansoff, some issues are identified through environment monitoring and differ according to the amount of information they contain. Strong signals are "the issues that are visible and concrete, thus allowing the company to make the calculation of their impact and draw up specific plans for response". On the other hand, weak signals or early signs are: "The first inaccurate indications of impending and impactful events; all that is known, is that there are threats and opportunities; those will undoubtedly emerge, but its form, nature and origin are not yet known."

Strong signals are easy to detect, it is easy to agree on their interpretation. On the contrary, weak signals are often so vague that are easily lost. It is hard to believe them; in other words, they are uncertain, irrational and have no credibility.

Ansof's idea was to show that the world is awash in information, often ambiguous, inaccurate and incomplete. Still, that it can be transformed into significant advantages for companies. Ansoff's starting point is the information a company receives from its environment. The information, knowledge accuracy and what is about to happen (ANSOFF, 1984). HILTUNEN (2008) conducted a thorough analysis of weak signals and addressed the signal's three dimensions: **The sign**, number and /or visibility; **the question**, or else, the emerging question; **the interpretation**: the receiver's understanding of the signal meaning(under organizational point of view, this may be the signal importance to an organization in the future). The author suggests that the weak signal objective evaluation should be done by the sign and the question's size, for example, the use of indicators; and the subjective evaluation should be done by the interpretation dimension.

The terms used to refer to these signals are varied: early sign (NIKANDER; ELORANTA, 2001; NIKANDER et al., 2002), first warning sign (KAPPELMAN; MCKEEMAN; ZHANG, 2006), symptoms, weak signals (ANSOFF, 1975, 1984; WEBB, 1987), future signal (HILTUNEN, 2008), warning sign (OGC, 2009). A content comparison of these different terms shows that the authors refer to identical or very similar phenomena. The terminology used in this study is early sign.

In projects context, these early signs are of great importance, especially in innovative projects for having various associated uncertainties. NIKANDER; ELORANTA (2001) address the issue in project management context. The authors studied a number of early signs that have been identified in interviews by project managers. In addition to the signs, they tried to identify the problems cause; the problems and solutions for each signal and prepare a hypothetical dependence between these factors, which are shown in Figure 2.2, furthermore, they developed a model for trying to manage the early signs in management. On the other hand, SANCHEZ; LEYBRNE (2006) evaluated the use of early warnings in research and development projects in

Spain. They found that the treatment is mostly used in large projects and in companies with more investment in these projects, however, they did not evaluate how early signs were treated.

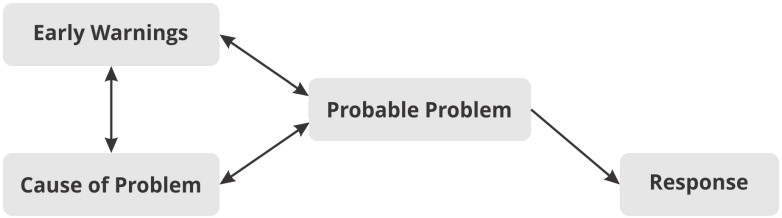


Figure 2.2: Hypothetical Dependencies.
Source: NIKANDER; ELORANTA (2001)

KAPPELMAN; MCKEEMAN; ZHANG (2006) made an extensive research in the literature to develop an early signs preliminary list. The authors with experience in managing IT (Information Technology) projects added several signs based on their experiences. Then, they invited 19 IT project management experts to assess the list. Based on their comments, the authors added new items and other existing ones were modified to develop a list of 53 signs. In a following step, the authors invited 138 IT project managers to participate in a signals classification, using a range of 1 (very unimportant) to 7 (very important). Fifty-five of them responded to the survey, producing a response rate of about 40% per cent. From the responses there were extracted 12 signs related to people and processes that were indicated by the experts as the most important.

Several studies on early signs of project management treat early symptoms trying to identify the necessary management actions. Practices such as sensemaking are used in order to understand the signs in order to contribute to better project management. The search for sense is particularly important in a project-based environment. Once certain sense is given to a decision and to its context, the actions (programs and projects), to be developed from the sense conception, become better understood and can be implemented in a more natural, efficient and effective way.

2.5 Sensemaking

Sensemaking is the process by which organizations and individuals work uncertainties, ambiguities, changes and problem situations generating inventions and new situations that result in actions that lead to problem solution and environmental stability. The most important thing is that there is sense in the identified sign or else, it is plausible to those involved WEICK; SUTCLIFFE (2001, 2011).

For WEICK; SUTCLIFFE (2001) sensemaking has seven properties, which are:

- **construction of identity:** “The secret is a matter of who I am, as suggested by the

discovery of how and what I think." Sensemaking begins at the individual level with the maintenance or establishment of a personal identity. In the interaction with the environment the result is observed, being the sense affected by the various needs of individuals in organizations, such as being part of something, evoluting, being effective, standing out, confirming, integrating, representing a institution, etc;

- **retrospection:** "To know what I think, I review what I have said before." The present is always recognized and based on past experiences, tacit knowledge, including in past decisions on adaptation plans and objectives. To make the abstract concrete people sometimes act and then try to identify the reason for their action. Weick reinforces the idea that actions are recognized only after its full implementation.

- **enactment:** "I create the object to be seen and examined when I say or do something."

- **social:** "What I say, I highlight and finish are determined by who I socialized with and how I was socializing, as well as by the public who will evaluate the conclusions I reached."

- **continuous:** "My speech is transmitted across time, it competes for the attention with other ongoing projects and is represented after it is finished, which means that my interests may have already changed."

- **extracting signals:** "What I highlighted and finished as thought content is only a small part of the statement that becomes outstanding because of the context and social organizations."

- **plausible:** "I need to know enough about what I think, to continue with my projects".

In a case study conducted in Scandinavia, CHRISTIANSEN; VARNES (2009) evaluated how managers and teams understand the creation of meaning. The authors found that the creation of meaning from rules to the practice is implemented by numerous translations based on the context, the history, the patterns and processes. On the other hand, SIMON (2006) conducted a survey with innovative project managers and found that *sensemaking* is one of the characteristics of a project manager in the innovation context, because through this feature the manager is able to treat individual and collective creativity. As a *sensemaker*, the manager creates sense of team effort reflecting the project's collective representation in a shared meaning, through informal communication and formal meetings with all stakeholders, whether internal or external to the project. Some activities are reported to this characteristic, they are:

- **Learning by doing:** The manager uses an inductive discovery process to understand the project and place the others involved in project activities;

- **Interpret the situation:** The manager does not impose their understanding, but try to put the issue in the project's perspective, resulting in a meaning co-construction for the team member;
- **Translate the project objectively with activities and tasks:** It is not just to perform a labor division, but also to make the team realize the meaning of each one in the project;
- **Revealing assumptions and beliefs:** When there is disagreement, the manager should clarify the real meaning by identifying the beliefs being used and assumptions made by the parties;
- **Building a shared meaning:** The project's significance is always reminded, not only in formal meetings, but also in daily tasks.

The information sense construction process, in *sensemaking* vision is driven by people's beliefs and actions within an organizational structure. Beliefs and past experiences influence the meaning construction process, once there is a tendency to think that the meaning attributed to something is compatible with what is believed and what has been lived in the past. The actions influence, and at the same time, are influenced by the meaning construction process; once to make sense of a particular event, one acts according to the same logic; and to justify the actions, they fall back upon the sense used. Bearing that in mind and thinking in a software project development environment full of various information sources and uncertainties; it becomes necessary to create sense of the signs that were detected.

2.6 Related Work

This section presents some of the related work, in particular highlighting the principal contributions associated to the context of this document.

Loch (LOCH; DEMEYER; PICH, 2011) criticize the actual practices in project management. These are based on preplanning. They have suggested the use of different approaches by combining uncertainty and complexity. For this, they suggest a prior diagnosis about the level of uncertainty and complexity. They divide this diagnostic in four phases. These phases are presented in Figure 2.3 and described below:

- Phase 1 - Concerns the structure of the project's problem to identify the goals and the factors of the performance that should be achieved and the actions needed to achieve them;
- Phase 2- Divides the problem into parts or sub-problems, based on market forces or project modules, for example.

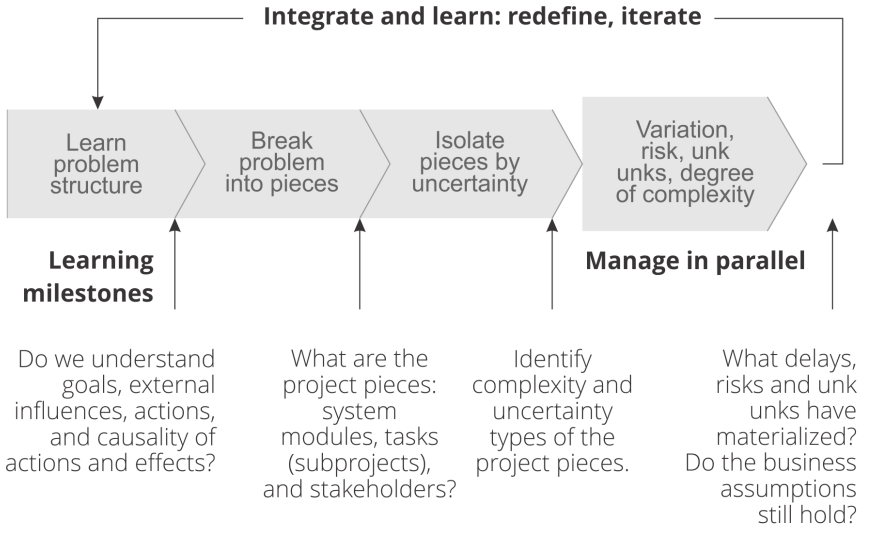


Figure 2.3: Project Management Methods as Uncertainty and Complexity.
Source: Adapted from LOCH; SOLT; BAILEY (2008)

- Phase 3- Evaluates the knowledge level of each part of the problem, defining the uncertainty profile.

- Phase 4- The management of each problem is done in parallel.

To manage these sub-problems, the authors suggest to identify the best method by the combination of uncertainty and complexity, considering uncertainty as the knowledge gap, as can be seen in Figure 2.4 and described below:

- **Low complexity and low uncertainty:** through instructionism one can manage projects, ie standard practices such as PMBOK Guide (PMI, 2013) is sufficient and effective to have success in this issue type;

- **Low complexity and high uncertainty:** to overcome the knowledge gap, a learning in the process should exist. This learning can be done by improvisation method, when life experiences direct the actions to be taken; when planning and execution occur simultaneously, or by experimentation; as in trial and error, which based on a short term plan, it includes the situation's periodic assessment, making it possible to modify the plan or even to redo a part of what has been done.

- **High complexity and low uncertainty:** the authors suggest the selectionism method that generates multiple solutions to the same problem, selecting the most appropriate one in the certain moment;

- **High complexity and high uncertainty:** The authors suggest more information before applying the selectionism.

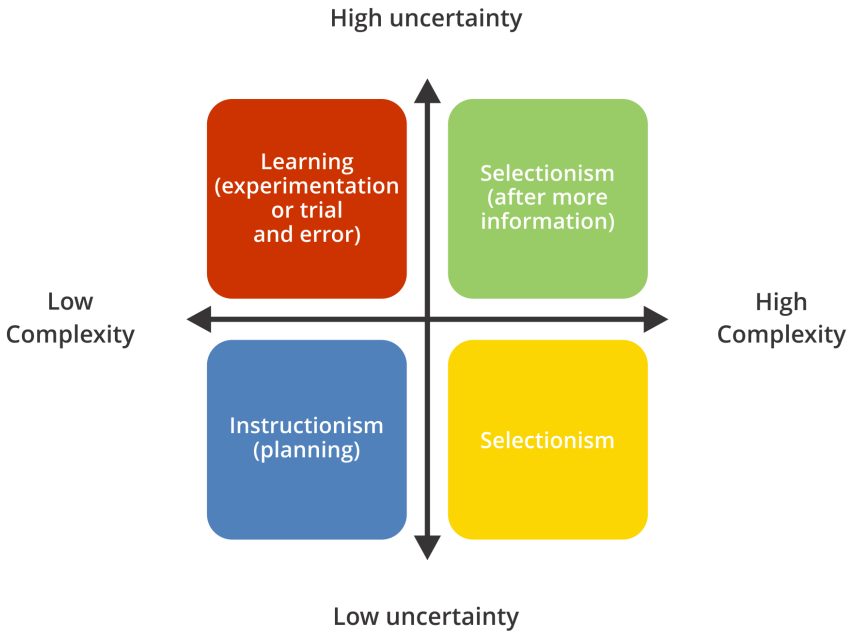


Figure 2.4: Management Methods According to Uncertainty and Complexity.
Source: Adapted from LOCH; SOLT; BAILEY (2008)

This process is iterative and gradual; with the project progress, the unknown becomes better known. The management must also evolve, so that more and more it cold be considered a plan in which a small variation is expected.

Shenhar e Dvir (SHENHAR; DVIR, 2007) presents an adaptive approach called by the authors as 'Diamond Approach', which is designed to correctly classify the project and choose the best way to manage it. The approach is divided into four dimensions: novelty, technology, complexity and pace. The **new** represents is how new the product is to market, its consumers and potential users, it even presents the extent to which buyers and users are familiar with that type of product, its benefits and how they can use it. On the other hand, the dimension of **technology** depends on the extent to which the project uses mature or new technology. The **complexity** is a project scope measure in which features are reflected such as number of tasks and the interdependence degree between them. The **pace** is related to the time dimension and the existence of deadlines that drive the work.

Differently, Clenden (CLEDEN, 2009) in his book says that knowledge plays a central role in uncertainty management, allowing the project manager model the events that may happen. To Cleden, uncertainty is much more than the absence of facts; it is fundamentally a knowledge gap which may comprise several different elements (CLEDEN, 2009). The author says that one way to predict uncertainty is the adoption of strategies centered on knowledge which provide ability to visualize the project's future states; allowing the manager and his team analyze different scenarios by building predictive models on how these variables change over time. The better the model, the less uncertainty about the future, and the better decision making.

In their book *Managing the Unexpected* WEICK; SUTCLIFFE (2001, 2011), the authors use the mindfulness term to describe a state of mind of being alert to the unexpected situations possibility that arise. The idea comes from an analysis of certain organizations types that face particularly difficult challenges in uncertainty management. These organizations carry out complex operations and work in highly unpredictable environments where the error potential can have very serious consequences. Examples include nuclear power generation plants, flight decks of aircraft carriers and fire fighting teams. Weick and Sutcliffe call them High Reliability Organizations (HROs).

The mindfulness concept summarizes the differences between culture and management processes which are common to HROs examined by the authors. Although the severity of these challenges are not in general faced by a typical project, the lessons are no less pertinent.

Mindfulness is a comprehensive and holistic approach containing uncertainty typically high uncertainty environments. HROs have cultivated mindfulness because in case of any failure, the proportions are catastrophic and it is simply unacceptable. Furthermore, mindfulness requires a fundamental change in attitude that is neither cheap nor easy. It requires a great commitment, and out of HROs, relatively few projects are betting that high. But there is a number of key principles from which valuable lessons can be learned. Weick and Sutcliffe found that successful HROs tend to share five key attributes, which are:

- **Failure Concern:** to find signs of emerging unexpected events, you have to look for them. The best way to do this is to become concerned about failure; either continuously worrying about the failure possibility, being aware of its early signs, questioning whether there are different explanations for seemingly obvious results; or not investigating the way they usually do any anomalous output. Fundamentally, becoming concerned about the possibility of failure should not be seen as a negative attitude.

  Organizations calling on the team to believe that the mantra 'failure is not an option' may be missing a key point: uncertainty is always present and the worst thing one can do is denying its existence. Failure is much more an option for each project. Project teams that succeed are likely to be the only ones to keep it, they are at the vanguard of their minds.

- **Reluctance to simplify interpretations:** as project managers struggle to understand what is happening within the project, there is a natural tendency to look for evidence to support preconceived ideas and reject what does not fit. However, all evidences must be considered on their own terms.

  Hypothetically speaking, it might be supposed that a software module development delayed. If the project manager has already expressed doubts about the developer's skill level before, it is easy to interpret the latest delay as a confirmation of that

developer's lack of experience. But one may wonder if it is really where the problem is; and whether the original work estimate was unrealistic or not. If so, then the labor reallocation to a more experienced developer would not solve the problem. All that can be discovered is the real problem delay - a potentially more serious problem in the way of the project estimated tasks that could mean that all development activity had been underestimated.

Managers need to avoid coming into obvious explanation and thus fail to consider viable alternatives. Simple explanations are attractive but bring the risk of oversimplification with them.

- **Sensitivity to operations:** early signs tend to be subtle and their insignificance is easy to ignore. Consequently, problems may erroneously be detected, often for some time before its negative aspects attention attraction. Even if the transition period is over, the problem effects are of low amplitude and difficult to realize without superb surveillance. Unless the team is sensitized and highly attuned to such anomalies, the clues are lost until the fault is no longer latent and materialize into a full problem.

  Become aware of the warning signs (what Weick and Sutcliffe refer to as 'maintain situational awareness') is difficult. It requires an attitude change in the whole team, not just in the project manager. It is an intensive resource - both in terms of the effort made to detect warning signs, as on the resources to track, analyze and determine if there really is a latent failure.

  Measuring progress with the project plan can be self-delusional, particularly the plan itself is based on considerable uncertainty and is just what we like seeing to happen.

- **Commitment to resilience:** A commitment to resilience means recognizing that any project aspect may be subject to uncertainties. There are no ways out of bounds. All that matters is that the team is ready and willing to face any uncertainty symptom as soon as it is detected.

- **Respect for expertise:** When a project is off track, it is not uncommon to hear someone say, that they knew it was coming, if someone had asked them about X, they could have told them that there had been a problem. Encouraging problem ownership would ensure that individuals did not shrink their shoulders when they saw the problem developing and would assume that someone else would deal with it. But it also means that the responsibility of dealing with problems must reside where the experience is greater. Under normal conditions, this is determined by the decision-making hierarchy in the project. But in crisis times, this can become a bottleneck.

  Quick action to avoid an unexpected result evolve what is necessary for a crisis,

but it takes time to communicate vital information to the project manager (or other stakeholders) in the chain.

The decision maker does not automatically have the problem's clearest understanding. Sometimes those that detect the problem have the best idea for its solution, but that information is not always communicated, or the message is filtered out along the way.

Whenever a quick action is needed, trust becomes important. The project manager must be prepared to trust the team members to make important decisions. For this to work, there must be a shared understanding by all staff of the project objectives and the threat posed by uncertainty.

Research suggests that the new product development process and results depend on the perceived uncertainty about the external environment (BURNS; STALKER, 2009; CAPON et al., 1992; ZIRGER; MAIDIQUE, 1990). However, these studies do not explain precisely how organizations adapt to the development process when an external environment is considered highly uncertain.

There are several uncertainty sources perceived on the environment: technological uncertainty, consumer uncertainty, competitive uncertainty and resource uncertainty, (CLARK, 1985; DUNCAN, 1972a; JAUCH; KRAFT, 1986; MILLIKEN, 1987).

O'CONNOR; RICE (2013) presented a study in companies with 12 innovation projects. The authors grouped four uncertainty areas (technology, market, organization, resources) and later, latency and criticism. From these areas they developed a *framework* for managing uncertainty. However, the implementation of *framework* is unclear; the authors presented a step-by-step on how to reproduce it. Although the resource uncertainty area is very similar to risks related to project resources.

MARTINSUO; KORHONEN; LAINE (2014) presented how to deal with uncertainty in program management. In particular, the authors want to understand how the portfolio managers deal with the threats and opportunities that generate uncertainties. In other words, they want to understand the consequences of uncertainty in portfolio management. They seek alternative interpretive and control strategies that managers use when facing different types of uncertainties.

In (JOHANSEN et al., 2014) the authors prepare a *framework* for uncertainty management, which aims to identify, analyze and monitor the project uncertainties. In *framework* steps 1 and 2 are process preparation; then, a process for identifying, analyzing and development to explore and control the uncertainty must be followed, and finally two stages are shown to follow the uncertainty in projects.

In step 1 the question is asked: "When the process should be done?" It is recommended to run *workshops* of uncertainty with the duration between 2 - 4 hours to 2 days, depending on the project size and subject/topic to be discussed in the process. Suggesting that the process focuses on the uncertainty for the following 3 to 6 months in advance, and the more general

uncertainty which is linked to the project objectives and benefits. In step 2 the question: "Who should participate in the process?" Typical stakeholders participating in this *workshop* are: the project owner/sponsor, the project manager and his team, and the project consultants.

Then, the uncertainty management practice is presented to identify, analyze and monitor the project uncertainty. A process of 9 steps is presented: Step 1 is to establish the context - the project objectives; in step 2 an analysis of the stakeholders should be performed. The analysis determines the interest and influence degree; steps 3 to 6 the opportunities and threats to the project are identified and a probability for each is assigned; in step 7 decisions and actions are taken; in step 8 a matrix with the uncertainty occurrences probability is implemented; in step 9 changes in the matrix are interpreted. When the process is done, the following step is their monitoring.

The practices adopted in (JOHANSEN et al., 2014) are interesting for a greater knowledge of the project and uncertainties information search, however, the presented process is very similar to risk management practices.

2.7 Closing Remarks

This chapter presented some issues related to these proposals, including: risks, uncertainties, uncertainty sources, early signs and *sensemaking*. Then, the related works have been explored. Among these, (ANSOFF, 1975) presents his theory of weak signals; (NIKANDER; ELORANTA, 2001) address the early signs in project management environment issue. Additionally, (KAPPELMAN; MCKEEMAN; ZHANG, 2006) approaches it in the IT project context; (WEICK; SUTCLIFFE, 2001) introduces the term Sensemaking that can be applied in the organization context; (LOCH; SOLT; BAILEY, 2008; LOCH; DEMEYER; PICH, 2011) indicate the use of differentiated approaches according to the combination of uncertainty and complexity; (SHENHAR; DVIR, 2007) shows an adaptive approach that serves to correctly classify the project and choose the best way to manage it; (CLEDEN, 2009) says that knowledge is a key role in uncertainty management; (WEICK; SUTCLIFFE, 2011) uses the mindfulness term to describe a state of mind to be alert to the possibility of unexpected situations that arise.

3

Research Method

"Imagination is the beginning of creation. You imagine what you desire, you will what you imagine and at last you create what you will."
George Bernard Shaw

This chapter presents the methodological approach selected for this research. The scientific method is necessary, among other reasons, to make the research results more reliable and able to be reproduced independently by other researchers. Initially, we present a brief introduction to Evidence-Based Software Engineering (EBSE) followed by the presentation of the methodology and its steps.

3.1 Context

According to DENZIN; LINCOLN (2000), qualitative research is a scientific research field practiced by different subjects, traditions and paradigms. This can be defined as an activity that an observer located in the world makes use of practical materials and interpretation. These materials which include field notes, photographs, recordings, conversations, interviews, documents, etc. are transformed into a series of representations of the world. For doing so, an approach to interpretation is needed so that the researchers studying the world things for seeking meaning, provide a sense of the phenomena of interest.

In this context, MEREDITH et al. (1989) discuss that qualitative methodologies applications allow more significant results for managers when compared to those produced by traditional methods. Thus, the realization of this work meets this agenda because it is supported in the techniques of Evidence-Based Software Engineering to investigate a real importance phenomenon for companies.

KITCHENHAM; DYBA; JORGENSEN (2004) propose that Software Engineering should be based on evidence, analogously to what is done in medicine, providing means whereby better evidence from research may be integrated with practical experience and human values in the decision making process considering the software development and maintenance.

The methodology adopted in this chapter and the research classification is presented in Section 3.2. For doing so, as theoretical basis, in the following subsections it is presented a brief introduction to evidence-based software engineering, systematic literature review and action research, then the methodology adopted for this proposal is going to be explored.

3.1.1 Evidence-based Software Engineering

Evidence-based software engineering aims to provide means by which the best evidence from research can be integrated with practical experience and human values in the decision-making process considering the development and software maintenance (KITCHENHAM; DYBA; JORGENSEN, 2004). The essence of evidence-based paradigm is systematically collect and analyze all available data about a phenomenon for a more comprehensive and broader perspective than one can capture through a single study.

The paradigm based on evidence gained forces initially in Medicine as Evidence-based Medicine (EBM), which aims to integrate the best research evidence with clinical experience and assessment of patients. KITCHENHAM; DYBA; JORGENSEN (2004) work was the first to establish a parallel between Medicine and Engineering Software regarding to evidence-based approach. KITCHENHAM; DYBA; JORGENSEN (2004) believe that software engineering can provide evidence-based mechanisms needed to help the professional to adopt appropriate technologies and avoid unsuitable ones, aiming at the best practices and procedures. Some studies suggest that software engineering professionals (researchers) must consider the use of evidence-based software engineering support to improve their decisions about which technologies to adopt (DYBA; DINGSOYR; HANSSEN, 2007; KEELE, 2007; KITCHENHAM; DYBA; JORGENSEN, 2004; KITCHENHAM, 2004; OATES; CAPPER, 2009; TRAVASSOS; BIOLCHINI, 2007).

Software engineering based on evidence gathers and evaluates existing evidence in a technology through a five-step methodology (DYBA; DINGSOYR; HANSSEN, 2007):

1. Transforming the problem or need for information into a research question;
2. Searching the literature for the better available evidence to answer questions;
3. Critically evaluating the evidence about its validity, impact and applicability;
4. Integrating the evaluated evidence with practical experiences, values and clients circumstances to make decisions;
5. Evaluating the steps 1 to 4 performance and searching for ways to improve them.

3.1.2 Systematic Literature Reviews

Systematic literature review is an approach to assess evidence in a systematic and transparent manner. In a conventional literature review the research strategy and results evalua-

tion criteria are usually hidden from the reader, which means that the procedures may be done in an irreproducibility manner, *ad hoc* and evidence that do not support the researcher's preferred hypothesis might be neglected. However, in a systematic literature review the study strategy and the assessment criteria must be explicit and all relevant evidence found during the inquiry are included in the analysis (KITCHENHAM; DYBA; JORGENSEN, 2004; OATES; CAPPER, 2009; KITCHENHAM et al., 2009).

A systematic literature review "is a way of evaluating and interpreting all available research relating to a particular research question, topic area, or phenomenon of interest" (OATES; CAPPER, 2009). TRAVASSOS; BIOLCHINI (2007) states that systematic reviews "provide the means to perform comprehensive literature review and not biased, giving their results have scientific value". In addition, KITCHENHAM; DYBA; JORGENSEN (2004) claim that systematic reviews address to present a fair assessment of a research topic using a reliable, accurate and auditable methodology.

KITCHENHAM; DYBA; JORGENSEN (2004) and TRAVASSOS; BIOLCHINI (2007) present some of the reasons for conducting a systematic review:

- Summarize existing evidence about a phenomenon;
- Identify gaps in current research;
- Provide a framework to position new research; and
- Support the generation of new hypotheses.

KITCHENHAM (2004) summarizes the steps of a systematic review in three main phases: Planning the review, Conducting the revision and Presenting the revision. These steps are described below.

3.1.2.1 Planning a Systematic Review

As in any scientific endeavor, a systematic review of the literature needs a detailed protocol describing the process and the methods to be applied. The most important activity during the planning phase is the formulation of research questions to be answered as all the other aspects of the review process depend on them (DYBA; DINGSOYR; HANSSEN, 2007). To KITCHENHAM (2004), before undertaking a systematic review researchers must ensure that it is necessary and the protocol should be able to answer some questions:

- What are the objectives of this review?
- What sources were searched to identify primary studies? Were there any restrictions?
- What were the criteria for inclusion / exclusion and how they are applied?

- What criteria were used to evaluate the quality of the primary studies?
- How were the quality criteria applied?
- How was the data extracted from primary studies?
- How was the data synthesized?
- What were the differences between the studies investigated?
- Why was the data were combined?

Through these and other questions, the researcher plans and documents all necessary information to carry out the systematic review.

3.1.2.2 Conducting the Revision

The primary studies selection, or else, the execution of the selection process defined in the protocol for the pursuit of studies and subsequently data extraction and evaluation are part of the implementation phase of the systematic review execution. For the studies selection, inclusion and exclusion criteria are used. The information extraction and evaluation are conducted through forms and may be supported by a software tool. The steps, according to TRAVASSOS; BIOLCHINI (2007), summarized for the review implementation are:

- Searches in the defined sources: the process should be transparent, repeatable and documented, as well as the changes that occur in the process;
- Primary studies selection with the inclusion and exclusion criteria defined;
- Data extraction from general information studies to answers to the research questions. Forms are a good way to record all the necessary data and the use of a computational tool can support the data extraction recording and subsequent analysis;
- Assessing the studies quality is important to balance the importance of different studies, reduce bias (tendency to produce "biased results" that systematically separates from true results), maximize internal and external validity and guide recommendations for future research;
- Data synthesis is performed according to the research questions.

3.1.2.3 Presenting the Results

The last step of a systematic review consists on writing a review report and its evaluation, according to the synthesis, and data analysis. Lately, the results are consistently presented with tabulated information and the research question, highlighting similarities and differences between the results, or else, highlighting the possible data combination and analyzes (KITCHENHAM, 2004).

3.1.3 Action Research

Most of the empiric research methods attempt to observe the world as it is currently. The action researchers aim to intervene in the studied situations with the explicit objective of improving the environment. The action research has its origin associated to the first interventionist practices done by DICK (2004) in the decade of 1940 in psychotherapy. Currently, it is used in several other areas as education, business and nursing. Its goal is to perform simultaneously research and action. The action is usually associated with some transformation in a community, organization or programme, while research is characterized by a greater transforming phenomenon understanding by the researcher (research community) or interested (client), or both (SANTOS; TRAVASSOS, 2008).

A prerequisite for action research is making the problem owner disposed to contribute both to identify a problem and to engage in an effort to solve it. In action research, the problems owners become research collaborators. In some cases, the investigator and problem owner may be the same person. In addition, it is important for the action research that the researcher engage in a critical reflection process about their past, adding the researcher's current and planned actions to identify how they actually helped (or not) to solve the problem (EASTERBROOK et al., 2008).

According to THIOLLENT (2011), action research is not about a simple data survey, but in a survey in which the researchers intend to play an active role in the very reality of the observed facts. THIOLLENT (2011) states that its planning is very flexible, and unlike other types of research, it does not follow a series of rigidly ordered phases. Despite this, some authors propose a set of steps to be performed during a search process using action research.

According THIOLLENT (2011), in action research there are practical goals of immediate nature as proposing solutions when it is possible and follow corresponding actions or at least raise the participants' awareness regarding to the existence of solutions and obstacles. Although it is not compatible with controlled studies strand or the experimentalism assumptions (neutrality of the observer, isolation of variables, etc.), the action research is nonetheless a form of experimentation in a real situation in which researchers consciously intervene (CHECKLAND; HOLWELL, 1998). In it, participants are not reduced to guinea pigs and play an active role. From the observation and evaluation of the changes made and also the disclosure of the obstacles found during the process, there is an information gain to be captured and returned as knowledge element (SANTOS; TRAVASSOS, 2008).

EASTERBROOK et al. (2008) argue that a lot of software engineering research is actually a disguised action research. Indeed, many key ideas in software engineering were originally developed by experiencing them in real development projects and reports on experiences. In this sense, DITTRICH; FLOYD; KLISCHEWSKI (2002) describes the cooperative systems development as an ideal action research way for empirical software engineering. By adopting the action research structure more explicitly, it is likely that the design and evaluation of such

research may become stricter.

According to DAVISON; MARTINSONS; KOCK (2004), the different types of action research usually include the following activities: **Diagnosis**: It consists in finding the search field, stakeholders and their expectations in a holistic perspective; **Planning**: Step where actions are defined for the diagnosed framework; **Intervention**: Corresponds to the planned actions implementation; **Evaluation**: Activity which we perform the action effects analysis facing the theoretical support used as a starting point for the actions definition; **Reflection and Learning:** It involves the information flow between participants and other organization parts.

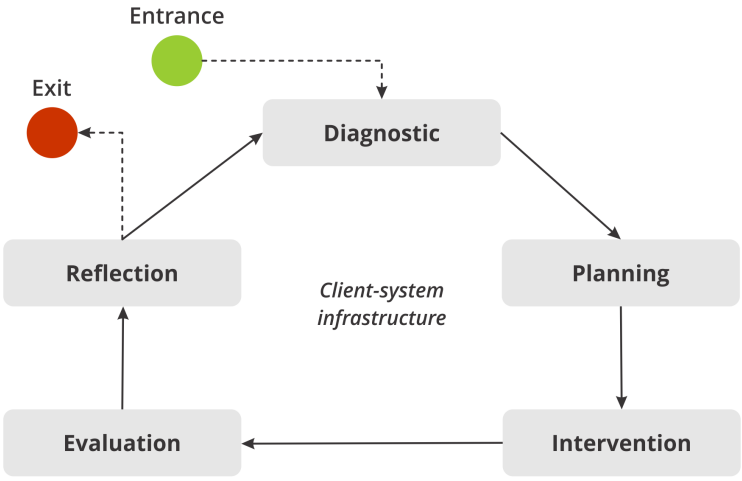


Figure 3.1: The Action Research Cycle.
Source: Adapted from DAVISON; MARTINSONS; KOCK (2004)

This process may be incrementally conducted. It usually occurs when the diagnosis can not be fully done. In addition to these activities, the research environment requires a contract/agreement that legitimizes the actions, potential benefits for both parties (researchers and organization) and other issues, which make up the so-called client-system infrastructure.

3.2 Adopted Method

The research method used in this work is based on the principles of Experimental Software Engineering which is grounded on driving primary and secondary studies in different investigation stages (SPÍNOLA; DIAS-NETO; TRAVASSOS, 2008). It is divided into two phases: design and evaluation of the proposed approach. In addition, this research chose an inductive approach method based on qualitative data supported by the structuralist procedure method according to MARCONI; LAKATOS (2010) classification who claim that the purpose of

inductive arguments is to take the conclusions whose content is much wider than the assumptions on which they were based. Other methods of essential procedures for conducting the re-

search were carried out such as the ones presented by DIAS NETO; SPINOLA; TRAVASSOS (2010) and shown in Figure 3.2.

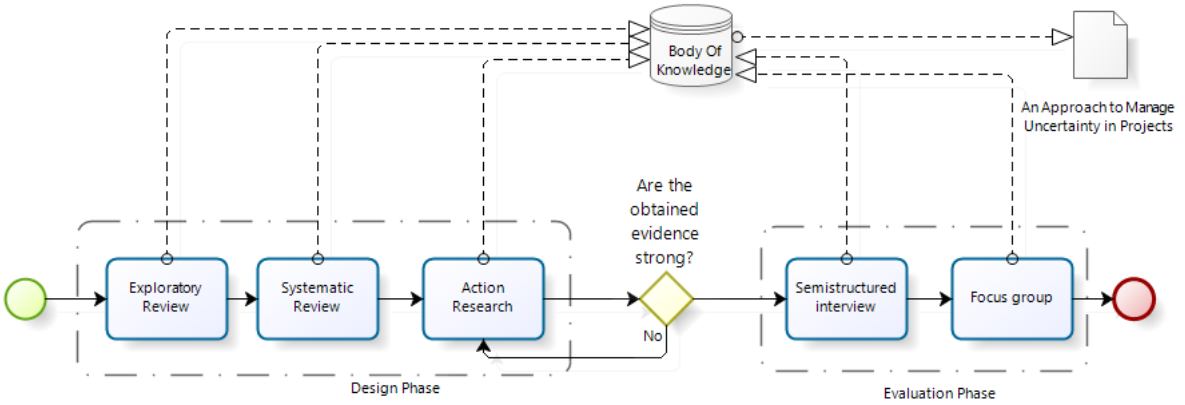


Figure 3.2: Adopted Method.
Source: the author

Based on inductions, the research proposes an approach to uncertainty management in software projects that brings together a number of challenges and best practices as well as models and tools. The evidences collected as described and shown in Figure 3.2 are going to support the approach construction. The body of knowledge presented in Figure 3.2 is formed by the discussion sections' composition of each Chapter of this work. The methodological framework of this research is summarized in Table 3.1

Tabela 3.1: Methodological Framework

Approach Method	Inductive
Procedure Method	Structuralist Systematic Literature Review Action Research Survey
Nature of the Variables	Qualitative

An inductive approach method is "a mental process by which, starting from sufficiently observed particular data, a general or universal truth is inferred, not contained in the examined parts" (MARCONI; LAKATOS, 2010). The induction is done in three stages according to MARCONI; LAKATOS (2010):

- Phenomena observation in order to discover the causes of its manifestation;
- Discovery of the relation by comparison with the aim of discovering a constant existing relation between them; and
- Generalization of the relation between phenomena and similar facts.

The nature of research variables is qualitative. For MARCONI; LAKATOS (2010), the qualitative paradigm is concerned with analyzing and interpreting deeper aspects describing the complexity of human behavior by providing more detailed analysis of the investigations, habits, attitudes, behavior, trends etc. Qualitative methods have the advantage of providing more exploratory information and help refine the proposals that best fit the data.

The procedure methods, more concrete research steps defined for the survey, are presented in the following sub-sections:

3.2.1 Design Phase

The design stage in Figure 3.2 involves a few steps and the execution of secondary and/or primary studies in order to obtain an initial proposal of the proposed approach

In this research an informal literature review was performed with the aim of identifying the basic concepts and the main research sources in the area of domain (MARINHO et al., 2013; MARINHO; SAMPAIO; MOURA, 2014a). According to BRERETON et al. (2007), having this information is essential for a more precise protocol definition for the systematic and comprehensive evaluation for the existing data identification in the area of domain.

Having identified and known the key concepts of a research area, the following activity is to obtain scientific evidence to allow the analysis of the area of domain maturity. According to KITCHENHAM; DYBA; JORGENSEN (2004), one of EBSE search procedures may be holding a systematic literature review. In this scenario, a research protocol was prepared and carried out in order to obtain and analyze the possible outcomes of preliminary studies conducted and published in a research area (MARINHO et al., 2014d). In this activity of the proposed methodology the systematic review results are going to allow, among other results (KITCHENHAM; DYBA; JORGENSEN, 2004): (1) identify the scientific evidence published in a research area; (2) identify gaps and needs in a research area; (3) indicate possible directions to follow in future research.

In addition to the first two steps, an action research was conducted (MARINHO et al., 2015a,b). According to DICK (2004), it has been common to use action research in the research paradigm context based on evidence in these domains as a means of linking theory and practice and academia and industry in both directions. The action research aimed to evaluate the related uncertainties in an innovative project of software implementation and obtain applied practices which may be formally developed and guide efforts to reduce uncertainties and promote project success.

The result of this evaluation also consists on the body of knowledge formalization that allows a first version of an approach to manage uncertainty in projects to the software industry construction (MARINHO; SAMPAIO; MOURA, 2014b; MARINHO et al., 2014c).

3.2.2 Evaluation Phase

As the design phase is completed, the evaluation phase of the proposed approach was be elaborated. A diagnostic guide with researchers and specialists was planned for that phase. In this study it will be adopted the strategy of a qualitative and exploratory research to evaluate the conceptual approach description. To perform data collection it was decided to apply interviews and an focus groups with researchers and experts from project management area.

According to MANZINI (2003) a semi-structured interview is focused on a subject on which we made a script with the main questions that were complemented by other questions related to momentary interview circumstances. In addition to that, HAIR JR et al. (2005) claim that this approach could result in emergence of unexpected and clarifying information thus, improving the findings. An interview occurs when the researcher talks directly with the respondent asking questions and recording the answers. In addition to using the interviews as data collection, they also enable the researcher to get feedback on a particular research topic (HAIR JR et al., 2005).

After the first three steps, an approach formulation could be developed with the aim of solving any search problem area. When the approach is formulated it is advisable to conduct researches with industry experts in order to obtain an evaluation and possible improvements for it. At this point of the methodology, researches (*survey*) are good evaluation mechanisms of such evidences. The *survey* in software engineering context is used to identify a vast population of individuals' characteristics. A questionnaire is used most of the time to conduct the survey, but interviews or data recording techniques can also be used (EASTERBROOK et al., 2008). Semi-structured interviews with experts and theorists were held in the project management area with major questions complemented by other inherent ones to momentary circumstances of the interview.

Furthermore, a focus group (FG) with project management experts was conducted. The focus group is adopted to support researches in different areas, offering instruments to simultaneously collect qualitative data from a group of people (SHULL; SINGER; SJØBERG, 2008). In this thesis, the focus group was applied in the evidence-based software engineering context to obtain a proposed approach's evaluation.

3.3 Closing Remarks

This chapter presented the basic concepts of evidence-based software engineering, systematic literature review and action research. After that, the methodology was based on secondary and primary studies implementation, as a support mechanism for obtaining scientific evidence in a domain area. The methodology consisted of two phases: the design and the assessment phase. The design phase consists of the following steps: informal literature review and literature systematic review and action research. The assessment phase consisted of semi-

structured interviews with experts and a focus group with experts in the field for the approach evaluation.

4

Uncertainty Management Systematic Literature Review

"An optimist is someone who believes the future is uncertain."
Anonymous

The threats identified by uncertainty in day-to-day of a project are real and immediate and the stakes in a project are often high. The project manager faces a dilemma: decisions must be made now about future situations that are inherently uncertain. This chapter presents a systematic review of uncertainties in software project management. The aim of this chapter is to investigate: (i) the relation of uncertainty to innovative projects; (ii) the best practices to manage uncertainties in software projects; (iii) the sources of uncertainty in projects; and (iv) techniques or strategies used to contain uncertainties in projects (MARINHO et al., 2014d).

4.1 Systematic Review Process

This section describes the course of each step in the methodology used to carry out this systematic review study. We followed Kitchenham's methodological guideline for systematic reviews (KITCHENHAM, 2004). A systematic review protocol (see Appendix A) was written to describe the plan for the review. Details on the course of these steps are described in the following subsections.

4.1.1 Search Environment

Before starting the researches, we decided to create a directory in the cloud. A free web store service was used by all researches to store all artifacts used; for example, electronic versions of publications, generated datasheets, partial reports and other documents. This enabled a total standardization and control of artifacts, so all researchers could access them as if they were in a local environment, thought they were remote.

Furthermore, some datasheets were developed which were used in all phases. They datasheets facilitated the data organization in many aspects; for example, a standard to enumerate searched publications, filters to extract objective information and much more.

4.1.2 Research Questions

These are the research questions which guided the systematic review:

- SRL-RQ1: How is it possible to reduce the uncertainty in software projects?
- SRL-RQ2: What practices, techniques or strategies can help reduce the uncertainties in software project management?
- SRL-RQ3: What are the sources of uncertainty perceived?
- SRL-RQ4: What is the relation between uncertainty and innovative projects?

The research question SRL-RQ1 was formulated in order to investigate ways to reduce the uncertainties presented by the literature, that is, how to turn the unknown into known, how to explicit something that was not noticeable to the manager and the project team. The SRL-RQ2 was developed aiming to investigate practices, techniques and strategies in the primary studies which enhance the uncertainties reduction in software projects. The research question SRL-RQ3 was conducted to investigate whether there is a confirmation of the results found in the exploratory review, as shown in Section 2.3.1. SRL-RQ4 was formulated with the objective of verifying a statement of MOURA (2011) in which he says: *"Uncertainty has a relation with projects'innovation level, ie there is a natural relation between software projects that have innovation degree and uncertainties"* and it aimed to present data to the relation between uncertainty and innovative software projects.

4.1.3 Search Strategy

According to KITCHENHAM (2007), a strategy should be used for the primary studies detection, with the key words definition, digital libraries, journals and conferences. The strategy used in this research is presented in the following subsections.

4.1.3.1 Research Key Terms

From the previously defined research questions, the key terms are identified. After identification, the translation of these terms into English is performed as it is the language used in the searched electronic databases and at major conferences and journals of research topics.

Furthermore, synonyms are identified with an expert in the research theme's guidance for each of the key terms. As a recommendation, the identified key terms are going to be searched in singular and plural, for this variation, we used the asterisk character (*) that is

accepted in many digital libraries and allows the word variations that are referenced with the symbol.

The terms and synonyms identified are presented below:

- Project Management;
- Software Project Management;
- Uncertainty;
- Project Uncertainty, Uncertainties in Project;
- Uncertainty management;

4.1.3.2 Search String

According KITCHENHAM (2007), the strings are constructed from the questions structure and sometimes adaptations are necessary according to the specific needs of each database. Thus, the search strings were generated from the key terms combination and synonyms using OR and AND, and possible peculiarities of digital libraries and adaptations by this, were registered. The search strings used are listed below:

((uncertainty <AND> ′software project management′) <OR> (uncertainty AND ′project management′) <OR> (′uncertainty management′ <AND> ′software project′) <OR> ′project uncertainty′ <OR> ′uncertainties in project′)

4.1.4 Search Strategy and Search

A systematic review incorporates a search strategy for a research aiming to identify and retrieve even the slightest possibility of publications superset which meet the systematic review eligibility criteria. They are conditions to determine if primary studies are about the systematic review research questions. The search results are transformed into in a sequential publication list of the chosen engines. Each resource has a different community with differing interests, using different language and examining different issues. The engines provided different search syntaxes as well. Therefore, different resources might have required different search strings.

After that, we conducted initial studies for all phases of the major study,that we called “pilot studies”. These were performed to align a phase-to-phase understanding among researchers, all search engines mechanism tests and adjust of some search terms. Only IEEE Explore search engine showed problems, which were solved with simply adjustments in the search terms for adapting to the search engine mechanism. The study only proceed when the two researchers agreed with the pilots results.

The resources used to perform the searches were:

- IEEEXplore Digital Library (httt://ieeexplore.ieee.org/)
- ACM Digital Library (http://portal.acm.org)
- Elsevier ScienceDirect (www.sciencedirect.com)
- Springer Link (http://link.springer.com/)

The scoping study used an initial list of resources, and an initial uniform search term. Some terms were modified in the sources, because changes occurred in some resources.

Other sources were initially considered as potential for the searches:Google, Google Scholar, Wiley InterScience, InspecDirect, Scopus and Scirus. However, these were later excluded from the final list of sources because they were already indexed by some of the sources already listed in the search.

To search all results from sources, all researchers grouped to search publications. The sources (engines) were divided among all. Each researcher was responsible to find results in your engine and, finally catalogued. Then, when was performed the search, where was identified 3044 publications, according to results from engines mechanisms. The searches results were extracted in Bibtex files to merge in the datasheet developed to consolidate all results from all engines. After exclude duplicated results from datasheet, we found 2933 articles to start the first phase.

4.1.5 Paper Selection

The idealized selection process had two parts: an initial document selection of the research results that could reasonably satisfy the selection criteria, based on a title and the articles abstract reading, followed by a final selection of the initially selected papers list that meet the selection criteria, based on the introduction and conclusion reading of the papers. To reduce potential bias, the selection process was conducted in pairs, in which both researchers worked individually on the inclusion or exclusion of the paper after that a comparison of spreadsheets was done. The possible divergence was discussed and then a consensus was reached. If there was not a consensus, a third researcher should be consulted. In case the doubts still remained, the work would be inserted in the list.

In the pilot study performed before the first phase beginning, the first ten results in all engines were catalogued and all group read the titles and the abstracts and discussed about them to calibrate comprehension. Other pilot study was performed having five more publications done, because the researches were not ready to continue after the first pilot. After a reliability agreement, the first phase initiated. Each researcher read the publications'titles and abstracts to select or exclude the publication. Together, they discussed about their results to gather them together according to a new datasheet agreement. Out of the initial selection of 2933 papers, 111 articles were selected to second phase.

After the first phase and before second phase, a new pilot study was done. Then, we selected a single article to be read by the researchers team aiming a consensus for both. In this phase, the introduction and the conclusion should be read. Similarly to the first phase, each researcher read the articles individually and later discussed its results together. Selection phase two, the researches eliminated 88 and selected 23 papers to be read for the data extraction phase.

4.1.6 Data Extraction

Before this stage, a new pilot was done to calibrate this design. We selected two relevant articles found by the authors (relevant for better quality in defined criteria) and we compared the extraction data performed so far with our data extraction. Thus, a pitot was carried out with an article found by us with one of the 23 selected works. In the data extraction phase, researchers must read the papers selected for extracting structured information according to the datasheet model.

Were selected 23 works but during the extraction phase, the extractors identified 2 articles that showed no relevant citations or possible reasons to be extracted, thus, there were 21 articles. For each publication there were extracted information about the attributes defined in the datasheet.

From each study, there was extracted a list of shares, where each share described answer a research question. Or else, each simple sentence that answered one or more research question was considered a quota. We had a total of 165 quotas extracted from 21 studies. These shares were recorded on a datasheet.

4.1.7 Data Synthesis

The data extraction stage was over. The two researchers worked on the synthesis work to generate combinations of quotas with answers of the research questions.

There was a good level of inter-rater agreement, differences in opinion were discussed in a joint meeting, and it was easily resolved without the need of involving a third researcher arbitrating, as planned.

4.2 Systematic Review Results

This section describes the analysis of the data extracted from our selected studies. As already mentioned in the methodology Section 4.1 of this work the systematic review process adopted had four main stages: Data Search, Data Selection, Data Extraction, Quality Assessment and Data Synthesis.

4.2.1 Data Search

In the Data Search phase the searches were extracted from four sources. The Figure 4.1 shows the results obtained on each stage at systematic review process. The survey was conducted for the period being between 1994 and 2013.

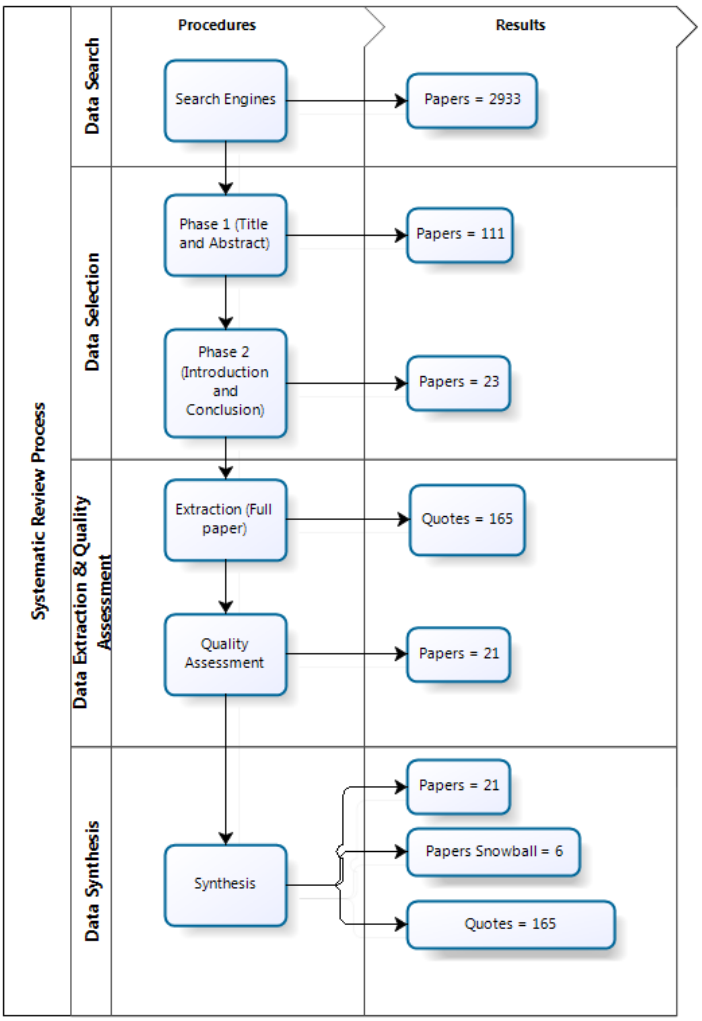


Figure 4.1: Results Obtained on Each Stage at Systematic Review Process.
Source: the author

Thus, the total of 3.044 papers were found in the period; at least 111 articles were identified and classified as duplicate articles. The search process was completed with a total of 2.933 articles ready for the next selection stage.

4.2.2 Data Selection

The Data Selection was divided in two phases: Phase 1: Title and Abstract analyses; and, Phase 2: Introduction and the Conclusion analyses.

In Phase 1, after checking the titles and abstracts, 111 articles were selected for the following phase. A total of 2,822 articles were eliminated. Among the criteria used, it may be highlighted: “0 - Not applicable” (this is a research non related with management or uncertainties), with 52%; “Outside the uncertainties in project management area”, with 38% and “2 -It is about risks in projects” with 10%.

In Phase 2, after reading the introduction and conclusion, just 23 papers were selected for the extraction phase. A total of 88 articles were eliminated. Among the criteria used we highlighted: “1- Outside the uncertainties in project management area ” with 59%, “2 - It is about this risks in projects” with 34%, followed by “0 - Not applicable”, with 7%.

Table 4.1 illustrates the list of engines and its absolute contributions for each research phase.

Tabela 4.1: List of Engines and its Absolute Contributions

Engine	Automatic selection	1st Selection	2nd Selection	Extraction
ACM	548	10	2	2
IEEE	722	63	15	13
ScienceDirect	569	11	4	4
SpringerLink	1094	27	2	2
Total	2933	111	23	21

4.2.3 Data Extraction and Quality Assessment

From the selected studies list it was carried out Data extraction & Quality assessment phase. This process is described below:

- All selected studies (papers) were read in full for data extraction and quality assessment;
- The researchers analyzed the inclusion and exclusion criteria for each paper. Papers that have failed on the inclusion criteria were excluded and updated in datasheets, informing the exclusion criteria.
- For each included paper, its data were extracted through quotes. All quotes was recorded on a specific form. At the same time, its quality assessment was carried out in accordance with the quality criteria;

Out of 23 works selected in the previous stage, the researchers worked with 21 articles. Two were eliminated for not answering the research questions. Additional studies were identified by search technique *snowball*, or else, covering the studies references already found. This

technique allowed us to identify high-quality works that were not found by the automatic search. 6 works that contributed to the discussion were added to be held in Section 4.3. 6 works out of 4 are books and 2 are journals that are not indexed by *engines* the selected research.

4.2.4 Data Synthesis

In the Synthesis phase 165 quotas were analyzed, in which 30 answered the first research question (SRL-RQ1: How is it possible to reduce the uncertainty in software projects?); 73 answered the second research question (SRL-RQ2: What practices, techniques or strategies can help reduce the uncertainties in software project management ?); 44 answered the third research question (SRL-RQ3: What are the sources of uncertainty perceived?) e 18 the last question (SRL-RQ4: What is the relation between uncertainty and innovative projects?).

The geographical distribution of the uncertainties related to studies in project management was as follows: The United States was ahead with 13 articles; England, with 3; Brazil, China and Singapore with 2; and Australia, Scotland, Finland, Israel and Pakistan, with 1. Considering the studies evaluated in the extraction and adding the works found by snollball Figure 4.2 represents the distribution of works by country.

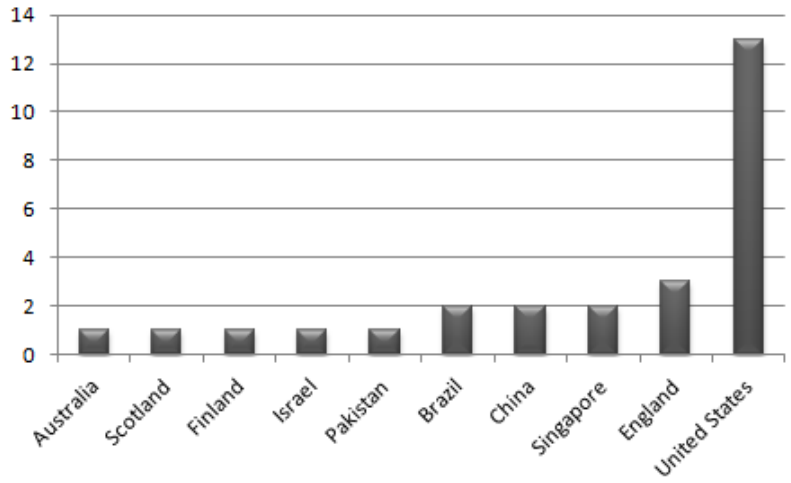


Figure 4.2: Distribution by Continent.
Source: the author

Figure 4.3 illustrates the distribution of studies identified the by selection process throughout the years. We note that in the last 10 years it has been published 20 out of 27 of the papers included in the study. It demonstrates and confirms that research on uncertainties in project management have been growing since the last decade.

Figure 4.4 shows the distribution of documents found by search engines. Being 48% of the works found in IEEE Xplore.

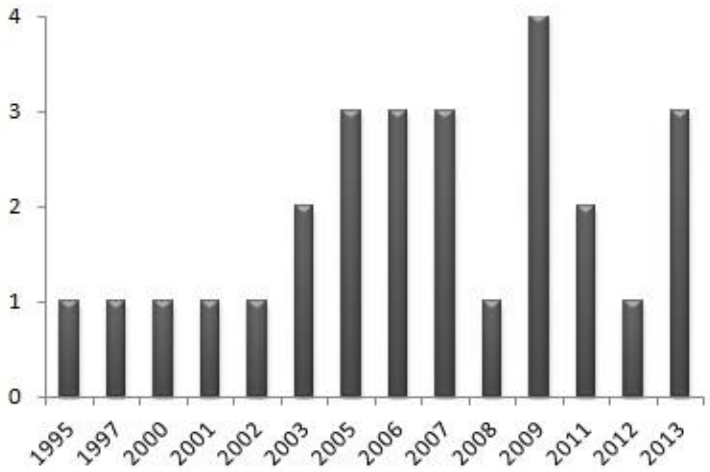


Figure 4.3: Distribution by Years.
Source: the author

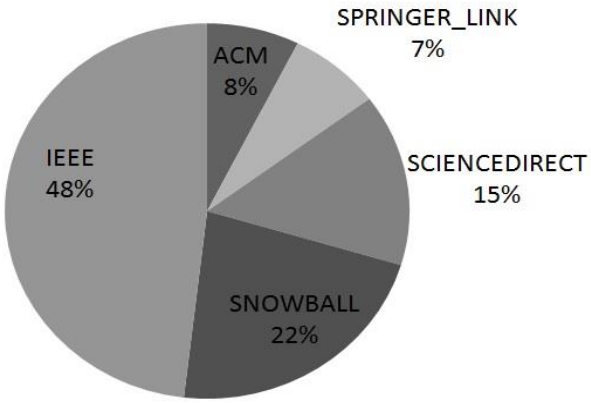


Figure 4.4: Distribution by Search.
Source: the author

Figure 4.5 shows the distribution of works by type of publication, showing that most of the studies, 44% ,were published in journals, followed a 41% of the annals of events (Conferences, Workshops and symposia) and 15% in books. Table 4.2 displays a list with the number of studies returned by event. It can be noticed that most of the studies were published in some editions of the PICMET annals (*Portland International Conference on Management of Engineering and Technology*), followed by the IJPM periodicals (*International journal of project management*) and the third, JPIM (*Journal of Product Innovation Management*).

Tabela 4.2: Number of Studies Returned by Source

Publish in	Quantity
Portland International Conference on Management of Engineering & Technology	5
International journal of project management	4

Books	4
Journal of Product Innovation Management	3
Engineering Management Conference	2
International Conference on Software Engineering	1
IEEE International Conference on Systems, Man, and Cybernetics (SMC)	1
IEEE Software	1
IEEE Transactions on Engineering Management	1
IEEE Transactions on Systems, Man and Cybernetics	1
International Conference on System Sciences	1
MIT Sloan Management Review	1
Small Business Economics	1
SIGPLAN conference companion on object oriented programming systems languages and applications	1

4.3 Discussion

In this section, the results for each research question are presented. In Section 4.3.1 the evidences are presented about the possibility of reducing uncertainty in software projects. In Section 4.3.2 evidences on how the techniques or strategies that favor uncertainties reduction in project management are presented. In Section 4.3.3 uncertainties sources are perceived in the studies. In Section 4.3.4 the more innovative the project is, the larger the uncertainties become is presented. All evidence is properly referenced by 27 studies (SHENHAR; DVIR, 1995; SHENHAR; BONEN, 1997; TATIKONDA; ROSENTHAL, 2000; JAAFARI, 2001; DE MEYER; LOCH; PICH, 2002; MACCORMACK; VERGANTI, 2003; WARD; CHAPMAN, 2003; FREEL, 2005; LITTLE, 2005; REN; YEO, 2005; ATKINSON; CRAWFORD; WARD, 2006; CHYTKA; CONWAY; UNAL, 2006; WANG; LIU, 2006; ROMITO; PROBERT; FARRUKH, 2007; SHENHAR; DVIR, 2007; LOCH; SOLT; BAILEY, 2008; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; LEVY; HAZZAN, 2009; SPERRY; JETTER, 2009; WANG; LI, 2009; LOCH; DEMEYER; PICH, 2011; WEICK; SUTCLIFFE, 2011; CLEDEN, 2012; HAIDER; HAIDER, 2012; MARINHO et al., 2013; O'CONNOR; RICE, 2013; RUSSO; SBRAGIA; YU, 2013).

We made clear that the 27 studies agree on defining risk in technical terms as "state of knowledge in which each alternative leads to a result set, with the probability of occurrence of each result known by the decision maker". Uncertainty "the state of knowledge in which each alternative leads to a result set, with the probability of occurrence of each outcome is not known by the decision maker".

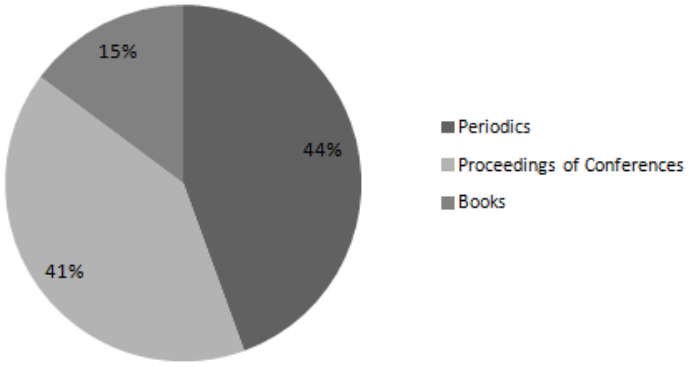


Figure 4.5: Distribution by Type of Publication.
Source: the author

4.3.1 SRL-RQ1: How is it possible to reduce the uncertainty in software projects?

This question aimed to investigate the possibility of reducing uncertainties in software projects. From 27 studies analyzed, 30 quotes were found and classified. There are 5 ways to manage uncertainties in projects identified by the research. They are: 9 approaches adopting techniques and strategies to facilitate uncertainties reduction; 8 address adapting management style to the projects type; 6 approach dealing with uncertainty when they happen; 5 approach understanding the uncertainty sources to better manage each type of project; 2 address identifying uncertainties in order to turn them into risks. In Figure 4.6 shows the five ways. These practices are summarized in Table 4.3. All ways to reduce uncertainties were given a label RSLW + a number for better identification.

Tabela 4.3: Ways to manage uncertainties in projects

Label	What to do?	Papers
RSLW1	Adopting techniques and strategies to facilitate the uncertainty reduction	(DE MEYER; LOCH; PICH, 2002; REN; YEO, 2005; ROMITO; PROBERT; FARRUKH, 2007; SHENHAR; DVIR, 2007; LOCH; SOLT; BAILEY, 2008; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; CLEDEN, 2012; RUSSO; SBRAGIA; YU, 2013).
RSLW2	Adapting management style to the type of projects	(SHENHAR; BONEN, 1997; REN; YEO, 2005; SHENHAR; DVIR, 2007; DE MEYER; LOCH; PICH, 2002; MARINHO et al., 2013).

RSLW3	Dealing with uncertainty when they happen	(JAAFARI, 2001; WANG; LIU, 2006; ROMITO; PROBERT; FARRUKH, 2007; SHENHAR; DVIR, 2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; CLEDEN, 2012; MARINHO et al., 2013).
RSLW4	Understand the sources of uncertainty to better manage each type of project	(TATIKONDA; ROSENTHAL, 2000; DE MEYER; LOCH; PICH, 2002; ROMITO; PROBERT; FARRUKH, 2007; WARD; CHAPMAN, 2003; SHENHAR; DVIR, 2007; LOCH; SOLT; BAILEY, 2008; MARINHO et al., 2013).
RSLW5	Identify uncertainties in order to turn it into risk	(TATIKONDA; ROSENTHAL, 2000; LOCH; SOLT; BAILEY, 2008).

4.3.1.1 RSLW1 - Adopting techniques and strategies to facilitate the uncertainty reduction

It is tempting to wish to eliminate all uncertainty, but the high levels of necessary resources even to get close to project goal are, in the most exceptional cases, unjustified. In fact, great efforts for uncertainty sources eradication often divert attention from the real goals. Eradication is rarely the answer, it is more feasible to manage uncertainty within acceptable levels. This leads to another guiding principle for uncertainty management: The objective is the uncertainty containment, not its elimination, as the evidence makes it clear:

> "*It must be mentioned, that uncertainty can not be eliminated completely. Still, continuous reflective learning and information sharing make it manageable by reducing it significantly* (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)."

Although there are no easy answers or fast solutions, we may say that uncertainty can be "tamed", part of the answer lies in recognizing the nature of the problem and select the right technique (or strategy) to work. Like any good craftsman, the project manager must have of a set of comprehensive tools for managing uncertainty and - equally important - a good knowledge of the capabilities and limitations of those tools (CLEDEN, 2012). For different types of problems, the manager and the team should have strategies, mindset and different paradigms (REN; YEO, 2005), as highlighted in the evidence:

> "*Some of strategies aim to restrict the source of uncertainty, thereby reducing the likelihood of problems arising* (CLEDEN, 2012)."

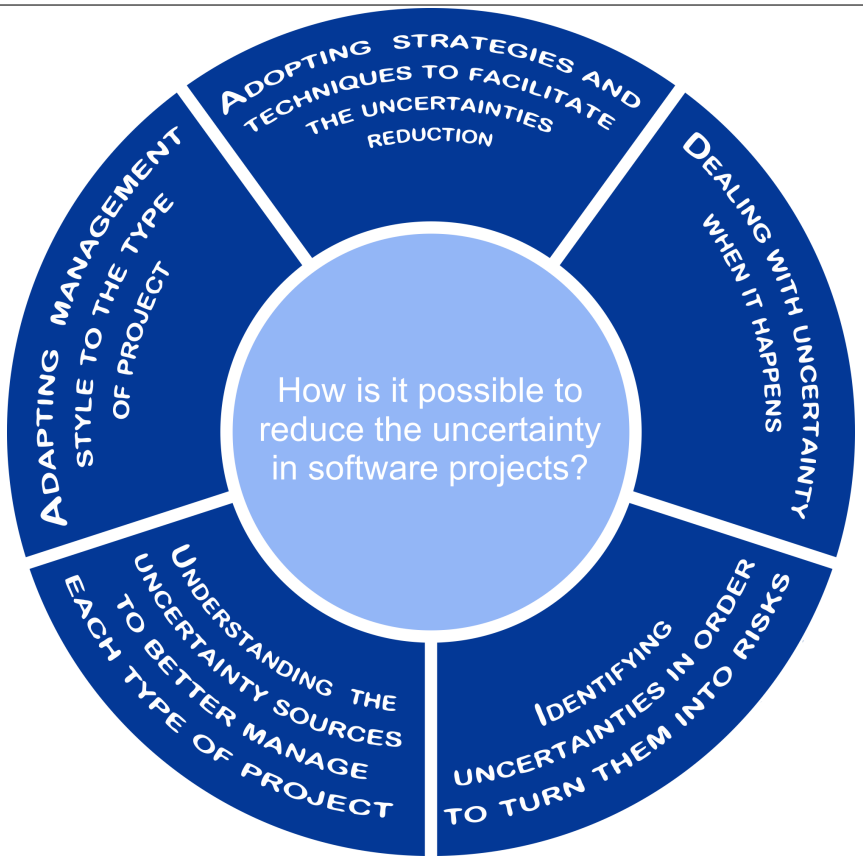


Figure 4.6: Ways to Manage Uncertainties in Projects Identified by the Research.
Source: the author

"*We can use different strategies at different stages in the lifecycle* (CLEDEN, 2012)."

"*Some strategies of the team facilitated the management of uncertainty in...* (RUSSO; SBRAGIA; YU, 2013)."

"*uncertainty requires methods that go beyond risk management* (LOCH; SOLT; BAILEY, 2008)."

4.3.1.2 RSLW2 - Adapting the management approach to the type of projects

The authors described the importance of evaluating and analyzing a project's uncertainties and complexities and so, adapting their management style to the situation (MARINHO et al., 2013), as the evidence makes clear:

"*assess and analyze uncertainties and complexities in advance, and so fail to adapt their management style to the situation* (MARINHO et al., 2013)."

"*Firms need to understand the uncertainty inherent in particular project types so that they may select among, plan for and execute projects appropriately* (TATIKONDA; ROSENTHAL, 2000)."

It is also addressed in some studies that projects fail because managers applied the wrong management style to the project (REN; YEO, 2005), as the evidence stresses:

> "*Projects failed because managers applied wrong management style to projects* (REN; YEO, 2005)."

It is important to point out that project managers cannot predict the future, but can perceive the uncertainties in their projects and choose an appropriate management style to use (SHENHAR; BONEN, 1997; TATIKONDA; ROSENTHAL, 2000; DE MEYER; LOCH; PICH, 2002). Some pieces of evidence comment about these:

> "*Our basic proposition is that project management style differ with each specific kind of system and that management attitudes must be adapted to the proper system type* (SHENHAR; BONEN, 1997)."

> "*When the proper style is employed, we claim, that the chances for project success are much higher. However, when a wrong style is utilized, or the when the system is misclassified,this may result in substantial difficulties and delays in the process of the system creation* (SHENHAR; BONEN, 1997)."

4.3.1.3 RSLW3 - Dealing with uncertainty when they happen

Some uncertainty types cannot simply be solved through an analytical approach. Such as: a number of events, random combinations, they may contribute to an unexpected result. Pharmaceutical companies have struggled with this problem. Despite extensive testing programme, there is always the risk of an unlikely combination of external factors (other drugs usually administered by the patient) to react causing harmful side effects (JAAFARI, 2001; WANG; LIU, 2006; ROMITO; PROBERT; FARRUKH, 2007; SHENHAR; DVIR, 2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008).

> "*...However, on complex projects within a changing environment, uncertainty will not necessarily diminish over time. Thus, it will be necessary to continuously sense the project variables, re-evaluate the status of the objective function, take action and re-adjust the project strategies* (JAAFARI, 2001)."

Project managers can try to contain uncertainty at its source but they can hardly ever have a hundred percent of success. Therefore, a project needs strength and should be able to rapidly detect and respond to unexpected events. A project manager must decide how best to cope with unexpected results (CLEDEN, 2012; MARINHO et al., 2013).

> "*Managers'attitudes and understanding of uncertainty do not create or eliminate it. But this understanding affects the way managers make sense of the situation and decide on alternative actions* (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)."

4.3.1.4 RSLW4 - Understand the sources of uncertainty to better manage each type of project

Uncertainty can arise from deficiencies in various sources, such as contextual information about the project, our understanding of underlying processes, past events explanations and speed (or time) change. We may ask where these factors happen within a project and what aspects of a project plan are particularly vulnerable to each uncertainty type. To answer those questions, first it is interesting to see the elements that make a typical project. Then, we need to examine what happens when the scale and complexity of the model increases. Thus, it is possible to choose styles and strategies to manage the project properly, as highlighted in the evidence

> "*the presence (although not the identity) of unknown unknowns was successfully predicted by diagnosing gaps in the team's knowledge about certain subproblem areas* (LOCH; SOLT; BAILEY, 2008)."

> "*these four areas which can be seen as a starting point for project managers to observe and identify uncertainties and thereby assist in the project's success* (MARINHO et al., 2013)."

4.3.1.5 RSLW5 - Identify uncertainties in order to turn them into risk

Strategies can be used to contain the uncertainties. These strategies can help you learn more about the nature of uncertainty, for example, through the formulation of the problem that it represents or the modeling of future scenarios to prepare for them.

> "*The industry structure looks understandable, and the effect of actions taken can be traced. Through learning, uncertainty has been transformed into risk* (LOCH; SOLT; BAILEY, 2008)."

Once an uncertainty is revealed, strategies, such as risk management can be used in project management (WARD; CHAPMAN, 2003; LOCH; SOLT; BAILEY, 2008; CLEDEN, 2012).

> "*This means that the process of risk analysis (that is, the steps taken to identify and quantify project risks) transforms some, but not all, of the uncertainty into risks. What remains is latent uncertainty* (CLEDEN, 2012)."

4.3.2 SRL-RQ2: What practices, techniques or strategies can help reduce the uncertainties in software project management?

This question sought to identify practices to support the software projects management that help reduce the uncertainties. Out of 73 quotas extracted for that matter, 18 practices,

techniques or strategies for managing projects focusing on reducing uncertainties were found. These practices are presented in Figure 4.7 and described below together with their references of studies that support each of them. An evidence before the explanation is presented. These practices are summarized in Table 4.4. All practices were given a label for better identification and to be added to the body of knowledge as shown in Figure 3.2.

Figure 4.7: Practices, Techniques or Strategies that can Help Reduce the Uncertainties in Project Management Software.
Source: the author

Tabela 4.4: Practices and Strategies that Help Reduce the Uncertainties

Label	Practices	Papers

RSLP1	Identifying the project type to adopt appropriate management	(SHENHAR; DVIR, 1995; SHENHAR; BONEN, 1997; REN; YEO, 2005; ATKINSON; CRAWFORD; WARD, 2006; SHENHAR; DVIR, 2007; LOCH; SOLT; BAILEY, 2008; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; CLEDEN, 2012; LOCH; DEMEYER; PICH, 2011; WEICK; SUTCLIFFE, 2011; MARINHO et al., 2013; RUSSO; SBRAGIA; YU, 2013).
RSLP2	Managing the expectations of stakeholders so that they flexibly accept changes	(DE MEYER; LOCH; PICH, 2002; REN; YEO, 2005; ATKINSON; CRAWFORD; WARD, 2006; WANG; LIU, 2006; LOCH; SOLT; BAILEY, 2008; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; LEVY; HAZZAN, 2009; LOCH; DEMEYER; PICH, 2011; RUSSO; SBRAGIA; YU, 2013).
RSLP3	Ability to formulate qualitative measures of success	(ATKINSON; CRAWFORD; WARD, 2006; SHENHAR; DVIR, 2007).
RSLP4	Identifying early warning signs to manage the uncertainties	(DE MEYER; LOCH; PICH, 2002; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; LOCH; DEMEYER; PICH, 2011; RUSSO; SBRAGIA; YU, 2013).
RSLP5	Sensemaking	(ROMITO; PROBERT; FARRUKH, 2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; WEICK; SUTCLIFFE, 2011; RUSSO; SBRAGIA; YU, 2013).
RSLP6	Management flexibility and ability to respond to changes	(JAAFARI, 2001; DE MEYER; LOCH; PICH, 2002; LITTLE, 2005; CHYTKA; CONWAY; UNAL, 2006; WANG; LIU, 2006; SHENHAR; DVIR, 2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; MARINHO et al., 2013).
RSLP7	Managerial ability to perceive uncertainty and deal with them	(REN; YEO, 2005; JAAFARI, 2001; DE MEYER; LOCH; PICH, 2002; WANG; LIU, 2006; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; WANG; LI, 2009; MARINHO et al., 2013).

RSLP8	Team willing to learn and develop new ideas in order to generate knowledge	(JAAFARI, 2001; DE MEYER; LOCH; PICH, 2002; REN; YEO, 2005; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; LEVY; HAZZAN, 2009; MARINHO et al., 2013; RUSSO; SBRAGIA; YU, 2013).
RSLP9	Creation of flexible contracts	(DE MEYER; LOCH; PICH, 2002; RUSSO; SBRAGIA; YU, 2013).
RSLP10	Building trust between team, management and customer	(DE MEYER; LOCH; PICH, 2002; WANG; LIU, 2006; WEICK; SUTCLIFFE, 2011).
RSLP11	Verify information outside environment of the project	(DE MEYER; LOCH; PICH, 2002; SHENHAR; DVIR, 2007; WEICK; SUTCLIFFE, 2011; MARINHO et al., 2013; O'CONNOR; RICE, 2013).
RSLP12	Understanding the sources of uncertainties	(MACCORMACK; VERGANTI, 2003; SHENHAR; DVIR, 2007; MARINHO et al., 2013; O'CONNOR; RICE, 2013).
RSLP13	Project Managers must incorporate the investigation of uncertainties in projects	(CHYTKA; CONWAY; UNAL, 2006; SHENHAR; DVIR, 2007; MARINHO et al., 2013; O'CONNOR; RICE, 2013; RUSSO; SBRAGIA; YU, 2013).
RSLP14	Learning method	(REN; YEO, 2005; WEICK; SUTCLIFFE, 2011; RUSSO; SBRAGIA; YU, 2013).
RSLP15	Creativity techniques	(REN; YEO, 2005; WEICK; SUTCLIFFE, 2011; RUSSO; SBRAGIA; YU, 2013).
RSLP16	Managers should facilitate communication within the organization	(DE MEYER; LOCH; PICH, 2002; LITTLE, 2005; REN; YEO, 2005; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008).
RSLP17	Managers should facilitate self-organization and the team adaptability	(REN; YEO, 2005; WEICK; SUTCLIFFE, 2011).
RSLP18	The Collaborative Work	(REN; YEO, 2005; SHENHAR; DVIR, 2007; LEVY; HAZZAN, 2009).

4.3.2.1 Identifying the project type to adopt appropriate management

To reduce the failure probability of a project it is important to characterize it properly, so knowing in advance if there is a related uncertainty to their goals and solutions adopting a

management model that fits the project type (SHENHAR; DVIR, 1995; SHENHAR; BONEN, 1997; REN; YEO, 2005; ATKINSON; CRAWFORD; WARD, 2006; SHENHAR; DVIR, 2007; LOCH; SOLT; BAILEY, 2008; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; CLEDEN, 2012; LOCH; DEMEYER; PICH, 2011; WEICK; SUTCLIFFE, 2011; MARINHO et al., 2013; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

> "*It is necessary to understand in what way projects are different from each other in order to suit the right situation to the particular project* (MARINHO et al., 2013)."

4.3.2.2 Managing the stakeholders' expectations so that they flexibly accept changes

Software projects can create high expectations for clients. One needs to manage them, keeping clients informed and aware of the project uncertainties, as well as creating a bond of trust between project members and clients (DE MEYER; LOCH; PICH, 2002; REN; YEO, 2005; ATKINSON; CRAWFORD; WARD, 2006; WANG; LIU, 2006; LOCH; SOLT; BAILEY, 2008; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; LEVY; HAZZAN, 2009; LOCH; DEMEYER; PICH, 2011; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

> "*With uncontrolled uncertainty, a lot of time and effort must go into managing relationships with stakeholders and getting them to accept and respond to unplanned changes* (REN; YEO, 2005)."

> "*A lot of time and effort must go into managing relationships with stakeholders and getting them to accept unplanned changes* (DE MEYER; LOCH; PICH, 2002)."

4.3.2.3 Ability to formulate qualitative measures of success

Ability to formulate qualitative measures of success for projects is another tool that should be added to the arsenal of project management. Projects with low uncertainty can often be assessed through quantitative measures of success, such as time and cost, and tangible performance measures related to their tangible final deliverables. This requires ability to develop assessment frameworks of sensitive performance that match the project complexity, ie, It is necessary to understand what their contributions are to results in general, setting goals in advance for projects success, aligned with business goals of the organization (ATKINSON; CRAWFORD; WARD, 2006; SHENHAR; DVIR, 2007), as the evidence makes clear:

> "*Ability to formulate qualitative success measures for projects is another tool that should be added to the project management armoury to assist in uncertainty managing projects* (ATKINSON; CRAWFORD; WARD, 2006)."

4.3.2.4 Identifying early warning signs to manage the uncertainties

Early identification of signs of a change can become a significant competitive advantage, because it can show an interruption in the current cycle, a break, beneficial or dangerous, for business. In the projects context, the early signs are of great importance, especially in innovative projects by having several associated uncertainties. The idea is to identify the cause of problems, and the solutions for each signal (DE MEYER; LOCH; PICH, 2002; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; LOCH; DEMEYER; PICH, 2011; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

> "*...to identify unforeseeable uncertainties is through the perception of early signs* (RUSSO; SBRAGIA; YU, 2013)."

> " *That is why identifying relevant ones from the contextual uncertainty by means of environmental scanning or other analytical models is an important part of project management* (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)"

4.3.2.5 Sensemaking

The search for meaning is particularly important in a project-based environment. Once given way to a decision and its context, the actions (programs and projects), to be developed from the conception of meaning, become better understood and can be implemented in a more natural, efficient and effective way (ROMITO; PROBERT; FARRUKH, 2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; WEICK; SUTCLIFFE, 2011; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

> "*An important insight into understanding uncertainty in this respect is provided by Karl Weick, he argue understanding and sensemaking affect strategic decisions, and consequently, performance of the firm* (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)."

> "*For the early recognition of these signs, it is necessary to understand their meaning, through sensemaking* (RUSSO; SBRAGIA; YU, 2013)."

4.3.2.6 Management flexibility and ability to respond to changes

Complex and uncertain projects changes, requires greater flexibility and reflection, as a new way to generate knowledge, the managing way, the project manager and the performance of the team should change as the profile and the uncertainty evolve. Projects with many uncertainties must be open to creativity and experimentation. Thus, the flexibility and the ability to communicate the changes is fundamental (JAAFARI, 2001; DE MEYER; LOCH; PICH, 2002; LITTLE, 2005; CHYTKA; CONWAY; UNAL, 2006; WANG; LIU, 2006; SHENHAR; DVIR,

2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; MARINHO et al., 2013), as the evidence makes clear:

> "*Projects are very complex and uncertain, which emphasizes the need for greater flexibility and reflection as a new way of generating knowledge and functioning* (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)."

4.3.2.7 Managerial ability to perceive uncertainty and deal with them

The ability to take reasonable decisions to ensure there is necessary support to get everyone involved in the project; personal ability, such as intuition and trial to perceive uncertainties; ability to maintain a good relationship and build trust are favorable points for reduction and perception of uncertainty in a project (REN; YEO, 2005; JAAFARI, 2001; DE MEYER; LOCH; PICH, 2002; WANG; LIU, 2006; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; WANG; LI, 2009; MARINHO et al., 2013), as the evidence makes clear:

> "*The way uncertainty is perceived by project managers depends on personal skills, intuition and judgment* (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)."

> "*The project manager's role and the planning and monitoring activities change as the uncertainty profile evolves. So flexibility and the ability to communicate changes is key* (DE MEYER; LOCH; PICH, 2002)."

4.3.2.8 Team willing to learn and develop new ideas in order to generate knowledge

Crisis management and continuous observation of threats and/or opportunities must be controlled by the team. When new information arises, everyone should be willing to learn and then formulate new solutions (JAAFARI, 2001; DE MEYER; LOCH; PICH, 2002; REN; YEO, 2005; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; LEVY; HAZZAN, 2009; MARINHO et al., 2013; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

> "*When enough new information arises, they must be willing to learn and then formulate new solutions* (DE MEYER; LOCH; PICH, 2002)."

4.3.2.9 The creation of flexible contracts

Creating flexible contracts for innovative projects help mitigating resistance to changes necessary for the project. Obviously, to have a flexible contract it is important to keep project stakeholders well informed (DE MEYER; LOCH; PICH, 2002; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

> "*The manager's job is to anticipate and soften resistance by creating flexible contracts and keeping stakeholders well informed* (DE MEYER; LOCH; PICH, 2002)."

"*the indications of facilitating factors for the management of uncertainty:... Contractual terms with suppliers including unknow unknows* (RUSSO; SBRAGIA; YU, 2013)."

4.3.2.10 Building trust between team, management and customer

With uncertainty, a lot of time and effort should be invested to manage relationships with stakeholders and get them to accept unplanned changes. The relationship is characterized by trust between clients, managers and teams. Trust, once conquered, help alleviate the strategies change meetings during the project (DE MEYER; LOCH; PICH, 2002; WANG; LIU, 2006; WEICK; SUTCLIFFE, 2011), as the evidence makes clear:

"*The relationship is characterized by trust and relieves both the management team and the subcontractors of having to anticipate every little event*" (DE MEYER; LOCH; PICH, 2002).

Project managers must have such skills as relationship management, trust-building,and political skills (WANG; LIU, 2006).

4.3.2.11 Verify information outside the environment of the project

Actions relevant to organizations or groups within the organization (suppliers, competitors, consumers, government, shareholders, etc) can affect the product, as well as doubts about the likelihood or nature of changes in the environment general condition (socio-cultural trends, demographic changes) (DE MEYER; LOCH; PICH, 2002; SHENHAR; DVIR, 2007; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008; WEICK; SUTCLIFFE, 2011; MARINHO et al., 2013; O'CONNOR; RICE, 2013), as the evidence makes clear:

"*Judging the source and relevance of information that comes from the outer project environment and, thus, represent contextual uncertainty is an intuitive process rather than a rational one, since the rational processes are isolated from the surrounding world* (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008)."

4.3.2.12 Understanding the sources of uncertainties

Project management can be conducted focused on resolving the project uncertainties, for doing so, it is necessary to understand where the uncertainties of projects can arise, ie, what are the possible sources of uncertainty? Understanding the sources we may be able to make the necessary changes as the project progresses (MACCORMACK; VERGANTI, 2003; SHENHAR; DVIR, 2007; MARINHO et al., 2013; O'CONNOR; RICE, 2013), as the evidence makes clear:

"*it is necessary to understand the areas of uncertainty in a project to be able to contribute to its success* (MARINHO et al., 2013)."

"*the team must define the current uncertainty set, i.e., the specific uncertainties within the four categories of uncertainty...that can be converted into assumptions to be tested* (O'CONNOR; RICE, 2013)."

4.3.2.13 Project managers must incorporate the investigation of uncertainties in projects

Ongoing investigation of uncertainties is important for members of the projects act in a proactive way and the organization to benefit strategically. The articles show that managerial knowledge aligned with the research uncertainties may contribute to transformation of uncertainties in risk (CHYTKA; CONWAY; UNAL, 2006; SHENHAR; DVIR, 2007; MARINHO et al., 2013; O'CONNOR; RICE, 2013; RUSSO; SBRAGIA; YU, 2013).

"*The use of uncertainty management within project management can be a determining factor in project success* (MARINHO et al., 2013)" , as the evidence makes clear:

Knowledge plays a central role in the management of uncertainty, allowing the project manager model the events that may happen. Uncertainty is much more than the absence of facts; it is fundamentally a gap in knowledge which may include several different elements (CLEDEN, 2009).

One way to predict uncertainty is adopting strategies focused on knowledge that provide the ability to visualize future states of the project. Allowing the manager and his team analyze different scenarios by building predictive models on how these variables change over time. The better the model, the less the uncertainty about the future, and the better decision making is, as the evidence makes clear:

"*Notice that for a risk to be identified, we must have a basic level of knowledge concerning the problem. What is the threat? What impact might it have? Where is the project vulnerable and how might we fix this? This is a knowledge-centric view* (CLEDEN, 2009)."

4.3.2.14 Learning method

That includes experimentation and improvisation. The more we experience knowledge of a particular subject the more we reduce uncertainty; Improvisation itself can be a differentiator for innovative projects in the quest to deviate from uncertainties, seeking new goals (REN; YEO, 2005; CLEDEN, 2009; WEICK; SUTCLIFFE, 2011; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

"*learning strategies: give the project manager, and the organization as a whole, the ability to improve and benefit from experience over time* (CLEDEN, 2009)."

"*in the uncertainty projects, the majority used a learning method...* (RUSSO; SBRAGIA; YU, 2013)"

4.3.2.15 Creativity techniques

Some articles suggest creativity techniques such as: Brainstorming, feasibility study, market research to obtain knowledge (REN; YEO, 2005; WEICK; SUTCLIFFE, 2011; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

"*Encourage diversity and stimulate the creativity of empowered team members* (REN; YEO, 2005)."

4.3.2.16 Managers should facilitate communication within the organization

A propitious environment for communication can be a differentiator of organizations. Some articles suggest that innovative projects with small teams and located in the same environment have facility to pass the information received (DE MEYER; LOCH; PICH, 2002; LITTLE, 2005; REN; YEO, 2005; PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008), as the evidence makes clear:

"*Managers need to participate in and facilitate free flowing communication and conversations which are absolutely critical to success* (REN; YEO, 2005)."

4.3.2.17 Managers should facilitate self-organization and the team adaptability

They need to encourage diversity of thought and interaction, breaking organizational and hierarchical structures. The team needs to adapt to changes. They also need to interact feedback constantly with market and technology providers. The managerial focus should be on group dynamics to keep large project objectives in mind, instead of labor control (REN; YEO, 2005; WEICK; SUTCLIFFE, 2011), as the evidence makes clear:

"*The managers should facilitate evolutionary, double-loop learning, and facilitate self-organization, innovation, and adaptability* (REN; YEO, 2005)."

4.3.2.18 The Collaborative Work

The democratic management style is best appropriated, very tight control will lead an innovative project clutter and the project vision becomes an illusion. Collaborative working is essential in projects with many uncertainties (REN; YEO, 2005; SHENHAR; DVIR, 2007; LEVY; HAZZAN, 2009), as the evidence makes clear:

"*The development team is collocated in a collaborative workspace* (LEVY; HAZZAN, 2009)."

4.3.2.19 Some techniques

Other techniques which help in reducing uncertainty were placed into just one article cited which were: quality agreement with the client, continuous integration, involvement of the specialist user in the project, short iterations (LITTLE, 2005); Open mind to culture, stakeholder analysis; multidisciplinary team, multiple specialties together help in creating differentiated alternatives and phase uncertainties; external view of the problem reported by the team client (RUSSO; SBRAGIA; YU, 2013).

4.3.3 SRL-RQ3: What are the sources of uncertainty perceived?

This question sought to investigate what the sources of perceived uncertainty in software projects are. From the 27 studies analyzed, 44 quotes were found. In the studies surveyed there is not a single label to the sources, it is common in some articles to speak from a particular source that is a single uncertainty, but classified differently, for example: market source (WANG; LIU, 2006; LITTLE, 2005; SPERRY; JETTER, 2009; ROMITO; PROBERT; FARRUKH, 2007; MARINHO et al., 2013; O'CONNOR; RICE, 2013), external source (RUSSO; SBRAGIA; YU, 2013) and novel source (TATIKONDA; ROSENTHAL, 2000; SHENHAR; DVIR, 2007) represent a single source of uncertainty. For doing so, we try to group the uncertainty and create a unique classification for these sources. Among those quotas found (they could cite more than one source, if they are in the same sentence), we found: 16 references to market uncertainty; 15 references to technological uncertainty; 14 for environment uncertainty and 9 for socio-human uncertainty. The following describes the sources of uncertainties grouped by research:

4.3.3.1 Market

Market uncertainty indicates how new products are to the market, consumers and to potential users. It represents the extent to which buyers and users are familiar with that type of product, its benefits and how they can use it, as the evidence makes clear:

"*Market uncertainty, reflecting the uncertainty faced in determining customer requirements for the product under development* (MACCORMACK; VERGANTI, 2003)."

The level of market uncertainty indicates the external uncertainty, and also reflects the uncertainty of the project goal. It also indicates the easiness of knowing what to do or what to build and how to introduce consumers to the product, as the evidence makes clear:

> "*If the market needs are well known, the project probably won't need much steering. Conversely, if they aren't well understood, the ability to steer the project to the desired goal rather than to the initially stated objective will be critical* (LITTLE, 2005)"

Market uncertainty comprehends client, suppliers, partners and current market situation (TATIKONDA; ROSENTHAL, 2000; DE MEYER; LOCH; PICH, 2002; WANG; LIU, 2006; LITTLE, 2005; SPERRY; JETTER, 2009; ROMITO; PROBERT; FARRUKH, 2007; SHENHAR; DVIR, 2007; CLEDEN, 2012; MARINHO et al., 2013; O'CONNOR; RICE, 2013; RUSSO; SBRAGIA; YU, 2013), as the evidence makes clear:

> "*Market uncertainty indicates how new the product is to the market, to consumers and to potential users. It represents the extent to which buyers and users are familiar with this type of product, its benefits and how they can use it* (MARINHO et al., 2013)."

4.3.3.2 Technology

Technological uncertainty depends on the extent to which the project uses new technology or mature technology. The level of project technological uncertainty is not universal, but subjective, and depends not only on what technology exists, but also what is accessible to the organization. It is therefore, a measure of the amount of existing new technology compared to mature technology available for use in the project. The technological uncertainty causes, among other things, an impact in the project, in the communication, in the freezing time of the plan and the number of planning cycles. It can also affect the technical expertise that the project manager and their team members need to have (SHENHAR; BONEN, 1997; TATIKONDA; ROSENTHAL, 2000; DE MEYER; LOCH; PICH, 2002; FREEL, 2005; LITTLE, 2005; WANG; LIU, 2006; ROMITO; PROBERT; FARRUKH, 2007; SPERRY; JETTER, 2009; MARINHO et al., 2013; O'CONNOR; RICE, 2013), as the evidence makes clear:

> "*technology is a source of uncertainty* (TATIKONDA; ROSENTHAL, 2000)."

> "*Technology complexity refers to the difficulty to complete the project, such as whether new technology is used* (WANG; LIU, 2006)."

> "*Project teams building new products often want use the latest technology, so these projects will have a high degree of technical uncertainty* (LITTLE, 2005)."

4.3.3.3 Environment

This source indicates the uncertainties of the external and internal organizational environment. Organizational theories emphasize that organizations must adapt to their environment if they are to remain viable. Environmental uncertainty can arise from the actions of

different organizations (suppliers, competitors, consumers, government, shareholders, etc.) and this may affect the project. Doubts about the probability or nature of changes in the environment (socio-cultural trends, demographic changes) can lead to a number of environmental uncertainties (TATIKONDA; ROSENTHAL, 2000; FREEL, 2005; WANG; LIU, 2006; CLEDEN, 2012; MARINHO et al., 2013; O'CONNOR; RICE, 2013), as the evidence makes clear:

> "*Uncertainty in the economic environment - Dynamic economy:representing dynamics in the economic environment, based upon changing information requirements and government regulations/legislation; Hostile economy:representing hostility of the economic environment, based upon the relative extent to which innovation was compelled by legislation, regulation and standardization* (FREEL, 2005)."

> "*Environmental uncertainty indicates the degree of uncertainty of the external and internal organization environment* (MARINHO et al., 2013)."

4.3.3.4 Socio-Human

The socio-human source considers the relationships between people within an organization. It is necessary to consider religious issues, politics, different values, personal experiences and cultural training. Any of the mentioned factors can affect project performance and results. Project managers need to deal with social differences and avail themselves of each team member's particularity and their potential in order to assist in the project success everyone, as the evidence makes clear:

> "*Uncertainty associated with project parties* (ATKINSON; CRAWFORD; WARD, 2006)."

> "*People's attitudes, beliefs, cognitions and behaviors are determined by their personality in a great part. People's personality is reflected by their thoughts, behaviors, and life styles. Because of the unique role that personality plays in the human behaviors, it is reasonable to expect the personality will also play a part in professional software development process* (WANG; LI, 2009)"

4.3.4 SRL-RQ4: What is the relation between uncertainty and innovative projects?

This question sought to investigate the relationship of the uncertainties with innovative projects and aspects of how we manage them. One of the findings is that the evidence report that innovative projects are more likely the occurrence of uncertainties. The following evidence of the studies is reported.

"*The more innovative a project is, the greater the probability of occurrence of unforeseeable uncertainties* (RUSSO; SBRAGIA; YU, 2013)."

"*projects with novel technologies have high uncertainty* (TATIKONDA; ROSENTHAL, 2000)"

"*Management practices that are effective in established businesses are often ineffective and even destructive when applied to Radical innovation projects because of higher levels of uncertainty inherently the latter* (O'CONNOR; RICE, 2013)."

"*Understanding the characteristics of Radical Innovate projects and the nature of the uncertainty that pervades them is critical to developing appropriate managerial practices* (O'CONNOR; RICE, 2013)."

"*innovation is positively correlated with environmental uncertainty* (FREEL, 2005)."

"*high levels of uncertainty generate more innovation* (FREEL, 2005)."

Innovation and projects aim at the innovation development, being them a new product, process or service, it should be on the executive diary, along with the understanding of the business environment changes and the action plan needed to respond to these changes or influence them (MARINHO et al., 2013).

Various perspectives emerge from the literature to explain why companies have difficulty in managing the various sources of uncertainty associated with converting innovations in innovative companies. Understanding the innovative project characteristics and the uncertainty nature that permeates them is critical for developing appropriate management practices (O'CONNOR; RICE, 2013).

Where uncertainty about future events is high, tolerance of uncertainty may be particularly necessary (ATKINSON; CRAWFORD; WARD, 2006). Management practices that are effective in established companies are often ineffective and even destructive when applied to innovative projects because of uncertainties inherent in these projects (O'CONNOR; RICE, 2013).

Flexibility is required on projects where goals are unclear or open to negotiation, the strategy is emerging and the project is highly subject to external influences. Keeping options open, and adopting a flexible and robust management approach can be much more effective than prematurely freeze projects plans relying on conventional control mechanisms to measure performance (ATKINSON; CRAWFORD; WARD, 2006).

Strategies, techniques, best practices are important to manage or contain the uncertainties in innovative projects. The recognition of the uncertainty sources in projects can be a determining factor in the success of the project. One needs to clarify what can be done, decide what should be done, and to ensure that management is carried out based on the uncertainty level observed in the project.

4.4 A Description of the Approach Evolution - First Version

At this stage of the research the first draft of the proposed approach in this thesis was prepared (MARINHO et al., 2014c). So, the Figure 4.8 was designed to represent the approach stages.

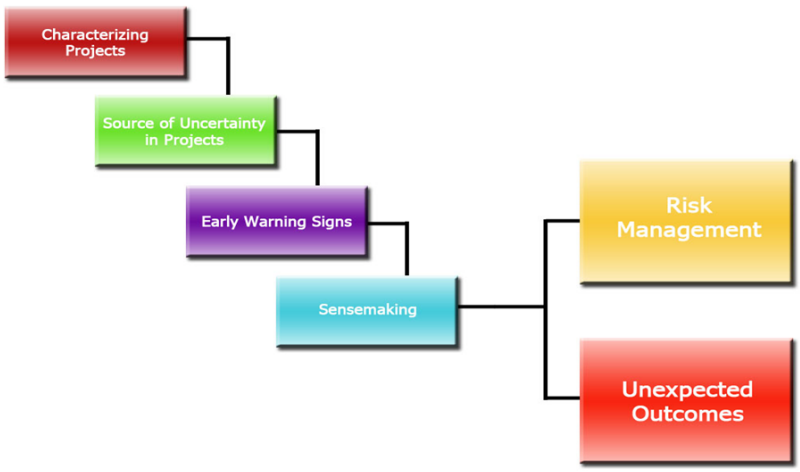


Figure 4.8: An Approach to Manage Uncertainty in Software Projects - First Version.
Source: the author

The responses for the four research questions presented and summarized in Section 4.3 were the base for the approach development. Note that the research question 4.3.1 presents ways that managers are adopting to manage uncertainties. The approach was based on the 5 ways to establish a step-by-step management. They are mapped as follows: the *Adapting management approach to the type of projects* is presented in **Characterizing Projects**. In **Sources of Uncertainty in Projects** the phase *understand the sources of uncertainty to better manage each type of project* is presented; In **Early Warning Signs**, **Sensemaking** and **Risk Management** are presented in a way to *identify uncertainties in order to turn them into risk* and to *dealing with uncertainty when they happen*, we present the Unexpected Outcomes and the adoption of techniques, strategies and practices are mapped through the research question 4.3.2 which has a number of *adopting techniques and strategies to facilitate the uncertainty reduction*.

Hereinafter, the stages of this approach's first version are described:

- **Characterizing Projects:** The focus of this stage is to choose the best management approach to be be taken according to projet uncertainties.
- **Sources of Uncertainty in Projects:** At this stage, the focus is to identify which uncertainty sources are more unknown in the project.
- **Early Warning Signs:** This is the perception stage of the early signs that are present in the project.

- **Sensemaking:** This stage is the creation of meaning to the perceived signs and risk transformation.
- **Risk Management:** Once the risks are identified they can be managed through risk management.
- **Unexpected Outcomes:** If any unexpected event happens, the project team has to be prepared to react. At this stage, the team must choose how to react to events.

So, a first version of the approach built on the systematic review was introduced in (MARINHO et al., 2014c).

4.5 Closing Remarks

This chapter presented a systematic review of uncertainty management in software project. Various approaches to project management does not consider the impact that uncertainty has on project management. The threats posed by uncertainty are real and immediate and the stakes in a project are often important. The project manager faces a dilemma: decisions must be made now about future situations that are inherently uncertain. The use of uncertainty management in projects can be a determining factor for the success of the project.

This research's results show that the number of works on uncertainties related to project management has been growing since the last decade. There was also an increasing awareness of the challenges of project management. During the systematic review process some information was identified: companies have difficulty in managing the uncertainties associated with converting innovations in innovative projects; the analyzed studies agree that uncertainties cannot be extinct from projects, but they may be "tamed". Our research has identified 5 good practices to manage uncertainties in software projects; there were also investigated what the sources of uncertainty perceived in studies which were summarized in 4; they are: technological uncertainty, market, environment and socio-human; there were identified and cataloged 18 techniques and/or strategies for the recognition of the problem nature and uncertainties containment in projects. In addition, the approach's first version was built from this review and can be found in (MARINHO et al., 2014c).

5

Uncertainty Management Action Research in a Software Project

"Uncertainty is the essence of life and it fuels opportunity"
Tina Seeling

According to DICK (2004), it has been common the use of action research in the evidence-based research paradigm context in these domains as means of connecting theory and practice, or else, academia and industry in both directions. For SJOBERG; DYBA; JORGENSEN (2007), the action research represents "the kind of study where a more realistic research scenario is found", once it involves a real industrial context to investigate concrete actions results. Therefore, this Chapter explores actions taken in a real project aiming to reduce the uncertainties.

5.1 Applying an Action Research in a Software Development Project

To develop and report the action research it was used the model described in (DOS SANTOS; TRAVASSOS; ZELKOWITZ, 2011) derived from the authors' experience in conducting different studies of action research in Software Engineering. Each step of the action research will be presented.

5.1.1 Diagnosis

The study was carried out in the high performance research group at the Information Technology Center at the Federal University of Pernambuco, Brazil, under the name of HPCIn.

5.1.1.1 Problem Description

Throughout years the group attempted to manage projects under the traditional model, however they were not so successful. So they went on to implement an agile approach in which vast improvements were obtained. Even so, the project did not guarantee the expected success neither by team or the sponsors. The first project the group adopted the agile approach was the one known as "Dynamically Reconfigurable System for High Performance Computing," whose main objective was to implement the acceleration simulation for the petrol industry, in particular for an oil company in Brazil. It was developed in a hybrid computing model utilizing not only solutions based on common PCs in order to form a cluster, but also inside a new hardware architecture based on reconfigurable electronic devices, worldwide known as FPGA (Field Programmable Gate Array). The idea was to use a new cluster model which due to its intrinsic characteristics of parallelism, can supply larger computing resources which are smaller and consume less energy. The project was developed but not successfully completed.

Once the project was over, even though it did not continue, the research group developed and awakened interest in other Oil company sponsors groups. They immediately put forth a new project called "High Performance Solutions for Modeling and Seismic Migration Based on FPGA devices". This project aimed to implement the 2D algorithm in a reconfigurable and scalable platform for the simulation models processing in order to recognize strategic points for the petrol extraction which are currently extremely complex and require a high amount of computer processing. In that case the client, the manager and the team adopted an agile model and it was developed between 2008 and 2011 (MEDEIROS et al., 2012).

The 2D Seismic project was partially delivered. In this case, the client, the manager and the team adopted an agile model but forgot that both the solution and the target had a large uncertainty level related to them. Furthermore, they failed to observe the uncertainty sources, such as technological uncertainty, which was a factor that was quite relevant for the project.

Despite the partial project delivery and because of major technological uncertainties, the results achieved aroused interest in the sponsors for a new investment, so they signed a new project with the group. This time the project called "Modeling and 3D Migration Using FPGA's" is going to be called 3D Seismic Project. The project took place between 2012 and 2013. Due to the great group's concern with the commitment to deliver a quality product that effectively contributed to the customer, it was proposed by the manager to conduct an action research to investigate which practices and tools could contribute to project success taking into consideration its related uncertainties. The practice was accepted by the project coordinator (a teacher responsible for the group) and all the team members.

5.1.1.2 Project Context

The 3D Seismic Project aimed to provide the study and development of a computer system based on a hybrid architecture with coprocessors implemented from FPGAs

reconfigurable logic devices. The hardware and software modules design developed were tested on a reconfigurable platform. This system is able to solve problems with a high computational performance, being of interest to the Oil and Gas sector with performance comparable to multi-core technologies and GPUs or better. To further clarification of the issue, this process can take months to complete a certain region simulation, and at the same time, the competitiveness with oil discoveries in Brazil in the pre-salt layer, whose volume is estimated to be about 10 billion barrels of oil (STATISTICS RELATING TO PETROBRAS, 2013), requires new strategies implementation to accelerate the definition of favorable drilling points for its extraction. With the obtained results of this project Oil company may achieve gains in performance if compared to general purpose CPUs. Such project was made for 21 people, with 1 coordinator, 1 consultant, 1 project manager, 1 chief scientist, 1 administrative secretary, 3 technical leaders, 8 computer engineers and 5 trainees. Besides UFPE Center for Informatics and Oil company, the following organizations were involved: the University Foundation, responsible for administrative and legal support to the project and a third party, that we will call here XW, company responsible for a FPGA board development specified by the project team.

5.1.1.3 Research Subject

According to the scenario previously presented, the investigation subject is defined as: a continuous uncertainty investigation related to the project; an evaluation of which practices, techniques and strategies may contribute for the uncertainty reduction.

5.1.2 Planning

In this section the planning phase is described and it starts with a literature technical survey where some papers on the research subject are examined. So the intervention focus could be organized with the research objectives and expected results establishment. Finally, instruments, tools and techniques used in the research are going to be presented.

5.1.2.1 Action Focus

The action research was to **goal** establish practices, techniques and strategies that could manage uncertainties in software projects and generate an approach to manage them. Our **research question** was: what practices, techniques and strategies may contribute to uncertainty management in software projects? As **expected results** create an approach that can be adopted by software projects to reduce uncertainties. It was pointed out that as the action researchers agree with THIOLLENT (2011), action research is not only a simple data collection but a research where researchers want to play an active role in the very reality of the observed facts, or else, throughout all the research process we operate actively in the project in order to support the uncertainties management.

5.1.2.2 Operacional Definitions

Aligning with our focus, we established techniques for better conduction of action research; they were: semi-structured interviews, focus groups, follow-up meetings, retrospective meetings and follow-up activities. To support our activities we used **tools** such as: a specific directory in the project server to store all artifacts produced and used in the research, as well as electronic versions of publications, generated data sheet, partial reports and other documents.

5.1.3 Actions

The actions that were carried out during the research will be presented:

Action 1 - Adapting Management Style to the Projects Type: As shown by HPCIn group, the adopted methods were not appropriated in the research and product development, so we decided to investigate how better adapt the group‘s management style to their need in order to apply a better approach that helped in managing uncertainty.

Action 2 - Project Planning: Due to technological uncertainties, the stakeholders were asked to attend meetings for a better project understanding. The brainstorming technique was used in four meetings attended by two Oil company leaders, as well as the coordinator, consultant, project manager, chief scientist and 3 technical leaders. In addition, the project manager asked the chief scientist and 3 technical leaders a study in the area to verify the project feasibility. After that, we created a macro schedule (Oil company requirement) and adopted an agile planning, which raised all the user stories we learned so far (among them there were various activities of studies and prototyping). We applied the *planning poker* at that stage, except from the secretary, all staff was involved in the estimation process and we applied the rate of error percentage of the team (based on the history, because as we mentioned, all data from 2D design was managed in an agile way). adding the error percentage, the activities completion estimation was 18 months. However we still had uncertain components, such as: outsourcing the development of a FPGA board, the team suffered a little personnel turnover, we had restrictions imposed by the client in choosing the company that would develop the board, and as we were still in a university, we depended on the Administrative Foundation. Based on those uncertainties, we asked our client a deadline of 24 months.

Action 3 - Creating Prototypes: For innovative projects there are uncertainties related to the goals and the solution. In most projects those aspects are both learned and defined as part of project execution. For R&D projects the development cycle must contain research and prototype construction to converge on a goal by supporting a solution. Thus, we tried to perform prototyping since the beginning of the project.

Action 4 - Continuous Early Warning Signs Investigation: We established an early signs investigation during the project. A constant observation was carried out during project implementation. We investigated which early signs arose during the project, we did a retrospective with the reported signs and performed a sensemaking to make a

decision regarding the perceived signals every fortnight. The signs investigated in the project were listed by NIKANDER; ELORANTA (2001) and KAPPELMAN; MCKEEMAN; ZHANG (2006). Because of limited page number, Table 5.1 just contains signals observed during the project development. We must highlight that we also had a risk plan to the **known unknowns**.

Tabela 5.1: Early Warning Signs Investigation

Source	Early Sign	Event/Decision/Result
Socio-Human	Intuition	**Event:** Despite believing in the board development in a short term of twelve months, the team had the intuition that the outsourced company would not deliver it on time. In spite of the CEO of the outsourced team's technical knowledge, the company was new in the market, as well as its team. **Decision:** We warned our clients so, but they insisted on developing it with XW, then we prepared an alternative for delivery. We tried to modularize the maximum our application to suit the other board. Furthermore, we had three FPGA boards with inferior performance that we would build with XW company, but we made them an alternative to the project delivery. **Result:** That alternative for delivery saved the project. XW company did not finish the project on time, so we delivered our algorithm on the boards we had.

Socio-Human	Personal Behavior in general	**Event:** At the end of one year of project in November 2012 the team had an important milestone that has not been achieved due to lack of knowledge of the technology used. At the time we were in a face to face meeting with one of the stakehoders. The stakehoder, began to be rude with team members. Reaching the point that they would not provide the staff's payment, until the milestone was delivered. The team, that had had several achievements so far, started to get demotivated and some members started to get sick. **Decision:** A meeting with the stakehoder, that had suggested not to provide the resource was conducted. During the meeting on one hand, there were presented the reasons to continue investing in research and on the other hand, the concern that management had with team members. The stakeholder then decided to provide the resource. Still, the team kept demotivated because it had not pleased the customer, then we had a motivational meeting in order to raise the morale of the team and we invited a psychologist to show that the team together could reach the necessary milestones. **Result:** The staff began to change their attitude and began to get more, expected results before the agreed period.
Socio-Human	Insinuations	**Event:** XW company, suggested that, some project milestones were delayed because our team did not know how to test what was sent to us. **Decision:** We developed a test environment, documented the procedure performed, the environment variables, the machines used so that XW could reproduce the tests and we as passed on the activity for them, we engaged the stakehoders for process verification. **Result:** XW found that they were wrong, assumed the mistake and began to be more judicious when sending results.

Socio-Human	Project members were overloaded	**Event:** The technical leader of the architecture team was overwhelmed. **Decision:** We began to apply techniques such as pair programming, dojo technique and encouraged the other team members learning **Result:** Team members began to be more independent from the technical leader and we decreased the number of errors we had.
Environment	Personnel changes	**Event:** There was a concern to keep people in the project and in case of changes, finding the right people for the project. **Decision:** The environment were changed with the aim of turning it nice for the building process team. Stations, chairs, tables, white boards were exchanged. We also added a coffee machine, a refrigerator and games for the team. When we needed to select people, we invited a psychologist and created dynamics based on agile methodologies and sociodrama. **Result:** The stimulated to work team and people who joined them during the process in that environment got easily involved due to the chosen profile in the dynamics.
Environment	Planning,unrealistic	**Event:** There was a concern for planning and delivery even of what was not known in the project, although we have presented it to our customers. One of the customers did not agree with the, requested deadline, demanding,the project being delivered within 12 to 14 months. We had a schedule for 24 months. **Decision:** We invited our clients to a face to face meeting and presented the entire project backlog, the estimation process, the team error percentage (based on historical). **Result:** After the meeting a contract for 18 months was agreed and if necessary, an extension of 6 months more. The extension was necessary as we completed the project in the 24 months we had estimated.

Environment	Preliminary Plans /Project Plans /Proposal, Material	**Event:** Even believing in the team, the clients, had to present their Oil company senior managers, how they were tracking, and what was happening in the project in a detailed way. **Decision:** From the beginning of the project a plan of communications, responsibilities and a macro-schedule were established and how, the client, would monitor the team. **Result:** Throughout the whole project the customers knew the development stage, its problems and that made the iteration between team and client closer.
Environment	Initial information / lack of information	**Event:** The initial information on the subject were not so clear for the project. **Decision:** Several studies, interactions were encouraged with the aim of deepening the knowledge. The scientific leader worked as a bridge to encourage the research and,knowledge dissemination. **Result:** Knowledge was spread through the whole team.
Environment	Functional, performance and reliability,requirements as well as coverage are not documented	**Event:** There was not, any project documentation. **Decision:** We started to document all that was needed for the project construction. **Result:** We created a repository where all documentation, supported the team and the algorithms maintenance.
Environment	IT operations infrastructure and network infrastructure problems have major impact on project team productivity	**Event:** Seismic tests we needed servers with a good memory capacity but did not have them. **Decision:** We requested that a purchase of two servers was inserted and we talked to the computer center infrastructure coordinator for its support to help us when we needed. **Result:** We bought the servers and were able to perform various required test types.

Environment	Management Style	**Event:** The group was concerned to adapt the project management style for, trying to reduce the impacts of uncertainty mainly because we were not familiar with the technology. **Decision:** A study was conducted in order to adapt the management style to the type of project. **Result:** We have adopted several practices to manage the project such as: stakehoders'expectations management, qualitative measures of project success, early signs identification, flexible management when facing changes, stimulus to generate team ideas, creativity techniques such as: brainstorming, feasibility study, collaborative work, continuous integration and multidisciplinary team.
Environment	lack of communication & Because of XW delays, much of the information on the plate development was not passed on.	**Event:** Meetings with XW were requested in order to get closer to the, outsourced staff's work. **Decision:** We presented them the importance of the activities good progress and one of the stakeholders joined the monitoring process. **Result:** The board development monitoring by XW become more active.
Technology	Success criteria of the project undefined	**Event:** In the 2D project there was no success definition. **Decision:** A meeting was conducted between team and stakeholder to define project success criteria. **Result:** There have been various criteria. Among them, the plan to deliver the boards we had (with lower performance) the algorithm, was a success criterion in case XW company did not finish the FPGA boards in time.

Technology	Control progress / monitoring in general	**Event:** We conducted a general project schedule in which the activities of XW (responsible for the, FPGAs board development) were interconnected, with our activities, the project manager and XW had meetings every fortnight or when necessary but started to notice that XW were not prioritizing the project activities and were postponing, several deliveries. **Decision:** Our concern about the project short deadline was presented to XW. **Result:** Important decisions such as prioritizing the contingency plan were made based on the project control.
Technology	Approved project budget less than budget estimated by the project team	**Event:** A survey of project needs was conducted but the available funds would not exceed. **Decision:** R$ 1,515,319.18 We agreed that when there was a need, we could reallocate resources to a more priority rubric. **Result:** It was necessary to perform two rearrangements during the project, that have been immediately approved, by the stakeholder.
Technology	No contingency budget for known risks and changes rate	**Event:** Despite knowing the possibility of the company not to deliver the FPGA board, there was no budget available to buy another board or hire another company. **Decision:** We expressed our concern to XW. They understood it but could not invest more resources in the project. So, it was agreed with XW that if the board was not delivered, it would involve a refund of a percentage of the agreed amount so we could hire another company. **Result:** XW accepted the deal giving priority to the research and accepting the challenge as a way of creating a non yet existing market in Brazil.

Market	The main project stakeholders did not participate in the major review meetings	**Event:** The main stakeholder (Oil company) was not able to participate in important project meetings. **Decision:** We started to document the meetings and activities, done and send them a summary **Result:** The stakeholder themselves found it an excellent alternative, thanked the information sending, and made sure they were updated with what was happening, in the project.

Action 5: New Members Inclusion: Another problem we had was the constant change of employees and the impact on the insertion of a new team. So, before the project we adapted two spaces we had in the university campus to make it into a collaboration environment, a room for creating ideas. In addition, two team members left during the course of the project that led us to find a psychologist help to hold meetings with staff to define the professional profiles necessary for the group. Developed a sociopsycho dramatic approach for selection and new team members inclusion. This procedure was adopted by the group and was assessed as positive by both team that had participated in the choice of new members and participants of the dynamics.

Action 6 - Dealing with Uncertainty when They Happen: Project managers may try to contain uncertainty in its source, but never have one hundred percent success. Therefore, we try to be able to quickly detect and respond to unexpected events in our project. For unexpected results a project manager must then decide how best to deal with the uncertainty.

5.1.4 Evaluation and Analysis

This section explores the study results, such as the learning design. Thus, these results will be exploited with the purpose of their organization and reflection on the knowledge gained from the actions.

After two years of project we completed the delivery as planned. The board we had ordered was not ready because the XW company had not completed its development in time, and because of that, our project was delivered in a lower performance board but with all algorithm working and processing seismic images properly. The customers received the project in time and said the goal was achieved and because of that other projects could be ordered.

We conducted interview with the team to assess the project completion and all the interventions made during the it. The team agreed that all practices embedded in the project contributed to its success, they praised the care taken in the research that was conducted with the project and that way contributed to: the staff acquire more knowledge, learn more about

the project, learn how to behave when facing uncertainties and early signs, act when something unexpected happens and actually run the risk plan.

We interviewed the project coordinator, the consultant, the scientific leader and technical leaders, they were all in favour of interventions. The coordinator said in his interview that: "adopted practices ensured the project and the team success", yet, "At first, the uncertainties were plenty, but with this management style we could reduce uncertainty and achieve our goals". The scientific leader said: "It was like I was working from home, the environment, the people were united with one goal, of course there were differences, but all had cooperation in mind. The interventions were essential for doing so." One of the technical leaders said: "Despite all technological uncertainties, the XW not having delivered the board, we showed our customers that our team managed to reach the goal" The consultant said: "The elaborated practices here should be written for other people to use!".

5.1.5 Reflections and Learning

Based on the actions performed, we identified that there are some practices/strategies that can help the uncertainty management, the table 5.2 presents a summary associating the practices used and occurred events.

Tabela 5.2: Adopted Practices

Label	Practices / Strategies / Techniques	Events
RAP1	Management methodology adaptation	A prior team to this project adopted the traditional approach and then agile approach, but because of the uncertainties involved in the project they could not deliver an outcome that could add value to the customers. In the beginning of the project we decided to get to know the project and adapt the management approach then it was done throughout the project.
RAP2	Consultation to past projects	In the early design phase we consulted the past projects to prepare the initial planning, data such as team effort, activities duration, costs and lessons learned have been checked.
RAP3	Brainstorming	At the beginning of the project the technological uncertainty was high. We adopted the brainstorming technique to explore the creative potential of the project's collaborators on problem solving. The technique was used also to identify the risks and other steps to general problem solving.

RAP4	Prototyping	Due to technological uncertainties, we decided to build prototypes to align the real needs with the customer and try to reduce uncertainty (unknown).
RAP5	Early signs identification	The early signs list was evaluated at every retrospective team meeting.
RAP6	Mindfulness culture	Throughout the project life cycle the culture of mindfulness was stimulated once it describes an alert state of mind for the possibility of unexpected situations arise.
RAP7	Stakeholder management	We intensified the stakeholder management of the project: 1- in the client's context, bringing the customer to the next project, presenting the problems and solutions that have occurred in the project, making a closer followup 2- monitoring in the team context we were always attentive to the real needs of the staff and members individually.
RAP8	Creativity Techniques	Creativity should be an essential part of the project team mentality. It is an important tool to break with an error cycle in which the lessons are not really learnt and management strategies are stagnant. It is also the driving force behind change and improvement. Besides, it offers the opportunity to reach a better solution. It was always encouraged on our team by questioning and playing "What if" game, making the team to look at other perspectives, encouraging members not to get rid of failures but reflect on the events.
RAP9	Group Cohesion	Throughout the whole project, we encouraged and motivated the team with a constructive thought, sharing the same idea.
RAP10	Continuous Integration	Throughout the whole development we worked integrating the verified code continuously. Doing so, we reduced the possible integration errors, bugs in the code and the product running uncertainties are reduced.
RAP11	Short Iterations	We worked with short interactions and always presented what was done to the customer at the end of each interaction.

RAP12	Collaborative Work Stimulus	The incentive to collaborative work was always present in the project. Collaborative work allows a team arrive where individuals would not arrive alone, making the company progress and its employees grow together.
RAP13	Scenario Building	We performed the scenario building which is an intuitive leap to envision a future result early in the project to analyze the possible problems that could occur and define the possible deliveries with the client .
RAP14	Risk Management	The activities cycle of risk management defined by the PMBOK was adopted in the project

5.2 A Description of the Approach Evolution - Second Version

Figure 5.1 shows a approach evolution in an illustrative way. All activities are focused on the project manager and the team. In the characterization phase of the project the best methodology available is chosen for the project's context. In the figure it is represented as the rails of a train which may guide the project to the best way, but it is not enough. Uncertainties are everywhere, the project manager must be aware about the uncertainty sources; furthermore, to verify which uncertainty source is the weakest. They need to pay attention on early warning signs that surrounds them and create a sensemaking. Thus, they may conventionally use the traditional risk management but unfortunately not all uncertainties may be noticed, so they must be prepared to some unexpected outcomes. When the uncertainties happen there are four ways to deal with them: suppressing, adapting, detouring or reorienting.

During the action research process, the suggested stages in the initial version presented in 4.4 were adopted in 3D Seismic project, but there has been an evolution of the approach since strategies, practices, techniques were inserted. For example, in the first version there was an early signs identification stage, but there was no way to conduct the project manager to identify what they could be. Thus, it was found in the work of NIKANDER; ELORANTA (2001), SANCHEZ; LEYBRNE (2006) and KAPPELMAN; MCKEEMAN; ZHANG (2006) which were the early signs perceived by project managers, so a continuous early warning signs investigation during the development of the project was inserted, as presented earlier in Table 5.1.

However, only the table was not enough, I came across the article HAJI-KAZEMI; ANDERSEN; KRANE (2013), which stated that during the development of already known

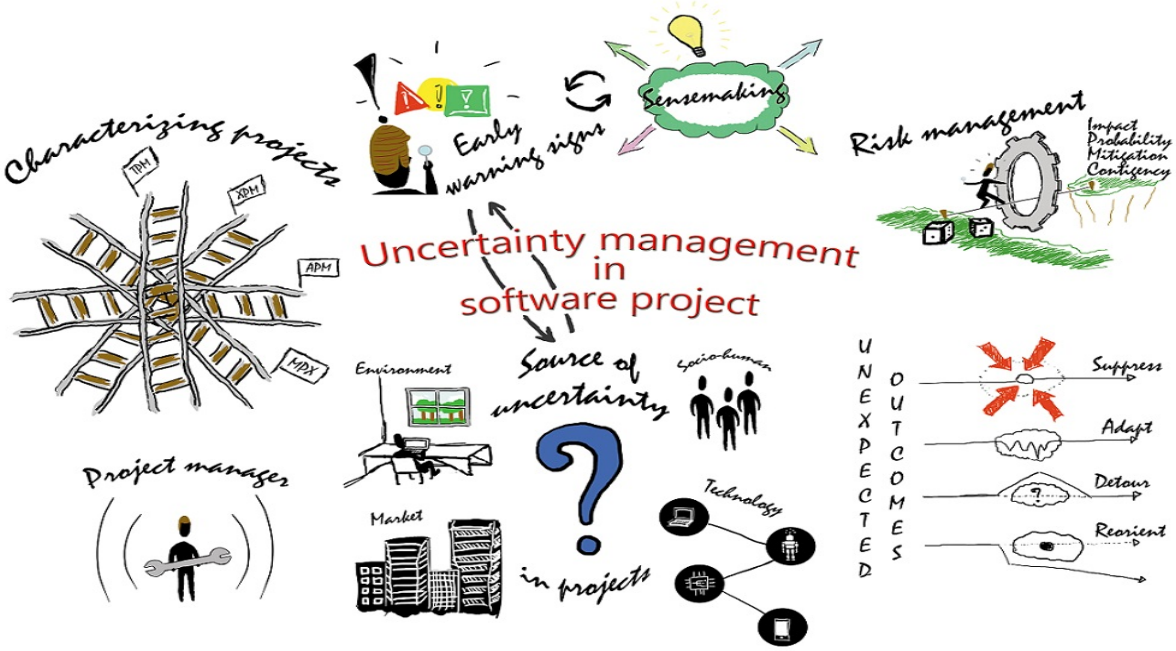


Figure 5.1: Uncertainty Management in Software Projects.
Source: the author

practices in project management, it is possible to detect early signs, but there was no instruction on how the project manager could improve the early signs' perception. In this case I found in the literature, especially from the articles collected in the systematic review, how the project manager could be more aware of early signs and I came across the work of WEICK; SUTCLIFFE (2011).

Weick and Sutcliffe use the term **mindfulness** to describe an alert state of mind for unexpected situations. The idea comes from an analysis of organizations (HROs) facing particularly difficult challenges in uncertainty management. These organizations carry out complex operations and operate in highly unpredictable environments where the potential for error can have very serious consequences. In the early signs research phase it is necessary to practice mindfulness.

Weick and Sutcliffe found that successful organizations tend to share five key attributes; they are:

- **Failure Concerns:** in order to find the signs, it is necessary to watch out for them; questioning whether there are different explanations with seemingly obvious results. The best way to accomplish that is to make the project team aware of the failure possibility;

- **Reluctance to simplify interpretations:** the project manager struggles to understand what is happening within the project and there is a natural tendency to look for evidence to support preconceived ideas and reject what does not fit. However, all evidence must be considered;

- **Operations Sensitivity:** the early signs tend to be subtle. Their trifles sometimes make them easy to ignore. As a result, many problems may remain undetected. The entire team must be ready, alert to detect, monitor, analyze and determine if there really is an uncertainty associated with the identified signal;

- **Commitment to resilience:** recognize any project aspect may be subject to uncertainty. There are no off-limits aspects. All that matters is that the team is ready and willing to face any uncertainty symptoms as soon as they are detected;

- **Skills Consideration:** when a problem arises within the project, experts in a given subject can be the best strategy to solve them, although other members should not simply push the problem to the them; instead of that, the team must try to learn with the expert and the problem resolution.

Thus, adapted to the software projects context, the attributes to establish a Mindfuness culture within the project, then to better identify the early signs.

In Sensemaking stage, we searched in the systematic review work and through the snowball technique which the essential activities would be to create sense to the identified signs. The activities that the project manager has to perform in this phase are compatible with Simon's work SIMON (2006) and involves:

- **Interpret the signal:** The manager does not impose his understanding, but he tries to bring the issue in the project perspective, resulting in a co-construction of the meaning for project's team members;

- **Objectively Translate the Sign:** Transforming the sign is not only carry out task distribution, but also to make each team member realize their meaning in the project;

- **Reveal assumptions and beliefs:** When there is a conflict, project manager should clarify the real meaning, by identifying the beliefs in use and the assumptions made by the stakeholders;

- **Building a shared meaning:** The project relevance must always be remembered, not only in formal meetings, but also in daily tasks.

So, we added four sensemaking activities to the approach. We also adopted: a defining success criteria, prototyping, scenario building, group cohesion, consultation to past projects, stakeholder management, continuous integration, short iterations and added them in the approach‘s second version, that can be found in (MARINHO et al., 2015a,b).

5.3 Closing Remarks

This chapter presented an action research conducted in a software project carried out in the Information Technology Center of Federal University of Pernambuco. A step-by-step of activities was presented in 3D Seismic project run between 2012 and 2013. The project was delivered to the customer according to management of uncertainties involved and it was considered a successful case by those involved. The practices carried out in the project were added to the approach, thus generating a second version that can be found in (MARINHO et al., 2015a,b).

6

Assessments to an Approach to Manage Uncertainty in Software Projects

"Uncertainty is the shadow of the effort in the light of wisdom."
Thimer

This chapter presents the methods carried out, the interviews' results and focus group conducted with project managers and project management researchers. The interviews and focus group aimed to assess the previous concepts and add the emergence of new practical ones found (MARINHO et al., 2015c).

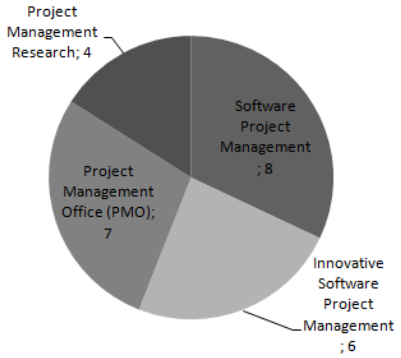
6.1 Interviews with Specialists

In this section is presented the summary of participants, the sampling, data collection and data analysis.

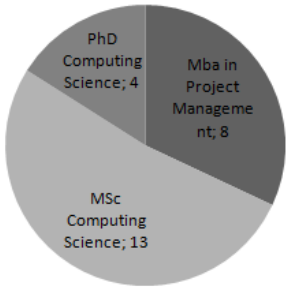
6.1.1 Participants

A total of 25 people with professional or academic experience in project management were interviewed. Among the interviewees, 4 were researchers from the project management area and 21 were project managers involved with information technology. Among the 21 project managers; 6 were working with innovative software projects and 7 responsible for the Project Management Office (PMO), as shown in Figure 6.1(a). The qualification of interviewees is: one is postdoctoral, 3 are doctors, 13 have a master's degree and 8 specialization or Master's in Business Administration (MBA), as shown in Figure 6.1(b). It used as reference the table from the SEBRAE (2015) to classify the kinds of organizations interviewees, were from: 10 profit-making, 8 governmental organizations, 5 the academic area and two from non-profit organizations, as shown in Figure 6.1(c). The size of the organizations: 15 were large, 6 were medium, 1 small and 3 micro enterprises, as shown in Figure 6.1(d). The Brazilian market

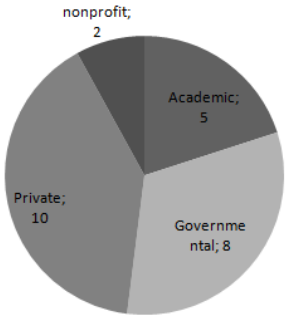
which the organizations serve: 14 national; 6 regional; 4 global and 1 multinational, as shown in Figure 6.1(e).



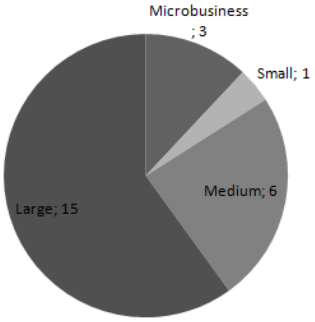
(a) Kind of interviewees



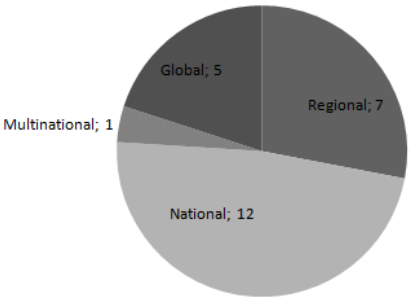
(b) Qualification of interviewees



(c) kinds of organizations



(d) Size of the organizations



(e) Brazilian market

Figure 6.1: Participants

The Table 6.1 presents a summary of the participants'data, which are going to be labeled by a P1 to P25 code. In Table 6.1 PM is the abreviation of project management and RPM is Research in project management. The professional experience level of the interviewees vary from 6 to 35 years and the time of involvement with project management ranges from 2 to 20 years.

Tabela 6.1: Summary of Interviews

Code	Role	PM Experience	Education	Company Type	Size	Market
P1	PM	19	MSc Computing Science	Governmental	Large	Regional
P2	PM	18	PhD Computing Science	Academic	Large	National
P3	PM	7	MSc Computing Science	Private	Microbusiness	National
P4	PM	15	Mba in Project Management	Private	Medium	National
P5	PM	13	MSc Computing Science	Private	Medium	National
P6	PM	11	MSc Computing Science	Governmental	Large	Multinational
P7	RPM	30	PhD Computing Science	Academic	Large	National
P8	PM	16	Mba in Project Management	Private	Medium	National
P9	PM	8	Mba Software Engineering	Governmental	Large	Regional
P10	RPM	2	MSc Computing Science	Private	Large	National
P11	PM	9	MSc Computing Science	Academic	Microbusiness	National
P12	PM	2	Mba Software Engineering	Private	Large	Global
P13	PM	10	MSc Computing Science	nonprofit	Large	Global
P14	PM	6	Mba in Project Management	Private	Large	Global
P15	RPM	5	PhD Computing Science	nonprofit	Small	National
P16	PM	9	Mba in Project Management	Private	Medium	National
P17	PM	5	PhD Computing Science	Academic	Microbusiness	National
P18	PM	10	Mba in Project Management	Private	Medium	Global

P19	PM	20	MSc Computing Science	Governmental	Large	Regional
P20	PM	12	MSc Computing Science	Private	Medium	National
P21	RPM	8	MSc Computing Science	Academic	Large	Regional
P22	PM	5	MSc Computing Science	Governmental	Large	National
P23	PM	5	MSc Computing Science	Governmental	Large	Regional
P24	PM	12	MSc Computing Science	Governmental	Large	National
P25	PM	10	Mba Software Engineering	Governmental	Large	Regional

6.1.2 Sampling

One of the inevitable and sometimes uncomfortable methodological decisions in the qualitative research and interview work is the decision about who, how many people and how often interview. Those are questions associated with the selection of interviewees that can not be answered with simple formulas or universal recipes (VALLES, 2000). There is no usual mathematical formulas for calculating the sample size for large or small universes, confidence levels, sample error or variance calculations available to the researcher in the qualitative level (VALLES, 2000).

A common strategy to define the theoretical sample is the saturation or the redundancy principle defined by GLASER; STRAUSS (2009). According to these authors, the researcher must judge the closing of the sample according to the theoretical saturation of a subject. Saturation means that once similar cases start to be recurrent, the investigator acquires some empirical confidence that there is no additional data that may contribute to the development of research (DORAIRAJ; NOBLE; MALIK, 2011; ADOLPH; KRUCHTEN; HALL, 2012).

6.1.3 Data Collection

Initially, a protocol with a set of questions was developed to guide the interviews. It was evaluated by two researchers from the project management area. After its construction, 3 project managers were invited to conduct a pilot study in order to check: whether the questions were well prepared; the need of new questions and the balance of the interview time. The pilot was

carried out and a few adjustments were made, so two researchers evaluated the initial protocol and reassessed it. Then, the protocol in Appendix B was established to guide the interviews.

The project managers were emailed and informed about the research so they would agree or not on being interviewed. The interviews were scheduled at time and location interviewer and participant mutually agreed. Face-to-face one-to-one interviews were conducted with the participants using open-ended questions. Face-to-face interviews provided the opportunity not only to gather verbal information but also to observe the body language of the participants during the interviews. They were voice-recorded for the convenience, with the participants'permition. Although GLASER; STRAUSS (2009) advises against recording interviews, it was found convenient to maintain a record and to analyse the data at ease. The Table 6.2 shows the interviews duration.

Tabela 6.2: Data Collection Time

Participant	Interview Time (hour)
P1	01:41:38
P2	00:36:08
P3	00:49:21
P4	01:09:16
P5	00:41:55
P6	01:46:13
P7	00:43:33
P8	00:57:02
P9	00:29:56
P10	00:43:58
P11	00:58:22
P12	00:48:05
P13	0:52:52
P14	01:06:08
P15	00:25:09
P16	00:40:17
P17	01:19:39
P18	01:03:56
P19	00:32:56
P20	00:35:48
P21	00:39:18
P22	01:00:33
P23	01:10:57
P24	00:49:13

P25	00:49:26
Total	22:31:39

6.1.4 Data Analysis

All data during a specific data collection phase was collected and analyzed in a subsequent data analysis phase. Voice recording the interviews helped concentrate on the conversation. After that, each interview was transcribed and reviewed line-by-line to explore the data meaning by searching for similarities and differences. Key points from the data were collated and then assigned a code or a summary phrase.

The codes are characterized by evidences that going to call quotes. To quotes extraction and classification the software ATLAS.ti[1] was used. In analysis phase the quotes were identified, they were constantly compared each code with the codes of the same interview, and those from other interviews.

6.1.5 Interview's Results

In this section, the findings found during semi-structured interviews are going to be presented. The interviews' findings are going to be shown according to protocol orientation. For each extracted quote, the following format was adopted: [QU participant number: sequence of the extracted quota].

Besides, as an evaluation form of the concepts presented and treated during interviews; a network was elaborated, as shown in Figure 6.2. According CRONBACH; MEEHL (1955) a network is an assessment tool of a set of defined terms in a research. Figure 6.2 was developed through evidence extracted from the interviews' transcripts, it presents the concepts that were expressed by participants. It is worth highlighting that the evidences are represented by a project manager's sentence portion to confirm the concepts; the answer types: **yes or no** are not counted in network.

The network's central concept was **uncertainty management** that had 27 evidences and 7 interconnected concepts. As the evidences presented, they demonstrate the need for a management aimed to uncertainties in the software context.

The concept of **characterizing the projects** which was appointed as necessary by the 25 managers has a total of 14 evidences found in the interviews transcripts reporting the need to characterize the project according to their type.

The **success dimensions** were identified as necessary for all projects and some evidences were found during the participants' speech, such as: 4 for efficiency and effectiveness,

[1] http://atlasti.com/

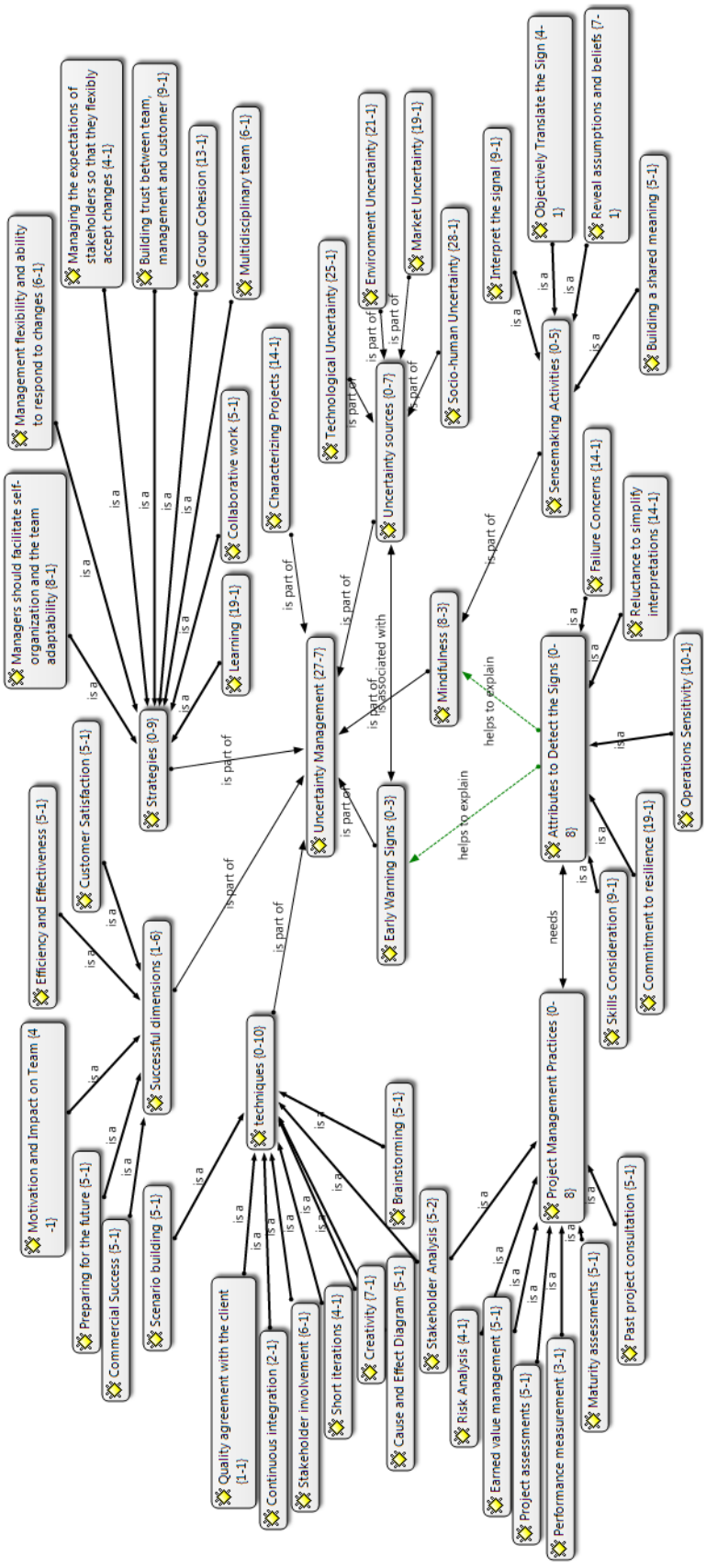


Figure 6.2: Uncertainty Management Network.
Source: the author

5 for customer satisfaction, 4 for motivation and impact on the team, 5 for commercial success and 5 for preparation for the future. Despite little evidence of the five successful attributes in a software project with uncertainties, we believe that the project manager's positive responses are points that should be considered within uncertainty management.

The **uncertainty sources** presented in this research, since the exploratory studies and confirmed in the systematic review, were assessed using evidence from the transcripts. The network validates the four sources through the practical perspective. All sources are presented in an extremely strong way through the network. The total evidences for each source were: technological uncertainty has 25; uncertainty environment 21; market uncertainty 19 and socio-human uncertainty 28. It showed that all participants could see the four sources within the project context.

The concept of early warning signs is interconnected with **attributes to detect early signs** identified as necessary in the project managers'responses; they were well represented through the evidences. For each attribute were found: 14 for failure concerns, 14 for reluctance to simplify interpretations, 10 for operations sensitivity, 19 for commitment to resilience and 9 for skills consideration.

Additionally, activities for **sensemaking** to a certain sign that were placed by participants as they should happen, had the following amount of evidence: 9 to interpret the signal, 4 to objectively translate the sign, 7 to reveal assumptions and beliefs and 5 for building a shared meaning.

It is believed that the concept of mindfulness found in the evidences is related to **attributes to detect early signs** and **sensemaking**. All attributes and activities need to be related to mindfulness, which is the state of mind which is alert to the possibility of unexpected situations that arise. For being able to manage uncertainties the project team need mindfulness to develop other concepts.

All early signs detection practices asked the participants were pointed positively by project managers, among the closed questions. Some evidence pointed in the network were found.

Among the techniques that have been identified as necessary to manage uncertainties, the construction of decision tree, besides having a low approval rate in the the interview's closed part, was not even found in a single evidence during the review process. On the other hand, quality agreement with the client was appointed as required by 20 managers, but only one evidence of this practice use was found.

Among the strategies, these stand out: learning, constructive thinking, building trust between team, management and customer, managers should facilitate self-organization and the team adaptability, managing the expectations of stakeholders so they can flexibly accept changes; that were mentioned by managers and more than 5 evidences were found which validate the need to adopt these strategies in uncertainty management.

Through the interviews and findings, it is believed that the concepts to manage uncer-

tainties in the software context are 7: Characterizing Projects, Uncertainty Sources, Early Warning Signs, Mindfulness, Techniques, Strategies and Successful Dimensions that are shown in network.The next sub-sections present a discussion of the interviews topics.

6.1.5.1 Uncertainty According the Participants

At the beginning of each interview the participants were asked what they understood by uncertainty and it was realized that the issue was still not clear to everyone, for example, P5, P12, P16, P19 and P21 associated uncertainties to risks in projects such as presented in the following evidences:

"When we talk about something uncertain we associate it with risks" [QU5:3];

"I imagine that it is related to risk issues, but I'm not sure about the definition" [QU12:1];

"I do not see much difference between risk and uncertainty, but perhaps indeed there is" [QU16:2];

"For me it's a big risk" [QU19: 1];

"In everyday life I could not distinguish what I do with risk management" [QU21:1].

The other participants answered the questions with statements that are according to the theoretical definition presented in this work 2.3.

For example, P4 relates uncertainty to the lack of team's experience:

"I think uncertainty is the result of team's unpreparedness that is ahead of a certain project" [QU4:1].

P6, P10, P7, P11, P20 and P23 claim that the concept of uncertainty is related to lack of sufficient information or lack of knowledge:

"Those are things I'm not aware of, or else, they are things I had not thought, I had not identified that they can somehow influence on project objectives" [QU6:1];

"We are looking for an area of expertise often unknown; this can be considered as uncertainty" [QU10:3];

"They are events that may affect the project's smooth running or the project goals' achievement, such events that, unlike traditional events denominated risks, we do not have any knowledge" [QU7:1];

"Uncertainties are doubts you have" [QU11:3];

"I think uncertainty in project management are threats that the project team do not even know they have" [QU20:1];

"Project management uncertainty is related to conditions, unknown needs, unknown environmental factors, such as these, this set of information and assumptions necessary for the project that you do not properly know" [QU23:1].

P13 and P25 have a more perceptive vision, or else, the limitation of noticing the signs:

"I can understand uncertainty as lack of a domain on some project dimension" [QU13:1];

"In my view of uncertainty, it will wriggle out of all your risk of scope, what you really did not anticipate" [QU25:1].

P9, P13, P18, P15 and P21 have a definition related to lack of predictability or not having an occurrence probability:

"They are something we can not predict or things that we predict but do not know how to bring forward" [QU9:1];

"How can you develop the project? Which way? The less clear, the more uncertain! Or else, it is something that we have little or low predictability of what can happen, or what we do not even know what might happen" [QU13:2];

"it is everything that I can not get a minimum predictability of what will happen" [QU18:1];

"Uncertainties are all those variables that we can not predict" [QU15:1];

"Uncertainty is just one unknown element that we can not foresee, or else, those difficulties and mishaps that we can not measure on a project's thinking and starting time" [QU21:1].

P10 adds more information pointing out the lack of control:

"Any situation you have no control, which may or may not happen in your project's context" [QU10:1].

P5 points out that the risks come from uncertainties:

"In my opinion, uncertainty is a step before the risk" [QU14:1]

P2 considers uncertainty as part of a project's flow:

"I think that at first, no project has 100% chance to work, every project is an experiment and uncertainty for me, I think it is part of any project's flow" [QU2:5]

6.1.5.2 Uncertainty Management Makes Sense According Project Management

Participants were asked what they understood by the term uncertainty management and if the term made sense to them. All managers agreed that it made sense and justified it as presented in the following evidences. P1 presents the survey aspect, observation, and a perception through threats can be identified:

> *"I think it's much on the way you develop an activity in the team, developing mainly in the project management, or something that can help them to realize, to probe; I think it's a matter of survey, perception; observation based on experience, based on methods; so they can identify whether there is the likelihood of becoming a threat" [QU1:10].*

> *"The project is plunged into an environment and I'm having a probe, this probe will take notice of everything that happens and then it will try to map as long as it realizes that any event may become a threat to the project, after that, the quantification and qualification process starts, or else, the risk management process initiates" [QU1:11].*

P6 resembles with P1 when he introduces the uncertainty management matter as something that has a set of techniques to manage risk revealing:

> *"Uncertainty management would be techniques or mechanisms to help me identify the things that I could not predict so far and that can somehow impact my project; apart from the risks that I used, the risk management techniques that have helped me to identify risks in the project, so it would be another set of techniques that would help me to expand perhaps my horizon of observation to help me identify the things I still do not know and then bring them to the risk management scope." [QU6: 4].*

P1, P7 and P20 believe that teams need to be prepared to deal with the unexpected and the uncertainty management, which is a different way of thinking; it helps in the uncertainty transformation:

> *"I love to use a phrase that is: the better we are prepared to what we can be prepared, the better we will be able to deal with the unexpected." [QU1:13]*;

> *"These uncertainties occur unexpectedly, you do not have visibility because the information may be incomplete. In my opinion, uncertainty management goes through a transformation stage, from uncertainties to certainties, then the management starts long before you get visibility. When you use the word management, it refers to a set of processes or techniques that allow visualization of the complete information." [QU7:3].*

"I believe it is thinking outside the box. it is being able to visualize based on your experience or visualize something that is beyond what you can reach." [QU20:3].

P22 indicates that uncertainty is the unknown, we need to work on that unknown to obtain more knowledge:

"Uncertainty management would be just working on the possibilities we do not know. Or else, better understand the nature of the project to seek greater security and knowledge." [QU22:3]

P11, P17 and P21 point it out as a form of prevention, or else; the uncertainty management matter as an analysis of uncertainty sources and project preparation to prepare themselves for them:

"A survey of what we have as uncertainties in the project, an analysis of what these uncertainties are and planning on how to deal with them." [QU11:2];

"Even though being an uncertain fact, I can try to take some managerial actions for it; if one of these uncertainties happen, I may manage not to entirely lose my project, shall we say." [QU17:2];

"The better we are prepared to what we can be prepared, the better we will be able to deal with the unexpected." [QU1:21].

P18 believes it is necessary to avoid events that may harm the project but if it happens, one must be prepared in the best way:

"Somehow, prevent it from happening; if it can not be avoided, at least we should be able to take some advantage or be less harmed." [QU18:3]

6.1.5.3 Characterizing Projects

All participants agreed that characterizing the project defining the best method and the best activities can help reduce uncertainties. As presented in the following evidences:

"If you have no technical knowledge, it may not work out; then its methodology has to be adapted." [QU11:5]

"When it comes to project innovation it is undoubtedly necessary to characterize the type of project well, because it is so uncertain that it is needed and almost mandatory having enough information to support one and reduce their error likelihood; for doing so, one has to have an uncertainty management." [QU14:3];

"I have the conviction that there is a number of methodologies for all projects, there is a right measure for everyone; but I believe that if we use a range of methodologies, tools, practices and procedures that we have available and make the proper adjustment, we'll have a greater chance of success than simply not using anything or using much empirical things or very strict things; because if it is too rigid, I will not be able to solve uncertainty problems or make any kind of prevention; any kind of preparation for something uncertain that may happen." [QU18:5]

"An innovation project such as a start up. A project that innovates in some sense. If I choose a very closed approach, very documentary, very bureaucratic and everything else, I can have a..., I may increase, say, the chance that an event that I have no control leverage itself, shall we say." [QU17:4].

"The problem is choosing which appropriate methodology for each type of project. Because there are projects with very strict methodologies that complicate them, and there are projects that it is fundamental to have this strict kind of methodology." [QU19:2]

Project managers from different organizations believe that a project can be better managed when there is a knowledge of project type and they correctly choose a methodology; even in these excerpts presented in [QU14:3] and [QU17:4] it was presented the relation between uncertainty and innovation projects, stating that for projects that have innovative elements uncertainties are larger and therefore, need to be well characterized to better choose the management type and reduce the uncertainties that exist.

The following evidences show that today's project managers use their feeling to characterize the best approach or they use a known approach and the evidences show that the fact of not having a direction can be a difficulty found:

"We have to have a methodology adapted to the project. Sometimes what I do is by intuition and sometimes I try to anticipate uncertainties based on feeling." [QU9:3]

"The problem is when you deal with something totally new. You do not have a history, you are in a complicated situation. In fact, you work on trial and error basis. You get started; and as it develops, you get the measure for that is needed for that new project." [QU12:2]

"Let's assume I'm going to do a project with given technology which I do not know, I do not domain. If I have a methodology in which my team's training is weak, or if in the human resource capture phase I choose the wrong people, I will not be able to get along with these uncertainties. I need a strong team to solve the problems that may arise by chance, so what can I do? I usually do an initial preparation

when I can have a team preparation approach and that preparation will make a difference, because the lack of technical knowledge can be treated at that time and then, uncertainty is reduced." [QU11:4]

"If there is a way to adapt and if there was a way to guide, it should be something adaptive because phenomenon nature is uncertain." [QU16:3]

The next evidence shows the need to have something flexible and adaptive which can guide the project manager to choose the best approach for the project type:

"I believe that the more uncertain a project is, the less prescriptive the approach has to be; in this case I think that a methodology maybe be not adequate, but perhaps a set of guidelines for you to make a decision, for example: considering a project's characteristics, can is more aligned with the agile philosophy, it could be such a set of guidelines." [QU13:6]

6.1.5.4 Successful Dimensions

Aligning it with the systematic review findings 4 and subsection 4.3.2.3, in which the need to have an ability to formulate success measures in projects was presented, especially in projects where uncertainty is present, this section discusses the project success dimensions in the face of uncertainty.

SHENHAR; DVIR (2007) state that currently, projects are among the most widespread phenomena in modern organizations and even in the global dynamics context of business-related projects; it is no longer enough to stick to the triple constraint (time, budget and requirements) for project success evaluation. But DE BAKKER; BOONSTRA; WORTMANN (2010), presents survey results to the success concept in projects. According them, the project success is still traditionally measured by time, budget and requirements meeting.

Therefore, as suggested by SHENHAR; DVIR (2007), in this work it is understood that to define project success it is necessary to understand what their contributions are to the general business results; setting targets for projects in advance aligned with the organization's business goals. A practice that should be followed at this stage by the manager is the **ability to develop qualitative measures of success** so Shenhar and Dvir defined five measure groups; they are:

- Project Efficiency;
- Impact on the customer;
- Impact on staff;
- Commercial success;
- Preparation for the future.

project efficiency is a short-term measure: if the project has been completed or not according to plan. If it was completed on time; if the budget is within the estimated expenditure. The compliance with the resource constraints indicates a well-run and efficient project, but does not guarantee that it will succeed and benefit the organization in the long run. However, managers can not overlook the market time. This can be a critical component of a given project.

The **impact on the customer** represents the stakeholders' dimensions. It is necessary to clearly present how the project results improved the client's life or business. It is a dimension that includes the product performance measures, functional requirements and technical specifications. It also includes the customer's satisfaction level.

The dimension **impact on the team** reflects how the project affects the team. Good leaders encourage and inspire their team members and make the project a learning experience. This dimension assesses the cumulative impact: the team satisfaction, loyalty, enthusiasm and also an organization's indirect investments in its members, thereby measuring the team's learning extent and growth.

commercial success reflects the direct and commercial impact that the project has on the organization. In the business context, it should assess the sales and profits levels as well as cash flows and other measures. In many cases, this dimension is represented by a business plan which outlines the expected future sales, resulting product's growth and profits.

preparation for future deals with the long-range project benefits. It reflects how well the project helps the organization create new opportunities, being them new business processes, new services or new skills.

In semi-structured interviews, there has been an investigation on these five dimensions, the evidences and a report of the observations made by the researcher are going to be presented here.

Regarding to **project efficiency** 22 respondents out of 25 agree with this dimension, but interesting excerpts to be presented here came out, such as:

> *"If we consider project efficiency in traditional terms: cost, time, and etc., in innovative projects I think this is a bit complicated... uncertainty is closely related to innovation, because innovative projects usually have a high uncertainty degree, it is not exclusive; I can have a project that is not innovative but having a high uncertainty degree; but it is common that innovation projects have more uncertainty, then it is more complicated to evaluate their efficiency using efficiency parameters." [QU18:6]*

> *"I think projects are unique situations to generate a single result and you may not need efficiency but effectiveness. You need to reach the objectives and not to have the maximum performance. You have a lot of unpredictability, a number of things you can not plan in advance, but you can impound and maintain the objectives, so, you manage to be effective. I doubt a lot if you can be efficient; because the more*

innovative and uncertain, the more difficult it will be for the project to be efficient." [QU13:8]

Two evidences presented create a dilemma: on one hand, one has to have a measure which establishes time, cost ... for our clients, on the other hand, there are projects that are so uncertain that determining efficiency becomes complicated, but to be effective you need it. Only to remind each word's context:

- Efficiency consists in doing things right: it is generally linked to the operational level, how to perform the operations with fewer resources, less time, less budget, less people, less raw material, etc.
- Effectiveness consists on doing the right things: it is generally related to the management level.

Thus, the manager needs to check how innovative and uncertain the project is and consider together with the stakeholders the **efficiency and effectiveness**.

According to **impact on customer** this dimension acceptance was unanimous, but many participants suggested changing the dimension name to **customer satisfaction** as some following evidence:

"I do not know if you have there, but more important than impact, is customer satisfaction!" [QU8:10]

"If you don't give visibility to your customer of that is being done, you end up leaving a great deal to be desired" [QU15:13]

"There is no project if you don't know what impact the customer will have." [QU22:18]

In this work the term satisfaction and customer impact is going to be adopted. Many participants in the interviews said that this should be the first dimension of all.

Regarding to **impact on staff**, 23 out of 25 participants believe that it needs to be verified, some evidences are presented, as the following:

"A team's motivation when developing an innovative project successfully; success in this case is measured by customer satisfaction, with a product that is on the market and is gaining position, it's great! Imagine it in an uncertain project, where you have to learn. There are people who work more motivated because there is a relation between novelty and the project." [QU18:7]

"I think that more than the impact, the team motivation degree on a certain project should be checked." [QU5:5]

The team motivation issue was presented in several interviews; for this dimension it is going to be called in this work **motivation and impact on the team**.

On the other hand, 20 out of 25 agreed with the dimension of **commercial success**. One of the main reasons why 5 have not agreed is depicted by the following evidence:

> *"Not all that is generated becomes a product. This criterion is not enough to impact much, because sometimes it takes too long before this factor becomes concrete. Of course it is important, but not essential." [QU16:4]*

This dimension is considered important by 20 participants, but the manager needs to assess whether the project is aligned with the commercial factor.

Finally, the dimension **preparation for the future**, that was also agreed by all participants. Some evidences supporting the dimension need are:

> *"You need to think ahead; it stands to reason that not everything which is visualized becomes concrete, but you need to have a plan and rush for having it realized; then a strategic plan is important because if you do not know which way to go, anywhere serves, and anywhere may be the decline." [QU14:6]*

> *"The project vision is exactly restricted to the project, but if we start to evaluate it at a higher strategic level and at a portfolio level, (...) when you create an innovative project, you already have the ability, or at least you have the ability to imagine what consequences it will bring with it." [QU18:8]*

When these key dimensions are used, the project's success becomes a dynamic concept with implications in short and long term. The first dimension; efficiency and effectiveness can be evaluated in a short term. The second and third will change their form as the project progresses, in the assessing form of the specifications suitability for the customers' needs and the team interaction quality. The fourth dimension can be assessed only after having achieved a substantial sales level and when there is a project's revenue break-even point. The fifth dimension is evaluated after a few years when the long-term benefits begin to show their results. The five dimensions are not exclusive; organizations can define additional dimensions for specific projects.

6.1.5.5 Uncertainty Sources

During the interviews the project managers were asked about the types of uncertainties they faced. The following subsections present some of the evidences from the four sources.

Technologic Uncertainty:

Some of the evidences extracted from the interviews are presented below to portray technological uncertainties witnessed by project managers:

"We needed to develop an advanced system, we work with of this type of technology every day, but the system that we would develop was particularly different and we needed to learn a specific programming language to work with it, we even prototyped, but in the final version implementation time, it had to be integrated with a particular technology and then we began to prepare all staff to deal with that software, we went through an internal training phase, we didn't find professionals in the market who could share this knowledge, then the team itself had to learn the technology. It was a great technological uncertainty, I know what I have to do, but don't know how to do with that tool." [QU11:6]

"We once went to make a kind of kindle reader for a company where I worked. It was a reader for the visually impaired, or else, instead of the screen, it raised reading pins and we did not have all technological knowledge needed; then so, it was a project that was planned to be delivered in an X time; I do not remember whether it was a year, but at the end of the second year, we were running out first prototype. Then so, due to many technological uncertainties, the project more than doubled the time." [QU13:10]

The manager P4 states that the project's technological uncertainty level is not universal, but subjective; that is so because it depends on the technological *Know-how* that exists or that is accessible to the company:

"What for me today is updated, may be not from the moment I do not seek up-to-date knowledge of information. We face these situations. In one of our projects this information related to tools and technology ended up impeding the project too, in relation to these more current things, and that generated a nonconformity." [QU4:6].

The participants P6, P10, P20, P23 say that technological uncertainty depends on the extent to which the project uses new technology and mature technology. It is therefore, a measure of new technology amount, comparing it with mature technology for using in the project:

"I worked some years ago in a project that was based on flash-related technology and what happened (...) a very large investment of resources, time and effort was made to build a robust flash based platform and then, when the project was already beginning to identify potential trading partners, it happened that html5 came strongly and flash become increasingly less adopted; so all that effort that was made to develop it in flash had to be rethought and redone. Before we started the project we didn't think about it; it was really a technological uncertainty." [QU6:9]

"We had a web system to be developed and the challenge of not knowing all services of another system; of these two systems integration, so there was a very large uncertainty level

in this project, where the team developed a system and there was integration with other system and that heavily impacted on project development management." [QU10: 5]

> *"A project that I participated had a very large innovation; they would recognize the footballer who was on the pitch; it involved a very large technological uncertainty, several technologies that the team did not know." [QU20:4]*;
>
> *"We had a large project that was the Electronic Judicial Process and it used some technologies that we didn't know, we were not even trained to do that, and it meant not taking over certain tasks. The decision of not taking it was because the team was not confident to do so." [QU23:7]*

Environmental Uncertanty:

Environmental uncertainties may come from the external environment, such as shown below:

> *"Uncertainty is one of the factors that the external environment generates effect on the internal environment." [QU1: 12].*

The external uncertainty impact can influence the project, such as shown by P2:

> *"We ordered a plate to our project. That plate would help in terms of performance, but the external environment fled from our sight, it was not our responsibility and the manufacturer failed to produce the board." [QU2:2].*

Even though, it is possible to have internal uncertainties to the project:

> *"I worked in two public companies and the environment uncertainty was total. Bureaucracy, especially in the judiciary; you were developing a project and then, there was a judge who said: I do not want this anymore, or a judge would come and say: This is not this way, even if you gave reasons that it should be the way we presented, the judge said he wanted it his way. This uncertainty environment in the public sphere, especially what I experienced in the judiciary, was giant! It demotivated anyone." [QU3: 5].*

Political uncertainty is also an environment uncertainty:

> *"Many times you are on a project and it happens to change their government, and this impacts a lot." [QU9:5].*

"You began to make every effort on a project to be developed, but then the uncertainty was the continuation of that project based on political interests of a particular group. When, for example, a political body has a certain manager who is there for political affiliation matters, the interests are not focused on the project. What I saw several times were things like: "we will cancel this project because it was done in the previous administration and I do not want anything from them"; with no logical explanation for the project's cancellation but personal and political interests." [QU6:10]

"There is an enormous power game in government organizations, there is a person willing that the project may go forward because they understand that the project is important and another group willing that the project does not go forward simply because it was designed by the opposition group." [QU6:11]

A bureaucracy within the environmental context can be considered an environmental uncertainty factor as shown by P13:

"When I take a project based on a bid, it is based on a definition, a priori, of the requirements with references term and unfortunately, we define everything we'll need then. But we know how software development is: it is uncertain, malleable and we have to adjust it during its development. Because of the environment, I had to discuss this type of project with the team several times and decide between doing what was right and what was specified. So, sometimes we failed in delivering a better product because we had to fulfill what was in the bid and would be audited by a political body. Because of that, we had to deliver results below than what we could do. The conservative and rigid environment prevented us from delivering a better quality product which would make end users more satisfied and ultimately, if we delivered something better, we would have some non-conformities from what was required." [QU13:11]

Personal interest, ego and the power game are social and human uncertainties, but impact on the environment; as shown by P24 and P21:

"We handle with judges and there is no hierarchy between them. A certain judge asked our area for a project that, in our point of view, was very interesting to the organization. But at the end, the software project was simply not used because the other judges did not want to. As they have no hierarchy, one can not force others to use, then an interesting software was developed, but was not used." [QU24:4]

"As soon as I joined the company, I started a project that was like the company's flagship; it was a systems security project that would be used by some MERCOSUR countries for information exchange and in this project we would use a lot

of technology that, until that time, was unknown to the company. When new employees started working there, it was proposed a new market approach which the newcomers knew, but there was a lot of fear from the the older staff part; not only because of the technological uncertainties, but also because of personal issues, ego competitions; once those people were there for longer time and were responsible for that function; the new ones came and tried to impose the way to develop things." [QU21:5]

Market Uncertainty:

It represents the extent to which buyers and users are familiar with this type of product, their benefits and the way they can use it. It indicates the the market's uncertainty level, also affecting the ease in knowing what to do or what to build and how to market the product to consumers, as shown by P3:

"In our project we changed the business model and 3 times; we are changing the fourth now. In projects like this, startup, the main point is the market uncertainty; and the more you know it's uncertain, you get surprised when you put hands on it, when you visit the customer, talk to the user, speak with specialized people; it changes all the time." [QU3:6].

The economy is another factor related to market uncertainty, as told by P4, P9 and P13:

"97% of our contracts are contracts with public companies, then the change in the country's scenario directly impacts the company." [QU4:13];

"We got tablets for the project, anything here is done via public bidding. We had acquired them for an X price; a company won, but with the dollar variation, the company was having trouble delivering the tablets." [QU9:6];

"It's happened here in large projects, what cost around 6 million and it was canceled. We had two years of contracted project, we had a team, but it was canceled because of the economy, the company's revenues did not come to what it was expected, so it was canceled." [QU13:12].

P14 speaks about uncertainty related to consumer market acceptance and P15 talks about lack of customer interest due to market changing:

"I met a person who impressed me a lot, it's someone who got a 100 thousand reais funding to develop a game; he had everything well designed, well engineered, so he got the funding and began to develop the game. When he finished the project and placed it on the market, unfortunately the game wrecked and had no acceptance, why? I believe he did not know the players'real needs at that time, then the product was not accepted in the market." [QU14:7]

"We had a project that lasted four years which had a high volume of investment and because of marketing issues, we had to stop. For you to have an idea, the entire line was abandoned. Simply because the market and the client were no longer interested. The decision came from the client who said he did not want to innovate on the product and that we had to stop. It was a telecommunications project geared towards ADSL networks, so we developed research in ADSL lines optimization area , signal level and developed algorithms for that.It was an innovative and promising area, but because of the company, we had to stop and no one expected it." [QU16:6]

Socio-Human Uncertainty:

The social-human uncertainties take into account the relations between people in an organization. Some people can not work together, as shown by P1:

"I had an excellent developer, but he was a " myselfteam" ... I think he was afraid of being replaced and the difficulty I had was to make him work with six other people, so I had to consider it still in the management." [QU1:6].

Mental health factors, as portrayed by P3 and an event presented by P5:

"One of the developers of my team was very good, one of the best I've met, but he had depressive problems that impacted on my project, having a customer waiting, I could not count on him." [QU3:7].

"I'll give you a very clear example of what happened here in the company. We have a project today, which began to be handled by two people, then, I took out one of them and left only one working. What happened? In the last minute the client hammered out that he did not want anything remote once it was an integration project. He wanted our employee there! All right, then! I bought the ticket and I made the arrangements for the employee to go. On Sunday night the employee's wife called me, saying he had had a panic attack; he is very afraid of flying and since Friday, when he received the news that would travel, he came into his bedroom and did not leave. She said she would take him to the airport under medication effect and I told her to talk to him saying that he would not go; that we would cancel his trip. And then on Monday morning I made a quick knowledge transfer, spoke to the employee who was with him when the project began, then I boarded this other guy instead, but this is something that was not in my risk management: 'member of the team being afraid of flying'. This is an uncertainty! I think no manager would put it in a risk matrix, it would not fit in risk management." [QU5:4]

The team motivation, as P4 said:

(...) it is hard to create a permanent team and this certainty lack of maintaining a dedicated team that you can invest in their training within the company, generates a great uncertainty. You have to be motivating people all the time to reduce the loss uncertainty [QU4:10].

Diseases, accidents, better proposals, region changes that can happen; so managers have no control over them, as P6 said:

"... people can become seriously ill, have an accident, they can simply get a very good proposal be attracted and leave the company they are working; they may want to change country or region..." [QU6:12].

The uncertainty whether the customer will be participatory or not. If the client will act correctly:

"I do not know whether the customer will be participatory or not. Whether they are honest or not honest from the standpoint of what we agreed is what I can follow on, or not." [QU13:14]

The factor of adding an unethical employee:

"You put a person in the group, the group is cohesive, it works within a goal and a person comes into like a rotten orange in the middle of the others and begins to generate uneasiness." [QU18:15].

All these factors can lead into social and human uncertainties. As spoken by P13, it is not easy to predict behavior; but you need to understand it in order to format the team the best way:

"It is difficult to predict the stakeholders' behavior out there; it is difficult to predict how human relations are going to be here (within the organization) then, it is a situation that I experience a lot when a project starts. I wonder, for example, if a guy is going to get involved or not, and depending on his involvement level, I format the team in a different way." [QU13:13]

6.1.5.6 Early Warning Signs Detecting

From an uncertainty sources analysis it is possible to detect projects' early signs, but for this to be done it is necessary to adopt the practice of **mindfulness** that describes a state of spirit, or else; the team has to be alert to the various unexpected situations that arise. Mindfulness, the art to face the present forces in our current moment - whatever they are - with the fullness of our resources - the body's intelligence, intuition, reflection and learning from the past - to take increasingly wiser and compassionate decisions.

WEICK; SUTCLIFFE (2011) found that successful organizations tend to share five key attributes that can be partnered with software projects; they are:

- **Failure Concerns**;
- **Reluctance to simplify interpretations**;
- **Operations Sensitivity**;
- **Commitment to resilience**;
- **Skills Consideration**.

Based on the five attributes, the participants were asked whether they agreed with the actions to assess the projects' mindfulness level to early signs. In the first attribute **Failure Concerns**, the manager P14 commented the fact of observing both the success of a project and the failure:

> *"You need to look at both sides, because if I do not manage the failure; I do not look at the failing possibility, so what? If I have failure signs, I do not have contingencies; and if I do not have contingencies, I'll fail." [QU14:11].*

The manager P6 explained the importance of the team in signs identification help:

> *"I try to make the team assist me in the identification process of anything that might go wrong in the project, most of the time they are not things that will make the project to be canceled immediately, but are going to make our project a little more difficult." [QU6:13]*

And another one adds:

> *"Many times the employee is the eyes of the manager on the client; and that's certainly important." [QU15:6]*

But participant P12 warns that within his project the term failure is avoided:

> *"We do not use the failure, we set our goal, our goal is that... and we try to follow the goal; we do not get: if it fails, that will happen... because it is a kind of negativist thing and we get: our goal is that; we will achieve this goal, and then we try to trace and act in the maximum to achieve that goal." [QU12:5].*

P20 said something similar:

> *"Keeping one eye on failure is stressful, perhaps the manager has to do it! The team has to be light,carefree." [QU20:6]*

Demonstrating the concern of letting the team look at a negative point of view and get stressed out with this search. But managers P18 and P21 presents a more open way, presenting both opportunities to the team:

"I have a custom when working with a team; I teamwork in a very open and proactive way. I love receiving feedback, suggestions, criticisms; conversely, I am quite clear and objective in our success chances and our failure possibilities." [QU18:16].

"It is important that the team may get ready, because if they plan a project thinking that everything is going to end according to plan, that can create some problems; the team might get into despair and not to know how to react, ending up in failure." [QU21:8]

Manager P21 presents the importance of presenting the possible paths to the team so they feel they belong to the project. But P8 says that failure is a possibility that no one wants to face, so you have to look at it indeed:

"I find it interesting, so everyone feels responsible for the project and tries to do the maximum for it to happen; for having this happening, it is important to know the possibility of something else happen." [QU21:7]

"We align projects a lot and always think of the failure possibilities because we do not want to go towards that direction." [QU8:6]

Manager P17 adds that it is necessary for the team to have a coherent thought. It is more probable that, if we observe failure in a coherent way, getting help from the staff without being too negative can work well:

"If it's done in a systematic way so as not to create a totally pessimistic team, I think it can be touched; yes, like: let's have a coherent thought, that everyone may have a more probable opinion." [QU17:9]

Only 2 out of 25 participants did not agree with this stage. It is believed that, according to what was exposed by other managers, if the failure concern attribute was done collaboratively, presenting both sides of the coin it would be better managed. It is important that it is shown by the manager that the team is part of the project's environmental context and while making use of this attribute, the teams will not be stressed with the comments focused on the failure.

Regarding the **Reluctance to simplify interpretations**, the 25 believe that this has to be done by all project managers. Participants P12, P1 speak about the importance of observing several evidences:

"We try to keep an eye on everything." [QU12:6];

"All evidence must be observed. I tried to do this even without knowing; seeing these early signs." [QU1:19].

P2, P17 and P18 shows that in addition to observing, one must interpret the evidences the best way; trying to encompass all the possibilities:

"It is always necessary to be attentive to the signs. In my project, we always keep an eye on the team, the client, and the methodology. The manager has always to stay ahead of these interpretations." [QU2:9]

"It is like the policeman story, isn't it? You have an evidence, but can I only rely on its observation or do I have to go after other aspects? That is, I think it is not only a question of evidence, but the evidence investigation in a comprehensive way." [QU17:10]

"I should be aware of all the possibilities that this happens, we have to is working on this activity, trying to surround all the possibilities." [QU18:17]

Additionally P20, P25 and P23 say:

"You have to work with reflection and consider everything and everyone." [QU20:7]

"You have to gather all information and try to interpret it as well as possible, because that thing may have an impact." [QU25:6]

"I have these practices; whenever someone raises a sign I do not draw any conclusion I always say: we will investigate, let's see what's going on. It is not worthwhile to draw any conclusion now." [QU23:12]

In the case of **Operations Sensitivity**, all also agreed with this stage. The necessity of this topic was unanimous. Many managers try to maintain a dialogue with the team as P12 and P11 says:

"When we notice that the business is not going well or a person is very satisfied, I try to talk to the person, investigate what's going on." [QU12:7].

"Problems such as: someone came to work sad or some guy who spent all week on the same problem, then, why that guy did not solve the problem?"[QU11:11].

P15 adds the fact that one's close to the team to understand everybody's perception:

"In the projects I'm working closest I'd rather talk to people and understand each one's perception." [QU15: 7].

On the other hand, P18 thinks that the manager and staff should be alert, regardless of each one's capacity:

"I think you have to be attentive to treat this activity, to go after it, not only the manager figure; the whole team has to be aware (...) Has everyone got this facility? Or that ability? No, but just the fact of giving the team freedom to come and give you a feedback at any time (...)" [QU18:18]

In **Commitment to resilience**, out of the 25 interviewed, four did not agree with this attribute; such as manager P15:

"I think the team has to report the symptoms; if the team is analyzing the symptoms they perhaps may have a distorted view of the facts." [QU15:9].

According the interview's excerpt and the researcher's feeling, manager P15, like the others who did not agree, they are more traditional and centralizing managers. The majority that agrees with the attribute, talked things like:

"An incident will happen, what step are we going to take?" [QU1:24];

"See that I was beginning to equip myself with information, but in the beginning it was not so, I had to create that culture in the team." [QU1:26];

"You create a culture to enable them to identify and longer cope with these uncertainties." [QU10:10].

In addition, P2 and P3 told that the team needs to be prepared and this requires giving the staff autonomy:

"Innovation projects have uncertainties and it is necessary to know how to deal with them. When you train a person well, they are ready to face the uncertainties." [QU2:10]

"We always try to give maximum autonomy to the staff." [QU3:9]

P4, P10 and P20 complement it saying that it is necessary to have the team prepared for frustration and that they need to have the maturity to deal with uncertainties:

"You have to be prepared for frustrations and the team, that is highly motivated, too! One has to take attention to the team frustration when they do not reach the goals planned." [QU4:15]

"It is interesting for the team to have a high maturity degree and cope with uncertainty better." [QU10:13]

"The team should always be ready to face anything." [QU20:8]

P13 presents an aspect of the problem when it happen, how to cope with them:

"Contingently a problem happens, and on the exact moment I say: guys, we do not have to know why, but resolve it! Having this done, having the problem solved, we will analyse the cause and identify what the causes were." [QU13:18].

P23 talked a bit about leaving the team stimulated to learn from mistakes and know how to face failure to overcome problems. P23 spoke a lot about innovative projects:

" It is necessary to have a brave team. You have to have courage to face challenges; but courage is connected to something else: the support! One thing is having an environment where you feel welcomed to face a challenge. However, in an environment where people are challenged then fail, and are punished; they are discouraged to seek innovation, they will avoid any change ... So it's one of the things I try to avoid. If a person makes mistakes trying to get it right or is trying to make it better; provided it is not by irresponsibility, we have to encourage him!" [QU23:15]

The attribute **Skills Consideration**, only 1 of the 25 did not agree with this attribute. The other managers agree that the team members'experience should be taken into consideration.

"When I go through an experience, I absorb it and get smarter for the next time. The same thing has to happen with the team; they went through other experiences in other projects, so if they observe a particular problem in the current project, that may happen; I think they have to warn me. This is based on their experience." [QU6:16]

P18 said one had to learn from their mistakes:

"We have to learn from all the mistakes we made, both mistakes and successes" [QU18:20].

P11 says that the best way to work is to give freedom to the team:

"We make our team independent. The manager keeps an eye, verifies what is happening and when he is called, he intervenes." [QU11:20]

P13 speaks a little about their own learning and that this can be seen in day-to-day work:

"I started managing projects about 10 years ago I had no experience by then, I just read a lot and at some point losing, missing things, making mistakes and obviously learning, right? This made me able to move from making moderate judgments to make good ones." [QU13:7]

Alternatively, P21 presents that the divergence within the team is healthy and should be scored to reach a consensus:

> *"If there is anyone who is thinking that something else should be done, either that person did not understand what to do or the team did not see what that person is seeing, then the whole dispute has to be scored." [QU21:10]*

P24 concludes that it is interesting to observe the responsibilities and take into consideration:

> *"A team that can see where the guy is inserted in, what value he is adding to the project, the responsibility he has about the project." [QU24:4].*

Various software project management activities can be used to detect the early signs, but for doing so; managers and the team need to put into practice the mindfulness. As shown by several participants and some of the following evidences:

> *"We treat the importance of being always aware of this project, but we also explain the team the following: the success this project does not depend only on you. It will depend on other people and that is why it is important to pay attention on the other people's actions [QU22:12]*;

> *"All the time I'm looking at these personal uncertainties and asking how to solve them; asking one I know to lean against, to accompany, listen, talk, sound out, give advice." [QU23:10]*;

> *"I think mindfulness is fundamental to look for these signs, because that's how,in fact, we anticipate ourselves before the problem materialize. When you see, you can feel a lot. With sensitivity you realize before; even by the team's voice tone." [QU23:13].*

Hereinafter practices that have been mapped in this work and are familiar to project management which can be applied in the context of identifying early signs will be presented. The participants were asked whether they agreed that one can detect early signs through them.

23 Participants agree that the results of the step **plan risk responses** within the risk process can be considered an early signs detection form. The identified risks will undergo an options and actions development stage to enhance opportunities and reduce threats to project objectives. This planning can lead to risks identification that represent the questions for which the first signs can be developed. For example, if an identified risk is the supplier's prices rising, the early sign monitoring can consist of a periodic analysis of the market conditions.

19 participants agree that **Added value management**, which is a project management technique that allows the analysis through a set of basic variables related to the project, such as;

how its progress is, how much is going to be spent on the project if it continues at the same pace, etc. It is done by periodic project progress measurements throughout time, both in terms of cost and time, and it shows a comparison between the major parameters: planned value (PV), actual cost (AC), and added value (AV). Measuring periodically these parameters and evaluating the information, an early sign may appear alerting managers of possible deviations.

24 participants agree that **project evaluations** which is somewhat an inaccurate term, but is used in this work, pointing out that several assessment types /audits/ project verifications can reveal early signs. Many other types of assessment carried out for different purposes and which have as no main objective to detect the early signs, may reveal issues that are often relevant to monitor more continuously. If the manager and the team know the most delicate uncertainties sources in their project, they can insert an early signs investigation. As shown in the evidences:

> *"We work 100% immersed on it, it is where we mostly identify points that were hidden." [QU8:9]*

> *"The audit (...) you end up having to analyze evidence and always divergent points come, which are the signs so you can observe or improve what is being developed." [QU14:13]*

The 25 managers agree that **performance measurement** may be used for detecting early signs. Efforts to periodically collect the 'performance data' on the project are not meant for early signs detection. For example, projects control incurred costs, monitor the schedule. These measurements are performed as part of the monitoring effort and project control, but can easily be used as a basis for early signs identification.

The 25 participants agree that **stakeholders management** which collects and analyzes information to identify interests, expectations, influences and relationships with stakeholders in order to discover the needs, expectations and behaviors of project's interested parties which can clearly be converted into early signs; such as presented by P6:

> *"Knowing the people who you are dealing with, and roughly knowing what interests are in the project, the influences on the project and how you should deal with that person in a way that it does not become an obstacle for you but someone that may support whatever is done is a way to capture signals." [QU6:31]*

20 participants showed **maturity assessments**, which can be seen as a specific project analysis subgroup. With the organization's maturity assessment use, the methodologies' quality used by the organization projects are evaluated, generating 'maturity levels' presenting organizational weakness areas. Such weakness areas are obvious indications that the project might have problems related to a particular lack of skill. Early signs detection can be based on these

areas' monitoring and development during the project and contingently, these deficiency indications can lead to specific problems. Early signs can be connected to these activities to ensure the project's satisfactory progress. P6 says that:

> *"The greater the maturity of their projects, the more elements to make a more appropriate uncertainty management you have." [QU6:17]*

24 managers have **consult to past projects**, both within the organization and in the public domain, they are other idea sources to the problems that a project might face. The most relevant ones are typically similar, but also apparently very different projects may have characteristics that coincide with the project in question and which provide learning points. The objective is to explore the knowledge of what caused problems in these projects. Such knowledge of other projects can be found in the available documentation (eg descriptions in the public domain, lessons learned reports, interviews with people who were involved, formal databases, and people's experiences in the current project). As steps, they can be defined into two: First, the problems that occurred in previous projects should be found; and second, the problems' triggers must be identified to allow the early signs development.

In addition to these activities presented, if the project manager is always using mindfulness, he will be able to capture the early signs in any activity, as spoken by P23:

> *"Anytime we talk, you interact if you use mindfulness, then you catch something." [QU23:17]*

> *"Everything you stop to analyze or think about attentively can leave something. I think the signs are spread everywhere" [QU23:18]*

A concern that manager P23 has is related to a project manager's reflection moments. The manager has always many activities and begins not to notice the signs, as shown:

> *"The step in which you have been looking at a particular aspect, will shed light on that aspect; you will reflect on something and you can find signs there, it's difficult to have those moments and to enable the project manager mindfulness. Because you're usually doing five things at the same time." [QU23:19]*

6.1.5.7 Sensemaking

It is necessary to have the sign perception moment and furthermore, the meaning creation moment for each signal. The concept of *sensemaking* has much to do with its own terminology, or else; the process of making or generating sense of something still unknown, in a way that they may become coherent and stable events (ALDRICH; PFEFFER, 1976) what, how and why it is built are central questions of researchers interested in *sensemaking*. This is an approach that seeks to assess how interagents perceive, understand, feel their interactions and

how they use information and other resources in this process (DERVIN, 1998; WEICK, 1995). It is an activity in which the organizational actor performs observation, interpretation and understanding of the outside world, inferring logical meanings which came from the interior schemes use. It is the internal behavior and/or externalized through the senses, which allows the organizational actor as a reflexive actor (SCHÖN, 1983), build and project their movement through time and space (DERVIN, 1998).

The information is used by individuals who are not dissociated from their beliefs and past experiences. The process of organizational sensemaking takes the view that environmental meaning creation is an ongoing social process, and that from their beliefs and past experiences, individuals cut out pieces of previous experiences to build something plausible that make sense for them (DERVIN, 1998; SCHÖN, 1983; WEICK, 1995).

The reality is constructed from the meaning that is attributed to what is happening (WEICK, 1995). That is the premise of sensemaking organizational approach that seeks to study how information starts to make sense to people in the organizational environment.

In an attempt to reach a consensus on the meaning of organizational sensemaking, WEICK (1995) states that sensemaking treats surprises, environment understanding, meaning and action construction. For the author, the best way to understand what sensemaking is, is understanding that it is not interpreted as sensemaking is an authorship and construction process and differs from a passive interpretation process. Sensemaking deals with the search for the meaning creation to a situation which initially made no sense.

During the interviews, the project managers were asked about the four activities presented in Section 5.2. For the first **Interpret the signal** 24 of the participants agree. P11 states:

> *"The project manager has to be a very observant person. He can not be an introspective person, he has to deal with others in a very open manner." [QU11:14].*

For P18 it is necessary to know all the project variables and consider the team:

> *"As I received a signal, the first activity is to interpret it and I should not interpret it just from my experience or vision, I have to do it in the project's context(...) for that, I have to, aside from knowing the project, all its variables and interference, consider the team; assuming that I believe the best way to manage is to get the team with you in the project. It really makes sense when I get a signal. I may even have a predetermination of what I think that sign represents, I can interpret it and have my opinion, but I should adopt as a good practice, to take it to the whole team, so that they also collaborate and say what they are thinking." [QU18:23]*

The second activity **Objectively Translate the Sign** all participants agreed; some evidences are presented:

> *"You have to understand the sign it is as soon as it is perceived, you have to rationalize it, transforming it into something you can communicate or test." [QU1:35]*;

"The manager needs to be synthetic. I had this problem, how can I solve it?" [QU11:16].

"You have to be clear, practical and operational, even using clear words so that everyone who will receive that message is able to receive, understand, and if it is the case, operationalise it." [QU14:15]

The participant P13 despite of agreeing, says that sometimes it's hard to be objective, but it is necessary: *I think I should take an objective question to favour understanding, but it's hard sometimes to escape subjectivism [QU13:19].*

The third activity **Reveal assumptions and beliefs** was also pointed out by all managers as essential. How they present the evidences:

"A lot of what we end up doing comes from previous experiences. We take into account the people's views of the skills, but everything is always evaluated." [QU11:17].

P13 talks about the care that must be taken of; how it will be revealed:

"Every person has their life repertoire in relation to beliefs, cultures; way of seeing the world. I think it's important to discuss it, but always with care. Especially in international projects. I find it important; but taking the necessary care." [QU13:20].

P3 speaks a little of how you can move throughout a conversation:

"My beliefs fell apart after a conversation and you have to be susceptible to new opinions." [QU3:18]

P3 adds that the divergence factor is interesting to get a consensus:

"In this latest project, at the beginning, the team interpreted discordance as something negative; but we started talking that we have to disagree, even if it was for us to get to a common consensus." [QU3:19]

P17 speaks of the difficulty in revealing the assumptions and beliefs, but finds it important and necessary:

"I find it very difficult to get people to let go of past experiences, assumptions they have, beliefs, mainly traumas; say, trauma management as I usually mention. But it is necessary to reveal it." [QU17:16]

The last activity **Building a shared meaning** was also pointed out by all participants as important. As P6 presents:

"You have to align all information, once people are all in the same boat and share the information that is human knowledge, shall we say; because in the end, project management is mostly a jointing matter; if you have no coordination between the parties, the chance of having problems is much higher, as it is for everything; scope, risk, schedule, cost; everything is an articulation matter." [QU6:19]

and P11 states:

"All our team decide! Everything is done together with the team." [QU11:18].

P13 presents the collective sharing need:

"The project is a collective delusion. I think you can make it in a thousand different ways; the important thing is that it is in an unique way; shared to avoid divergencies, that it may be unique, going to a single and shared path so that people do not seek other direction." [QU13:21]

Additionally, P21 shows the need managers heve to share information to make the best decisions:

"The manager increasingly tries to share with the staff of other project managers or executive board some project decisions; just because they find it susceptible to cognitive bias, to keep it from getting biased more to one side than to the other" [QU21:9].

6.1.5.8 Strategies

Some strategies have been reported during interviews by managers.

23 agreed with **Managing stakeholder expectations for them, to accept the changes in a flexibly way**, P6 was one of them and he says:

"As a project manager and changing agent I can articulate and say why the change has to be implemented; I can say who will be the people affected by that change. I can list the benefits that come with that change, as well as the disadvantages that it will bring, but I will not always have the autonomy and influence to change one individual behavior to accept that change." [QU6: 20].

The strategy idea is always be managing expectations and mitigate possible changes that may occur in a project with many uncertainties, so as shown by P4:

"From stakeholders, each have their interest, then you have to be all the time with them, trying to understand the context of each one, so you can meet their expectations." [QU4:32]

In addition, P1 speaks about being always attentive to the needs and having a point in common between the client and the team; generally speaking:

> *"Always talk, whether as a guarantor, whether as a project manager, I am here in the meeting to understand the expectations, where do you think we should get? To find out if people think the same thing." [QU1:36]*

The 25 project managers agree that the strategy of **Flexibility in management and ability to react to changes** must exist, mainly in projects with many uncertainties. P1 comments:

> *"Flexibility is much more dealing with an unexpected situation and momentarily adequate yourself, having the ability to respond to that unexpected situation." [QU1:37]*

And adds:

> *"(...) the management has to be prepared to deal with the change, which is part of the work context." [QU1:38]*

P4 speaks of the relation between changes and innovative projects:

> *"I think there must be flexibility for the change need on innovative projects because you face unexpected things and then you need to readjust." [QU4:37]*

P23 adds:

> *"There is no way; if you are not adapted or prepared to change, to feel; you won't. There is no way to sit and get hold all the variables of the world and say: We will go this way! It is a certain failure." [QU23: 20].*

The strategy of **Creating Flexible Contracts** was reported by 16 out of 25 participants. There was a rejection of 9 because of the difficulty to contract. The manager P15 said that:

> *"I think the contract may be superficial, but not flexible." [QU15:10].*

As for the managers who work in the public sector that were interviewed, they did not agree with the creation of contracts, not to give grounds for not so serious companies; problems that occur during the bidding of a contract, such as approached by P18:

I'll share an experience in the public sector; in the private sector you have much more flexibility than in the public. The public sector is somewhat complicated for you to draw up a contract that has a lot of flexibility,; so if you leave a very flexible thing in a bidding, you are doomed; the probability to hire something you do not want is too large; then having flexibility in contracts is complicated, depending on the sector. I imagine that in the private sector having flexibility in a contract is possible because you can put clauses that indicate a way you may correct it, you may have a rescission , circumvent problems that may happen, which is not easy to do in a public contract." [QU18:24].

The 25 managers indicated that it was necessary to **Building trust between team, management and client**. P4 states:

"This is fundamental, empathy and trust consolidation; this trio, let's say, is fundamental; otherwise you find a hard time to manage a project." [QU4: 38]

P6 presents reasons for the confidence need:

"It is essential having a team that you trust and at the same time, a team that trusts you; I think your relationship is much easier, the information flows in a softer constant way; and it is the same with the customer; you have this open communication channel with the client so that they can understand that not always the results they were expecting are the ones we are going to deliver, maybe it is something which takes longer than what was planned, and in this case, the client being aware of what the reasons are, that that delay is justified, is something built through a trust between the parties (...) it is what I call cooperation." [QU6:23]

P13 and P14 say that trust between the three parties is necessary in projects with a lot of uncertainty:

"Transparency and visibility are essential to solidify the trust in uncertain projects" [QU13:26];

"looking at the customer, team and manager relationship, generating a trust waterfall is essential for projects with uncertainty. If you do not have it, at some point, it will break and will lead to losses for both sides, you must have it" [QU14:18].

P3 talks about the relation between making things clear by giving the stakeholders openness to build trust:

"In the project, we always leave it open, knowing the responsibilities, we leave the things clear." [QU3:20]

P20 speaks of how essential the sense of belonging within the projects is:

"The sense of belonging is very important, this is what will give me confidence, I find it essential(...)"[QU20: 9]

P17 talks about the importance of having that confidence to give greater flexibility in projects with uncertainties:

"When you have a good synergy among these three pillars, then sometimes people give flexibility because of that, they know they can trust the team; for example, I was late in a project, if they rely on their staff, they know the team will make a greater effort, will work much harder, or will deliver it with a better quality than was expected, but I think that is fundamental. It becomes a much lighter work for everyone." [QU17:17]

22 of the participants believe that **managers should facilitate self-organization and team adaptability**. One of the managers who has the characteristic of being very centralizer said:

"I think you have a project management methodology and it must be followed to the end. Once agreed, we have to follow the methodology. If something did not work, we take lessons learned and modify the next projects in a planned way" [QU15:11].

It is believed that this is not the best way of conducting projects, as P17 talks, he believes that adaptability is essential in projects with uncertainty and it is a way of stimulating a creative and not a robotic team:

"I delegated a lot of responsibility to the team itself to solve problems because they had to adapt to day-to-day. I did not have to dictate all the steps. Things keep changing. Facing uncertainties, it is necessary to make changes and the team must adapt. If they always depend on a person to dictate the way, I think it is terrible; because the team will always be with the same characteristic of that person, sometimes they will not have creativity, sometimes they will be robotic, sometimes the team will feel unable to make any contribution" [QU17:18].

Manager P13 talks about the importance of practice:

"This is a very important thing. Autonomous agents in the team who can make decisions is very important." [QU13:23]

P18 complemented with the need to give the team autonomy:

"I support and am in favour of having a team with the maximum possible autonomy and if this autonomy is not possible, we need to find mechanisms so that even with limitations, they can be as flexible as possible; as autonomous as possible, as ingenious as possible in activities they may perform." [QU18: 25]

Manager P23 discusses about change through posture:

"As soon as I joined the project, which was very uncertain, the team just received tasks; it was a very strict structure. Then I began to relax and said: "The problem is this one". How do you want to organize yourselves to solve it?" I think it was a differential; things started to move on and I get feedback that it was very important." [QU23:21]

Manager P6 says that this strategy is a strong ally to reduce uncertainties:

"I would say the manager he can facilitate, advise, can act as a mentor for the team to be self-organized and be able to adapt to changes; I think that this reduces a project's uncertainties." [QU6:24]

collaborative work can be seen as essential for a project development. The 25 managers agreed that the team needs to work collaboratively. According P14:

"I need to be concerned about the effect of my work on the others, on the project, etc.; this ant's work is important." [QU14:19]

P21 says that it is a differential to observe uncertainties:

"In my specific projects, the team as whole has the characteristic of sharing everything
among the members in a flexible way; everyone saw the growth opportunity, there was information sharing, the manager favored the information sharing among team members. They made everyone aware of what was happening, there was a very large information transparency, helping to look for uncertainties; because sometimes one realizes something and the other does not, and that helped a lot in the project." [QU21:10]

6.1.5.9 Responses to Unexpected Results

In face of uncertainties, some results are not expected; thus, it is necessary to prepare the team for how better react to unexpected events. To prepare the team, it is believed that the they may use learning techniques, constructive thinking and creativity techniques, such as the ones presented by the interviewees.

The **learning techniques** are pointed out by the participants as a differential in projects with uncertainty, as reported by the managers P11 and P23:

"We provide discussions about how we are doing things, we run courses and lectures; activities to share knowledge to reduce uncertainty in our project" [QU11:21].

"To qualify the team to minimize the problem. Promoting training; getting training is one of the best ways to prepare for project's uncertainties" [QU23:8].

P12 tells about the importance of knowledge dissemination within the team:

"We try to maintain an information access link with all lesson learned , all important information to disseminate that knowledge" [QU12:9].

The practice of lessons learned was presented as a strong ally to promote learning:

"What are the lessons learned? They are a great information source, and this, in my opinion throughout the time, experience has taught me that is the experience itself; it is sharing, you make public something that needs to be made; you need to give knowledge to more people, because what may not be important to you, may be very important to someone else; what you are not seeing, the other person can see something." [QU8:8]

P6 says that the learned lessons' technique should be applied throughout the project:

"The issue of lessons learned is another thing that is almost left out in most projects. People understand the lessons learned as something to be done at the end of the project and this is not the best time for you to make the lessons learned collection, because considering that each project is unique, the sooner I can identify the lessons learned and manage putting them into practice, the better" [QU6:6].

P4 highlights that beyond lessons learned, his company makes some technical intervals with employees and guests:

"In addition to the lessons learned here, we have two practices that are interesting: every month a person is designated to study a theme and give a lesson (...) and every three months we invite a professional from an outside company, from a university's training or teaching segment to talk to managers, bringing a real experience." [QU4: 39]

As well as in P5's and P10's organization:

"We have an event in which we have a technical interval. Every week we do it." [QU5: 9]

"We carry out the previous projects' visualization, lessons learned and training techniques used in the project context. Not only technical, but methodological management and of the process too, with workshops and technical sessions. I think these activities can reduce uncertainties in projects." [QU10:14]

P13 adds the importance of reflection in project teams and presents two more pair programming and mentoring practices:

"The team normally has retrospective sections, which is essential for learning; it behaves reflectively, and contingently schedules workshop sessions to discuss requirements and have a technical interval. One thing I suggest, is to try pair programming, especially with new members. Mentoring works well too." [QU13:24]

In the team led by P16, there are reading shifts for magazines and articles:

"(...)always staying up to date, having magazines and articles reading shifts, making people participate in events." [QU16:7]

P20 adds a practice for team doubts solution:

"Learning is important for anything.In one of the projects I participated, I put a jug and when doubts began to grow, we stopped to react. Another way is to put the doubts on a board, when they occupy the whole space, we stop to talk." [QU20:10]

P6 and P17 agree that it is necessary not only to collect information via lessons learned, but to investigate and disseminate them:

"The more experienced you become, the more aware you are of problems that may occur in your work scope, it also has to do with the question of the lessons learned; to use them properly, for you identify and disseminate them among other projects, they may also work as a learning source for the others." [QU6:26]

"(...)not just storing the lessons learned but be investigating, (but) disseminating that fact among the staff (...)" [QU17:12].

The **group cohesion**, in which the majority of the team members share the same mentality was appointed as a positive culture in the project and contributes to the unexpected resolution. P1 depicts the need to create that culture within the team:

"The team have to think that it has to be part of the solution, not just a messenger of the problem, that's cool! It is very important you start to create this culture" [QU1:39].

P6 agrees with P1 when he says that union helps in problem solving:

"If you have everyone on the same boat willing to help each other, the problem solution becomes easier." [QU6:27]

P14 indicates the commitment need:

> *"It necessary that a person is committed, wear the shirt; achieve the objectives" [QU14:20]*

P20 says that when the team is in synchrony it is better to solve problems:

> *"When everyone is in synchrony, things flow better" [QU20:11].*

Managers P11 and P16 discuss how it is done in their teams:

> *"You are part of the whole! If someone gives reasonable results there is something going on. So we try to verify what happened; it may be something personal; we have to adjust the profile, if there is no profile, we will try to search the profile which adapts better to that person." [QU11:22]*

> *"The important thing is to keep the team very close. From the environment to meetings; giving everyone a lot of freedom to express their opinion and respecting each person." [QU16:8]*

In addition to agreeing with group cohesion, P18 believes that the practice can help in project uncertainties:

> *"My idea of leadership and leadership management is an idea of team; in the sense that we are a group, and the group has a goal and our goal is common to everyone; under this assumption, if I can make my team wear the T-shirt, I can make them think as I think, with my goals; when I tell my mates about the project, I fully agree that this activity will help you to prepare for uncertainties." [QU18: 26]*

P17 discusses that despite the disagreements occur in the team. When everyone is integrated in favor of the project, it might be a differential:

> *"Align the objectives and make everyone focus on that objective independently of divergence between people. So, sometimes people diverged among themselves, but were working together for the project." [QU17:20]*

P5 believes that divergence is important, but requires convergence:

> *"We have a constructive disagreement which I find interesting here, because we get into a consensus later." [QU5:10]*

"Thinking differently and trying to identify things you had not seen before" [QU6:28]

It was what manager P6 spoke. The participants agree that stimulating **creativity** in teams may be a differential in face of uncertainty. Manager P13 highlights:

"Brainstorming, prototyping are part of our activities as a creativity stimulus! I think in projects with many uncertainties creativity is essential" [QU13:26].

P14 cited a well-known company that encourages, and even invests in the employees' creativity:

"We need to expose our creativity; I visited a company that does this very well, they say, in a simple way; "you have a period of time you can think and do whatever you want: initiatives and personal projects, and I financially support these personal projects." [QU14:21]

Manager P11 speaks a little about not doing always the same and stimulating the team:

"We have freedom within the project to play video games, listen to music, play the guitar, the keyboard; this process helps people's creativity. The main thing is to have a healthy environment that gives freedom to people! You are not creative when you only do the bread and butter job! We need to encourage people to leave the standard and the routine." [QU11:23]

and P18 talks about the relationship between creativity and innovation projects:

"Creativity and innovation are very close, I am quite favorable, normally including them in my projects that have innovation; I will use the term section,I mean, creativity sections." [QU18:27]

6.1.5.10 Technicals

Some techniques found in the literature as an important factor in reducing uncertainties in projects were asked to managers. Among them, quality agreement with the client was reported by 19 managers as something interesting to be adopted. Manager P14 said it was necessary, but adopted in a descriptive way, without much formalism to not complicate the process:

"A lot of formalism may ultimately bring many difficulties in projects'implementation, but I think you have to have a higher, more descriptive level" [QU14:22].

24 of the participants pointed out that continuous integration practice is a strong differential in projects and can reduce uncertainty. The 25 interviewees agree that the involvement of the specialist user in the project may reduce uncertainty.

23 managers pointed out short interaction; as reports P17:

"I think the small deliveries' effect is highly important. You have more time to be able to solve something. You did not spend so much effort, cost, time and so on. Doing something that is not correct, shall we say so" [QU17:22]

24 managers said that we must undertake stakeholder analysis as manager P6 said:

"Knowing the people who you are dealing with, and roughly knowing what are the interests in the project, the influences on it and how you should deal with a certain person in a way that they do not become an obstacle for you, but a person that supports whatever is done." [QU6:31]

25 of the participants believe that a multidisciplinary team formation is essential in projects; as P17 talks:

"I think you can give various aspects, for example, in solving a problem, several solution faces, several creativity points" [QU17:23].

25 managers believe that the brainstorming technique:

"I see brainstorming as one of these techniques, then; you along with the team think outside of a particular pattern, think outside the box" [QU6:33].

19 participants believe that the cause and effect analysis can be indicated to verify the projects' past, in a way to reflect and better prepare for the current project.

Only 9 managers were in favor of the tree-building decision technique. According to them, it is not a trivial technique, that can create a bound structure; as commented by P23:

"The feeling I get is that you will tie to it to person like: Came this way, do it this way! Creating a solution menu structured in a tree form" [QU23:23].

Everyone agrees that scenario building can be an ally to uncertainty management; as portrayed by P17:

"I think it's important because you think of several alternatives; you see several variables and the way they can influence the project" [QU17:24].

6.1.5.11 General Assessment of Interviews

Everybody was asked if the organization where they work adopts uncertainty management practices and an average of 3.72 was obtained. Then, it was asked if the companies they work would adopt an approach to uncertainty management and, an average of 7.88 was obtained. It was also asked if each of them, as project managers, would like to adopt the approach and an average of 9.32 was obtained. The last question was if the development of an uncertainty management approach to help people and organizations apply practices/strategies in projects, aiming to improve the projects' success was a necessary contribution to industry and academy; an average of 9.58 was obtained.

6.1.6 Interview's Discussion

According to the evidence presented, it was observed that the distinction between risk and uncertainty is still not clear to some project managers. But when many participants were asked what uncertainty was, the responses ranged from: lack of sufficient information or lack of knowledge; no perception or limitation to perceive signals. All evidence points to our theoretical definition provided in Section 2.3. It was still noticed that uncertainty is part of all projects and that is from uncertainty that risks arise.

During the interviews it was found that the term uncertainty management makes sense; it is necessary to develop in team management activities that can make them begin to realize; to probe and identify. From that identification, a probability is generated, consolidating a second stage which is risk management. Or else, the uncertainty management would be a way of providing technics or mechanisms that help identify the things the team can not predict so far, and that can impact somehow in the project. In addition, the uncertainty management should prepare the team to deal with the unexpected, the better the team is prepared, the better they will be able to handle the unexpected.

Based on investigations, some practices were found necessary for uncertainty management. Starting with the project's characterization, or else, the fact of using a range of methodologies, tools, practices and procedures that are available and make an adjustment according to the kind of project. It was also said that the more innovative the project is, the more susceptible to uncertainty it can be; then you need something that can guide project managers in a better characterization.

Another necessary practice within uncertainty management is continuously perform an uncertainty sources survey: technological, environment, market, social and human. Technological uncertainty depends on the extent to which the project uses new technology or mature technology. Moreover, project's technological uncertainty is not universal, but subjective; that is because it depends on the technological *know-how* that exists or is accessible to the company. The environmental uncertainties may be provided from the project's the external or internal environment; political, bureaucratic, self-interest and power game which impact the uncertainties in the project's environmental context. The market uncertainty is related user uncertainty, customer behavior, economics and socio-human uncertainty take into account the relationships between people in an organization. Mental health factors, staff motivation, diseases, accidents, better proposals; if the client is going to be participatory or not, if they are going to act correctly or not. All these factors can lead to social and human uncertainties.

The project manager must be aware of what uncertainties sources are most susceptible in their project and continuously assess early signs, but the manager needs to use mindfulness. For teams to practice mindfulness, the five attributes can be adopted: Concern for the failures must be carried out collaboratively by the team, with a coherent thought, for everyone in the team get involved with the project, knowing which way not to take, but always keeping an eye

on it. The Reluctance to simplify interpretations: the project manager must interpret all the evidence as well as they can and not to make the mistake to simplify interpretation. Operations Sensitivity: one needs to be sensitive to detect, monitor, analyze and determine if there is an early sign from an uncertainty. Commitment to resilience: Creating a culture within the team, so that they become able to deal with uncertainties, to identify and respond as well as possible. Skills Consideration: All the team are able to learn from the more the experienced, learning is the best way to respond the next time something happens

There were verified some practices that, according to previous research, could help identify early warning signs such as: planning risk responses, added value management, project assessments, performance measurement, stakeholders management, maturity assessments and past projects consultation. However, in this research it was established that if the manager uses mindfulness, all project management activities can detect early signs.

To translate early sign the best way, it is necessary to create a sense to it. The use of sensemaking generates sense for something subtle. To sense make, one must follow the four activities: Interpret the signal, Objectively Translate the Sign, Reveal assumptions and beliefs, Building a shared meaning. In Interpret the signal it is necessary to use the five attributes defined to interpret the signal. In this activity some attributes for the manager were identified during interviews; for example, the manager must be a good observer, know the project, always try to talk to the team, understand the different perspectives and use their feeling as well. In the second activity, objectively translate the sign; the manager needs to be synthetic, they need to rationalize it, transform it into something objective in a clear, practical and operational way. Reveal assumptions and beliefs: much of what is done comes from previous experience. One must take into account the people's views, but always be attentive to everything, because everyone has their own repertoire regarding to beliefs, cultures, way of seeing the world, which is good for the project, but in case any repertoire is not appropriate at any given time, the manager needs to act. Building on a shared meaning: The project consists of a team, everyone is building the product and for that, it is necessary to align all information and share knowledge.

Project managers can try to contain uncertainty, as a resulty they will not be one hundred percent successful. Therefore, a project requires strength and should be able to detect and respond quickly to unexpected events. This requires preparing the team in the best way to react quickly. During the interviews there were identified learning techniques, group cohesion and creativity techniques.

Learning is seen as a differential to deal with uncertainty by promoting the team's knowledge. It is possible to leave the unknown and reduce uncertainties. The managers interviewed pointed out various approaches to promote learning, they are: qualify the team through courses, lectures, technical workshops, training, technical intervals, team reflection, pair programming, mentoring and the most quoted of all: Lessons learned, which was appointed by the managers that should be performed throughout the project in an investigative manner and disseminating what happened to all staff.

Group cohesion is creating a culture where all project team wear the same shirt, despite of each one's differences, there must be a constructive divergence so everyone may come into common consensus. When there is group cohesion, the goals are aligned and everyone is inclined to contribute with one another and it makes it easier to solve problems.

Among the creative techniques used in organizations two were often cited: Brainstorming, used to encourage the team to think and prototyping, used to create a future system model to conduct trials and checks. The participants showed that the project environment can contribute to creation, the team members must be given freedom, be encouraged to break out the routine not to do only do the basics.

Among some practices/strategies that can be adopted in favor of the project so to reduce uncertainties include: managing stakeholders' expectations so that they flexibly accept changes. This strategy is to always try to manage expectations in order to mitigate the possible changes' impact that may occur within the project.

Another strategy is management flexibility and ability to react to changes. Flexibility is essential for the team to have the ability to respond to unexpected situations. The team has to be prepared to readjust so they may reach the project objectives.

The strategy of creating contracts was appointed by 16 managers as interesting, once the project is innovative and with many uncertainties. This can help to adjust the strategies during the project development, but 9 of managers working in the public sphere showed the difficulty in having flexible contracts because of the difficulties that they already face with outsourced companies.

When building trust between team, management and customer empathy is necessary and the consolidation of this trust to the relationship flow more smoothly. The team relies more on the manager and vice versa. the same way when there is trust between client and project team, the client knows the project's uncertainty, but relies more on the direction in which the project is being conducted. The synergy between these three pillars must exist with transparency, visibility and sense of belonging.

The strategy that managers should facilitate self-organization and adaptability was reported by 22 managers. The need for self-organization generates more autonomy to the team and makes them strengthened in face of uncertainty, but to do so, the project manager must act as a mentor to facilitate this self-organization. Still, change is common, the team has to adapt to the reality of project's needs. If the project manager dictates the rules, it will make the team feel unable to contribute and this can generate a robotic team.

Another essential strategy for developing projects with uncertainty is the collaborative work. The team member has to worry about the effect of their work on others and share experiences. This makes some perceive things that others did not, thus treating the project uncertainties.

It was found that some techniques can help reduce the uncertainties in software projects, such as **continuous integration** which consists on integrating the work several times a day,

ensuring that the code base remains consistent at the end of each integration. The **involvement of expert user** when this expert's experience can save a lot of time and money in the project. Giving active voice, and keeping track of insights can help in reducing uncertainties. The **short interaction** produces a stable, executable version of the product, along with all supporting documentation it can avoid wasting time and effort on something that was not a customer's real need. The **stakeholder analysis** can reduce the uncertainty regarding the parties. The **multidisciplinary team formation** can help in solving problems, since several experts can find a different solution to a given problem. The technique of **brainstorming** was indicated as a great alternative to create and analyze uncertainty sources. The **cause and effect analysis** can be indicated to check the project's past in away it may reflect and better prepare for the current project's uncertainties. Only 9 participants indicated the use of the **decision tree**, most said it was a tethered technic and may not have all the necessary solutions face uncertainties. The **construction scenarios** is highly indicated by the managers to show a project's future vision, it makes managers think about their project's uncertainty.

6.1.7 A Description of the Approach Evolution - Third Version

The Table 6.3 summarizes the concepts presenting the evidence codes that strengthen each concept. The concepts that emerged were added in the approach thus generating a new version.

Tabela 6.3: Uncertainty Management Evidences

Label	Practices	Codes
IP1	Characterizing Projects	[QU1:23], [QU9:3], [QU11:4], [QU11:5], [QU12:2], [QU13:6], [QU14:3], [QU16:3], [QU17:4], [QU18:5], [QU19:2], [QU21:3], [QU23:26], [QU24:1].
IP2	**Uncertainty Sources**	
IP2.1	Technological Uncertainty	[QU1:2], [QU2:1], [QU3:1], [QU4:6], [QU4:8], [QU5:6], [QU6:9], [QU8:4], [QU9:4], [QU10:5], [QU11:6], [QU12:3], [QU13:10], [QU14:8], [QU15:4], [QU16:5], [QU17:5], [QU18:9], [QU19:4], [QU20:4], [QU21:5], [QU23:6], [QU23:7], [QU24:3], [QU25:2].
IP2.2	Environment Uncertainty	[QU1:1], [QU1:12], [QU2:2],[QU3:5], [QU4:4], [QU4:7], [QU5:7], [QU6:10], [QU6:11], [QU9:5], [QU13:11], [QU14:4], [QU14:9], [QU18:10], [QU21:5], [QU21:6], [QU22:4], [QU22:6], [QU22:10], [QU24:2], [QU25:3].

IP2.3	Market Uncertainty	[QU1:5], [QU2:3], [QU3:6], [QU4:9], [QU4:11], [QU4:13], [QU4:18], [QU9:6], [QU11:8], [QU13:12], [QU14:7], [QU15:5], [QU16:6], [QU17:6], [QU20:5], [QU22:7], [QU28:8], [QU22:9], [QU25:4].
IP2.4	Socio-Human Uncertainty	[QU1:6], [QU1:7], [QU2:4], [QU3:7], [QU4:10], [QU5:4], [QU5:8], [QU6:12], [QU8:5], [QU10:6], [QU11:7], [QU11:9], [QU12:4], [QU13:13], [QU13:14], [QU14:10], [QU17:5], [QU17:7], [QU17:8], [QU18:11], [QU18:12], [QU18:13], [QU18:14], [QU18:15], [QU21:5], [QU21:6], [QU22:11], [QU24:2]
IP3	**Attributes to Detect the Signs**	
IP3.1	Failure Concerns	[QU1:4], [QU3:8], [QU6:13], [QU8:6], [QU11:10], [QU12:5], [QU13:15], [QU14:11], [QU15:6], [QU17:9], [QU18:16], [QU20:6], [QU21:7, [QU21:8].
IP3.2	Reluctance to simplify interpretations	[QU1:19], [QU2:9], [QU4:16], [QU6:14], [QU6:15], [QU10:8], [QU12:6], [QU14:12], [QU17:10], [QU18:17], [QU20:7], [QU23:11], [QU23:12], [QU25:6].
IP3.3	Operations Sensitivity	[QU4:17], [QU10:9], [QU10:11], [QU11:11], [QU12:7], [QU13:17], [QU15:7], [QU17:11], [QU18:18], [QU23:14].
IP3.4	Commitment to resilience	[QU1:24], [QU1:26], [QU2:10], [QU3:9], [QU4:15], [QU4:19], [QU4:20], [QU4:21], [QU10:10], [QU10:12], [QU10:13], [QU11:12], [QU11:13], [QU12:8], [QU13;18], [QU15:9], [QU18:19], [QU20:8], [QU23:15].
IP3.5	Skills Consideration	[QU6:16], [QU9:7], [QU11:20], [QU13:7], [QU15:8], [QU18:20], [QU21:12], [QU23:16], [QU24:4].
IP4	Mindfulness	[QU1:3], [QU22:12], [QU23:10], [QU23:13], [QU23:17], [QU23:18], [QU23:19], [QU25:5].
IP5	**Sensemaking Activities**	
IP5.1	Interpret the Signal	[QU1:34], [QU4:34], [QU4:35], [QU8:7], [QU11:14], [QU11:15], [QU13:16], [QU14:14], [QU18:23].
IP5.2	Objectively Translate the Sign	[QU1:35], [QU11:16], [QU13:19], [QU14:15].

IP5.3	Reveal Assumptions and Beliefs	[QU3:18], [QU3:19], [QU4:36], [QU11:17], [QU13:20], [QU14:16], [QU17:16].
IP5.4	Building a Shared Meaning	[QU6:19], [QU11:18], [QU13:21], [QU20:12], [QU21:9].
IP6	**Successful Dimensions**	
IP6.1	Efficiency and Effectiveness	[QU1:43], [QU4:46], [QU9:5], [QU13:8], [QU18:6].
IP6.2	Customer Satisfaction	[QU4:47], [QU8:10], [QU15:13], [QU22:18], [QU25:7].
IP6.3	Motivation and Impact on Team	[QU5:5], [QU14:5], [QU18:7], [QU22:5].
IP6.4	Commercial Success	[QU4:48], [QU5:11], [QU6:34], [QU6:35], [QU16:4].
IP6.5	Preparing for the Future	[QU1:42], [QU8:3], [QU14:6], [QU18:8], [QU19:3].
IP7	Strategies	
IP7.1	Learning	[QU4:39], [QU5:9], [QU6:6], [QU6:7], [QU6:26], [QU8:8], [QU10:14], [QU11:21], [QU12:9], [QU13:24], [QU15:12], [QU16:7], [QU17:12], [QU17:13], [QU17:19], [QU17:21], [QU20:10], [QU21:11], [QU23:8].
IP7.2	Constructive Thinking	[QU1:39], [QU5:10], [QU6:27], [QU11:22], [QU13:25], [QU14:20], [QU16:8], [QU17:20], [QU18:26], [QU20:11], [QU21:4], [QU22:17], [QU23:22].
IP7.3	Building Trust Between team, management and customer	[QU3:20], [QU4:38], [QU6:23], [QU13:22], [QU14:18], [QU17:17], [QU20:9], [QU22:13], [QU22:14].
IP7.4	Managers Should Facilitate Self-Organization and the Team Adaptability	[QU6:24], [QU6:25], [QU13:23], [QU15:11], [QU17:18], [QU18:25], [QU23:9], [QU23:21].
IP7.5	Management Flexibility and Ability to Respond to Changes	[QU6:24], [QU6:25], [QU13:23], [QU15:11], [QU17:18], [QU18:25], [QU23:9], [QU23:21].
IP7.6	Collaborative Work	[QU11:24], [QU13:27], [QU14:19], [QU21:10], [QU23:25].
IP7.7	Managing the expectations of Stakeholders so that they Flexibility accept changes	[QU1:36], [QU4:32], [QU6:20], [QU10:17].

IP7.8	Multidisciplinary Team	[QU4:40], [QU4:41], [QU6:32], [QU10:16], [QU12:10], [QU17:23].
IP8	Techniques	
IP8.1	Creativity Techniques	[QU1:40], [QU6:28], [QU11:23], [QU13:26], [QU14:21], [QU18:27], [QU21:13].
IP8.2	Stakeholder Involvement	[QU6:29], [QU10:15], [QU11:19], [QU14:23], [QU15:3], [QU17:15].
IP8.3	Cause and Effect Diagram	[QU3:21], [QU6:36], [QU13:28], [QU17:25], [QU18:29].
IP8.4	Brainstorming	[QU1:45], [QU4:44], [QU6:33], [QU14:25], [QU23:24].
IP8.5	Stakeholder Analysis	[QU1:31], [QU2:15], [QU3:15], [QU4:43], [QU6:31].
IP8.6	Short Iterations	[QU6:30], [QU14:24], [QU17:22], [QU21:14].
IP8.7	Continuous Integration	[QU4:49], [QU18:28].
IP8.8	Quality Agreement with the Client	[QU14:22].

From the interviews and the project managers' feedback, the approach was structured, keeping the initial stages presented in 4.4 and containing the activities of each stage, moreover; there have been added: a section of proactive strategies to reduce uncertainty and general orientations for project managers, as shown below:

- **Characterizing Projects:**
  - Identifying the project type to adopt appropriate management;
  - Analyzing stakeholders;
  - Defining Success Criteria;
- **Identifying Uncertainty Sources:**
  - Consulting past projects;
  - Cause and Effect Diagram;
  - Building scenarios;
  - Building the Knowledge Map of uncertainties sources;
- **Detecting Early Signs:**
  - Establishing Mindfulness Culture:

        - Analysis of Failure Concerns Attribute;
        - Analysis of Reluctance to Simplify Interpretations Attribute;
        - Analysis of Operations Sensitivity Attribute;
        - Analysis of Commitment to Resilience Attribute;
        - Analysis od Skills Cosiderations Attribute;
    - Checking the early signs table

- **Sensemaking:**
    - Interpret the Signal
    - Objectively Translate the Sign
    - Reveal Assumptions and Beliefs
    - Building a Shared Meaning

- **Risk Management**

- **Unexpected Outcomes:**
    - Find what strategy to adopt to confront the event
    - Learning when unexpected results happen

- **Proactive Strategies to Reduce Uncentainty:**
    - Short Iterations;
    - Continuous Integration;
    - Prototyping;
    - Stakeholder Involvement;
    - The creation of flexible contracts;
    - Brainstorming;

- **General Orientations for the Project Mamagers:**
    - Respond to changes
    - Managers should facilitate self-organization and the team adaptability;
    - Building trust between team, management and customer ;
    - Management flexibility;
    - Ability to respond to changes;
    - Managing the expectations of stakeholders so that they flexibly accept changes;

- Managers should facilitate communication within the organization;
- Collaborative Work;
- Multidisciplinary;
- Criativity;
- Group Cohesion;

6.2 Focus Group

To CAPLAN (1990), a focus group is a group of people joined to evaluate concepts and/or evidenced problems. VAUGHN; SCHUMM; SINAGUB (1996), argue that a focus group is a qualitative technique which can be used alone or together with other qualitative or quantitative techniques to further evaluate the participants' knowledge about a topic. The focus group main aim is to identify participants' feelings about a certain matter, product or activity. Its specific objectives vary according to the research approach. In an exploratory research, its purpose is to generate new ideas or hypothesis and stimulate the researcher's thinking, while in phenomenological or orientation research, it is to learn how the participants interpret the reality, their knowledge and experiences (SHULL; SINGER; SJØBERG, 2008).

6.2.1 Planning/Design

The participants were emailed and informed about our research so they would agree or not on being interviewed. At the invitation moment, it was sent a summary of the work. The Table 6.4 presents a participants'data summary, which is going to be labeled by a PFG1 to PFG6 code.

Tabela 6.4: Summary of Focus Group Participants

Code	Experience	Project Management Experience	Education
PFG1	MBA in Strategic Management of TIC, MSc Computing Science in Project Management area. Certificate ITIL, COBIT, CSM. Professor of Postgraduate and Higher Education in TI. He has 19 years of professional experience and is currently a manager at a government company.	15 years	Ongoing Phd

PFG2	MSc Computing Science in Project Management area. He has 8 years of professional experience and currently working as a Project Management Office in a private company.	3 years	Ongoing Phd
PFG3	MSc and Phd Computing Science in Project Management area. He has 17 years of professional experience and currently working as a Software Process and Quality consultant, MR-MPT.BR assessor and implementer, MR-MPS-SV implementer, MPT.Br assessor and implementer, Professor of Postgraduate and Higher Education in TI	6 years	Phd
PFG4	MSc Computing Science in Project Management area. He has 30 years of professional experience working as developer, analyst and manager. He worked with innovative software projects and is currently director of the Project Management Office of a public company.	17 years	Ongoing Phd
PFG5	MSc Computing Science in Project Management area. She has 17 years of professional experience and currently working as a Software Process and Quality consultant, MR-MPT.BR assessor and implementer, MR-MPS-SV implementer, MPT.Br assessor and implementer, Professor of Postgraduate and Higher Education in TI	7 years	Ongoing Phd
PFG6	MBA in Strategic Management of TIC, MSc and Phd in Industrial Engineering with a focus on Governance of TI. She has 20 years professional experience of which acted in coordination to develop innovation projects. She is currently a professor and researcher in the project management area	8 years	Phd

The focus group was conducted to evaluate the proposed approach to manage uncertainties in software projects. At the time of the focus group idealization, the approach was in the third version and there was a need to assess its structure and relevance.

Forms were designed for each approach activity and recommendations to help evaluate each stage of it, as well as slides for driving every step.

6.2.2 Conducting the focus group sessions

During the execution, the meeting was three hours and a half long. The FG meeting took place in a traditional classroom, with a data projector for presenting slides and fixed seat rows, which is not an ideal setting for the planned dynamics. However, it was possible to accommodate the participants and make the dynamics work.

The dynamic worked as follows: first, the participants were presented. The moderator introduced the focus group rules generally and as well as every approach step. The forms were distributed so that at least three participants would evaluate the activities. At the end of each assessment, the participants had to write the activity on a post-it individually and then stick it on a frame (made of cardboard) containing the approach's steps names (Characterizing Projects, Identifying Uncertainty Sources, Detecting Early Signs, sensemaking, managing the risks, responding to unexpected results, proactive strategies to reduce uncertainty and general orientations for the managers) indicating in which moment the activity/recommendation should be held in the approach and suggesting (in forms) improvements for each of them.

After that, the participants were asked to analyze the poster formation. First, all divergences were apointed by the moderator, then the participants were asked to get into an agreement; after that, there was a debate period in which the evaluators expressed each their points of view and came up with a single step for each activity/strategy/recommendation analyzed. To end up, the final result was presented and each participant was asked to give a general approach analysis.

6.2.3 Analyzing the data and reporting the results

Regarding the participants' evaluations, all approach structure evaluations were positive, as presented in evidence:

> *"His work is very well structured and coherent. The evidences collected prove that." [PFG6]*

> *"I found the approach structuring great, you drank from multiple sources to get a structure to equip the project manager with strategies that are used in their favor." [PFG5]*

"I found your strategy cool, I would like to have done more, but due to time constraints it is not possible." [PFG4]

"I found the approach structure very cool." [PFG3]

"Your approach shows what the project manager can have as a base to better manage their team in the face of uncertainty." [PFG1]

Some suggestions were identified by participants and adjusted to a new approach version, they were: Criativity should be put on Proactive Strategies to reduce uncertainty; Ability to Respond to Changes should be on Responding to Unexpected Results; and Creation of Flexible Contracts in General Orientations for the Managers

Participant PFG6 noted a concern with too many strategies used in managing uncertainties:

"I was worried about the overflow of issues, if there are not too many strategies." [PFG6]

But PFG1 and PFG3 said that the strategies/recommendations quantity is necessary for uncertainty management. They are pointed out by the evidence:

"I like the overflow, like the general recommendations fact." [PFG1]

"I do not think overflowing is a problem, you have gathered the necessary information from the literature that gives you support to uncertainty management. Giving the manager a chance to better understand how to reduce the uncertainties in their projects." [PFG3]

PFG5 pointed out that it would be interesting to map uncertainty management activities in the project life cycle and PFG4 agreed:

"Try to map it with a project's life cycle, for example, the characterization phase should be at a project's early stage. What time does each step should be more appropriate?" [PFG5]

"I think the life cycle is important." [PFG4]

So, an activities/strategies mapping in the approach for the project's lifecycle is going to be presented.

With regard to uncertainty management knowledge, the following evidences have been identified as essential for the project manager:

"I managed to see that there are new strategies and I was very pleased." [PFG5]

"I was happy to know things I did not know about" [PFG5]

"I will begin adopting uncertainty management in my project." [PFG2]

Regarding the focus group conduction, there were some compliments from the participants:

"I found it very good gf because you put the participants' point of view and I think we should check our point with yours later." [PFG2]

"The focus group was well led, well managed and objective. [PFG2]

"The focus group organization was well conducted and you managed to give an interesting emphasis for your approach. [PFG1]

"I found it very good to participate in the focus group, you managed it very well, it was well managed and I could learn a bit more" [PFG3]

The forms were analyzed, as well as the suggestions, and they were adjusted in the approach version presented in the next chapter. In general, the focus group served to give another point of view of professionals working with project management and made a positive assessment of the approach.

6.3 Closing Remarks

This Chapter showed how it was conducted, analyzed a series of semi-structured interviews conducted with 25 participants among them software project managers and researchers in project management. Yet, evidence for each stage of the uncertainty management was presented. Furthermore, a focus group with experts was conducted for the latest version of the proposed approach evaluation, to be presented in the next chapter.

7

An Approach to Manage Uncertainty in Software Projects

"A great piece of art is composed not just of what is in the final piece, but equally important, what is not."
Jim Collins

In an effort to keep their projects neat, many project managers are implicitly using similar ideas, although not always as formally as offered by the subject. This chapter is expected to help organizations and project managers to explicitly formalize an approach focused on managing uncertainty specifically related to software projects.

7.1 Introduction

Once it is impossible to predict the problem nature in advance, project managers can employ strategies that impregnate their projects with greater resistance. Throughout a project, a series of practices can be established in order to keep uncertainties managed.

This study was conducted through evidence-based software engineering, as explained in Chapter 3. In Chapters 4, 5 and 6 evidences were collected and analyzed which are the inputs for the presented approach defined in this chapter. Table 7.1 presents the approach stage mapping and the evidence body that were presented in tables 4.4, 5.2, 6.3. In Appendix C the approach is presented in a structured way.

Tabela 7.1: Body of Knowledge

Stage	Set of evidence
Characterizing Projects	
Identifying the project type to adopt appropriate management	RSLP1,RAP1,IP1
Analyzing stakeholders	IP8.5

Defining Success Criteria	RSLP3,IP6,IP6.1, IP6.2,IP6.3, IP6.4, IP6.5 IP8.8
Identifying Uncertainty Sources	
Consulting past projects	RSLP13, RAP2
Cause and Effect Diagram	RSLP13,IP8.3
Building scenarios	RSLP13, RAP13
Building the Knowledge Map of uncertainties sources	RSLP12, RSLP13, IP2
Detecting Early Signs	
Evaluating whether mindfulness attributes are being used	RAP6, IP3, IP3.1, IP3.2, IP3.3, IP3.4, IP3.5, IP4
Checking the early signs table	RSLP4, RAP5
Sensemaking	
Interpret the Signal	RSLP5, IP5.1
Objectively Translate the Sign	RSLP5, IP5.2
Reveal Assumptions and Beliefs	RSLP5, IP5.3
Building a Shared Meaning	RSLP5, IP5.4
Managing the Risks	RSLP5, RAP14
Responding to unexpected results	
Finding what strategy to adopt to confront the event	RSLP7
Learning when unexpected results happen	RSLP14, IP7.1
Ability to respond to changes	RSLP6, IP7.5
Proactive strategies to reduce uncertainty	
Short Iterations	RAP11, IP8.6
Continuous Integration	RAP10, IP8.7
Prototyping	RAP4
Stakeholder Involvement	IP8.2
Brainstorming	RAP3, IP8.4
General Orientations for the Managers	
Managers should facilitate self-organization and the team adaptability	RSLP17, IP7.4
Building trust between team, management and customer	RSLP10, IP7.3
Management flexibility	RSLP6, IP7.5
Managing the expectations of stakeholders so that they flexibly accept changes	RSLP2, RAP7, IP7.7
Managers should facilitate communication within the organization	RSLP16

Collaborative Work	RSLP18, RAP12, IP7.6
Multidisciplinary	IP7.8
Criativity	RSLP8, RSLP15, RAP8,IP8.1
Group Cohesion	RAP9, IP7.2
The creation of flexible contracts	RSLP9

The responses for the four research questions presented and summarized in Section 4.3 were the base for the approach development. Note that the research question 4.3.1 presents ways that managers are adopting to manage uncertainties. The approach was based on the 5 ways to establish a step-by-step management. They are mapped as follows: the *Adapting management approach to the type of projects* is presented in Section 7.1.1. In Section 7.1.2 the phase *understand the sources of uncertainty to better manage each type of project* is presented; Sections 7.1.3, 7.1.4, 7.1.5 are presented in a way to *identify uncertainties in order to turn them into risk* and to *dealing with uncertainty when they happen*, we present the unexpected results phase in Section 7.1.7. Note that the adoption of techniques, practices and strategies are mapped through the research question 4.3.2. The action research and the interviews with experts, which has a number of *adopting techniques and strategies to facilitate the uncertainty reduction* are going to be presented throughout the phases and in the elaborated guidelines. The Figure 7.1 shows an approach to manage uncertainties. Each phase of uncertainty management is going to be mentioned below.

7.1.1 Characterizing Projects

In order to minimize the probabilities of failure in a project it is important to distinguish it correctly, identifying whether or not an uncertainty exists in relation to aims and solutions, and adopting a model of management which is suitable for the kind of project. A stakeholder analysis should be added in order to better conduct the project objectives and the definition of success criteria. The Figure 7.2 shows the activities.

7.1.1.1 Identifying the project type to adopt appropriate management

The characteristics of projects can be depicted according to Figure 7.3. The first dimension regards to the objective of the project which could find itself with a level of certainty or uncertainty. While, the second dimension refers to the solution, that is, whether there is certainty about the solution which should be detailed. In case the dimensions are crossed, such as depicted in the Figure 7.3, it might be defined a classification of which model can be applied to manage the project. It is important to highlight that barrier between what is clear or not is purely conceptual, meaning that it can not be defined quantitatively. As a consequence, is an intuitive categorization to establish a better model for the project management.

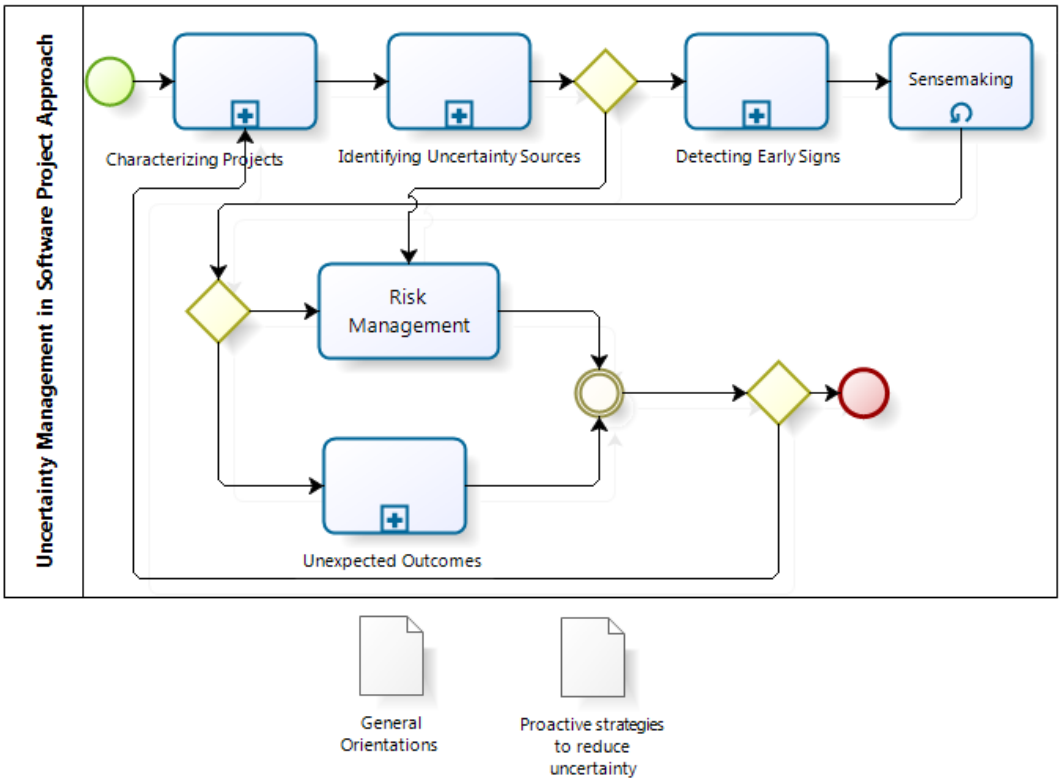


Figure 7.1: Uncertainty Management in Software Project.
Source: the author

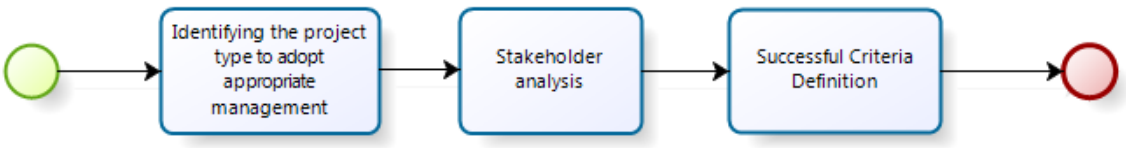


Figure 7.2: Characterizing Projects.
Source: the author

The projects can be classified as:

- **TPM:** Tradicional Project Management;
- **APM:** Agile Project Management;
- **XPM:** Extreme Project Management;
- **EPM:** Exploratory Project Management;

The projects placed in the **first quadrant** of Figure 7.3 can be executed by TPM or APM, being projects whose goals and solutions are clearly defined. In contrast, there are simple projects which were repeated several times in the past. There are well developed models or parts of them which are meaningful. They are projects which the organization is familiarized

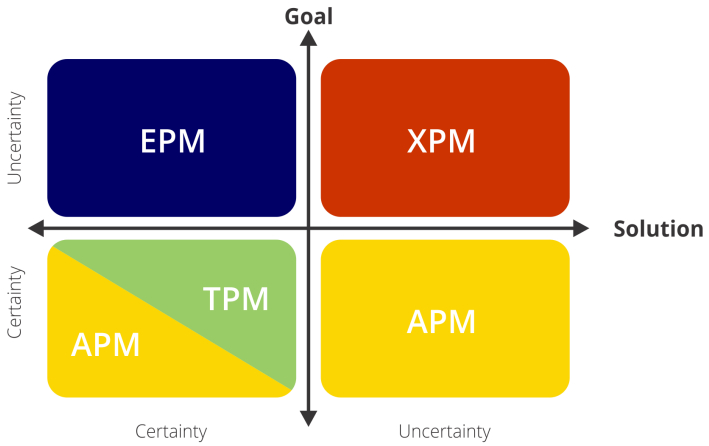


Figure 7.3: Characterization of Software Projects.
Source: the author

and the requisites are well known. With the requirements defined, the solution is going to be clearly defined and the work breakdown structure (WBS) may be elaborated. TPM models such as PMBOK (PMI, 2013) and PRINCE2 (OGC, 2009) work very well for these projects.

Placed in the **second quadrant** there are projects with clear objectives and part of the unknown solution - at once there is related risk. For these projects there is the indicated utilization of APM, since the requisites are not defined in a clear way adequately to elaborate the complete planning of a Project, as happens with TPM.

It is necessary to incorporate learning strategies for these projects' development. Practices such as XP (BECK; ANDRES, 2004), Scrum (SCHWABER, 2009), Kanban (ANDERSON, 2010) and Lean (POPPENDIECK, 2007) have contributed to reducing uncertainty. These practices address the work incrementally and with short planning for each cycle. This approach may help in understanding and building of new technologies.

In the **third quadrant** we have XPM projects. For this class of project there is high level of uncertainty in relation to the objectives and the solution. These are together apprehended and defined as part of the implementation of projects. They are generally R&D projects which run the risk of not be finished. For these projects, the cycle of development can count on investigations and the prototypes building, all converging towards an objective which supports a solution.

The projects in this quadrant are more speculative and uncertain. At first, a XPM project goal is vaguely defined, and has an early solution declaration. They are R&D complex projects that require a creative approach and an adaptive to changes team.

The projects located in this quadrant have the nature of being an "exploratory project" aiming to identify the target and the solution which are uncertain. In these projects, the team members and customers' collaboration should be intensified in order to contribute to the development and creation of ideas for projects. The following activities to develop these project types are recommended:

1. **Define how the project is going to be run:** It is of utmost importance in the project's early development stage to direct the team well for a first activities cycle. It is recommended using a customer's declaration as a guide. In subsequent cycles, the team and customer are going to benefit from the learning; thus, being able to better define the following cycles.

2. **Create Scenarios/Stories/Use Cases:** Used to describe how a person can use an application, these descriptions can be prioritized and assigned in the software development cycles. The advantage of using scenarios, stories and use cases is that the team has a vision of what is being built on the user's view and not the technology's.

3. **Prioritize Requirements:** The scenarios collection, stories and use cases provide insight about the requirements. For the client, it is better prioritize a written collection of what was requested; it allows them a generated sight to give priority their requirements. If it is the case, prototypes can be considered as part or the total of the first cycle's elements. The strategy is to create prototypes to obtain sufficient information to enable a better targeting of the following steps, making the prioritization of the items to be developed better defined. A prototype is going to show various ways in which a client can interact with the software. After using it, they are going to delete or add requirements to the list.

4. **Identify deliveries of the first development cycle:** Once the prioritization is done, it is time to decide which is the project's initial cycle. It is recommended to keep short cycles; about 1 to 2 weeks, in order to obtain short results that can be evaluated by the client.

5. **Check the continuation or not of the project:** Because the initial cycle can be exploratory, the sponsor must have the opportunity to assess the initial cycle plan's solidity and decide if it makes sense to continue. It is possible that the first cycle's outcome shows that the client's original idea may not be developed, and thus, lead them to a judgment that their original idea does not make sense. Thus, they can evaluate if they make the decision to continue adjusting the following steps or stops the product development. The decision to continue or not the project should take place at the end of each cycle. Decisions to stop a project are more likely to occur in the early cycles than in the subsequent ones.

6. **Plan the next cycles:** Each cycle completion is going to produce a clearer picture and to lead to a better goal definition. This clearer vision can be translated into a project redirection, and in turn; to a new prioritized deliveries list. The recently prioritized deliverable list may contain previous cycles results that were not concluded and new deliveries for the project. In either case, the prioritized deliverables list should be reviewed and updated for the following project stages.

7. **Assign activities:** The attribution should be done as a team exercise. This team involvement is important because of the XPM cycles' exploratory nature. Team members need to express their interest in one or more activities and also share ideas with their teammates. The attribution process is also an opportunity for team members to recruit others who share their interests and would like to develop a part of the delivery with them. The project manager should not pass up the opportunity to create synergy between team members with similar interests, and among other teams who will be working in parallel on different products. Any opportunity to create a collaborative work environment only increases the successful team's chances.

8. **Establish a cycle plan:** The plan establishment for each cycle is important to guide the team into the activities and goals establishment of each cycle, however, the team has to be ready to change at any time.

9. **Generate a list of lessons learned:** Client and team expect significant results at the end of each cycle that can redirect efforts, it requires efforts and shows that the team is on the right track. As the project moves into later cycles, the changes should decrease as the project team must have converged to a more clear and defined goal and an acceptable solution to achieve it. The following questions must be asked: What have we learned? What can we do to improve the goals achievement? What new ideas which have emerged should be followed? What should we do in the next cycle?

10. **Review the project objectives:** In each project cycle it is important to make some questions: What new information do we have? What can we eliminate? What are the findings that suggest changes in direction and goals setting? Are we converging on a more clearly defined goal? They should be asked to try to define the project's goal.

11. **Reorient the priorities the Requirements:** Client and project team should revisit deliverables and requirements. The following questions should be asked here: How does the new objective statement impact the delivery list? Are there any items to be removed? Is there any item to be added? How does the new functionality statement impact the goal?

In the **fourth quadrant**, even though it appears to make no sense at first sight, there are important projects which consist of solutions looking for an objective. As an example we can point the project of the WalMart with RFID technology. "Can you find an application (objective of the project) of RFID technology (the solution) which has business value?"(WYSOCKI, 2010). They are broadly applied in innovation projects where we can characterize them as projects looking for an application (goal) of a technology (the solution) which possesses a business value.

The projects of this quadrant are characterized by having a clear solution definition, but a great project objective uncertainty. The idea of this type of project is to explore alternatives for an application. Prototyping and research activities in order to better define the project goal are indicated to reduce uncertainty of project objectives.

The projects that are in this quadrant seek a goal for its solution, the search for information is essential. To overcome the lack of goal, learning techniques throughout the process should be adopted. This learning can be done by the improvisation method; when life experiences direct the actions to be taken, with planning and execution occurring simultaneously; or by experimentation; as in trial and error, which, based on a plan for a short period, it includes a periodic situation assessment, making it possible to modify the plan or even to redo a part of what has been done (LOCH; DEMEYER; PICH, 2011).

7.1.1.2 Analyzing Stakeholders

The project manager must identify all stakeholders; what their interests are and establish an importance sequence in the project. To perform the analysis, the manager can follow the following steps:

Identifying allies and opponents, that is; who are the stakeholders that somehow influence positively or negatively the project. This identification can be performed with the help of project team members.

Then, the team members may use the graph shown in Figure 7.4 divided into four quadrants to identify the stakeholder type.

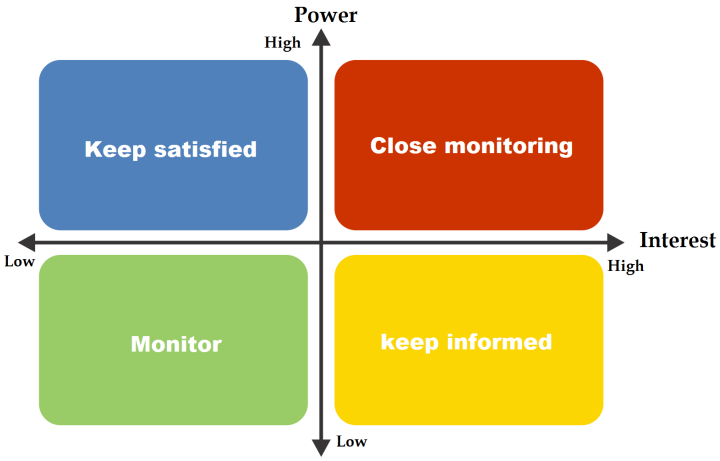


Figure 7.4: Power X Interest.
Source: Adapted from an unknown author

Each axis of the quadrants are described below:

- **High Power x High Interest:** This is the most critical stakeholders group. This group deserves a close monitoring, immediate and accurate information.

- **High Power x Low Interest:** These stakeholders deserve close attention, because despite not having much interest in the project, they have a high level of authority. They must be keep satisfied.
- **Low Power x High Interest:** The project manager should keep these stakeholders informed because of their high level of interest in the project, but they do not require as much attention as the stakeholders of high interest and high power do.
- **Low Interest x Low Power:** In this quadrant we find the project's stakeholders with low power and low interest. This group has low relevance and does not require much attention; so, just have them monitored.

Stakeholders who are on 1st and 2nd quarters need to be monitored; differently from the 3rd and 4th quarters who need an action plan. The manager can select the stakeholders in this quadrant and outline some actions, these actions may follow the following questions:

- **Who?** Who is the stakeholder;
- **What?** What actions can be performed;
- **Why?** Why the stock is going to inhibit the opponent and strengthen the ally;
- **What Impact?** Is there any impact of the action in the project;
- **Who is Responsible?** Who is going to be responsible for performing the action.

Thus, through these steps and their continuous realization, the manager should adjust the project to meet the stakeholders' needs.

7.1.1.3 Defining Success Criteria

The project's success can be measured in different perspectives, for it is interesting the manager and team establish with the client what measures are going to be used to track a project's success. In this research, five measures were established to guide the project manager; they are:

- **Satisfaction and Impact on Customer:** It is necessary to clearly state how the project results will be satisfactory to the client and what is impact going to on the client's business.
- **Motivation and Impact on the Team:** The team's motivation is a key factor that may contribute to a project with many uncertainties. It should be observed how the team is at the moment related to: motivation, loyalty and enthusiasm. Furthermore, to verify what are an organization's indirect investments in its members, thereby measuring the team's learning and growth extent.

- **Efficiency and Effectiveness:** represent compliance with resource constraints; they indicate whether a project is well managed and if it manages to meet the goals.
- **Commercial Success:** reflects on the direct and commercial impact that the project has on the organization.
- **Preparing for the future:** reflects on how well the project helps the organization creating new opportunities.

The five measures are not mandatory, the manager should see which dimensions are more suited to the context of their project. For example, perhaps a project is very innovative and uncertain and that, for the client, is not necessary to have efficiency restrictions; or a project is not meant to be sold but is going to be for the company's internal use, so there is no need to measure its commercial success. In addition, the manager needs to be creative and develop qualitative success measures, depending on the project's type, the manager together with the client may establish some qualitative measures and monitor it during the project development.

7.1.2 Identifying Uncertainty Sources

Uncertainty management starts with the understanding of the uncertainty sources. We may not always be aware of a specific uncertainty, but we can be alert to factors that may influence the success or failure of the project, it is important to understand the uncertainties sources. Figure 7.5 illustrates the four areas of uncertainty, which can be seen as a starting point for project managers to observe and identify uncertainties and thereby assist in the project's success. By accurately dimensionalizing the categories and characteristics of uncertainty, large established corporations can better prepare project managers and senior leaders to anticipate and be sensitive to possible courses of evolution that projects may face. The manager needs to verify which uncertainties remain within the project by analyzing the four sources:

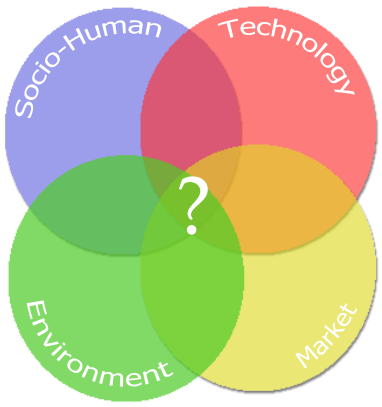


Figure 7.5: Source of Uncertainty in Projects.
Source: the author

- **Technological Uncertainty:** It depends on the extent to which the project uses new technology or mature technology.
- **Market Uncertainty:** Indicates how new the product is to the market, to consumers and to potential users. It represents the extent to which buyers and users are familiar with this type of product.
- **Environment Uncertainty:** It may arise from the actions of different organizations (suppliers, competitors, consumers, government, shareholders, etc.) which may affect the project. Doubts about the probability or nature of changes in the environment (socio-cultural trends, demographic changes).
- **Socio-human Uncertainty:** Considers the relationships between people within an organization. It is necessary to consider religious issues, politics, different values, personal experiences and cultural training.

The manager needs to ask themselves what is unknown or unclear in the project, among these four sources and thus, adopt strategies to know the project more. The following subsections present these strategies that help to clarify uncertainties. They are: consulting past projects, cause and effect diagram, building scenarios and building the knowledge map of uncertainties sources. The Figure 7.6 shows the activities.

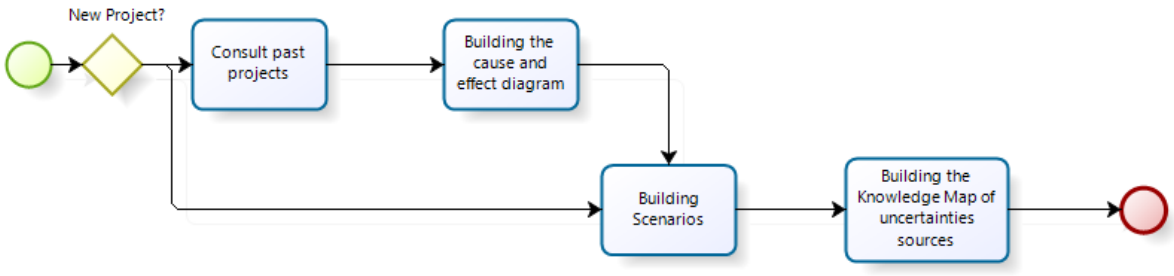


Figure 7.6: Identifying Uncertainty Sources.
Source: the author

7.1.2.1 Consulting past projects

During project management a knowledge base is formed by contributions, intuition, previous experience, from expert analyzes on project issues, successes and failures, previous activities performed, corrective and preventive measures taken.

In many projects, this knowledge is called lessons learned. The record of the lessons learned during the project management can be an important strategic issue for companies in the market competitiveness since mistakes made in previous projects can be avoided and successes repeated; contributing to the delivery quality of the product or service, according to the schedule

and costs established for the project. The record of the lessons learned properly structured, assimilated, evaluated and disseminated in the company should be part of the assets of the company organizations or even of their intellectual capital.

The registration and structuring of lessons learned can be made in several ways: database and specialized software, Excel spreadsheets, mind maps, photos and videos. The important thing is that the information is simple, clear, relevant, contextualized, traceable and easily located.

If the lessons learned from past projects are properly stored along with the other project documents, you can conduct a consultation in order to reduce the current project's uncertainties. Some steps are recommended for consultation of past projects:

1. Study the documents in the project repository;
2. Collected data from many sources;
3. Analyze the data trying to find similarities with the current project;
4. Make sure that a survey is well conducted in order to equip the team with knowledge to face the project's uncertainties.

7.1.2.2 Cause and Effect Diagram

The cause and effect diagram also called fishbone diagram provides a means to capture information. The model created by Ishikawa is a great tool for problem analysis. Its objective is to reach the root of the problem by detailing its causes. At the end of a diagram preparation, important information about the main causal factors for a given effect becomes visible.

The idea of using the cause and effect diagram at this stage is to look back searching for answers to a specific event, that is, before you start developing a solution, their potential problems are already known; it is going to be easier to define the solution, so these problems are avoided. Making use of cause and effect diagram, the team may get answers and make known several unnoticed factors.

Figure 7.7 illustrates a diagram model of cause and effect used for the project construction analysis. Each of the main pimples represents a cause. They can be detailed in sub-causes and these into other sub-causes until they are concluded by the root cause.

For the diagram construction, the following steps are recommended:

1. Define the problem: One must determine objectively what the problem is;
2. Structure diagram: All possible information should be gathered about the problem in question;
3. Group information: After putting together a team that can help create the diagram, it must present information through a brainstorming section;

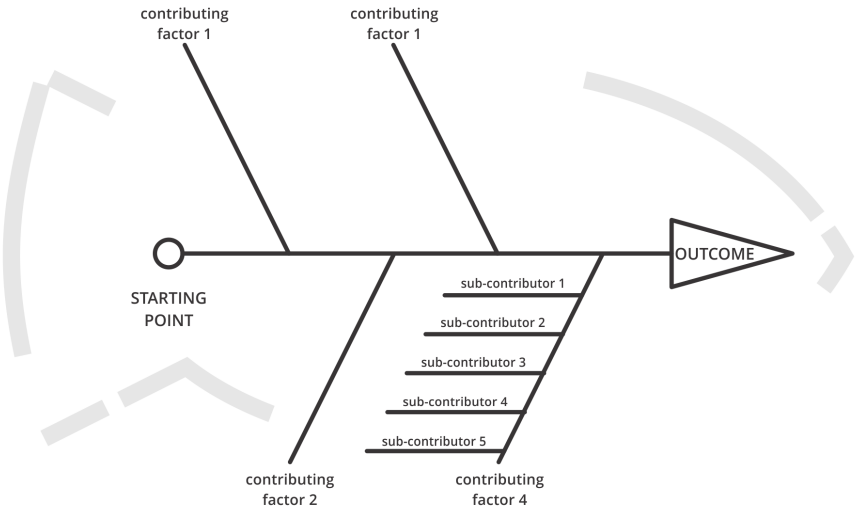


Figure 7.7: Cause and Effect Diagram
Source: Adapted from KENETT (2007)

4. Rate the causes: You must sort the information, pointing the main causes and conducting an analysis, defining which ones impact the problem more and what the possible solutions would be;

5. Conclude the diagram: Draw the diagram in a way to present the analysis made.

At the end of the process, the diagram provides information on the major causal factors for a particular outcome, and often in a considerable level of details. Many times, factors and relations previously ignored are revealed through the diagram construction process. It is often revealed a lack of knowledge of the causal factors, showing that there are uncertainty sources that need to be observed during the project development.

7.1.2.3 Building Scenarios

For new projects, a scenario construction may simplify the future results' analysis. When constructing a scenario, the team moves directly to the desired scenario and then, it must take a few steps back in order to discover how to get to the planned scenario, as shown in Figure 7.8.

Developing a scenario requires a future foreseeing to visualize a particular project state; either a milestone, or key point, most likely at the project completion. At this stage, it is not necessary to worry about the events sequence that leads there, the important thing is to design the set of scenarios. The scenario development may follow the following steps:

1. Perform a group session with team and stakeholders;

2. Perform the questions presented in Table 7.2 for the team;

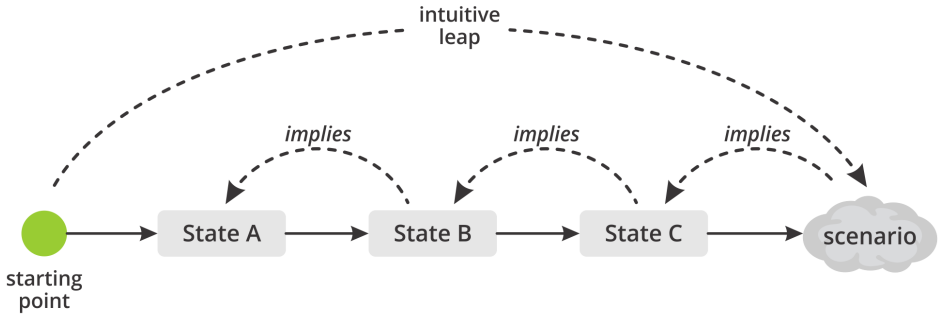


Figure 7.8: Scenario Example
Source: the author

Tabela 7.2: Questions to Guide the Construction of Scenarios

Negative Scenarios	Positive Scenarios
What are the three main bad scenarios for the project's completion?	How can the project finish successfully and exceed expectations?
What is the worst possible outcome?	What is the best possible outcome?
How the project could go wrong slowly, rather than catastrophically? What would the early symptoms be?	How can the project succeed even if some of the goals are not met?
Consider each stakeholder group. What is the failure of the project for each perspective?	Consider each stakeholder group. What is the success of the project for each perspective?
How can the project meet (or partially meet) its goals and still be considered a failure?	What aspects are going to determine the success of the project?

3. Apply the brainstorming technique;

4. Evaluate the scenarios, prioritize and rank.

After having gone through a variety of scenarios development, it is time to put them to work. Each scenario describes a project's future state. So then it is necessary to think back a bit, in order to understand how a particular state might happen.

Analyzing the scenario can reveal much about a project's uncertainty sources. It points to what needs to be known instead of what is not known. The team must pay attention to the specific observations and any patterns that may emerge, they can just keep the clues to uncertainties.

To build a scenario, good and bad ones should be taken into account. Focusing on good scenarios helps the team to understand what the conditions for success are. On the other hand, bad scenarios are going to help one understand what needs to be avoided and what factors contribute to those negative results. Achieving a balance is important, as focusing much on the positive can lead to problems which are being concealed and the concentrating on the negative,

can lead to a lot of effort to eliminate uncertainties, so the project fails to go forward.

7.1.2.4 Building the Knowledge Map of uncertainties sources

Knowledge maps are a practical way to deal with uncertainty in projects. The process of building a knowledge map helps clarify what is known about the project. In doing so, it is often possible to find out what the main knowledge areas where the boundary between what is known and what is unknown is. Building a knowledge map says nothing about uncertainties, but suggests there might be uncertainty. It is a way to identify potential trouble spots in the project. Knowledge map gaps highlight where one needs to investigate the previously unknown problems nature.

The knowledge level assessment in a given uncertainty source is performed through a number of questions:

- Is there prior experience (both directly and indirectly relevant)?
- How well understood are connections, relationships and dependencies between uncertainty sources?
- Is your knowledge of this domain changing rapidly?
- How confident are you that the risks are understood and documented?

With this question set, the manager should look to emerging standards. Is there lack of knowledge? Does it mean a particular weakness in the planning approach or project methodology? What is behind any significant knowledge gap?

Figure 7.9 is an example of a knowledge map about a project's uncertainties in which the regions with low scores indicate areas of high uncertainties that need more attention. The manager can use the following scale based on the existing knowledge about the project:

- 8-10: Prior knowledge is strong;
- 6-8: Good experience, although there are uncertainties;
- 4-6: Some key factors are known;
- 2-4: Information is available but not yet exploited. It is very little known;
- 0-2: No knowledge.

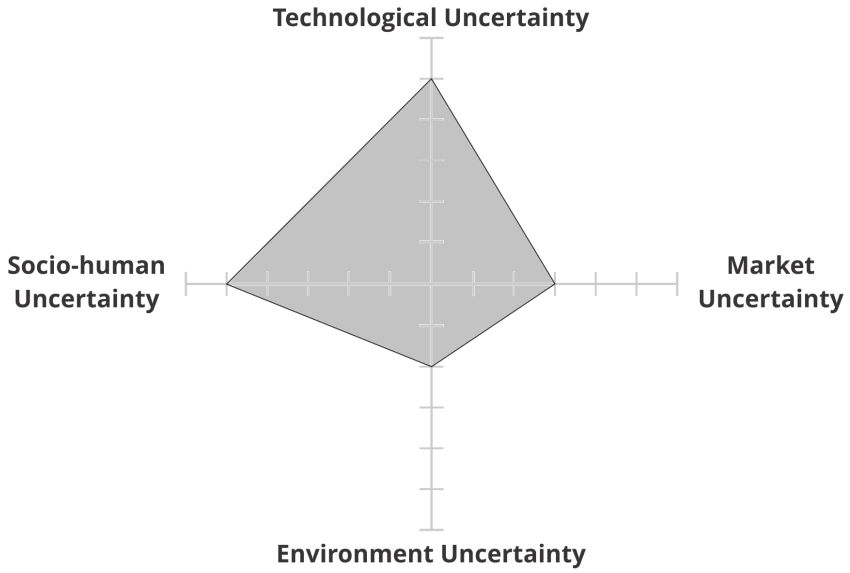


Figure 7.9: Example of a Knowledge Map of Uncertainties in the Project
Source: the author

7.1.3 Detecting Early Signs

Early signs can be verbally manifested, as contradictions in speech; non-verbally, such as messages tone and people's mood; in writing, as indicators report, and events such as late delivery by a supplier. Through early signs we could treat the first symptoms in an attempt to verify management corrective actions. For early signs anticipated recognition it is necessary to establish a mindfulness culture, as well as check the early signs table. The Figure 7.10 shows the activities.

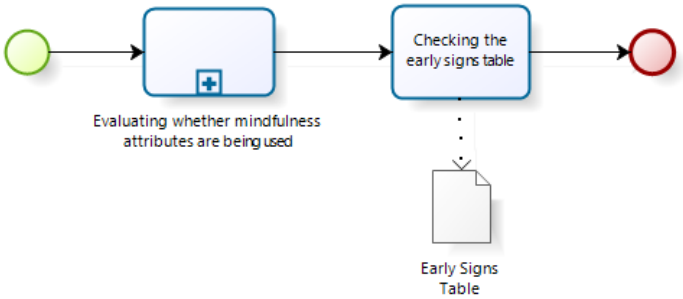


Figure 7.10: Detecting Early Signs.
Source: the author

7.1.3.1 Evaluating whether mindfulness attributes are being used

For being able to detect early warning signs in their projects, the manager needs to use the mindfulness concept. In this research, through the evidences found, it is presented a way the

team members may reflect on mindfulness in the project context. In addition, some guidelines are suggested. The Figure 7.11 shows the activities.

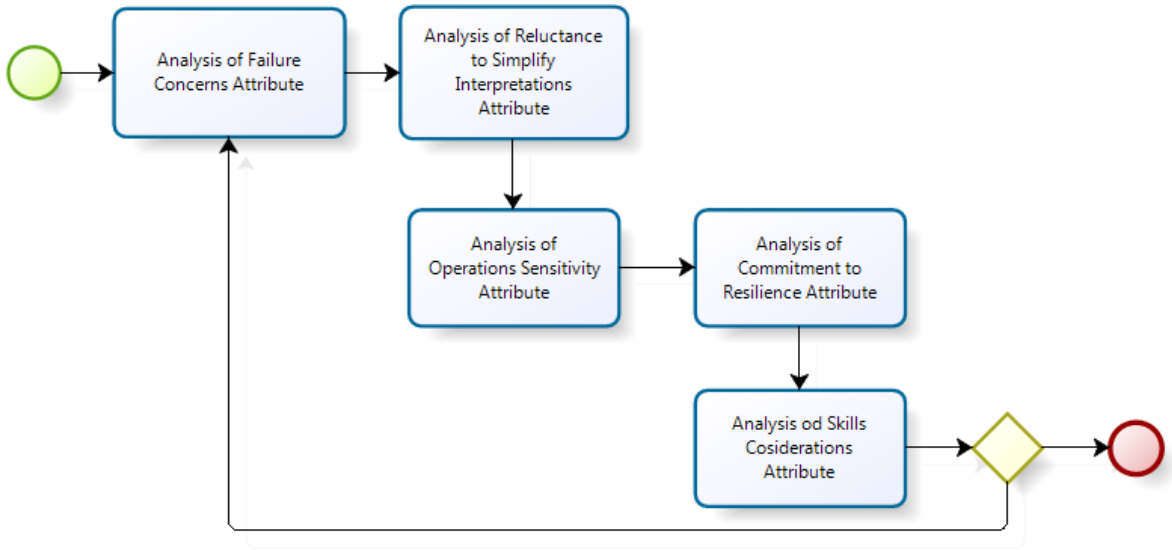


Figure 7.11: Evaluating Whether Mindfulness Attributes are Being Used.
Source: the author

The mindfulness concept can be established through five attributes based on evidences, that are presented below:

Failure Concerns: In order to find the signs it is necessary to watch out for them questioning whether there are different explanations with seemingly obvious results. The best way to accomplish that is to make the project team aware of the failure possibility;

To verify if the **failure concerns** is well applied in the project. The manager and the team should reflect on the following questions:

1. Does the team always look at the flaws and try to understand them?
2. When something unexpected happens, does the team always try to find out why the expectations were not met?
3. Does the team consider the early signs as information and try to learn from them?
4. Does the team consider the early signs like points that reveal potential dangers and not successes that demonstrate the ability to avoid disaster?
5. If a team member makes a mistake, is not this error used against them?
6. Do the team members report significant errors even if others do not realize that mistakes are made?
7. Do managers actively look for early signs?

8. Do team members feel free to talk to superiors about problems?

9. Are team members rewarded if they detect early signs or potential problematic issues?

The more positive feedback the project team is concerned about, the more healthily they deal with failure. The manager must use these questions to start thinking about ways to improve the project attribute application. Some actions are recommended:

- The manager should fostering the team reflective ability;
- The manager should fostering appreciative approach to deal with mistakes;
- The manager should sensitize the team members about the errors possibility so that they feel responsible and attentive to the signs;
- The manager must create a learning culture for everyone to share mistakes and experiences;
- The manager should fostering self-organizations, team cohesion, team spirit while introduce a critical approach to handle with failures;
- The team should review the projects goals and pay attention to the mistakes that should not occur.

Reluctance to simplify interpretations: The project manager struggles to understand what is happening within the project and there is a natural tendency to look for evidence to support preconceived ideas and reject what does not fit. However, all evidence must be considered;

To verify if the **reluctance to simplify interpretations** attribute is well applied in the project. The manager and the team should reflect on the following questions:

1. Do team members strive to challenge the status quo?

2. Do team members feel free to bring problems and difficult issues?

3. Do team members usually deepen their analysis to better understand the uncertainties in projects?

4. Are team members encouraged to express different world views?

5. Do team members listen carefully, and rarely someone's vision is not heard?

6. Are not team members punished when they report information that could disrupt operations?

7. When something unexpected happens, do team members spend more time analyzing than defending their vision?

8. Are skeptics highly valued?

9. Do team members trust each other?

10. Do team members show respect for each other?

The more positive responses, the more the project uses the **reluctance to simplify interpretations** attribute. The manager must use these questions to start thinking about ways to improve the project context. Some actions are recommended:

- The team must raise doubts to gather information: Try to look beyond the limits of their expectations;
- The manager should encourage mutual respect to differences so that everyone can voice their opinions;
- The manager should make the team think under other perspectives.

Operations Sensitivity: The early signs tend to be subtle. Their trifles sometimes make them easy to ignore. As a result, many problems may remain undetected. The entire team must be ready, alert to detect, monitor, analyze and determine if there really is an uncertainty associated with the identified sign;

To verify if the **Operations Sensitivity** attribute is well applied in the project. The manager and the team should reflect on the following questions:

1. In day-to-day, is the manager always paying attention to what's going on?

2. When problems happen, is someone with authority to act always accessible to team members?

3. Do team members have the power to solve unexpected problems that might arise?

4. During a normal day, do team members interact frequently enough to build a clear picture of the project's current situation?

5. Are team Members always looking for feedback on things that are not going well?

6. Are team members familiar with the operations beyond their own functions?

7. Do managers constantly monitor workloads and reduce them when they become excessive?

The greater the number of negative responses is, the less is the sensitivity to the operations. The manager must use these questions to start thinking about ways to improve the sensitivity for operations. Some actions are recommended:

- The manager should constantly stick to the information passed by the team, whether verbal or not;
- Team members should speak. Just because one member noticed something, one should not assume that the others noticed too, it is important to communicate;
- Team members must develop the ability to be skeptical: When you are skeptical it is likely to better assess the activities carried out and the comments raised can support or disprove a certain activity;
- The manager should provide feedback and encourage people to listen;
- The manager should spend time with team members following the daily work.

Commitment to resilience: It is recognizing that any project aspect may be subject to uncertainty. There are no off limits aspects. All that matters is that the team is ready and willing to face any uncertainty symptoms as soon as they are detected;

Resilience is the ability to withstand and cope with unexpected situations, it is a key feature for project teams involving many uncertainties. Resilient teams tend to find solutions to everyday challenges.

To verify if the **commitment to resilience:** attribute is well applied in the project. The manager and the team should reflect on the following questions:

1. Do most team members have skills to act on the unexpected problems that might arise?
2. Do team members learn from their mistakes?
3. Are there resources to training and continuous recycling of team members?
4. Do team members have more than enough training and experience for playing their role in the project?
5. Are project leaders actively concerned with the team members' skills and knowledge development?
6. Are the team members known for their ability to use their knowledge in an innovative way?
7. Is there a concern with team members' skills building?

8. Do team members have an informal contact network they may sometimes use to solve problems?

9. Do team members trust each other?

The greater the number of positive answers, the better for the project, as it shows a resilient team. If points like these are not applied in the project context, the manager and team need to reflect on how to improve the detected points. Some actions are recommended for the project to take into consideration the attribute **commitment to resilience**; they are:

- Accept that unpleasant situations and uncertainty are part of the project;
- Believe and nurture skills and team skills to deal with difficult situations and develop emotional intelligence;
- Always nurture team confidence, especially regarding to the belief that one is able to achieve goals;
- Learn to keep calm in all situations;
- Always find the positive and even fun side of stressful situations;
- Value the maturity of the team.

Skills Consideration: When a problem arises within the project, experts in a given subject can be the best strategy to solve them, although other members should not simply push the problem to the expert, instead of that the team must try to learn with the expert and the problem resolution. To verify if the attribute is applied in the project. The manager and the team should reflect on the following questions:

1. Is the team committed to do their job?

2. Does the team respect one another's activity nature?

3. If something unusual happens, does the team know who has the knowledge to respond to it?

4. Do the team members value expertise and experience on the hierarchical level?

5. In the project, do the most qualified people to make decisions make them?

6. Do team members usually become a problem owners until it is resolved?

7. In general, is it easy to obtain expert assistance if something comes up that the team does not know how to handle?

The larger the number of positive answers, the better for the project, because it shows that there is concern in applying the attribute. If points like these are not applied in the project context, the manager and team need to reflect on how to improve the detected points.

Some actions are recommended for the project to take the attribute into consideration the **Skills Consideration**; they are:

- Beware of the centralization fallacy: The manager needs specialists to think realistically. It is necessary let each one act autonomously within the project;
- Stimulate the imagination as a tool to manage uncertainty: Facing uncertainties, it is necessary to use the imagination. The use of scenarios (shown in 7.1.2.3) may be an ally in the search for possible solutions;
- Create flexible decision-making structures: Do not assume that the expertise is at the top of the hierarchy. When there are uncertainties or problems occur, try to divert to who can really help.

The manager must put into practice the five attributes in the day-to-day of the project in a way to stimulate the team integration based on the the present moment experience, fully aware with an open, non-judgmental attitude in every activity performed.

7.1.3.2 Checking the early signs table

During the project cycle the manager can make use of the early signs table presented in Table 7.3 in order to guide them. Table 7.3 presents the main early signs groups identified and some scholars'description (NIKANDER; ELORANTA, 2001; SANCHEZ; LEYBRNE, 2006; KAPPELMAN; MCKEEMAN; ZHANG, 2006).

Tabela 7.3: Early Signs

Early Signs Groups	Nikander	Sanchez	Kappelman
Gut feelings	Intuitive feelings, signal harder to detect, identify and interpret		
Personnel, project team	Nonverbal information, people's behavior, lack of contact with the client, unrealistic planning, change of people, lack of resources, professional skills	Commitment level of the people involved in the project, lack of specialized people	Team's lack of commitment with the scope and schedule, lack of skill or project team knowledge, overutilised specialist, undefined roles and responsibilities

Project manager, management	Project Manager Quality and management style		Lack of leadership with the team and communication with clients, poor training, lack of experience
Project Planning	Plans, reference material, contract, budget	Project connection with organizational strategy	No delivery milestones, indefinite success criteria, undocumented planning or estimation, no communication plan, no resources to manage expectations, no methodologies to manage, no documentation, no risk processes, lack of strategic alignment
Project Control	Progress control and monitoring, budget correction	cost and time deviation, meet technological goals	process Lack of progress control, no assessment of progress status, no reconciliation of schedule milestones, early delay is ignored, significant change after kickoff, overutilized team, no monitoring metrics
Working within the project	Early work, mobilization, repeated actions, organization type		
Communication	Message tone, knowledge conflict, insinuation	Communication between departments during the project	Communication break between *stakeholders*

Expression of parts	Lack of CEO support, lack of decision, trust disappearance, late recruitment	senior management support, interface with client, commitment level of the people involved in the project	Team's lack of commitment with the project, project team's lack of skill or knowledge , specialist is overutilized, undefined roles and responsibilities, lack of team experience with the technology
Documents	Quality, level, reports delivery time, changes in technical plans, incorrect revisions, lack of clarity in responsibilities	Quality documents	Lack of functions' documentation, performance, requirements and scope, no written commitment of the *stakeholders*, lack of *Business Case*
Differences and deficiencies in the project culture	First impression, terminology in projects, lack of experience, specific culture of a nation		Cultural conflict between the organizations involved
External sources	External Sources	Government regulations	

Once attentive to what the sources of uncertainties are, that there are knowledge gaps in the project, the manager should evaluate the related early signs. Table 7.4 presents the relations between the uncertainty sources and the early signs groups.

Tabela 7.4: Uncertainty Sources and Signs Early

Uncertainty Sources	Early Signs Groups
Socio-Human	Gut feelings
Socio-Human	Personnel, Project team
Socio-Human/ Environment	Project Manager, Management
Environment/ Market	Project Planning
Environment/ Marketing	Project Control

Environment/ Socio-Human	Working within the project
Environment/ Market/ Socio-Human/ Technology	Communication
Market	Expression of the parties
Environment/ Market/ Socio-Human/ Technological	Documents
Environment/ Market/ Socia-Human	differences and deficiencies in the project culture
Environment/ Market/ Socio-Human/ Technological	External Sources

In addition to the signs shown in Table 7.3 other signs can be seen during a project's course. The manager can use the five attributes to watch them.

7.1.4 Sensemaking

Once an early sign is identified it is necessary to create a sense to it. Figure 7.12 shows the activities cycle for sensemaking. The following subsections present these activities.

7.1.4.1 Interpret the Signal

When detecting an early sign, the manager must analyze the whole project context. They must know the project, all its variables and interference, and build a meaning considering the team information. This phase is related to the appropriacy of **construction of identity** of WEICK; SUTCLIFFE (2001), ie the project manager as a *sensemaker* begins interpreting the sign, but taking into account all factors which can be correlated with the project.

7.1.4.2 Objectively Translate the Sign

The manager needs to be clear in presenting the sign to the team involved in order to translate it into actions that make sense for all project members. At that time, they are invited to a **signs extraction** in order to contextualize the sign based on knowledge, experiences, beliefs, rules and other personal factors for each team member. So, the team may use the ***enactment*** to act and create constraint conditions or opportunities.

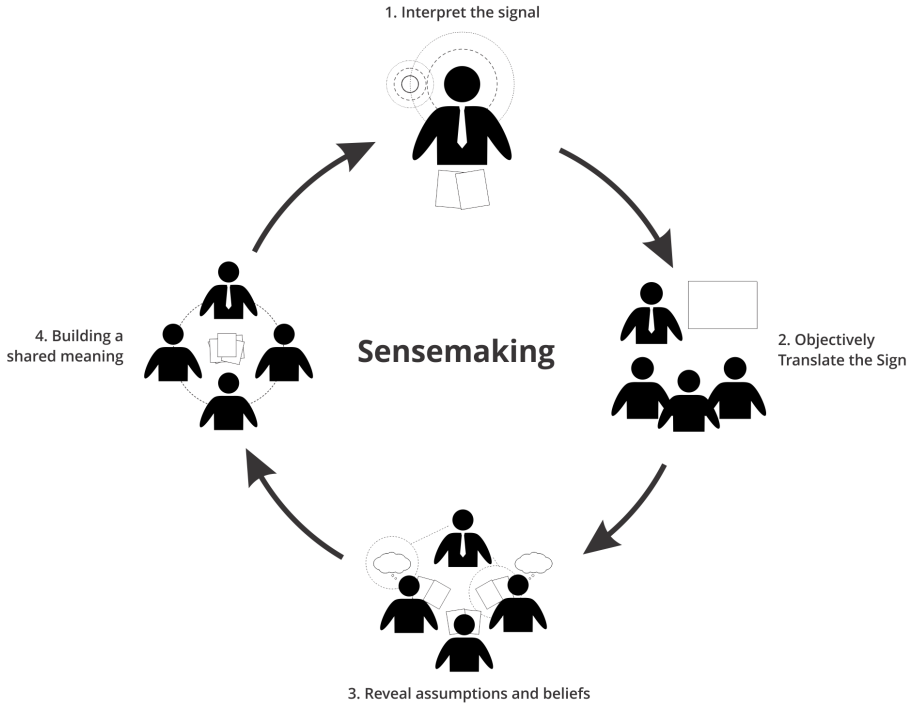


Figure 7.12: Cycle for Sensemaking.
Source: the author

7.1.4.3 Reveal Assumptions and Beliefs

Each team member's previous experience must be taken into account, as well as personal competence; however, the project manager has to stick to some of the team members, while sense creation, they are not able to let go of past experiences, assumptions, beliefs or trauma. The manager may ask each team member to perform a **retrospection** of what was raised and try to reveal assumptions and beliefs in order to be discarded.

7.1.4.4 Building a Shared Meaning

The collective meaning creation aims at information sharing, team members involvement, strengthening the appropriacy **social** of Weick, which is aligned with the ambiguity reduction strategy in the project's context. The expected result is a meaning which needs to be accepted by the team, that is, **plausible** for all members. It is important to remember that all actions taken are carried out continuously and dynamically within a given context and therefore, it may be necessary the cycle execution if changes happen.

7.1.5 Managing the Risks

If the signs are early detected and a sense for them is created, strategies can be used to contain the uncertainties. These strategies can help to learn more about the uncertainty nature, for example, through problem formulation by representing or modeling future scenarios and

preparing for them. Using discovery techniques such as the construction of a knowledge map. Once uncertainty is revealed, analytical techniques such as risk management can be used in project management (PMI, 2013).

7.1.6 Responding to unexpected results

When the unexpected happens, the team's shared vision automatically leads to actions that effectively face uncertainty. The project team's mentality has a much greater influence on the ability the project has to deal with uncertainty than one may think. Based on the evidences showed in Table 7.1 the following strategies are provided to deal with the unexpected. The Figure 7.13 shows the activities.

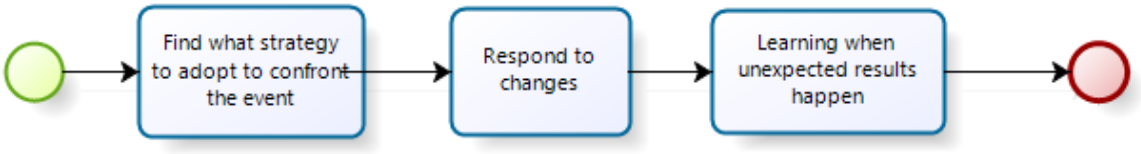


Figure 7.13: Unexpected Outcomes.
Source: the author

7.1.6.1 Find what strategy to adopt to confront the event

Project uncertainties will not cease, especially in a time of rapid change such as this knowledge era, since they are not under anyone's control nor are the probability factors known, so to be forearmed is the best possible solution.

Project managers may try to contain uncertainty at its source, but never have one hundred percent success. Therefore, a project requires strength and should be able to detect and respond quickly to unexpected events. For unexpected results, a project manager must decide how to best face the uncertainty. Figure 7.14 presents four possible ways of facing uncertainty.

- **Suppress**: It consists of strategies to reduce the uncertainty impacts, allowing the project to return gradually to the original plan;
- **Adapt**: A certain uncertainty level is accepted, however, one must be prepared to act quickly and limit the major impacts of any unexpected event;
- **Detour**: If possible, we should deviate from all uncertainty areas; unfortunately, deviate from them is not always possible. Some are unavoidable or too costly; one should be careful not to exchange an uncertainty for another; we can only deviate from what we know;

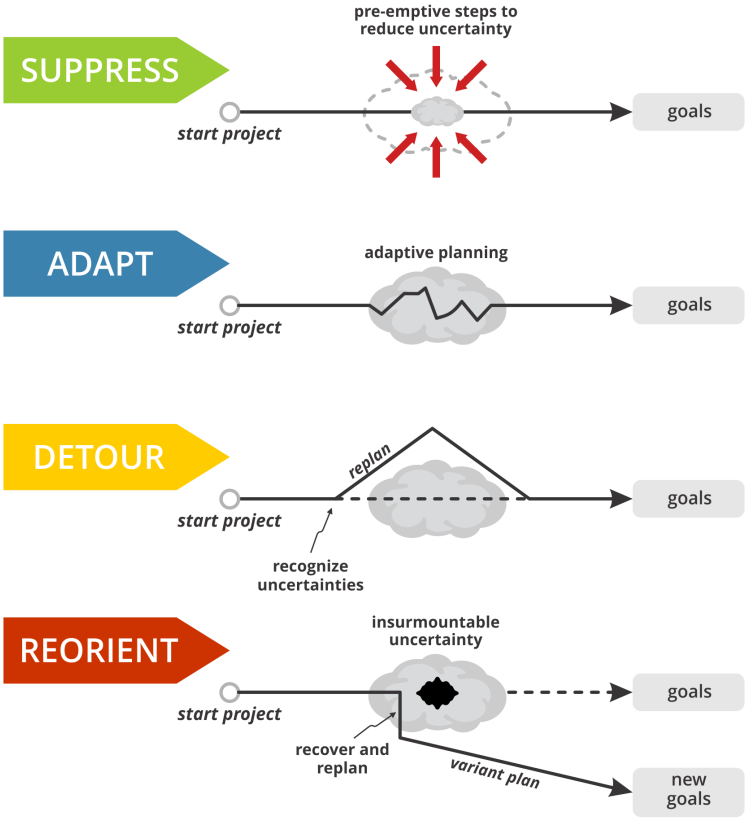


Figure 7.14: Ways to Confront Uncertainties.
Source:Adapted from CLEDEN (2009)

- **Reorient**: A more drastic deviation should be used only as a last resort; We must look for a different set of objectives for the project; used in cases when uncertainty drives the design to total failure.

Suppress:

The uncertainty may be removed or reduced by addressing its causes. When converting vague guesses and poorly understood issues in measurable problems. Project management may consider these assumptions through some activities, including:

- Identify the uncertainty sources;
- Accurately predict future scenarios;
- Analyze potential threats;
- Develop a tactical plan to solve the problems.

Adapt:

A certain uncertainty level is tolerated, usually when there are not enough resources to suppress it, or such actions would become expensive. The threat is contained by closely

monitoring main uncertainties and reacting to them; this means performing some activities, including:

- Always verify the uncertainty sources and early signs;
- Understand the main project's objectives in order to keep focused on the right things;
- Act quickly and decisively if the project plan needs change;
- Check continuously the project direction in relation to its goals.

Detour:

One may wonder if there is an alternative way to the same goals. This may not be the best path planned in the beginning of the project, but it becomes feasible, since large uncertainties are identified. In the case of deviation, one must be careful about avoiding a number of uncertainties and only substituting them for some different ones. This means:

- Clearly understand the project objectives;
- Being creative in identifying planning options;
- Evaluating alternative approaches' risks and benefits;
- Taking the initiative when better opportunities appear.

Reorient:

One may wonder if the level of uncertainty represents a very high much risk. Redefining the objectives may be a case to think about. The project members need to confront the choice between: failing a project or if an option to successfully deliver the project with alternative goals is feasible; to do so, the manager needs:

- Understanding the threat nature;
- Being honest about the success and failure chances;
- Keeping an open mind about redefining goals;
- Being persuasive in seeking the stakeholders' agreement to reorient the project.

7.1.6.2 Ability to respond to changes

Changes are often necessary in a project due to uncertainties. One may need to change the project specification or the contract terms with suppliers or customers. Changes must be monitored relating to the original project objectives.

Changing almost always involves uncertainty and opportunity elements. So when a software team faces a change, the first reaction may be to interpret it as a threat or danger. So, it is

common for team members to resist to changes. One way to deal with this problem is to involve people in all product transformation processes. When they feel part of the planning and transition process, they tend to feel more in control of the situation, resisting less to change. From the moment people accept the fact that a change may offer new opportunities and possibilities, the transformation process can successfully follow its path. Learning valorization and constant innovation are factors that may develop a more favorable culture to changes within a software development environment.

At the beginning of a project, the change managing process to be adopted must be agreed with all stakeholders. A formal, proactive change management that anticipates the change need is preferable to a process that only reacts after the need for change is obvious (IPMA, 2006). Some recommendations are given to managers:

1. Decide on the change management policy;
2. Identify all proposed changes;
3. Consider the consequences for the project;
4. Look for authorization for the changes, if necessary;
5. Obtain accepted or rejected changes;
6. Plan, execute, control and close approved changes;
7. Monitor changes effect against the project baseline;
8. Document lessons learned and apply them to future projects.

7.1.6.3 Learning when unexpected results happen

Some practices may be adopted aiming to the reduction and reaction to an unexpected event. The team needs to be willing to **learn and formulate new ideas in order to generate knowledge**. **Learning** can constantly help in reducing uncertainty and, in the case of unexpected events, the following five steps can be taken in order to draw lessons from the events:

1. **To be receptive to learning:** Teams and organizations can only learn lessons if they are receptive. Paradoxically, one of the dangers of success is the reluctance to admit the failure possibility. A manager should motivate the team including the belief in their abilities, but being realistic to situations. Success today is never a guarantee of success tomorrow;
2. **Objective observation:** The observation has to be objective. It is understood that an absolute observation is impossible because the manager and the team receive a lot of information from different sources, so it is important to objectively observe and not let preconceived ideas affect it;

3. **Take stock:** With the observations made, a lot of information is extracted. The team and the manager need to take stock of information and so take advantage if it;

4. **Finding the lesson:** One must be careful with the 'obvious lessons' because there are lessons that require a greater effort. Occasionally, there may not be a real lesson - a project may have been done with effective uncertainty strategies and still not have achieved the desired results. It is not worth getting agonizing over not successful situations if there is nothing really meant to learn. The manager and the team must focus on learning the most valuable lessons and act on them. Sometimes, a simple change may be all that is needed.

5. **Disseminate knowledge:** Past the lessons step, a solution must be created to not keep having the same problem and thus pass the knowledge on. More important than learning is to passing on the lessons learned. Many projects come to this stage but fail to capture or disseminate knowledge. Managers need to establish a repository of lessons learned.

7.1.7 Proactive strategies and practices to reduce uncertainty

Hereinafter, strategies that can be implemented in projects to reduce uncertainties are going to be presented.

7.1.7.1 Short Iterations

It is a defined period of time within a project in which the team produces a product's stable, executable version, along with all supporting documentation and needed artifacts to its release. The executable is demonstrable, allowing the team to demonstrate real progress to stakeholders and get feedback on what they are doing, so they may improve their understanding of what needs must be met and how to build them.

Each iteration is built based on the previous iteration's results and is going to produce an increase in the product; a step closer to the final product. Iterations have limited duration, which means that the schedule for an iteration should be considered fixed, and the scope of the iteration's content actively managed to meet that schedule.

An increase can be redone in an easier way, in case the team has not delivered the required results or when it becomes clear that it is in the wrong direction. A long project phase reduces the lessons learned and the feedback opportunity. Through iterations, it is possible to learn more of the project, thereby, suppressing uncertainties.

7.1.7.2 Continuous Integration

As software components are unitarily tested, they become available and are integrated, then a configuration is produced and subjected to the integration test. Thus, the integrated

software capacity grows as an iteration continues towards the defined project objectives. The proposal of continuous integration is the creation of a separate and independent development environment, environment where individual modifications are unified to the main project, the project is compiled, the tests are run, the documentation is generated and so on.

7.1.7.3 Prototyping

Its function is to assist the generated ideas validation. The prototype is an idea which is tangible, the passage from the abstract to the physical in order to represent held one, even if simplified, and provide assessments. The prototypes reduce the project uncertainties, as they are ways of addressing alternatives that are not well known and thus, help to identify a more assertive solution. To build a prototype, the project team can follow the following activities:

1. Formulate the questions: Define what are the issues that need to be answered about the idealized solutions;
2. Create a/some prototype(s): Create models that represent the open aspect and enable the test;
3. Test: The creation results are analyzed; in case they are negative, they must return to step 2, in case they are positive, they should follow to step 4;
4. Evaluate: The results are evaluated.

7.1.7.4 Stakeholder Involvement

To work with quality it is necessary to observe the the client's vision and perception of the product or service being offered. The **Involvement of the specialist user in the project** is a way to keep the client as part of the project team so that they may clarify the doubts that arise during the product or service development.

7.1.7.5 Criativity

Creativity is the ability to think and act in unique and creative ways. The project manager needs to explore the collective creativity of the project team and the organization they work within to benefit their project.

Creativity Techniques, such as: brainstorming, ideas menu, co-creation workshop can be used to obtain knowledge and can be applied in order to generate openings for the novelty within the team. Creativity should be an essential part of the project team mentality. It is an important tool to break with an error cycle in which the lessons are not really learned and management strategies are stagnant. Creativity is the driving force behind the change and improvement. Creativity offers the opportunity to reach a better solution. One may wonder how the project manager can stimulate creativity.

Creativity has no formula. To be creative it is often necessary to bring down barriers, ignoring rules and challenging what everyone accepts as a fact. The reason why creativity is important is that solutions are often effective in a different place than where the problem symptoms may appear. It is necessary a certain creative*insight* to distinguish between the problem and its underlying concepts. Table 7.5 lists some of the traits that encourage creative thinking.

Tabela 7.5: Traits that Encourage Creative Thinking

Traits	Description
Question Constantly	Question everything What are the facts? Where is the evidence? Consider bringing an outsider who does not share the same assumptions of the team and take note of another vision of the situation.
Play the " What if "	Changing a situation positioning can bring other possibilities.
Look other perspectives	Analyze the problem on a different point of view. Put yourself in the place of another member who will be affected in the project.
Do not flee from the flaws	A failure is often a step ahead towards other possible solutions.
Take time to reflect	Opportunities can be reduced by daily pressures. The project manager needs to take time to reflect and to get a broader view of the project.

When there are uncertainties in the project, the manager needs to judge whether a creative approach is appropriate to find a solution. Whenever this approach is appropriate, they need to decide which methods to use. Some steps are suggested:

1. Recognize situations in which there is uncertainty or where a new concept must be developed and in which a creative approach is appropriate;

2. Determine who can contribute to find a creative solution, whether from the project team or elsewhere inside or outside the organization;

3. Gather together the chosen people and explain the lack of knowledge which requires a solution and ask them to use their imagination in offering ideas;

4. Encourage brainstorming;

5. Discuss the feasibility and implications of implementing the best ideas;

6. Plan and execute the chosen solution;

7. Document the lessons learned and apply them in similar situations in the future.

7.1.7.6 Brainstorming

It is a technique to encourage a large number of ideas generation in a short time. Usually performed in groups, it is a creative process driven by a moderator, responsible for leaving participants free and a person who is going to stimulate creativity without letting the group lose focus. This technique can be very or little structured and it is going to depend on the project members. The results can vary considerably; from vaguely described, the potential problems' description.

7.1.8 General Orientations for Software Projects Managers

A project team with the right people combination is clearly desirable for any project manager, but it is not the only point needed. The project manager should know how to organize the team for success. Boehm's work (BOEHM et al., 1981) in the IT industry offers good advice for the project manager, which are still valid nowadays, they are:

- Do not put people unnecessarily in your project team. Larger teams do not mean best teams. If you choose the best people (and get the right mix), a smaller team size is going to be more effective in the fight against uncertainty.

- Observe the team members' skills, experiences and aspirations and put them in the right positions in the team.

- Offer a career progression plan. Each team member needs to understand what to do to improve their personal and professional level.

- Balance the team. Choose a team for their complementary skills. Strengths and weaknesses are going to balance the entire team with the right combination. A team with similar skills, experiences, attitudes and personalities can have a narrow focus because everyone will tend to think and act the same way.

- Be alert to problematic team members and remove them from the project as soon as possible.

Hereinafter some guidelines for the project manager on reducing uncertainties are presented based on the evidences showed in Table 7.1

7.1.8.1 Managers should facilitate self-organization and the team adaptability

According to HIGHSMITH (2009) high performance teams are self-organized. Self-organizing teams are organized in relation to the work that must be done, ie creating their rules and making their local decisions. But these teams have a leader who, although not delegating nor controlling tasks, points the north, shows the direction, and acts as an inspiring source and as a great *coach* who manages the team in order to create an environment where they feel empowered. Team's self-organization could be an ally in dealing with daily uncertainties, some activities are suggested:

1. Provide adequate resources for the project team;
2. Perform an analysis of the team's strengths and weaknesses to know where to act with more intensity;
3. Identify actions to reduce stress on the team;
4. Communicate openly and honestly with the team to reduce stress levels;
5. Share some of their responsibilities and tasks with the team members;
6. Set an example for team. Be well organized;
7. Let the team learn from the non-expected situations.

7.1.8.2 Building trust between team, management and customer

LORENZEN (1998) argues that when people work together towards common goals, exchanging information and knowing each other well, they build trust. Trust is more than a set of expectations for a particular event. COSTA (2000) says that trust is also accepting the challenge and the implications associated with the attitude of trusting. In the sense of integrity and reducing uncertainty, trust can be associated; based on the belief that the business partners actions lead to favorable returns (MARQUES; COELHO, 2004).

For SATO (2003), trust is "a set of expectations shared by all those involved in an trade". Complementing NAVARRO (2007) recognize trust as "a phenomenon that predisposes people to integrate and open up to trade, which promotes cooperation and knowledge transfer". Some factors contribute to building trust; they are:

1. Sincerity - Loyalty, honesty, truth, respect and conviction expressed by non-verbal behavior;
2. Credibility - To comply with what is promised and do what is said;
3. Consistency - Awareness of what is significant in maintaining agreements and coherence between speech and practice;

4. Transparency - clarity and accuracy in information sharing and availability for communication strengthen confidence
5. Commitment - The commitment to their principles and with the project.
6. Competence - Includes knowledge, skills and experience required to develop the software;
7. Ethics - The dynamism of social and business relations must be considered.

Some recommendations are suggested:

1. Use planning techniques properly and maintain proper communication with stakeholders;
2. Collect information about the interests of the various parties associated with the project;
3. To be honest and create openness with all individuals based on mutual respect;
4. Ensure that all key people participate in finding solutions or scenario planning;
5. Report properly and provide feedback on lessons learned.

7.1.8.3 Management flexibility

Software project management is not a universal activity with a set of rules and processes for all projects. Management is situational, ie, there is no 'one size fits all'. To succeed in the project it is necessary flexibility and ability to react to changes, ie, always adapt one's management style to the environment, technology, market and stakeholders. In 7.1.1.1 it was presented how to choose the management approach, but managers need to be flexible to needed changes in the project, to approaches adaptations. Some recommendations are suggested:

- Being informed about the organization's policies and procedures: To be familiar with the guidelines and principles governing the organization's work.
- Be fair: Managers should put aside any preconceptions and consider the team members needs.
- Be proactive: The manager must keep close to the team always looking for improvements in project development.
- Being ready to say no: Despite the need for a team member, there may be demands that are not suitable for the project as a whole.
- Be flexible: Even with proper planning, unforeseen events may occur and the project needs may change.

7.1.8.4 Managing the expectations of stakeholders so that they flexibly accept changes

Consumers and different markets behave and think differently. Thus, knowing the client is one of the most important issues that any software project manager must face. Managers need to know how their clients think; what their main problems are; how they make decisions, fund the project and communicate. Project teams should also understand how customers' organizations operate and know the people who represent their clients. Therefore, managers need to manage the organization members and the project team's expectations. As previously mentioned, as innovation increases in software projects, uncertainties also increase; so it is necessary to prepare the project stakeholders to flexibly accept changes that may happen. Here some recommendations for managers are displayed:

- Identify the stakeholders'preferred communication method:by using the most effective communication way, the manager is going to help ensure that the stakeholders keep updated with the content;
- Keep stakeholders involved in the whole process: Asking the right people the right questions, at the beginning and throughout the project;
- Map expectations. Ask them how they are going to measure the project success and what the expectations are;
- Classify the communication level for each stakeholder: those who prefer a basic overview; those who prefer a daily or weekly communication;
- Involve stakeholders in decision-making: The team probably has already identified a better decision-making, but presenting its findings to the interested parties may make them felt involved.

The manager must bear in mind that the way in which the project is conducted is of vital importance; not only its required specifications fulfillment, but the negotiations involved, the way they have been conducted; how the ultimate goal has been achieved.

7.1.8.5 Managers should facilitate communication within the organization

A project manager's effective communication skills of are crucial to the project's success, as managing a project involves formal and informal communication at different levels in the organization (VERMA, 1996). This communication type includes all activities and behaviors in which information and ideas are shared with the project manager and project team.

The manager must give directions, conduct meetings and impart information and ideas to and from the project team, superiors, clients, contractors, functional managers and other managers and staff outside the project; besides being a great listener. The objective is to achieve high performance through an open communication, develop reliable and

effective guidance. This is because the aspects such as confidence, security and autonomy of an organization generate great impact on the accuracy or distortion in project communication.

In such a way that, the project manager should be able to make themselves understood by those involved in the process, sharing the information needed for planning, management, control and coordination of project operations. It implies saying that the manager should stick to the fact that each person has a communication limitation, an ability to receive the information and decode it, because of cultural differences.

Thus, the manager must send them with an appropriate language so they are successfully interpreted, either verbally, orally or written; using the minimum number of communication channels to avoid ambiguity. In short; the project manager uses communication to ensure that the project team is working consistently with project opportunities and problems.

1. Define the communication plan early in the project;
2. Identify the target population for communication;
3. Determine what needs to be communicated;
4. Check the infrastructure to perform communication;
5. Look for feedback on the communication effectiveness;
6. Document lessons learned.

7.1.8.6 Collaborative Work

EMDEN; CALANTONE; DROGE (2006) present an extensive review on collaboration in product development. The authors define collaboration in product development as a kind of inter-organizational relation, characterized by high transparency levels and where each participant contributes with a significant portion of the project's final result. Currently, having agility in developing projects, creating a collective effort to solve problems, learning to delegate and working as a team is essential in certain professions. Collaborative work allows a team arrive where individuals would not do alone; allowing the company to progress and its employees evolve together with it. So, teams that know how to work collaboratively establish important connections that are reflected in the organization. Hereinafter, four steps to improve collaborative work on the team are going to be presented:

1. Create communication channels - The establishment of efficient communication channels is essential to collaboration among the team. However, care must be taken. Communication does not mean having long daily meetings where much is said and little is decided. The ideal is to create fast and efficient channels. A good example is the *stand up meeting* that it are meetings, usually daily, in which each team member talks about the work that they are developing, what were the difficulties found and what they are doing until the following day.

2. Using collaborative tools - To adopt appropriate tools to encourage the team. Collaboration is essential to support a more efficient work. Managers need to show the team the importance of using the chosen tools and show how they can make the work more efficient.

3. Be open and fair to the team - There is no use in encouraging collaborative work in a company if leaders are not open. The manager needs to hear their team and open up possibilities, be a person they can rely on and talk without difficulty.

4. Recognize the team interaction characteristics - A team is not simply the sum of several employees. The way each one interacts with one another is also critical and may often be the focus of some problems. You need to identify who are the team members that have a good interaction and format the team so they work more closely.

7.1.8.7 Multidisciplinary

Multiple specialties together help in creating differentiated alternatives and phase uncertainties. A team is multidisciplinary when each professional has knowledge in specific areas. Each team member contributes to the knowledge and practice of their own expertise area and learn from other areas. A multidisciplinary team presents diverse views and offer varied interpretations on issues. Some steps are suggested:

1. Know the team;

2. Participate (when possible) of the selection recruitment process;

3. Build a collaborative environment;

4. Encourage turnover of functions/roles;

5. Encourage the creativity development;

6. Encourage the multidisciplinary expertise development;

7. Encourage the team spirit development.

7.1.8.8 Group Cohesion

Constructive attitudes are much more likely to lead to constructive results. In this sense, **group cohesion** is an important strategy for uncertainty management. When most of the team members share the same mindset, it may become a positive culture in the project and contribute to the unexpected resolution. Some steps are suggested:

1. Share basic concepts;

2. Everything must be originated by the group (discovered or developed by the group, not by an individual);

3. It must be originated also in response to a problem or in the face of adversity;

4. The communication culture has to be shared with new team members;

5. The establishment of the "correct " behavior should be used in problem solving.

7.1.8.9 Creation of Flexible Contracts

It is a negotiation way in which there is a criteria establishment according to the project's nature. Negotiation is a means of getting what you want from others. It's a two-way communication to reach an agreement when both parties have a combination of common and conflicting interests, that is, to resolve a conflict between them. Negotiation occurs when the parties want to resolve their differences and continue the productive and rewarding relationship way, with an acceptable result for everyone, making use of collaboration and acceptance (VERMA, 1996).

In this way, in order to succeed in the project, managers must be able to negotiate with the technical specialists, all involved managers and top manages about resources, priorities and responsibilities. They must negotiate with clients regarding scope changes, schedule, budget and performance; and team members on the various issues related to project management throughout the project life cycle.

The project manager must be able to analyze and evaluate situations and then formulate an appropriate negotiation strategy and adapt a flexible style to fit specific situations and negotiators involved in the process. The best way to achieve this result is to encourage those involved to work seeking mutual gains. It is important the manager to point out what are the project uncertainties and from the uncertainties, verify the contracts flexibility possibility facing future changes that may occur.

7.2 Closing Remarks

Various project management approaches do not consider the impact that uncertainties have in project management. The threats posed by uncertainty are real and immediate, and the stakes in a project are often high. The project manager faces a dilemma: decisions must be made now about future situations that are inherently uncertain. Using uncertainty management within project management can be a determining factor in project success. This chapter presented an approach to manage uncertainties in software projects, in which strategies that can support professionals and researchers in identifying relevant challenges and developing solutions for managing software projects are presented.

Furthermore, Figure 7.15 was elaborated which shows an activities mapping of the uncertainty management approach to software projects under the life-cycle view of traditional

projects. This figure initially shows how the project manager can apply uncertainty management during the traditional life cycle of the project and in the Appendix D an illustration of the approach application is presented. It is worth noting that the approach can be applied to other types of projects. Figure 7.15 was built only to exemplify to the project manager how to adopt uncertainty management during the project development.

The Figure 7.15 that shows a map uncertainty management activities in the project life cycle and in the Appendix D an illustration of the approach application is presented.

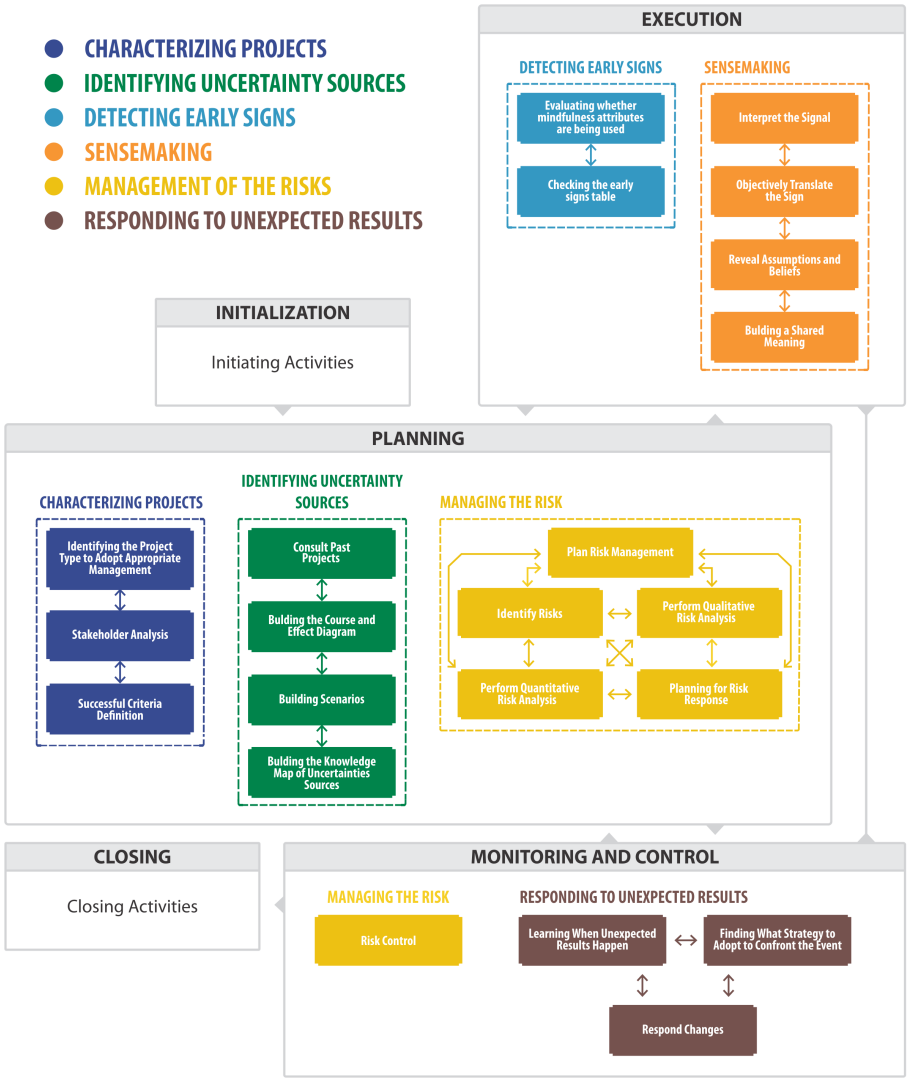


Figure 7.15: An activities mapping of the uncertainty management approach to software projects under the life-cycle view of traditional projects.
Source: the author

8

Final Considerations

"Uncertainty is the intolerance of the wise while certainty is the tolerance of fools."
Welton de Oliveira Rodrigues

It's no secret that many projects fail, regardless of the business sector, software projects are notoriously disaster victims, not necessarily because of technological failure, but more often due to uncertainties. Various approaches do not consider the impact that uncertainty has in project management. The threats posed by uncertainty are real and immediate, and the stakes in a project are often high. The project manager faces a dilemma: decisions about future must be made now; situations which are inherently uncertain. The use of uncertainty management within the project can be a determining factor in its success.

This thesis was built on evidence-based software engineering and provides subsidy for the need to address uncertainty in software projects in order to reduce the negative impacts caused by them. It also contributes by defining an approach to uncertainty management, as well as describing strategies and guidelines for team members. For this work, some activities were carried out:

- study of the art of uncertainties in software projects;
- an evidence-based software engineering methodology definition;
- literature's systematic review on managing uncertainty in projects;
- action research in an innovative project of software development;
- interviews with software project managers;
- focus group with project experts;
- an approach construction to manage uncertainties in the software projects.

Initially, an exploratory literature review was performed aiming to present the concepts related to this work, to raise clarification points such as: the understanding of risks

and uncertainties in the different knowledge areas, and how scholars address the uncertainty and uncertainty management concept. Thus, following evidence-based software engineering methodology and other steps, that are going to be described hereinafter, it was possible to answer RQ1.5 question.

A systematic literature review was conducted and presented in Chapter 4, helping to answer the research questions RQ1.1, RQ1.2 and RQ1.3. The systematic review research questions addressed: the possibility of reducing uncertainties in software projects; the techniques/strategies/ practices that favor uncertainty reduction in project management. What are the sources of uncertainty perceived in studies and the relationship between uncertainties and innovative projects.

To the research question SRL-RQ1: How is it possible to reduce uncertainty in software projects? The five possibilities to reduce uncertainties in the software projects were described. On question SRL-RQ2: What practices, techniques or strategies can help reduce uncertainties in software project management? 18 practices, techniques or strategies for managing projects focusing on reducing uncertainties have been described; To SRL-RQ3: What are the uncertainty sources perceived? The four uncertainty sources raised in exploratory literature review were confirmed and SRL-RQ4: What is the relation between uncertainty and innovative projects? A discussion about the relation between uncertainties and innovative projects was presented. Furthermore, the systematic review results showed that the number of works on uncertainties related to project management has been growing over the past decade, and point out that, despite uncertainties can not be extinguished from projects, some strategies should be adopted to make it out of the unknown and "tame" the project's inherent uncertainties.

An action research was elaborated in a software development project, also helping to respond RQ1.2 and RQ1.3. The research action objective was to perform the continuous uncertainty investigation related to the project; an evaluation of which practices, techniques and strategies may contribute for uncertainty reduction. Through the action research, it was possible to play an active role in the observed facts' very reality, ie, throughout the research process it was possible to actively act in order to support the uncertainties management. Some activities were carried out during the project development which were evaluated positively by the project members. All practices, strategies and techniques have been added to the approach presented in this work.

In the interviews, RQ1.4 question could be answered. During the interviews it could be noticed that the concepts which were detected during the first two stages of the methodology were solidified by the project managers' assessments, since there was an acceptance of the parties addressed throughout the interview; it was also stated that the concept of managing uncertainty makes sense for software project managers. During the interviews, it was found that concept is fully connected to: continuously observing the project so that through the members' perception threats may be identified; adopting strategies to be able to reveal risks; preparing the team to deal with the unexpected; obtaining greater knowledge; analyzing the uncertainty

sources and preparing projects to better face the unknown and pro-actively manage it so the project is prevented from harming events.

Furthermore, the focus group was conducted to evaluate the proposed approach to manage uncertainties in software projects. At the time of the focus group idealization, the approach was in its third version and there was a need to assess its structure and relevance. Regarding the participants' evaluations, all approach structure evaluations were positive and they said that the strategies/recommendations quantity was necessary for uncertainty management.

Thus, through the set step-by-step methodology, an approach was developed to manage uncertainties in the software projects, then pointing as answer to this thesis' main research question (**How to manage uncertainties in software projects?**) and thus confirming the assumption defined in the introductory chapter of this work. Still, the sub-issues elaborated in this thesis that helped to answer the research question were answered during the methodology's step-by-step, helping to build this job. Hereinafter, the sub-issues are going to be discussed:

RQ1.1: How do software project managers manage uncertainties?

When investigating the literature and seeking a way to manage uncertainties the systematic review was used and five ways to reduce uncertainties in software projects were related. They are: adopting strategies and techniques to facilitate uncertainties reduction; adapting management style to the type projects; dealing with uncertainty when they happen; understanding the uncertainty sources to better manage each type of project; identifying uncertainties in order to turn them into risks.

These were the ways reported by the scholars, in which, through them, the project manager could better manage uncertainties in projects. Then, an action research was established in order to manage a project, taking uncertainties into account, so adding other strategies and practices that were aligned to combat them. Adding the interviews and focus groups with project managers, it could be noticed that the strategies and guidelines structured are essential for managing uncertainty. So, the approach elaborated in this thesis focuses on how project managers can manage uncertainties in the software projects; or else, what was done separately or unconsciously by the project manager was compiled and turned into the approach proposed here in this work.

For questions: **RQ1.2 What strategies, practices and techniques do software project managers use to reduce uncertainties in their projects?** and **RQ1.3 What are the recommendations for managers who seek to manage uncertainties?**

Although there are no easy answers or fast solutions, we may say that uncertainty can be "tamed"; part of the answer lies in recognizing the nature of the problem and select the right strategy to work. The methodology used in this work helped answer the two questions; since at each stage, the strategies, practices and techniques which project managers used to manage uncertainties were presented. Table 7.1 presented a summary of all strategies, practices and recommendations found, as well as groups of evidence of each thesis development stage. All these strategies and recommendations have been formatted in an approach structure so the

software project manager might use as a basis for dealing with uncertainties in their projects.

RQ1.4 How is the concept of uncertainty management in software projects understood by managers?

Before start talking about the management uncertainty concept, it is important to point to the uncertainty in projects term, which a priori is not well established in the management area. As described in this thesis, risk itself is traditionally described as an uncertain event (PMI, 2013), which provides grounds for some scholars to argue that risk management should be referred to as uncertainty management in projects (GREEN, 2001; JAAFARI, 2001). However, it was presented that there is a strand that explores the distinction between the two terms, as discussed by WEICK (1995), CHAPMAN; WARD (2002), DE MEYER; LOCH; PICH (2002), ATKINSON; CRAWFORD; WARD (2006), SHENHAR; DVIR (2007) , LOCH; SOLT; BAILEY (2008); LOCH; DEMEYER; PICH (2011), PERMINOVA; GUSTAFSSON; WIKSTRÖM (2008). Even though, the distinction between risk and uncertainty was not clear for some, in interviews with project managers. But when asked what uncertainty would be, the responses ranged from: lack of sufficient information or lack of knowledge to no perception or limitation to perceive signals. What led to set up a basis for theoretical definition that was proposed in this thesis.

Uncertainty in projects is the resulting phenomenon of limitations in seeing signs that may affect a project success. Thus, it is something that can not obtain an occurrence probability, even if subjective. This difficulty may be generated by lack of experience, sufficient information, perceptive ability or even because of mindset of the people involved in the project. At this point, the organizational culture can have a strong influence.

In other words, it is believed that uncertainty in projects arises from individual experience (eg manager's, team members') such as: either lack of knowledge, understanding and/or awareness of the project's important elements, its environment and their interrelationship; so that one can not obtain the probability that might impact on the project success.

Once it was established the uncertainty definition, it is important to remember that the term "manage" can be defined as: organize, plan and execute activities to facilitate the work process. Activities related to the manager, administrator or leader. The manager organizes their work environment, makes decisions, directs the employees or group members' work.

In relation to the uncertainty management term, responding to R1.4, when project managers were asked, all responded that the term makes sense, it is necessary to develop management activities with the team that may make them begin to realize, probe and identify uncertainties, so that they start risk management. In other words, uncertainty management would be a way to provide strategies that help identify what the team can not predict so far and that could somehow impact the project. Uncertainty management should prepare the team to better manage projects in the face of uncertainty, for it better cope with the unexpected.

Thus, uncertainty management for software projects is the use a proactive mentality with a set of strategies and guidelines that includes attitudes, behaviors of projects and their

members. Uncertainty management is a mindset that emphasizes a proactive and reflective way of dealing with the unknown unknown, covering all levels of a project. As one of the managers, during the interviews said: "it is thinking outside the box to manage to improve your perception to get out of the unknown".

Then, corroborating with the thinking evolution in project management presented in the SPF (MOURA, 2011), which was introduced earlier this thesis, thus strengthening the uncertainty dimension and evolving in terms of literature studies, through bibliographic review, practice through action research; the view of who manages the project, through semi-structured interviews and focus group were used. Or else; the research conducted in this thesis focused in how the manager might conduct the project under the uncertainties perspective. In addition, the approach proposed in this thesis contributed to uncertainty management in a structured way through the stages and activities that were not presented in the SPF (MOURA, 2011), that is, this work becomes a positive evolution of the uncertainty petal in software project management strand.

RQ1.5 How can uncertainty management help the risk management process in software projects?

By doing the project planning, the manager assesses the risks, uses different methods and techniques for information on future tasks and its elements. In planning, corrective actions are taken; for which, a budget reserve is assigned in case a risk happens.

Therefore, dealing with known risks assumes a rather mechanistic approach. Managers often deal with risks through the corrective actions implementation in accordance with the plan to minimize costs and use the reserve budget only when necessary. The manager's main job in terms of risk management is to minimize the negative impact on the project's financial performance, preventing losses. Still, the project manager who only relies on risk management can work under the false impression that all the project's unknowns have been worked out;

The success of risk management measures will depend on how and when the identified actions are going to be implemented to combat the negative impact, which in turn depends on how well the uncertainty management strategies are applied. Risk and uncertainty management should therefore be considered complementary approaches.

It is believed that risk management is essential as it reduces the overall uncertainty level associated with the project and that there are many risk management well-established techniques which, if properly applied, can help in uncertainty management. As said during the development of this thesis: while risk management remains as an important strategy, the project manager also needs strategies to manage uncertainty, that is, to deal with areas that risk management does not reach.

Thus, uncertainty management becomes essential for risk management so that it provides strategies for the manager better make the unknown known. Considering these points, risk management can be seen as a process with an emphasis on effective planning using collection technique and data analysis. This thesis shows that uncertainty management actions

include risk management, providing strategies and recommendations for project members, so they have the means to conduct the risk process better and prepare themselves facing uncertainty that surrounds the project.

8.1 Latest Considerations

Among the studies presented none of them focus on software project management. Studies have contributed to build the approach developed in this thesis, such as Perminova (PERMINOVA; GUSTAFSSON; WIKSTRÖM, 2008) that strengthens uncertainty management presenting an extensive study of that it is indeed necessary to manage uncertainty and she presents an interesting discussion confronting risks researchers when they claim that uncertainties are managed by risks. This thesis agrees with Perminova's view that risk management does not manage uncertainties; furthermore, it presents an approach in a way uncertainties in the software projects are managed.

Weick and Sutcliffe (WEICK; SUTCLIFFE, 2001, 2011) showed a very effective research that focuses on large organizations bringing the concept of mindfulness. The approach presented in this thesis focuses on software project management and how the mindfulness concept can be applied in uncertainty management.

Shenhar and Dvir (SHENHAR; DVIR, 2007) make a great contribution to strengthen the uncertainty management area, but in their diamond model they are limited to adapt management style not demonstrating strategies to combat uncertainties or how to turn the unknown into known. On the other hand, Loch (LOCH; SOLT; BAILEY, 2008; LOCH; DEMEYER; PICH, 2011) contributes to manage uncertainty by making the unknown into known but does not show what the strategies for this transformation are or how to contain uncertainties, which is what is presented in this thesis.

Clenden (CLEDEN, 2009) despite his large contribution to uncertainty management, he presents several ways to obtain knowledge to reduce uncertainty, but he does not present scientific evidence or practices on how these forms were extracted and does not present an application in the project context.

Johansen (JOHANSEN et al., 2014) provides a process for uncertainty management, but does not show how the project manager and the team should be aware of the early signs to try to identify the associated risks as shown in the approach developed in this thesis. In addition, Johansen mentions "control and monitoring of uncertainties" which in fact, in his process, he is managing risks.

Martinsuo (MARTINSUO; KORHONEN; LAINE, 2014) has a reactive way of dealing with the team's lack of knowledge. He presents how to develop strategies to address a particular uncertainty, but does not address the uncertainty sources that may exist within the project and does not create a way to make the project manager be aware of the signs.

The work of O'Connor and Rice (O'CONNOR; RICE, 2013) in spite of relevant re-

search that has been prepared, the authors do not demonstrate uncertainty framework application and the source of uncertainties resources is described similarly to the risk management area, besides of not being clear about the latency and critic sources.

All these studies contribute to strengthening uncertainty management. This thesis focuses specifically in the context of software projects. The approach was created based on the literature and practice evidence, moreover, during the assessment phase it has been identified as a significant contribution to software project managers.

The developed approach, in addition to strengthening the need for uncertainty management, leads to a transformation of risk management into uncertainty management, ie uncertainty management here is something that encompasses project risk management. It is focused on transforming the unknown into known, that is; give visibility to what was not perceptible to the software project manager so that they can manage project risks.

8.2 Research Contributions

The results of this research contribute to software project management in two ways. First, the developing approach presents a way to manage uncertainties using the strategies and orientations that can support professionals and researchers in identifying relevant challenges and development of solutions for projects. Second, the research results provide the academic community a better understanding of the challenges of dealing with the uncertainties in project management and therefore, show gaps in the area that can be good opportunities for future research.

Some contributions can be highlighted on the research methodology used in this thesis. A study of the difference between risks and uncertainties in the different areas of knowledge was carried out and made available in (MARINHO; SAMPAIO; MOURA, 2014a). A study of uncertainty sources in projects was carried out and made available in (MARINHO et al., 2013) . A systematic review was conducted and data was made available in (MARINHO et al., 2014d,c). An action research was conducted and made available in (MARINHO et al., 2015a,b). Semi-structured interviews were carried out and made available in (MARINHO et al., 2015c) and a focus group was conducted under the guidelines of (SHULL; SINGER; SJØBERG, 2008).

Some of the results obtained during the development of this thesis were reported in publications, namely:

- MARINHO, M. L. M.; SAMPAIO, S. C. B.; LUNA, A.J.H.; LIMA, T. L. A.; MOURA, H. P. Dealing With Uncertainties in Software Project Management. In: the 15th IEEE International Conference on Computer and Information Technology (CIT-2015), Liverpool, 2015.

- MARINHO, M. L. M.; SAMPAIO, S. C. B.; LIMA, T. L. A.; MOURA, H. P. Uncertainty Management in Software Projects. Journal of Software, v. 10, p. 288,

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- MARINHO, M. L. M.; LIMA, T. L. A.; SAMPAIO, S. C. B.; MOURA, H. P. Uncertainty Management in Software Projects - An Action Research.. In: XVIII Ibero-American Conference on Software Engineering, 2015, Lima. XVIII Ibero-American Conference on Software Engineering, 2015.

- MARINHO, M. L. M.; SAMPAIO, S. C. B.; LIMA, T. L. A.; MOURA, H. P. A Guide to Deal With Uncertainties in Software Project Management. International Journal of Computer Science and Information Technology (Print), v. 6, p. 1-20, 2014.

- MARINHO, M. L. M.; SAMPAIO, S. C. B.; LIMA, T. L. A.; MOURA, H. P. A Systematic Review of Uncertainties in Software Project Management. International Journal of Software Engineering & Applications (IJSEA), v. 5, p. 1-21, 2014.

- MARINHO, M. L. M. ; SAMPAIO, S. C. B.; MOURA, H. P. Uncertainties in Software Projects Management. In: XL Conferencia Latinoamericana en Informática (CLEI 2014), 2014, Montevideo, 2014.

- MARINHO, M. L. M. ; SAMPAIO, S. C. B.; MOURA, H. P. An Approach Related to Uncertainty in Software Projects. In: IEEE INTERNATIONAL CONFERENCE ON SYSTEMS, MAN, AND CYBERNETICS (SMC 2013), Manchester, 2013.

- MARINHO, M. L. M. ; SAMPAIO, S. C. B.; MOURA, H. P. Um Estudo Relacionado a Incerteza em Projetos. In: II Simpósio Internacional de Gestão de Projetos (SINGEP 2013), São Paulo , 2013.

Other co-related work to this thesis were published:

- MARANHãO, R. G. A. ; MARINHO, M. L. M. ; MOURA, H. P. Narrowing impact factors for Innovative Software Project Management. In: ProjMAN - International Conference on Project MANagement, 2015, Vilamoura Algarve . Proceeddings of ProjMAN 2015, 2015.

- MARANHãO, R. G. A. ; MARINHO, M. L. M. ; MOURA, H. P. A Systematic Review of Innovative Software Project Management. In: XIV Simpósio Brasileiro de Qualidade de Software (SBQS 2015), Manaus, 2015.

- SAMPAIO, S. C. B.; MARINHO, M. L. M. ; MOURA, H. P. Reflecting, adapting and learning in small software organizations: an action research approach. The Twenty-Seventh International Conference on Software Engineering and Knowledge Engineering (SEKE 2015), Pittsburgh, 2015.

- SAMPAIO, S. C. B.; MARINHO, M. L. M. ; MOURA, H. P. Understanding Project Management Actuality in Small Software Development Organizations. In: 13 International Conference on Information Systems and Technology Management (13 CONTECSI), 2015.

- SAMPAIO, S. C. B.; MARINHO, M. L. M. ; MOURA, H. P. Systematic Review on Project Actuality. International Journal of Computer Science and Information Technology (Print), v. 6, p. 51-63, 2014.

- SAMPAIO, S. C. B.; MARINHO, M. L. M. ;MOURA, H. P. An Approach To Understand Project Actuality In Small Software Development Organizations And Contribute To Their Success. In: ProjMAN - International Conference on Project MANagement, 2014, Troia. Proceeddings of ProjMAN 2014, 2014.

Finally, to the researcher, this research enabled an academic maturity and subject knowledge deepening. Studies during this search and the consequent acquired knowledge made possible interaction with other researchers of the area.

8.3 Limitations

Some limitations could be observed in the study, even with all the cautions and attenuations promoted by the researchers. In relation to the used research method, the limitations are typical of qualitative studies, particularly in the generalization of the results. In relation to the systematic review, one of the greatest concerns in SLRs is selecting as many relevant studies as possible to answer the research questions, and a coverage of 100% of the sources that was possible by limitation of time and resource. Four electronic sources were chosen for the automatic search, being most of them from the list of sources relevant to Computer Sciences, according to KITCHENHAM (2007). Due to the limitations of the search engines, relevant articles still could not be found. Furthermore, there also is the influence of the researcher in the classification of the articles found in this process of review.

Additionally, in this study, with strong empirical basis, was not easy to find companies willing to participate with the desirable intensity. An action research was conducted in a software development project, limited to environmental factors of this project.

In relation to the interviews with project management professionals sample, it counted with the participation of twenty-five Brazilian professionals. This number of professionals influences in the generalization of the final results, as well as the focus group participants. Here there is a limitation of Brazilian professionals only.

8.4 Future Work

Considering the research scope, many opportunities to the continuity of the developed studies can be identified. Next, some investigation points are described which can be worked subsequently:

- To apply the approach in a software development project with the aim of identifying how it responds to the strategies and proposed guidelines as well as verify its effectiveness;
- Gamification the approach in order to guide, engage and motivate teams to continuously use the approach.
- To develop a computational tool to support the approach, so that it remains accessible to all organizations willing to use it;
- To identify how the models development and subjective assessments of the area of decision-making processes can be applied for uncertainty management in software projects.
- To adapt the approach and apply to other knowledge areas;
- To investigate the use of knowledge management practices that allow uncertainty reduction in project management practices in IT organizations and analyze the project success perception by their managers;
- Development of questionnaires to assess the strategies and guidelines adoption in software projects.

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Appendix

A

Systematic Review Protocol

The literature systematic review on uncertainty management in software projects had as researcher members the ones reported in Table A.1:

Tabela A.1: Systematic Review Team

Name	Affiliation	Function
Marcelo Marinho	Cin Federal University of Pernambuco (UFPE)	Researcher (Leader)
Suzana Sampaio	Cin Federal University of Pernambuco (UFPE)	Researcher
Hermano Moura	Cin Federal University of Pernambuco (UFPE)	Reviewer

A.1 Introduction

Systematic reviews provide means to perform revisions in the comprehensive and not biased literature, making their results have scientific value as mentioned by TRAVASSOS; BIOLCHINI (2007). Systematic reviews aim to present a research topic fair assessment, using a reliable, strict and auditable methodology (KITCHENHAM, 2007).

TRAVASSOS; BIOLCHINI (2007) features some of the reasons to conduct a systematic review: to summarize existing evidence for a phenomenon; to identify gaps in current research; to provide a framework to position new research; and to support the new hypotheses generation.

A systematic review starts with the protocol definition that specifies the research questions and methods that will be used to conduct it. According KITCHENHAM (2007), besides the research reasons and objectives the following items should be part of the protocol:

- Research questions that the research aims to answer;
- Strategies used to the primary studies research, including the terms used, digital libraries, journals and conferences;

- Inclusion and exclusion criteria of primary studies;
- Quality assessment procedures of the selected studies;
- Data extraction strategy and extracted data synthesis; and,
- Documentation and presentation strategy.

Thus, this document presents a systematic review protocol, part of a PhD research whose main objective is to investigate the uncertainties management strategies in software projects. This study aims to bring together appropriate procedures and tools to the management reality in a software projects uncertainty scenario.

A.2 Research Questions

In order to investigate what changes in software project management when there is a great uncertainty level and how to support management in this research uncertain scenario it focus on four more specific research questions:

- RQ1: How is it possible to reduce the uncertainty in software projects?
- RQ2: What practices, techniques or strategies can help reduce the uncertainties in project management software?
- RQ3: What are the sources of uncertainty perceived?
- RQ4: What is the relation between uncertainty and innovative projects?

A.3 Search Strategy

According to KITCHENHAM (2007), a strategy should be used for the primary studies detection, with the key words definition, digital libraries, journals and conferences. The strategy used in this research is presented in the following subsections.

A.3.1 Research Key Terms

From the previously defined research questions, the key terms are identified. After identification, the translation of these terms into English is performed as it is the language used in the searched electronic databases and at major conferences and journals of research topics.

Furthermore, synonyms are identified with an expert in the research theme's guidance for each of the key terms. As a recommendation, the identified key terms are going to be searched in singular and plural, for this variation, we used the asterisk character (*) that is

accepted in many digital libraries and allows the word variations that are referenced with the symbol.

The terms and synonyms identified are presented below:

- Project Management;
- Software Project Management;
- Uncertainty;
- Project Uncertainty, Uncertainties in Project;
- Uncertainty management;

A.3.2 Search String

According KITCHENHAM (2007), the strings are constructed from the questions structure and sometimes adaptations are necessary according to the specific needs of each database. Thus, the search strings were generated from the key terms combination and synonyms using OR and AND, and possible peculiarities of digital libraries and adaptations by this, were registered. The search strings used are listed below:

((uncertainty <AND> ′software project management′) <OR> (uncertainty AND ′project management′) <OR> (′uncertainty management′ <AND> ′software project′) <OR> ′project uncertainty′ <OR> ′uncertainties in project′)

A.3.3 Data Sources

According to KITCHENHAM (2007), the primary studies initial research can be performed on digital libraries, but this is not enough for a systematic review, other sources can also be searched. Research area researchers can also be consulted for more suitable material sources indication.

The criteria for sources selection are: availability to consult the articles on the web; presence of search engines using keywords; and, sources importance and relevance. So, with the search strings defined, research materials used for the primary studies search are listed as below:

- IEEEXplore Digital Library (httt://ieeexplore.ieee.org/)
- ACM Digital Library (http://portal.acm.org)
- Elsevier ScienceDirect (www.sciencedirect.com)
- Springer Link (http://link.springer.com/)

- IJPM - *International Journal of Project Management*

Due to the source search *Elsevier ScienceDirect* index the works produced in IJPM (considered by experts the largest international journal in the area) it was not necessary to perform the search again just in this journal.

Other sources were initially considered as potential for searches: Google, Google Scholar, SpringerLink, Wiley InterScience, InspecDirect, Scopus and Scirus. However, these were subsequently excluded from the final sources list for some of the following reasons:

1. Some because they are not present in significant or systematic reviews or for not having been recommended by experts;

2. Some for not allowing works viewing or downloading without payment or license the work performing institution does not possess;

3. Some for being already indexed by some of the sources previously listed in the survey.

Once potential primary studies have been obtained, they need an analysis so that its relevance is confirmed and works with little relevance are discarded. In view of this, in the following sections, inclusion and exclusion criteria are defined to help in these works analysis.

A.4 Study Selection

The studies that can be part of this research are: periodic articles, magazines, conferences and congresses. The possibility of books being used in the research is not discarded; however, the material availability is going to be assessed first. In addition, other unanticipated studies found that may contribute to research might be added.

Once potential candidate studies to become primary studies have been obtained, they need to be analyzed so that their relevance is confirmed; and work with little relevance are discarded. According to TRAVASSOS; BIOLCHINI (2007) inclusion and exclusion criteria should be based on research questions. So, some inclusion and exclusion criteria are defined in the following subsections, based on the works of KITCHENHAM (2007) and TRAVASSOS; BIOLCHINI (2007).

A.4.1 Inclusion Criteria

The studies inclusion is determined by the relevance (it is believed that the study is a potential candidate to become a primary study), concerning the research questions and decided by analysis of the title, abstract, introduction and conclusion of the study. Inclusion criteria were the following, as shown:

- Study presents, primarily or secondarily: Critical factors, challenges and problems in Uncertainty Management in Software Project
- Study presents, primarily or secondarily: Best Practices, lessons learned and success factors to be adopted in Uncertainty Management
- Study presents, primarily or secondarily: Techniques, Methodologies, Tools to support Uncertainty Management in Software Projects

A.4.2 Exclusion Criteria

As well as the title analysis, keywords, summary and conclusion, the studies will be excluded if they classified as some of the cases below:

- Study is not freely available for consultation on the web;
- Study clearly irrelevant, according to the research questions;
- Study not answer any of the research questions;
- Repeated study: if it is available in different search sources, the first search must be considered;
- Duplicate study: if two papers present similar studies, only the latest and / or most complete must be included, unless they have additional information;
- Study is not complete or has not been reviewed: Technical Report, Summary Extended, Presentation or Book;
- Study not in English.

A.5 Primary Studies Selection Process

After defining the research questions, the strategy used for the primary studies search and the inclusion and exclusion criteria, the primary studies selection process is described below:

- Initially, two researchers perform searches according to the search strategy described in the previous sections to identify potential primary studies, and from reading the works titles and keywords that the search returns, they exclude papers that are clearly irrelevant to the questions investigated. According to KITCHENHAM (2007), the initial search returns a lot of studies that are not relevant, not answering questions or even not being related to the topic in question. So, totally irrelevant studies are going to be discarded at the beginning and are not going to be maintained in any excluded study list;

- Then, each researcher establishes a list of potential primary studies. After that, the two lists are compared and the researchers turn them into a single list of potential candidates. If there is any disagreement on the inclusion or exclusion of a study, it should be included;
- From the unified list of potential primary studies candidate search results, all papers are evaluated by two or more researchers, by reading the summary and conclusion, considering the inclusion and exclusion criteria; then, to get into a final list of primary studies.
- The studies are going be documented on Form A (A.1)

Trabalhos Incluídos						
ID	**Fonte**	**Título**	**Autor**	**Local de Publicação**	**Tipo**	**Ano**

Figure A.1: Form used to store data relating to studies included

A.6 Studies Quality Assessment

In addition to the general criteria for inclusion and exclusion, it is considered important to assess the quality of primary studies (KITCHENHAM, 2004). Although there is no universal definition of what constitutes quality study, most checklists include questions that aim to assess the extent to which the bias is minimized and the internal and external validation are maximized (KITCHENHAM, 2004).

In the data extraction phase, each publication methodological quality of was assessed. Three factors were assessed as follows, and each were marked yes or no (PLACIDO et al., 2012; STAPLES; NIAZI, 2008; KITCHENHAM, 2007):

1. Does the publication mention the possibility of selection, publication, or experimenter bias?
2. Does the publication mention possible threats to internal validity?
3. Does the publication mention possible threats to external validity?

In addition, the four questions related to the research questions are added in order to check how much each study meets this research's goals, the same work can present results to the four research questions.

A.7 Data Extraction Strategy

To KITCHENHAM (2007), the objective of this step is to create data extraction forms to accurately record the information obtained from the primary studies. This should be designed to collect the necessary information questions. An electronic form is suggested by several studies, because according to experts, its use can facilitate further analysis. Thus, to support the extraction, data recording and subsequent analysis, then a spreadsheet in Excel software containing the studies, the extracted quotas and what research question is going to be answered was drawn up.

A.8 Collected Data Synthesis

After collecting the data, the information should be tabulated according to the research questions, tables should be structured to highlight the similarities and differences between the results of the study (KITCHENHAM, 2007; TRAVASSOS; BIOLCHINI, 2007). The data extracted from the studies are organized in tables through spreadsheets and from that, analyzes, comparisons and summaries of the data are performed.

KITCHENHAM (2007) writes in her paper that the data synthesis can be quantitative and/or qualitative; the first would necessarily be treated as a meta-analysis. To this research nature, and the questions it addresses, only works with qualitative data are going to be presented, then a qualitative synthesis is done. Synthesizing qualitative research involves trying to integrate studies that constitute findings and results in natural language, in which different investigators may use terms and concepts with some (or many) different meanings (KITCHENHAM, 2007).

A.9 Documentation and Presentation of Results

A systematic review final stage involves the analysis of results writing and results dissemination to potential stakeholders. Some studies indicate topics required for a systematic review presentation: Title (according to the research questions); Authors; Summary of the Work (context, objectives, methods, results and conclusions); Background (justification of the review need); Research Questions; Revision of the Method (search strategy, selection of studies, quality assessment, extraction and data synthesis); Included and Excluded Studies; Results; Discussion and Conclusions (KITCHENHAM, 2007; TRAVASSOS; BIOLCHINI, 2007).

B

Semi Structured Interview Protocol for Uncertainty Management in Software Project

B.1 Contact letter

Subject: [Interview] An invitation to participate in a semi structured interview to discuss issues related to Uncertainty Management in Software Project.

Principal investigator: Dr. Hermano Perrelli de Moura, Professor Center of Informatics (CIn), Federal University of Pernambuco (UFPE), Recife, Brazil.

Co-investigador: Marcelo Luiz Monteiro Marinho, student at UFPE/ CIn, pursuing a Doctoral degree in Computer Science.

B.1.1 Overview

The Project Research Group (GP2) in the Center for Informatics (CIn) at Federal University of Pernambuco (UFPE) is conducting a research to get a better understanding of the relevance of the uncertainty management in software projects topic.

In fact, this study is part of a wider research conducted by the investigators in order to identify practices/techniques/strategies adopted for manager in face of uncertainties in project management software to ensure the success of projects, as well as the expand the understanding of how these arrangements can help the organizations to attain greater enterprise agility and support its overall strategy.

We are inviting you to participate in interview about uncertainty management seeking to investigate the application of strategies on uncertainty issues. This study will require the recording of the interview for further analysis.

Tabela B.1: Interview Profile

Question Profile	**Questions**	**%**
Questions about basic research issues	3	12%
Questions related between practices and uncertainty management	9	36%
Questions related to respondent and its demography	9	36%
Questions related to Interview Analysis	4	16%
Total	**25**	**100**%

B.1.2 Purpose

The purpose of the study is to discuss some relevant aspects related to uncertainty management, by means of a semi structured interview. We are specifically interested in understanding the practices that influence positively the software project management in face of uncertainties. Our intent is to use the knowledge gained during this study to develop guidelines that can be used by the industry for improve the performance of the organizations and its projects.

We are inviting you because you have professional or academic experience compatible with the sample profile designed for this study, being a representative agent of the phenomena in study, and possessing the expertise that is relevant to this study.

B.1.3 Study Procedure

This is a semi structured interview comprehending the following question profile:
Relevant points:

- This interview takes, approximately, 60 minutes to be completed. If you do not feel comfortable in terms of knowledge to answer any of the questions, do not leave unanswered, you may feel comfortable in providing approximate answers. For research is more important an approximate answer than no response.
- This interview must be answered only by people who have had contact directly or indirectly with project management in organizations of varied nature.

B.1.4 Confidentiality

No one other than the named investigators will have access to the verbatim data collected by this instrument. The study outcome shall be presented as a summary of gathered data, but no personally identifying information shall be reported.

Audio data shall be transcribed using a professional transcription service or by the investigators. Only the named investigators shall have access to the interview transcripts. The

audio data, transcripts and field notes shall also be kept in a locked filing cabinet in the principal investigator's office. A back-up copy of the audio data will be made and stored in the co-investigators safety deposit box.

B.1.5 Remuneration/Compensation

No compensation shall be provided for participation in this study.

B.1.6 Benefit

The participant will receive the following intangible benefits from participating in this study:

1. The summary of the results will be shared to the participants that fill their email in the related demographic question. This information may be useful for improve the performance of their organizations and their projects.

2. Goodwill from participating in a study to investigate the application to investigate the strategies that can help reduce uncertainties in the projects, thus contributing to a development directives that can be used by the industry.

B.1.7 Contact for information about the study

If you have any concerns or desire further information with respect to this study, you may contact the co-investigator, Marcelo Marinho (mlmm@cin.ufpe.br).

B.1.8 Contact for concerns about the rights of research subjects

If you have any concerns about your treatment or rights as a research subject, you may contact the Secretary of the Board of Research (SEC-DPQ) in the UFPE Office for Research Affairs and Graduate Studies (PROPESQ) at +55 (81) 2126 7041 or dpq.propesq@ufpe.br.

B.1.9 Consent

Your participation in this study is entirely voluntary and you may refuse to participate. Your signature below indicates that you have received a copy of this consent form for your own records.

Your signature indicates that you consent to participate in this study. In some cases, the record of verbal consent, captured by the audio recording of the interview, is sufficient evidence of their acceptance to participate in the interview and equivalent to your signature.

B.2 Interview Protocol

This section presents the issues related to the study.

B.2.1 Questions about basic research issues

This section seeks understand how the subject perceives the organizational context that will be adopted as a background of the phenomena in study, by means of a subtle survey about this issues.

Tabela B.2: Questions about basic research issues - 1

Question ID	1	Construct	Beaconing issues
English		a.What do you understand by uncertainty in project management?	
Question Type		Answer	
Open-ended question (a)			

Tabela B.3: Questions about basic research issues - 2

Question ID	2	Construct	Beaconing issues
English		a.What do you understand by risks in project management?	
Question Type		Answer	
Open-ended question (a)			

Tabela B.4: Questions about basic research issues - 3

Question ID	3	Construct	Beaconing issues
English		a.What do you mean by "uncertainty management"? b. Does it makes sense to you? c. Can you realize some practical application of this concept in your everyday context?	
Question Type		Answer	
Open-ended question (a)			
Open-ended question (b)			
Open-ended question (c)			

B.2.2 Questions related between practices and uncertainty management

Tabela B.5: Questions related between practices and uncertainty management - 1

Question ID	4	Construct	Practices
English		a.Do you believe that characterize the project, defining the best methodology and the best activities can help reduce uncertainty? b. Would you have any examples?	
Question Type		Answer	
Open-ended question (a)			
Open-ended question (b)			

Tabela B.6: Questions related between practices and uncertainty management - 2

Question ID	5	Construct	Metrics
English		The literature suggests that the success of the project (especially innovative projects) should be measured by various dimensions. I am going to cite these dimensions and wish you indicate your level of agreement with them. a.Do you apply some other metric in your project to measure success?	
Question Type		Answer	
question (a1)		( ) Project Efficiency	
question (a2)		( ) Customer Impact	
question (a3)		( ) Team Impact	
question (a4)		( ) Commercial success	
question (a5)		( ) Preparing for the future	

Tabela B.7: Questions related between practices and uncertainty management - 3

Question ID	6	Construct	Practices
English		a. The literature classifies uncertainties on four sources (technology, environment, market, social-human). Considering the projects in which you participate which uncertainties can be classified according to these sources? b. Is there any other source of uncertainty that could be added to this classification? c. How it is done in your project to reduce these sources of uncertainty?	
Question Type		Answer	
Open-ended question (a)			
Open-ended question (b)			
Open-ended question (c)			

Tabela B.8: Questions related between practices and uncertainty management - 4

Question ID	7	Construct	Practices
English		Within early signs some stocks are considered to assess the level of mindfulness organizations to them. Some actions are considered to assess the level of mindfulness organizations to early signs. a. I am going to quote some of these and would like that you indicate to me is practiced or not. If so, how?	
Question Type		Answer	
question (a1)			
question (a2)			
question (a3)			
question (a4)			
question (a5)			

Tabela B.9: Questions related between practices and uncertainty management - 5

Question ID	8	Construct	Practices
English		a. Also in regard to early signs, do you believe that they can be identified by the following?	
Question Type		Answer	
Close-ended question (a)		( ) Plan Risk Responses	
Close-ended question (b)		( ) Earned Value Management	
Close-ended question (c)		( ) Assessments of project	
Close-ended question (d)		( ) Performance measurement	
Close-ended question (e)		( ) Stakeholders Management	
Close-ended question (f)		( ) Assess the maturity of projects	
Close-ended question (g)		( ) Consult past projects	

Tabela B.10: Questions related between practices and uncertainty management - 6

Question ID	9	Construct	Practices
English		a. The reality is constructed from the meaning that is attributed to what is happening. That is the premise of sensemaking organizational approach that seeks to study how information starts to make sense to people in the organizational environment, thus, the literature suggests some activities. What is your level of agreement with each of them. b. Could you give examples of how these activities can be performed in the projects.	
Question Type		Answer	
Close-ended question (a)		Interpret the signal	
Close-ended question (b)		Objectively Translate the Sign	
Close-ended question (c)		Reveal assumptions and beliefs	
Close-ended question (d)		Building a shared meaning	

Tabela B.11: Questions related between practices and uncertainty management - 7

Question ID	10	Construct	Strategies
English		a. I am going to list some strategies that can be adopted to manage uncertainties in projects. I would like you to indicate your level of agreement with each of them. b. Do you add some more practice?	
Question Type		Answer	
Open-ended question (a)		Managing the expectations of stakeholders so that they flexibly accept changes. How?	
Open-ended question (b)		Management flexibility and ability to respond to changes. How?	
Open-ended question (c)		The creation of flexible contracts. How?	
Open-ended question (d)		Building trust between team, management and customer. How?	
Open-ended question (e)		Managers should facilitate communication within the organization. How?	
Open-ended question (f)		Managers should facilitate self-organization and the team adaptability. How?	
Open-ended question (g)		Collaborative Work. How?	

Tabela B.12: Questions related between practices and uncertainty management - 8

Question ID	11	Construct	Technical
English		a. Considering the uncertainties some results are not expected, therefore, some techniques can be adopted with the aim reaction to a particular event not expected. I will mention a few and would like you to indicate if you agree with these practices, b. Do you suggest some more technical?	
Question Type		Answer	
Open-ended question (a)		Learning techniques. How do you do in your Project?	
Open-ended question (b)		Constructive thinking. How do you do in your Project?	
Open-ended question (c)		Creativity techniques. How do you do in your Project?	

Tabela B.13: Questions related between practices and uncertainty management - 9

Question ID	12	Construct	Technical
English		a.I am going to list a number of techniques and I would like that you pointed your level of agreement on the use of these techniques as an important factor for reducing uncertainties. b. Do you suggest some more technical?	
Question Type		Answer	
Close-ended question (a1)		Quality according to the customer	
Close-ended question (a3)		Involvement of the specialist user in the project	
Close-ended question (a4)		Short interactions	
Close-ended question (a5)		Stakeholder analysis	
Close-ended question (a6)		Multidisciplinary team	
Close-ended question (a7)		Brainstorming	
Close-ended question (a8)		Cause and Effect Analysis	
Close-ended question (a9)		Decision trees building	
Close-ended question (a10)		Scenario building	
Open-ended question (b)			

B.2.3 Questions related to respondent and its demography

B.2.3.1 Work experience

Tabela B.14: Questions related to respondent and its demography - 1

Question ID	13	Construct	Subject
English		How long is your work experience?	
Question Type		Answer	
Close-ended question		- Up to 1 year. - From 1 to 5 years. - From 6 to 10 years. - From 11 to 15 years - From 16 to 20 years. - More than 20 years	

Tabela B.15: Questions related to respondent and its demography - 2

Question ID	14	Construct	Subject
English		What is your currently job position?	
Question Type		Answer	
Close-ended question		- Business owner - CEO. - CIO. - Executive - Consultant. - Professor. - Researcher. - IT Professional. - Project Management. - Software Engineer. - System Analyst. - Agent of the Public Administration. - Graduate student. - Other:	

B.2.3.2 Education

Tabela B.16: Questions related to respondent and its demography - 3

Question ID	15	Construct	Subject
English		What is your level of education (completed)?	
Question Type		Answer	
Close-ended question		- Undergraduate. - Graduated. - MBA (Lato Sensu). - Master. - PhD. - Postdoctoral	

B.2.3.3 Project Management Experience

Tabela B.17: Questions related to respondent and its demography - 4

Question ID	16	Construct	Subject
English		How long have you participated or are you involved directly or indirectly with project management?	
Question Type		Answer	
Close-ended question		- Up to 1 year. - From 1 to 5 years. - From 6 to 10 years - From 11 to 15 years. - From 16 to 20 years. - More than 20 years.	

B.2.3.4 Organization

Tabela B.18: Questions related to respondent and its demography - 5

Question ID	17	Construct	Organization
English		In which of the following groups the organization in which you work (or I worked recently) would be better classified?	
Question Type		Answer	
Close-ended question		- For-profit organization. - Non-profit organization. - Government. - Academy.	

Tabela B.19: Questions related to respondent and its demography - 6

Question ID	18	Construct	Organization
English		How would you rate the size of the company where you work? Use as reference the table from the SEBRAE [1]	
Question Type		Answer	
Close-ended question		- Micro. - Small. - Medium. - Large.	

Tabela B.20: Questions related to respondent and its demography - 7

Question ID	19	Construct	Organization
English		In which industry sector your organization operates?	
Question Type		Answer	
Open-ended question			

Tabela B.21: Questions related to respondent and its demography - 8

Question ID	20	Construct	Organization
English		What is the better classification for the operation of the organization where you work?	
Question Type		Answer	
Close-ended question		- Local. - Regional. - National. - Multinational (present in up to 5 countries) - Global (present in more than 5 countries)	

Tabela B.22: Questions related to respondent and its demography - 9

Question ID	21	Construct	Organization
English		In which sector or department you work?	
Question Type		Answer	
Open-ended question			

B.2.4 Questions related to Interview Analysis

Tabela B.23: Questions related to Interview Analysis - 1

Question ID	22	Construct	Analysis
English		The organization where I work (or I worked) adopts practices to manage uncertainties	
Criteria		Assessment scale	
Numeric scale question		- Strongly Disagree 1 or 2 - Disagree 3 or 4 - Indifferent 5 or 6 - Agree 7 or 8 - StronglyAgree 9 or 10	

Tabela B.24: Questions related to Interview Analysis - 2

Question ID	23	Construct	Analysis
English		The organization where I work (or I worked) has interest to adopt an approach to managing uncertainty, You as project manager would be interested in adopt the approach.	
Criteria		Assessment scale	
Numeric scale question		- Strongly Disagree 1 or 2 - Disagree 3 or 4 - Indifferent 5 or 6 - Agree 7 or 8 - StronglyAgree 9 or 10	

Tabela B.25: Questions related to Interview Analysis - 3

Question ID	24	Construct	Analysis
English		The development of an approach to uncertainty management in software project to help people and organizations to apply strategies to improve project success is an extremely necessary contribution to industry and academy.	
Criteria		Assessment scale	
Numeric scale question		- Strongly Disagree 1 or 2 - Disagree 3 or 4 - Indifferent 5 or 6 - Agree 7 or 8 - StronglyAgree 9 or 10	

Tabela B.26: Questions related to Interview Analysis - 4

Question ID	25	Construct	Analysis
English		Have you any other suggestion to the ongoing research?	
Question Type		Answer	
Open-ended question			

B.3 References

1. M. Marinho, S. Sampaio, and H. Moura, "An approach related to uncertainty in software projects," in Systems, Man, and Cybernetics (SMC), 2013 IEEE International Conference on. IEEE, 2013, pp. 894-899.

2. Marcelo Marinho, Suzana Sampaio, Telma Lima, and Hermano Moura. A guide to deal with uncertainties in software project management. International Journal of Computer Science & Information Technology, 6(5):1-20, 2014.

3. Luna, A. J. H. de O. (2014). Protocol of the semi structured Interview for emergence of the Agile Governance Theory. Federal University of Pernambuco, Recife, Brazil. Retrieved November 07, 2014, from http://www.agilegovernance.org/theory

C

An Approach to Manage Uncertainty in Projects: An Structured View

The Figure C.1 shows an approach to manage uncertainties.

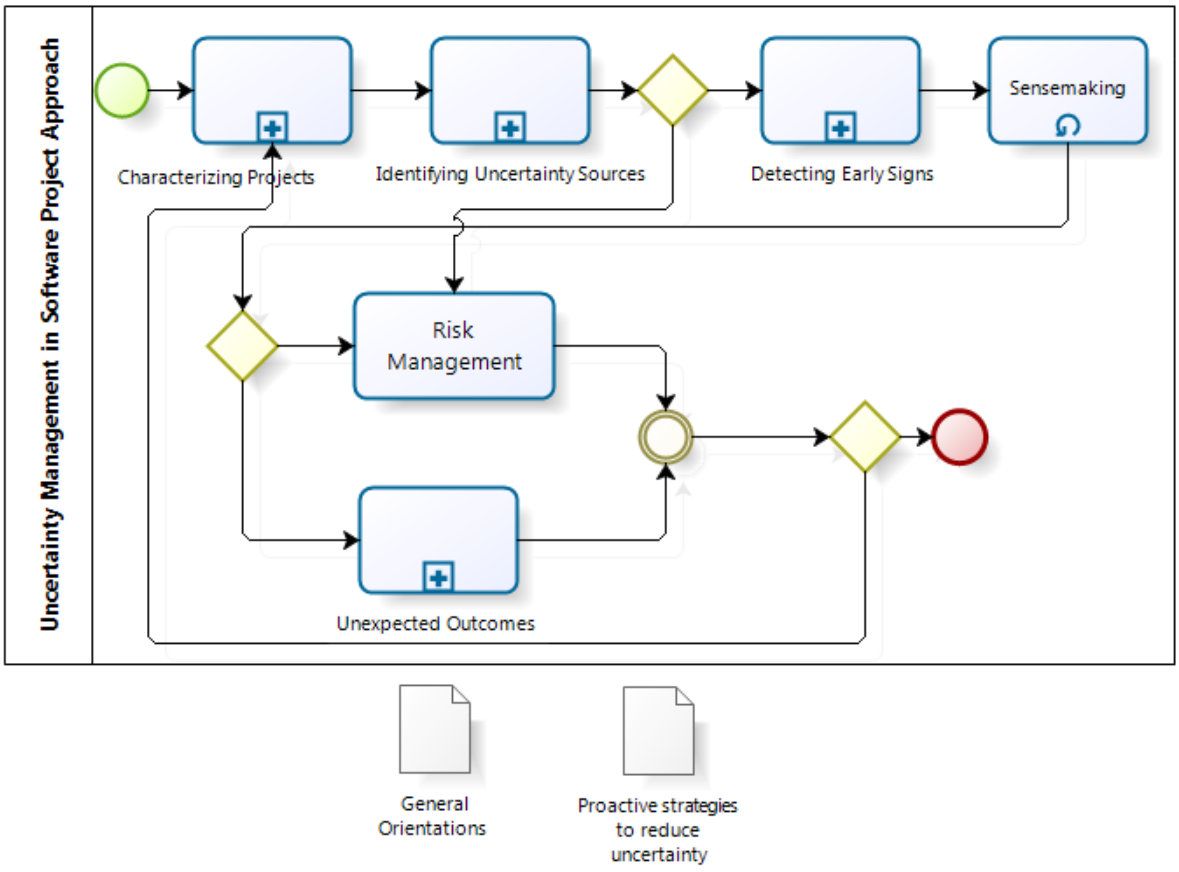

Figure C.1: Uncertainty Management in Software Project - An Structured View .
Source: the author

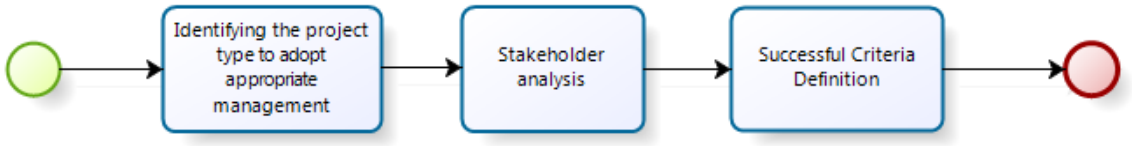

Figure C.2: Characterizing Projects.
Source: the author

C.1 Characterizing Projects

C.1.1 Identifying the project type to adopt appropriate management

Goal: To identify the management approach
Exit Criteria: Established management approach
Steps:

- To make an analysis of what is known in the project;
- To identify if the project goals are clear;
- To identify if the project solution is well established;
- To check in the quadrants Figure 7.3 which is the suitable approach for the project (Marinho et al, 2014);
- To select the approach to project management

Outcomes: Updated project plan

C.1.2 Stakeholder analysis

Goal: To make a stakehoders analysis.
Exit Criteria: Stakeholders analysis carried out; defined actions strategies.
Steps:

- To conduct a brainstorming with staff and identify who are the allies and opponents among stakeholders;
- To put the identified stakeholders in Interest X Power chart (See 7.4);
- To monitor the stakeholders of quadrants 3 and 4;
- Develop an action plan for stakeholders of quadrants 1 and 2.

Outcomes: Updated project plan

C.1.3 Successful Criteria Definition

Goal: To establish success Criteria
Exit Criteria: Established Success Criteria
Steps:

- Previously identify success criteria that can be used to measure the project;
- To conduct a Brainstorming with customer to define success criteria;
- To negotiate with the client the agreed criteria;
- To document in the project plan the success criteria.

Outcomes: Updated project plan.

C.2 Identifying Uncertainty Sources

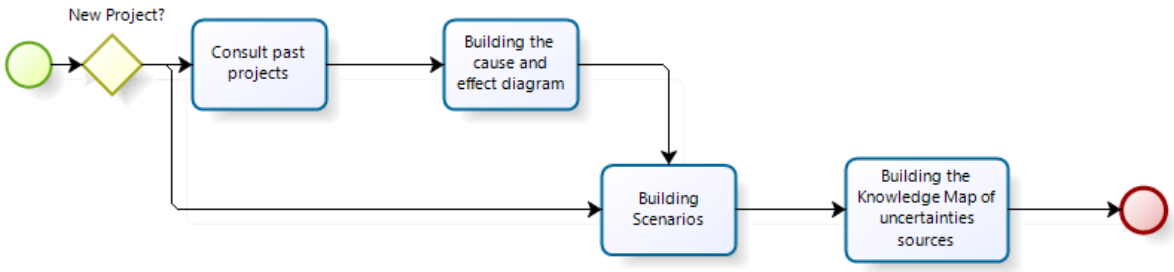

Figure C.3: Identifying Uncertainty Sources.
Source: the author

C.2.1 Consult past projects

Goal: To identify if the current project uncertainties were resolved in past projects.
Exit Criteria: Analysis of past projects made.
Steps:

- To study the documents in the project repository;
- Analyze the data trying to find similarities with the current project;
- Make sure that a survey is well conducted in order to equip the team with knowledge to face the project's uncertainties.

Outcomes: Information list related to the current project.

C.2.2 Building the cause and effect diagram

Goal: To identify unknown causes of a given outcome
Exit Criteria: Cause and Effect Diagram built
Steps:

- Define the problem: One must determine objectively what the problem is;
- Structure diagram: All possible information should be gathered about the problem in question;
- Group information: After putting together a team that can help create the diagram, it must present information through a brainstorming section;
- Rate the causes: One must sort the information, pointing the main causes and conducting an analysis, defining which ones impact the problem more and what the possible solutions would be;
- Conclude the diagram: Draw the diagram in a way to present the analysis made.

Outcomes: Cause and Effect Diagram; List of project's unknown causes.

C.2.3 Building Scenarios

Goal: Project's possible scenarios construction.
Exit Criteria: Project's possible scenarios identification.
Steps:

- Perform a group session with team and stakeholders;
- Perform the questions presented in Table 7.2 for the team;
- Evaluate the scenarios, prioritize and rank.

Outcomes: Scenarios built.

C.2.4 Building the Knowledge Map of uncertainties sources

Goal: Building the knowledge map of uncertainties sources.
Exit Criteria: Knowledge Map built.
Steps:

- The knowledge level assessment in a given uncertainty source is performed through a number of questions:
    - Is there prior experience (both directly and indirectly relevant)?

- How well understood are connections, relationships and dependencies between Source Uncertainties?
- Is your knowledge of this domain changing rapidly?
- How confident are you that the risks are understood and documented?

- With this question set, the manager should look to emerging standards. Is there lack of knowledge? Does it mean a particular weakness in the planning approach or project methodology? What is behind any significant knowledge gap?

Outcomes: Knowledge Map.

C.3 Detecting Early Signs

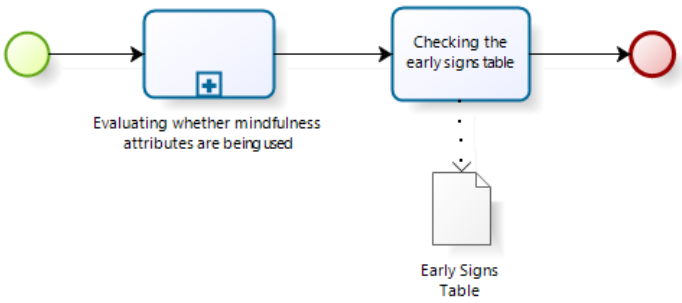

Figure C.4: Detecting Early Signs.
Source: the author

C.3.1 Evaluating whether mindfulness attributes are being used

C.3.1.1 Analysis of Failure Concerns Attribute

Goal: Analyze The Failure Concerns Attribute
Exit Criteria: Failure Concerns attribute analyzed
Steps:

- The manager and the team should reflect on the following questions:
  - Does the team always look at the flaws of all sizes and try to understand them?
  - When something unexpected happens, does the team always try to find out why the expectations were not met?
  - Does the team consider the early signs as information and try to learn from them?

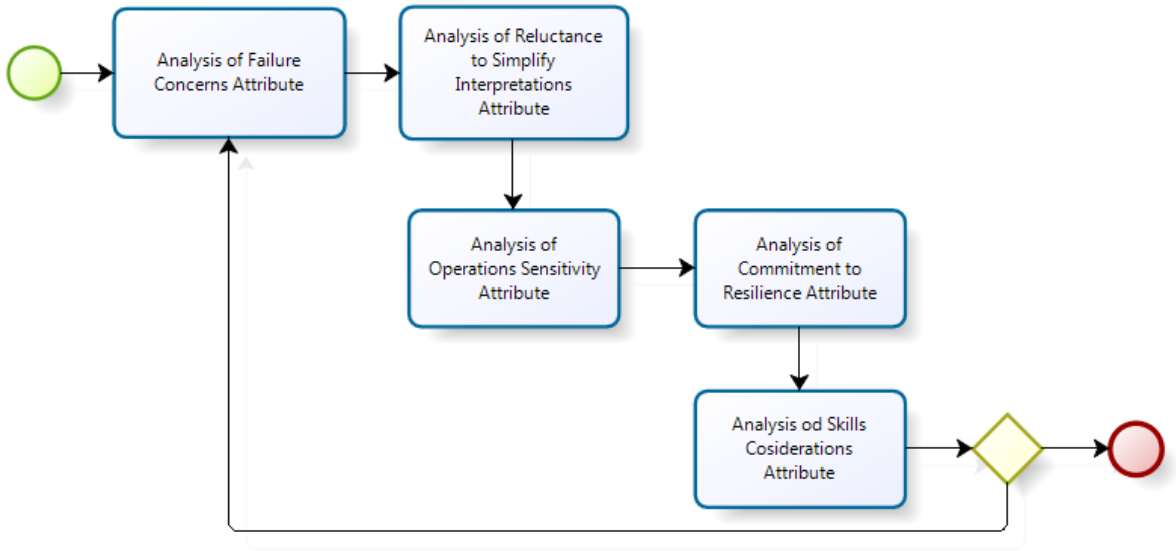

Figure C.5: Evaluating Whether Mindfulness Attributes are Being Used.
Source: the author

- Does the team consider the early signs like points that reveal potential dangers and not successes that demonstrate the ability to avoid disaster?
- If a team member makes a mistake, is not this error used against him?
- Do the team members report significant errors even if others do not realize that mistakes are made?
- Do managers actively look for early signs?
- Do team members feel free to talk to superiors about problems?
- Are team members rewarded if they detect early signs or potential problematic issues?

- The more positive feedback the project team is concerned about, the more healthily they deal with failure. The manager must use these questions to start thinking about ways to improve the project attribute application. Some actions are recommended:

  - The manager should fostering the team reflective ability;
  - The manager should fostering appreciative approach to deal with mistakes;
  - The manager should sensitize the team members about the errors possibility so that they feel responsible and attentive to the signs;
  - The manager must create a learning culture for everyone to share mistakes and experiences;

- The manager should fostering self-organizations, team cohesion, team spirit while introduce a critical approach to handle with failures;
- The team should review the projects goals and pay attention to the mistakes that should not occur.The team should review the projects goals and pay attention to the mistakes that should not occur;

Outcomes:
Sensitized members with the errors possibility Members alert to the early signs

C.3.1.2 Analysis of Reluctance to Simplify Interpretations Attribute

Goal: Analyze of Reluctance to Simplify Interpretations Attribute
Exit Criteria: Reluctance to Simplify Interpretations analyzed
Steps:

- The manager and the team should reflect on the following questions:
  - Do team members strive to challenge the status quo?
  - Do team members feel free to bring problems and difficult issues?
  - Do team members usually deepen their analysis to better understand the uncertainties in projects?
  - Are team members encouraged to express different world views?
  - Do team members listen carefully, and rarely someone's vision is not heard?
  - Are not team members punished when they report information that could disrupt operations?
  - When something unexpected happens, do team members spend more time analyzing than defending their vision?
  - Are skeptics highly valued?
  - Do team members trust each other?
  - Do team members show respect for each other?
- The more positive responses, the more the project uses the reluctance to simplify interpretations attribute. The manager must use these questions to start thinking about ways to improve the project context. Some actions are recommended:
  - The team must raise doubts to gather information: Try to look beyond the limits of their expectations;

- The manager should encourage mutual respect to differences so that everyone can voice their opinions;
- The manager should make the team think under other perspectives.

Outcomes:
Information acquired by the team;

C.3.1.3 Analysis of Operations Sensitivity Attribute

Goal: Analyze of Operations Sensitivity
Exit Criteria: Operations Sensitivity analyzed
Steps:

- The manager and the team should reflect on the following questions:
  - In day-to-day, is the manager always paying attention to what's going on?
  - When problems happen, is someone with authority to act always accessible to team members?
  - Do team members have the power to solve unexpected problems that might arise?
  - During a normal day, do team members interact frequently enough to build a clear picture of the project's current situation?
  - Are team Members always looking for feedback on things that are not going well?
  - Are team members familiar with the operations beyond their own functions?
  - Do managers constantly monitor workloads and reduce them when they become excessive?
- The greater the number of negative responses is, the less is the sensitivity to the operations. The manager must use these questions to start thinking about ways to improve the sensitivity for operations. Some actions are recommended:
  - The manager should constantly stick to the information passed by the team, whether verbal or not;
  - Team members should speak. Just because one member noticed something, one should not assume that the others noticed too, it is important to communicate;

- Team members must develop the ability to be skeptical: When you are skeptical it is likely to better assess the activities carried out and the comments raised can support or disprove a certain activity;
- The manager should provide feedback and encourage people to listen;
- The manager should spend time with team members following the daily work.

Outcomes:
Team Semsibility for daily work

C.3.1.4 Analysis of Commitment to Resilience Attribute

Goal: Analyze of commitment to resilience
Exit Criteria: Commitment to resilience analyzed
Steps:

- The manager and the team should reflect on the following questions:

  1. Do most team members have skills to act on the unexpected problems that might arise?
  2. Do team members learn from their mistakes?
  3. Are there resources to training and continuous recycling of team members?
  4. Do team members have more than enough training and experience for playing their role in the project?
  5. Are project leaders actively concerned with the team members' skills and knowledge development?
  6. Are the team members known for their ability to use their knowledge in an innovative way?
  7. Is there a concern with team members' skills building?
  8. Do team members have an informal contacts network they may sometimes use to solve problems?
  9. Do team members trust each other?

- The greater the number of positive answers, the better for the project, as it shows a resilient team. If points like these are not applied in the project context, the manager and team need to reflect on how to improve the detected points. Some actions are recommended for the project to take into consideration the attribute commitment to resilience; they are:

- Accept that unpleasant situations and uncertainty are part of the project;
- Believe and nurture skills and team skills to deal with difficult situations and develop emotional intelligence;
- Always nurture team confidence, especially regarding to the belief that one is able to achieve goals;
- Learn to keep calm in all situations;
- Always find the positive and even fun side of stressful situations;
- Value the maturity of the team.

Outcomes: A resilient team developed

C.3.1.5 Analysis od Skills Cosiderations Attribute

Goal: Analyze of skills cosiderations
Exit Criteria: Skills cosiderations analyzed
Steps:

- The manager and the team should reflect on the following questions:
  - Is the team committed to do their job well?
  - Does the team respect one another's activity nature?
  - If something unusual happens, does the team know who has the knowledge to respond to it?
  - Do the team members appreciate value expertise and experience on the hierarchical level?
  - In the project, do the most qualified people to make decisions make them?
  - Do team members usually become a problem owners until it is resolved?
  - In general, is it easy to obtain expert assistance if something comes up that the team does not know how to handle?
- The larger the number of positive answers, the better for the project, because it shows that there is concern in applying the attribute. If points like these are not applied in the project context, the manager and team need to reflect how to improve the detected points. Some actions are recommended for the project to take the attribute into consideration the Skills Consideration; they are:
  - Beware of the centralization fallacy: The manager needs specialists to think realistically. It is necessary let each one act autonomously within the project;

- Stimulate the imagination as a tool to manage uncertainty: Facing uncertainties, it is necessary to use the imagination. The use of scenarios may be an ally in the search for possible solutions;
- Create flexible decision-making structures: Do not assume that the expertise is at the top of the hierarchy. When there are uncertainties or problems occur, try to divert to who can really help.

Outcomes:

Creativity encouragement in the face of uncertainty Experts considerations taken into account

C.3.2 Checking the early signs table

Goal: To check the early signs table
Exit Criteria: List of project's early signs built
Steps:

- To analyse the attached Table and check if any of the signs are happening in the project;
- To analyse if there are any identified signs not found in the Table 7.3;
- To contantly apply the mindfuness' five attributes to analyze signs;

Outcomes: Project's early signs list ;

C.4 Sensemaking

Goal: Sensemaking
Exit Criteria: Sign sensemaking done
Steps:

- Interpret the signal: When detecting an early sign, the manager must analyze the whole project context. They must know the project, all its variables and interference, and build a meaning considering the team information;
- Objectively Translate the Sign: The manager needs to be clear in presenting the sign to the team involved in order to translate it into actions that make sense for all project members;
- Reveal assumptions and beliefs: Each team member's previous experience must be taken into account, as well as personal competence; however, the project manager has to stick to some of the team members, while sense creation, they are not able to let go of past experiences, assumptions, beliefs or trauma;

- Building a shared meaning: The collective meaning creation aims at information sharing, team members involvement;
- To put the analyzed data in the risk list.

Outcomes: Risk list

C.5 Risk Management

Goal: Do risk management

Exit Criteria: Risk management done

Steps:

- Plan Risk Management (PMBOK,2013);
- Identify Risks (PMBOK,2013);
- Perform Qualitative Risk Analysis (PMBOK,2013);
- Perform Quantitative Risk Analysis (PMBOK,2013);
- Planning for Risk Response (PMBOK,2013);
- Risk Control (PMBOK,2013);

Outcomes: Managed risks

C.6 Unexpected Outcomes

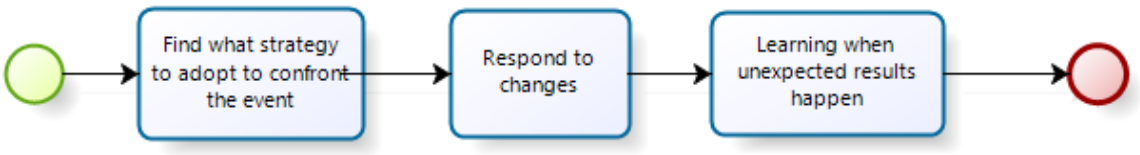

Figure C.6: Unexpected Outcomes.
Source: the author

C.6.1 Find what strategy to adopt to confront the event

Goal: Adopt a strategy to confront the event
Exit Criteria: Strategy to adopt to confront the event done
Steps:
Choice among suppress, adapt, detour and reorient and follow the steps
Suppress:

- Identify the uncertainty sources;
- Accurately predict future scenarios;
- Analyze potential threats;
- Develop a tactical plan to solve the problems.

Adapt:

- Always verify the uncertainty sources and early signs;
- Understand the main project's objectives in order to keep focused on the right things;
- Act quickly and decisively if the project plan needs change;
- Check continuously the project direction in relation to its goals.

Detour:

- Clearly understand the project objectives;
- Being creative in identifying planning options;
- Evaluating alternative approaches' risks and benefits;
- Taking the initiative when better opportunities appear.

Reorient:

- Understanding the threat nature;
- Being honest about the success and failure chances;
- Keeping an open mind about redefining goals;
- Being persuasive in seeking the stakeholders' agreement to reorient the project.

Outcomes: Updated project plan.

C.6.2 Respond to changes

Goal: To respond to changes.

Exit Criteria: Changes made.

Steps:

- Decide on the change management policy;
- Identify all proposed changes;
- Consider the consequences for the project;
- Look for authorization for the changes, if necessary;
- Obtain accepted or rejected changes;
- Plan, execute, control and close approved changes;
- Monitor changes effect against the project baseline;
- Document lessons learned and apply them to future projects.

Outcomes: Updated project plan.

C.6.3 Learning when unexpected results happen

Goal: Learning when unexpected results happen.

Exit Criteria: Established learning culture.

Steps:

- To be receptive to learning;
- Objective observation;
- To take stock;
- To find the lesson;
- To disseminate knowledge.

Outcomes: Lessons learned list.

D

An Illustration of the Approach Application

To illustrate the approach application, the historical data of a real project will be called in this work Project Eagle, for confidentiality reasons. All information identifying the authors, institutions and project details were suppressed or modified, but the relevant facts to the approach application are original. During project development, risk processes were applied.

D.1 Project Context

Eagle project was developed during 2008-2011 in a research institute, which will be called X; it was demanded by a government company which will be identified as company A. The objective of the project here modified [1] was to develop an algorithm for modeling and simulating aeolic images in integrated circuits boards with the use of hardware languages. It is noteworthy that, during this period, no company in the country had developed a similar project and the needed application for other companies in the world was unknown.

Initially, project Eagle was established through a term of commitment between organizations for a period of two years, comprising two-step deliveries with the possibility of renewals and schedule adjustments according to the customers. The team consisted of 16 people; among them, the lead researcher Thomas, representing the institute X; Angelica, a project manager (with 6 years experience), four team leaders and the rest of the team. Except from Thomas, the whole team was made up of doctoral students, master's or undergraduate in scientific research projects. Representing the company A, two professionals were involved, that will be called John and Rinaldo.

All the team project members had knowledge gaps about the technologies to be applied in the project development. Knowledge related to integrated circuits boards was already appropriate for them, but they did not dominate the aeolic images problem. At the management level, there was not a detailed schedule previously studied by the parties, there was only a previous set of activities to be developed during a period of two years; there was neither a detailed estimate

[1] Being innovation project, protected by terms of confidentiality, some data has been modified, but the same relevant features highlighted in the description remains.

of project costs; there was only an agreed macro value between the parties. Angelica, as the project manager, initially decided to adopt a traditional approach, however, after two months of project, she decided to change it to an agile approach based on Scrum. Eighteen months later, she requested the project's removal and was replaced by another manager.

These are some problems that occurred during the project:

- The delivery time was extrapolated for two more years;
- The client Rinaldo, after the application of Scrum, did not understand his role and often wanted to take the role of a " dictator manager", even shouting at project members;
- From the two project milestones, only one was achieved, and for not having criteria to assess well-established project deliveries, Rinaldo did not want to accept its delivery claiming he had observed that some criteria (not established previously) had failed;
- Company A's bureaucracy for legal formalities of the project;
- Some team members were not committed to the project;
- The little knowledge of the technology used;
- High staff members turnover.

D.2 Applying the Approach

The illustration will be developed applying the approach stages (Characterizing Projects, Identifying Uncertainty Sources, Detecting Early Signs, Sensemaking, Managing the Risks, Responding to unexpected results) on the steps of the project life cycle according to Figure 7.15.

D.2.1 Planning

During the project planning phase, the stages Characterizing Projects, Identifying Uncertainty Sources and Managing the Risks could be applied. Figure D.1 illustrates the stages and their consequences.

At the stage **Characterizing Projects**the first activity to be developed is **Identifying the project type to adopt appropriate management**.

Despite the cooperation agreement set a goal for the project, it was not clear to the team or the client how the goal would be achieved, or what the solution to the final product would be; therefore, XPM would be the best model for project management because it was characterized

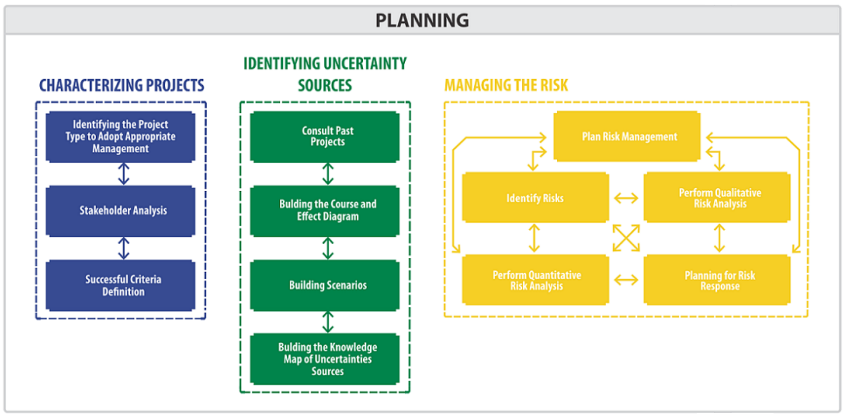

Figure D.1: Planning.
Source: the author

with high uncertainty level relating to the objectives and solutions. For further information see 7.3.

With the adoption of XPM recommendations in the project's early stages, Angelica could lead the team to carry out some exploratory studies in order to gain more knowledge about what would be produced based on John and Rinaldo's statements. So the team would build scenarios to guide them on the various ways. In addition, the scenarios would provide insights into the requirements to be developed. The requirements prioritization could have been conducted in more appropriately way, aligned with the scenarios. The prototyping would be a differential for obtaining information, a continuous development assessment of the project would or would not be performed from small development cycles and customer follow-up. With the project continuation, small cycles and group cohesion would make a difference in its development and in the pursuit of its goal.

Considering the **General Orientations for Project Managers**, Angelica could have suggested the **Creation of Flexible Contracts** based on information obtained after this activity.

With the second activity application, **Analyzing stakeholders**, the parties involved should be analyzed as shown in Figure 7.4. John would have been monitored closely, since he has high power and high interest. On the other hand, Rinaldo, for having high power but low interest, would have been kept satisfied. John would be classified as an ally to the project and Rinaldo as an opponent, because of his evident attitudes during the Scrum approach application. So, in addition to keep him satisfied, it would be necessary to take actions to turn him into an ally to the project.

In the third activity, **Defining Success Criteria**, the criteria to be used for project success assessment should have been discussed. Considering the analyzed project, once it is a research work; the following measures should have been established: preparing for the future, satisfaction and impact on customer and motivation and impact on the team as well as pre established performance criteria by the parties based on the first cycles of XPM.

Considering the **General Orientations for Software Projects Managers**, Angelica

could have adopted team's self-organization and adaptability. She could have even changed to agile approach that values the measures mentioned, however, the change was due to the fad of using agile approaches; nevertheless, at that moment, the team still had doubts about the goal and the solution.

Still in the planning stage, in the stage of **Identifying Uncertainty Sources** the first activity will depend on an assessment of the team's past projects. In this illustration in question, the activity would be **Building Scenarios** in order to identify which positive and negative scenarios could happen during the project development. Angelica could have used the questions presented in table 7.2 to scenario building, which would have led the team to observe certain standards that could emerge during the project execution, then observing where it was necessary to obtain more knowledge.

The following activity would be **Building the Knowledge Map of Uncertainties Sources**, which would help clarify what is known about the project. In the illustration in question the team could have built a map as follows: technological uncertainty; there was a lot of uncertainty of the logic circuit and algorithm production to generate the images, but the information was available; then, it would be classified as (2-4) in the project's knowledge scale; relating to the environment; the way the company A worked was initially not known, but several factors were; so it would be classified as (4-6); in relation to the market; the researcher, the manager and the leaders had a good experience and could pass it on to the other members, so it would be (6-8); Finally, socio-human; the team was fresh, so was the interaction with John and Rinaldo; then it would be (2-4). The elaborated knowledge map graphic representation shown in Figure D.2 demonstrates the need for further research on technological uncertainty and socio-human sources. Thus, it would be ideal if the team sought more information about these issues and was aware of the project's early signs.

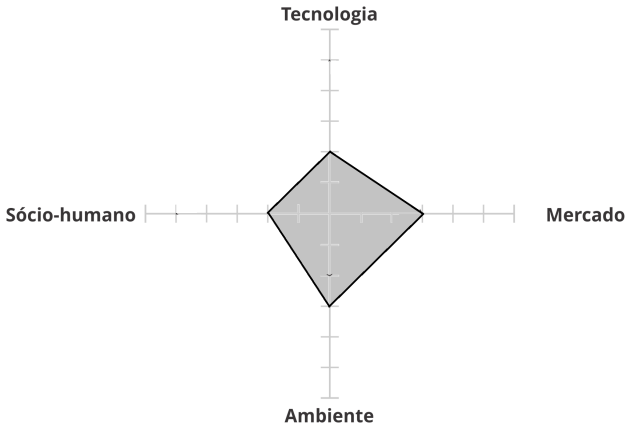

Figure D.2: Map.
Source: the author

The next stage is **Managing the Risks** which follows the processes presented in PM-

BOK (PMI, 2013).

D.2.2 Execution

During the project execution phase, Detecting Early Signs and Sensemaking stages could be applied. Figure D.3 illustrates them and their consequences. It is noteworthy that these stages should be applied continuously throughout project implementation, for this scenario will be reported some cases that happened in the project Eagle.

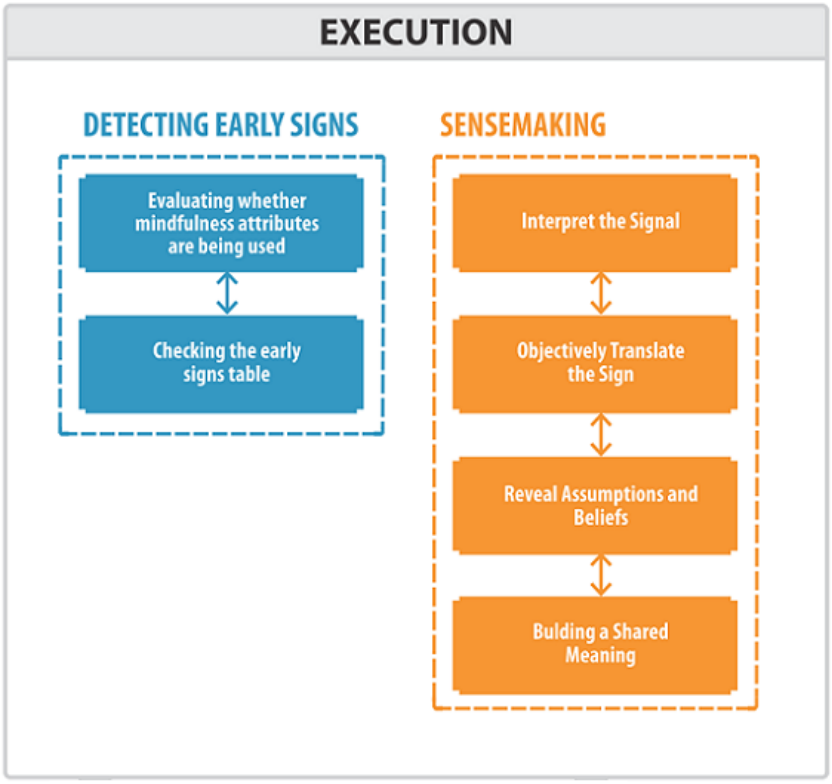

Figure D.3: Execution.
Source: the author

At the stage of **Detecting Early Signs** the first activity to be developed is **Evaluating whether mindfulness attributes are being used**, which unfolds in five sub-activities (analysis of failure concerns attribute, analysis of reluctance to simplify interpretations attribute, attribute sensitivity analysis of operations, analysis of commitment to resilience attribute, attribute analysis od skills cosiderations) that analyzes the attributes needed for full attention of the staff.

In this illustration in analysis, we assume that in the first 10 months of project occurs an evaluation of five attributes: failure concerns, reluctance to simplify interpretations, operations sensitivity, commitment to resilience and skills consideration.

Regarding the issues of **failure concerns**, Angelica could have used the questions presented in 7.1.3 section, that the more they are answered negatively, the higher they indicate the need to follow some recommendations. In the approach application, the number of questions 1, 3, 4, 5, 6, 7 and 9 would be answered negatively. Therefore, Angelica would need to follow the

recommendations prescribed in the approach in order to sensitize the team to the possibility of errors and create a learning culture in them.

In relation to questions 3, 5, 8, 9 of attribute **Reluctance to simplify interpretations**, they would be answered in the negative way, thus the manager would have to strengthen collaborative work and group cohesion so that team members trusted and respected each other.

For the attribute **operations sensitivity**, questions 4, 5, 6 would be answered negatively. Angelica would have to stimulate communication within the team; the members' critical sense and provide feedback to all members.

In addition, **commitment to resilience** would obtain 1, 3, 9 as negative responses. The manager should naturally show the team that unpleasant situations and uncertainty are part of the project; furthermore, she should believe and nurture the team skills to deal with difficult situations, adding emotional intelligence development in order to stimulate learning and calm maintainability in all situations, promoting the team's maturity.

Finally, to questions 2, 5 and 6 of the attribute **skills consideration** would be answered in a negative way. Angelica would have to stimulate creativity in the face of uncertainty and stimulate that a particular problem was forwarded to an expert as quickly as possible.

The second activity to be developed is **Checking the early signs table**. Angelica would have to evaluate the Table 7.3 in all project retrospective. For this illustration purposes, the signals detected in a retrospective will be used, which were:

1. **Gut feelings:** In every meeting with Rinaldo he demonstrated to be authoritarian and disrespectful to the team. It was clear the team's discontentment in the situation.

2. **Personnel:** Most team members were trying to achieve positive results, but it was noted the lack of interest of one of the team leaders, Paulo.

3. **Project Planning:** Despite the team advances,the planning was not reflecting their capacity for development.

4. **Communication:** Two team leaders always came to meetings without proper integration of activities;

Hereinafter, Angelica should have moved to the second stage called **sensemaking** as shown in Figure 7.12 and applied the four activities in the order of the signs presented:

1. **Interpret the signal:** Rinaldo is exceeding his power over the team; **Objectively translate the sign:** the client has become a threat to healthily conduct the project; **Reveal assumptions and beliefs:**To check if any belief deviates from what it seems, for example: to verify if any member thought Rinaldo wanted to abort the project, if in fact, it was happening; **building a shared meaning:**to outline actions to prevent the client interfered in the team;

2. **Interpret the signal:** Paulo is not developing well his activities; **Objectively translate the sign:** Paulo was not interested in the project; **Reveal assumptions and beliefs:** to check if any belief deviates from what it seems; for example: One may wonder if Paulo is going through a problem; **building a shared meaning:** If confirmed, it is necessary that someone is in charge of Paulo's activities;

3. **Interpret the signal:** Despite the team advances, she has been handing out the activities with recurrent delays due to bad planning; **Objectively translate the sign:** Schedule was poorly designed; **Reveal assumptions and beliefs:**to check if any belief deviates from what it seems, for example, one may wonder if the team is not interested; **building a shared meaning:** the schedule needs to be revised;

4. **Interpret the signal:** There is not a very good relationship between two project leaders; **Objectively translate the sign:** The bad relationship between the two leaders is impacting the project progress; **Reveal assumptions and beliefs:** to check if there is any belief that deviates from what it seems; for example, if there has been any problem between them; **building a shared meaning:** A conversation between manager and members should be carried out to understand what is happening, thus, try to establish a partnership in favour of the project;

Thus, the team should update the risks list based on the information collected during the previous stages of the approach's application.

D.2.3 Monitoring and Control

During the monitoring and control project phase, the stage 'responding to unexpected results' could be applied. Figure D.4 illustrates the stages and their implications.

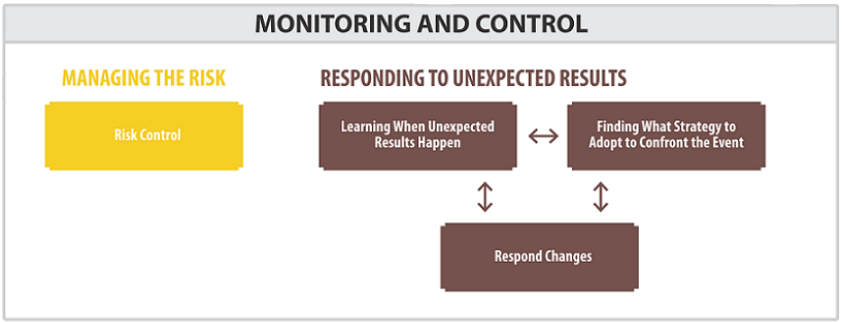

Figure D.4: Monitoring and Control.
Source: the author

To contextualize the future activities application, a fact that occurred in the 12th month of the project will be described: the team knew what should be done to get into step 1 of the product; the objective was known and the solution to which the team should get too; however,

in redoing the planning with the team, Angelica realized that to complete the project, they would need an additional 24 months of development and thus, she scheduled a conversation with John and Rinaldo to request a project extension as well as a financial reshuffling but they did not accept it and asked the team to focus on the set activities so that the delivery would be performed in the following 12 months, according to the term of commitment.

Considering the approach application, Angelica should respond to an unexpected result, since the clients favored adjustments in the schedule, early in the project. Firstly, Angelica should apply the activity **Finding what strategy to adopt to confront the event**, which could be adapted as shown in Figure 7.14 and then, she should have talked to the clients about a schedule adaptation so that in the following 12 months they achieved a common sense and did not extrapolated the deadline. Secondly, she should apply the activities **Learning when unexpected results happen** and **Ability to Respond to changes** so the team would answer to the changes and take as base the first year learning to carry out the following activities of the 12-month project.

D.3 Closing Remarks

For the Eagle project team the uncertainties were many, at first they did not know what the goal or the real solution were. The clients were used to work with innovative projects but created administrative bureaucracies during them. Angelica had managed projects, but not innovative ones. The various problems that happened in this project could have been solved on the perspective of project management considering uncertainties. If Angelica knew the approach, she could have practiced the stages, activities and suggested guidelines. With the approach application, initial uncertainties could have become known and the constant early signs monitoring and sensemaking would have helped the team to observe the invisible. However, it is highlighted that the approach application in the project could have changed its development and the evidence used in the illustration could be different.