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# A PROPOSAL FOR R&D PROJECT PORTFOLIO MANAGEMENT IN THE ELECTRIC POWER SECTOR

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Eduardo Kazumi Yamakawa

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Esta Tese foi julgada adequada para obtenção do Título de "Doutor em Engenharia de Produção" e aprovada em sua forma final pelo Programa de Pós-Graduação em Engenharia de Produção

Local, 03 de março de 2017.

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This work is dedicated to my wife, my children, my parents, friends, teachers and my classmates and work colleagues.

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"This path has one very distinct characteristic: it is not prefabricated. It doesn't already exist. The path that we're talking about is the moment-by-moment evolution of our experience, of the world of phenomena of our thoughts and emotions. When we realize that the path is the goal, there's a sense of workability. Everything that occurs in our confused mind we can regard as the path. Everything is workable."
(Pema Chödron, 2008)

## RESUMO

As empresas de energia elétrica brasileiras devem despender um percentual de sua receita operacional líquida (ROL) em projetos de pesquisa e desenvolvimento (P&D) por força da lei. Esses projetos ao final são auditados pela Agência Nacional de Energia Elétrica (ANEEL) para assegurar que os resultados esperados dos projetos sejam alcançados técnica e financeiramente e se os projetos não atendem aos critérios de avaliação da auditoria da ANEEL, as concessionárias podem ser penalizadas financeiramente através da glosa parcial ou total dos valores dos projetos, sendo que esta é uma grande preocupação das concessionárias que teve grande incidência de respostas em uma survey realizada com concessionárias de energia elétrica no Brasil. Para reduzir os riscos dos projetos e ter uma carteira de projetos otimizada alinhada à estratégia da empresa, as concessionárias de energia poderiam utilizar um processo de gerenciamento de portfólio de projetos (PPM). Porém, a teoria de como o gerenciamento de riscos é aplicado e como é integrado à PPM ainda é escassa, constatado a partir de busca na literatura. Nesse sentido, o objetivo desta tese foi desenvolver uma proposta de cálculo de riscos ordinais que não indicam valores absolutos de risco mas sim valores que podem ser comparados uns com os outros de modo a formar um ranking de riscos para projetos de P&D e realizar a otimização de portfolio, bem como comparar as propostas simuladas computacionalmente com os dados reais de concessionárias de energia elétrica brasileiras. Os métodos de pesquisa incluíram uma survey com empresas de energia elétrica, revisão da literatura, e o desenvolvimento de uma proposta de PPM em projetos de P&D. Por meio da proposta desenvolvida foi possível selecionar um portfolio de projetos ótimo com o maior alinhamento com a estratégia, menor risco de reprovação financeira e que utilizou um percentual máximo do orçamento disponível para projetos de P&D na empresa de energia elétrica estudada e as comparações das simulações computacionais com os resultados reais foram similares.Os resultados obtidos por este trabalho visam contribuir com a evolução da teoria sobre gestão de portfolio de projetos, auxiliando aplicações onde se faz necessário otimizações de portfolios de projeto com redução de riscos.



**Palavras-chave:** Gestão de portfólio de projetos. Otimização multiobjectivo. Concessionárias de energia elétrica.

## ABSTRACT

Brazilian power utilities must spend a percentage of their net operating revenue (NOR) on research and development (R&D) projects required by the law. These projects are ultimately audited by the Brazilian Electricity Regulatory Agency (ANEEL) to ensure that the expected results of the projects are technically and financially achieved and if the projects do not meet ANEEL's audit evaluation criteria, the concessionaires can be penalized financially through of the partial or total return of the project values, and this is a major concern of the power utilities that had a high incidence of responses in a survey conducted with electric power concessionaires in Brazil. To reduce project risks and have an optimized portfolio of projects aligned with the company's strategy, energy utilities could use a project portfolio management (PPM) process. Project portfolio risk management allows companies to manage them more effectively than if the risks of each project were managed individually. However, the theory of how risk management is applied and how it is integrated into PPM is still scarce, as evidenced by a search in the literature. In this sense, the objective of this thesis was to develop a proposal for calculation of ordinal risks that do not indicate absolute values of risk but rather values that can be compared with each other in order to form a ranking of risks for R&D projects and to perform the optimization of portfolio, as well as to compare the proposals simulated computationally with the actual data of Brazilian power utilities. The research methods included a context diagnosis, with data collected in ANEEL database and a survey with electric power companies, a literature review, and the development of a PPM proposal in R & D projects. By means of the developed proposal it was possible to select an optimal project portfolio with the best alignment with the strategy, lower risk of problems in the audit and that used a maximum percentage of the budget available for R&D projects in the power utility studied and the simulation comparisons The results obtained by this work aim to contribute to the evolution of the theory about project portfolio management, helping applications where it is necessary to optimize project portfolios with risk reduction.



**Keywords:** Project portfolio management. Multi-objective optimization. Electricity power utilities

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## LIST OF ABBREVIATIONS AND ACRONYMS

AHP - Analytic Hierarchy Process

ANP - Analytical Network Process

BSC - Balanced Scorecard

DEA - Data Envelopment Analysis

ELECTRE - Elimination and Choice Translating Reality

IRR - Internal Return Rate

MADM - Multi-Attribute Decision Making

MCDA - Multicriteria Decision Aid

MCDM - Multicriteria Decision Making

MAUA - Multi-Attribute Utility Analysis

MAUT - Multi-Attribute Utility Theory

NPD - New Product Development

NPV - Net Present Value

ODSS - Organizational Decision Support System

PMI - Project Management Institute

PPM - Project Portfolio Management

PROMTHEE - Preference Ranking Method for Enrichment Evaluation

R&D - Research and Development

ROA - Real Option Analysis

ROI - Return on Investment

VAR - Value at Risk

# GLOSSARY
## (Electricity Power Sector)

**ANEEL**

The Brazilian Electricity Regulatory Agency that has the mission to provide favorable conditions for the electric power market to develop a balance between the agents and the benefit of society.

**ANEEL AUDITING MANUAL**

The objective of the manual is to assist in evaluation processes of results obtained through the execution and inspection of each project. Furthermore, the manual defines the scope, terms and periods for the technical and accounting audit report for each cycle and program and the coverage of contracting costs that may be recognized as an investment made in the respective program.

**ANEEL R&D MANUAL**

The R&D manual contains the guidelines and procedures for filling out, submitting, analysing, approving, following-up, inspecting execution and finalizing R&D projects and programs. Step-by-step guides on how to use R&D program and project forms, as well as the on-line management system, are part of this manual.

**AUDITING**

An official inspection of the power utility´s R&D projects' technical and financial controls, typically by an independent body of specialized auditors.

**AUDITOR**

A person appointed and authorized to examine accounts and accounting records, analyse the generated products and the project team, compare the planned schedule with the held schedule and verify the scientific contributions and project originality.

**DISTRIBUTION POWER UTILITIES**

Power utilities responsible for the electric power distribution system that is the final stage in the delivery of electric power that carries electricity from the transmission systems to the final consumers.

## GENERATION POWER UTILITIES

Power utilities responsible for electric power generation from other sources of primary energy, such as water, gas, wind, steam, solar, nuclear, etc. The generation system is connected to the distribution system through the transmission system.

## MONEY DISALLOWANCE

When there is a problem in the ANEEL audit, and the project is totally or partially reproved, the total or partial amount of money that was invested in the project has to be returned to the R&D account corrected by the special system reference rate Settlement and Custody (SELIC).

## POWER UTILITY

A company that has the concession from the government to operate and commercializes electricity in a defined area.

## RESEARCH & DEVELOPMENT (R&D)

Research and development (R&D) comprise creative work undertaken on a systematic basis to increase the stock of knowledge, including the knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. The term R&D covers three activities, namely (OECD, 2002):

- **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
- **Applied research** is also original investigation undertaken to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.
- **Experimental development** is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems, and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in the R&D units and informal or occasional R&D in other units

**R&D PORTFOLIO CONTROL TEAM**

The multifunctional team that manages the portfolio of R&D projects of the company and analyse technical deliveries and performs the financial control of projects.

**R&D PROJECT MANAGER**

Responsible for the power utility for one or more projects in the company where he/she will inspect the technical deliveries and make the financial control and approval of projects' expenses.

**R&D PROJECT COORDINATOR**

Responsible in the technology institute or the university for the development of R&D projects, and he/she will ensure the technical deliveries, write the technical reports and make the financial control.

**R&D PROJECT SELECTION COMMITTEE**

Committee of technical experts who analyse and select the R&D projects that will compose the power utility´s R & D project portfolio.

**TRANSMISSION POWER UTILITIES**

Power utilities responsible for the electric power transmission system that is used to transfer electrical energy from generating power plants to the electric power distribution system.

**SUMÁRIO**

# 1 INTRODUCTION

Project portfolio management (PPM) is an emerging aspect of business management that focuses on how projects are selected, prioritized, integrated, managed and controlled in the multi-project context that exists in modern organizations (Young and Conboy, 2013). By managing projects from a portfolio level, PPM aims to improve the performance of the project portfolio as a whole (Killen, 2013). Having a good PPM to handle many simultaneous projects is becoming a key competence to implement their strategies and keep the competitiveness (Dietrich and Lehtonen, 2005; Killen et al., 2008; Martinsuo and Lehtonen, 2007). PPM is an essential part of the operational planning process for both private and public organizations (Solak et al., 2010). The success of portfolio management is dependent on the context (Martinsuo, 2013); therefore, PPM needs to be applied appropriately to each situation. In addition, successful PPM depends on an organization's structural alignment with the needs of PPM (Kaiser; El Arbi; Ahlemann, 2015).

The strategic fit can be defined as the degree to which the objectives and demands of a portfolio's projects are aligned with the objectives and demands of the organizational strategy (Unger et al., 2012). The alignment of project objectives, and the alignment of project demands, such as resources that are allocated across a portfolio such that the most effective resources are provided to those projects with the highest strategic relevance (Dietrich and Lehtonen, 2005; Meskendahl, 2010 ).

Despite the advancement in project management processes and tools, project management remains a highly problematical endeavour (Fernandes et al., 2014). In fact, project failures are still a common phenomenon, especially in R&D or new product development portfolios or in dynamic and complex environments (Ekrot et al., 2016). Portfolio success can be defined as (1) the project success over all projects considering the constraints of time, budget, scope, plus customer satisfaction (Cooper et al., 2001); (2) the exploitation of synergies between projects within the portfolio that might additionally increase the overall portfolio value (Cooper et al., 2001); (3) the portfolio fit to a company's business strategy (Cooper et al., 2001) and (4) the portfolio balance in terms of as risk, area of application and use of technology (Elonen and Artto, 2003; Martinsuo and Lehtonen, 2007). A risk management approach for project portfolio regards alignment and redistribution of resources among the projects and considers additional portfolio risks. Then, portfolio risk management can be used to improve

the transparency, the revelation of problems transferences (Sanchez et al., 2008). Risk management can significantly improve the success of research and development projects (Salomo et al., 2010; Wang et al., 2010). A portfolio-wide approach facilitates the adjustment and allocation of resources among the projects and allows the consideration of additional risks of the portfolio and interdependencies between risks. Thus, portfolio-wide risk management encompasses risk management at the project and portfolio levels (Teller, 2013). A broad project portfolio and business-oriented risk management perspective that can manage individual project risks is observed in the literature (Artto et al., 2000). Project portfolio risk management can enable companies to manage risks in a better way than would be possible if project risks were managed independently from each other (Aritua et al., 2009; De Reyck, et al., 2005). Thus, portfolio risk management can avoid failures and improve the possibility of the project portfolio success (De Reyck et al., 2005; McFarlan, 1981).

Portfolio techniques are powerful tools that allow products and R&D projects to be analyzed in a systematic manner, providing an opportunity for the optimization of a company's long-term growth and profitability (Mikkola, 2001). Business strategy describes the way in which a firm decides to compete in the market compared to its competitors (Varadarajan and Clark, 1994; Walker and Ruekert, 1987). It is more difficult to make strategy work than to make strategy (Hrebiniak, 2006). In this issue the project portfolio management can be applied. Projects and especially project portfolios are very importante in implementing the intended strategy (Dietrich and Lehtonen, 2005; Grundy, 2000; Shenhar et al., 2001). There are a few studies exploring single aspects of the linkage between strategy, project portfolio management, and business success (Meskendahl, 2010). The objectives of project portfolio management are: maximization of the financial value of the portfolio, linking the portfolio to the firm's strategy, and balancing the projects within the portfolio in consideration of the firm's capacities (Cooper et al., 2002). The strategic fit of the project portfolio describes the degree to which the sum of all projects reflects the business strategy. Even the acceptance of strategic fit be one of the major objectives of portfolio management, the literature on it is limited (Srivannaboon and Milosevic, 2006). Companies with a efficient project portfolio management achieve a higher level of strategic alignment (Coulon et al., 2009). Project portfolio management has to achieve an optimal alignment

of projects to each other and should pursue projects that are in line with the business strategy (Meskendahl, 2010).

## 1.1 Research opportunities and research question

From the content analysis of the articles set the most useful opportunities were identified and they are presented at the Table 1.1.

Table 1.1 – Research opportunities from the literature

| Refe-rence | Research Opportunity | Notes |
|---|---|---|
| Bhatta-charyy a et al. (2011) | Develop a project selection method using optimization techniques to solve the problem for the large amount of data. | Used in this work because the analysed amount of data was large and an optimization technique (Particle Swarm Optimization) was used. |
| Daim et al. (2013) | Develop methods for electric utilities to manage the renewal of the portfolio of R&D projects | Used in this work to verify through a survey if the electric utilities in Brazil already had methods to manage the renewal of their R&D project portfolio. |
| Hynuk et al. (2009) | Inclusion of tools and techniques to integrate an assessment of the risk management process by providing a perception of risk | Used by considering the ordinal risk to have a project ranking regarding the risk of the projects being reproved at the ANEEL audit. |
| Smith-Pereira et al. (2010) | Application of a tool developed for other types of analysis in the portfolio management in addition to the project selection for the portfolio | Used the ordinal risk ranking through a MCDA analysis as an additional tool to the project selection |
| Solak et al. (2010) | Integrate the risk of selection projects for the portfolio considering risks associated with | Used to integrate the criteria to calculate the ordinal risk of problems in the ANEEL audit and elaborate a ranking based on these ordinal risks for each |

| | | |
|---|---|---|
| | investment decisions by introducing other features aiming to capture risks | project to support the project selection |

All the presented research opportunities in Table 1.1 were used in the development of this work to support the choice of an optimization technique to solve problems with large amounts of data (PSO), to assess the process management risk, to use another type of analysis in portfolio management in addition to the project selection (risk analysis) and to integrate the risk of selection projects for a portfolio using a multicriteria proposal to calculate the ordinal risk of each.

The energy sector have one of the highest quantities of articles regarding PPM show the importance of this sector for the economy and research, and even having already some articles published there are still some opportunities that were not addressed by the articles in the articles set. In the analised articles regarding the energy sector there was no previous study has investigated the electric power utilities are starting to use PPM for R&D projects, and this lack of studies for the sector may be valuable for analysis concerning PPM improvement and the effectiveness of the project portfolio. The presence of a large degree of uncertainty leads to high R&D risks, resulting in many R&D failures. Therefore, it is important to manage R&D risks through all R&D stages to improve R&D project success rates and the major purpose of risk management is to increase success rate of an R&D project (and portfolio), which will lead to corporate success (Wang et al., 2010). In project management, there is no consistent definition for risk (Perminova et al., 2008). In the project management body of knowledge (Project Management Institute, 2013), risk is considered as ‘‘an uncertain event or condition that, if it occurs, has a positive (opportunity) or negative (threat) impact on project objectives such as time, cost, scope or quality.’’ However, many practitioners and researchers in project management still consider risk to be more related to adverse effects on project performance (Smith and Merritt, 2002; Ward and Chapman, 2003). Research on risk management in the context of project portfolios is scarce, there is limited research investigating how formal risk management at the project level interacts with the integration of risk information at the portfolio level and how this interaction affects project portfolio success (Teller et al., 2014).

By considering an additional and/or alternative decision criteria, a portfolio that is dominated with respect to some criteria may make up for the deficit in these criteria by a very good performance in one or

several other criteria and thus be non-dominated in a multicriteria setting. Moreover, the analysts may have differences in their perception of the relative importance of different attributes. As a result, a multicriteria model based on more than two objective functions allows for a higher flexibility in modeling the objectives of companies, and, combined with an appropriate utility approach, is likely to lead to better representations of their preferences (Ehrgott et al., 2004).

The multiobjective optimization (MO) is the problem of simultaneously optimizing two or more conflicting objectives subject to certain constraints and many real-world problems involve simultaneous optimization of several conflicting objectives and the portfolio optimization problem is an example of this category of problem (Metaxiotis and Liagkouras, 2012). The evolutionary algorithms (EAs) became one method of choice for optimization problems that are very complex to be solved using deterministic techniques. The EAs are well suited to multiobjective optimization problems (MOP) as they are inspired by the biological processes which are always multiobjective (Metaxiotis and Liagkouras, 2012). Generally, the various objectives functions in the portfolio selection problem are in conflict with each other, every time that it is necessary to optimize more an objective the other objectives may have problems as a result. Therefore, the objective in multiobjective optimization of evolutionary algorithms (MOEAs) is to find the Pareto front of efficient solutions that provide a trade-off between the various objectives (Metaxiotis and Liagkouras, 2012).

A comparative study was performed using genetic algorithm (GA), memetic algorithms (MA), particle swarm optimization (PSO), ant colony optimization (ACO), and shuffled frog leaping (SFL). Two benchmark continuous optimization test problems were solved using all algorithms. The PSO method was generally found to perform better than other algorithms in terms of success rate and solution quality, while being second best in terms of processing time (Elbeltagi et al., 2005). For this reason the PSO was used in this study for the project portfolio optimization proposal. In Brazil, the electrical power utilities of generation, transmission and distribution sub-sectors must invest a percentage of their net operational income (NOI) in annual R&D projects, and national law 9.991/2000 regulates this. They also must ensure that the projects meet the guidelines set by the regulating body, the Brazilian Electricity Regulatory Agency (ANEEL). The R&D projects are contracted by the power utilities and when these projects are finalized, they are audited by ANEEL. If the projects do not meet the guidelines,

financial penalties apply; therefore, it is important to reduce the risk of noncompliance, and PPM practices can be significantly valuable in this context. The Brazilian R&D program in the power utilities offers a valuable context for investigating how project portfolios should be managed to help the R&D projects to meet the guidelines by reducing the risk of noncompliance and consequently have some penalties. This context was then chosen for analysis. In the next section, the research opportunities are presented.

The PPM has been discussed by many researchers for more than 40 years (Supachart et al., 2008). The PPM has largely developed around the elements (or components): providing a centralised view of all the projects in an organisation, enabling a financial and risk analysis of projects, modelling interdependencies between a family of projects, incorporating constraints on resources shared between projects, enabling prioritisation and selection of projects, ensuring accountability and governance at the portfolio level, allowing for portfolio optimisation and providing support in the form of standardised processes and software tools (De Reyck et al., 2005). However, despite the relatively extensive literature on PPM, evidence of its value has been unclear whether there are specific PPM elements that add more value than others or indeed, whether they add value at all (De Reyck et al., 2005). Portfolio management can be understood as a set of processes, but there is still a lack of consensus on what are the core processes of PPM are (Padovani and Carvalho, 2016). Analyzing the literature, for this work the first research opportunity to be developed was to determine the main PPM elements or components and develop a proposal to use these components in a process that can be useful for the R&D projects' portfolio management for power utilities in Brazil.

Risk management is a structured process for assessing and analyzing portfolio risks with the objective of capitalizing on the potential opportunities and mitigating those events, activities, or circumstances that can impact the portfolio. Risk management identifies and explores the potential improvements in portfolio component performance that may increase quality, customer satisfaction, service levels, and productivity for both the portfolio components and the organization. Risk management may generate new portfolio components as well. The objective of portfolio risk management is to accept the right amount of risk commensurate with the anticipated reward to deliver the optimum outcomes for the organization in the short, medium, and longer term. Portfolio Risk Management includes providing reserves (or

contingencies) across the threat pool within the component programs and projects (Project Management Institute, 2013). The PPM can also be considered the management of resources and other constraints, the coordination of the collection of projects and the management of interfaces among projects (Elonen and Artto, 2003; Olsson, 2008). A broad project portfolio and business-oriented risk management perspective that can manage individual project risks is observed in the literature (Artto et al., 2000). Project portfolio risk management enables companies to manage risks in a better way than would be possible if project risks were managed independently from each other (Aritua et al., 2009; De Reyck, et al., 2005). Nevertheless, theoretical research on how risk management is applied to and how to integrate it with PPM is scarce (Sanchez et al., 2008; Teller and Kock, 2013). From the analysis of the literature and the arguments presented, the second research opportunity was to determine how to calculate an ordinal risk and create a ranking of projects ordinated by risk to figure what are the project with more potential risk and try to reduce the project portfolio risks in the project selection. This opportunity was developed for power utilities because the criteria used for the calculation regarded the risks of having problems in ANEEL audit.

The R&D program of ANEEL during its first phase from 1999 to 2007 allocated approximately R$ 1.65 billion[1] to approximately 3,000 projects, which means an average of R$ 550,000[2] per project. From 2008 to 2015, the total of 1,660 new projects received an investment of approximately R$ 4.6 billion[3], which means an average of R$ 2.77 million[4] per project (ANEEL, 2015). As the average value per project is a significant financial value, if the power utilities have their projects reproved totally or partially in the ANEEL audit, they will experience financial loss. Therefore, the third research opportunity was to develop a proposal that optimize three objectives that are to minimize the risk of failure in PPM by having the projects with smallest risks in the portfolio,

[1] Equivalent to about US$ 507 million (US dollar rate from December, 2016: R$1 = US$ 0,31).

[2] Equivalent to about US$ 169 thousand (US dollar rate from December, 2016: R$1 = US$ 0,31).

[3] Equivalent to about US$ 1.4 billion (US dollar rate from December, 2016: R$1 = US$ 0,31).

[4] Equivalent to about US$ 851 thousand (US dollar rate from December, 2016: R$1 = US$ 0,31).

maximize the budget spent on R&D projects and maximize the adherence to company´s strategy.

From the previous research opportunities, the research question "how to reduce risk and at the same time optimize the project selection in PPM?" emerges.

The objectives of this thesis are presented in the next section.

## 1.2 Research objectives

The general objective of this work was to develop a proposal using the main PPM components to optimize the project portfolio, regarding ordinal risk, strategy alignment for each project and the project portfolio budget and assess the results of the computational simulations of the developed proposals, comparing these results with the actual data from the R&D projects from the Brazilian power utilities.

### 1.2.1 Specific objectives

The general objective of this work can be achieved through the following specific objectives:

a) Determine the main PPM components from the literature analysis.
b) Investigate the existence of PPM in Brazilian electric power utilities and other aspects of its application through an exploratory survey.
c) Develop a proposal for ordinal risk calculation for the R&D projects and assess this proposal.
d) Develop a proposal to select the optimal portfolio of R&D projects and evaluate this proposal.

## 1.3 Thesis structure

Besides this introduction that presents the context, the research opportunities and objectives of this study, this text contains five chapters. Chapter 2 presents the research design for this work. It presents research methods for the context diagnostics, where data on R&D projects were collected from the ANEEL database and a survey conducted with electric power utilities. This chapter also describes the literature analysis regarding bibliometry and content analysis, as well as the identification of research opportunities from the literature. Then, research methods and techniques to develop the portfolio management proposal for R&D projects are outlined.

Chapter 3 provides the theoretical basis for this research presenting the existing PPM process components from the literature, including research opportunities. It also describes the theory used to support this thesis, e.g. the power utilities' PPM processes described in the literature and a generalization of their processes in a single process, the multicriteria decision aid (MCDA) theory, a brief explanation of particle swarm optimization (PSO) and the PSO algorithm that was used.

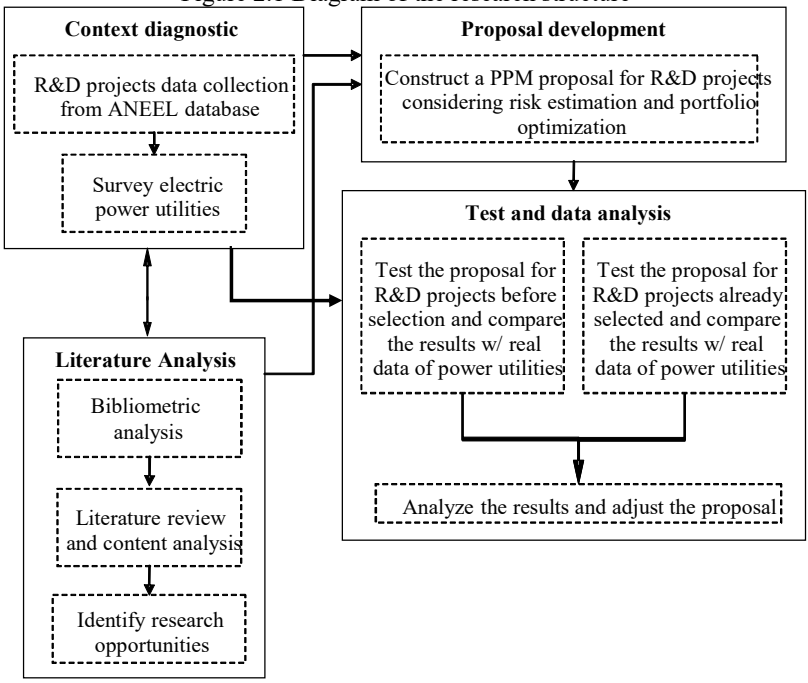
Chapter 4 presents and discusses the results, including: (i) an exploratory survey carried out in the electric power utilities in Brazil, (ii) a proposal for portfolio risk reduction, (iii) a proposed PPM process for R&D for power utilities, (iv) the results of computational simulations using the proposed models and actual data and (v) the results from computer simulations using the developed proposal employing real data.

Chapter 5 establishes the conclusion of this work, its limitations and recommendations for future research.

# 2 RESEARCH DESIGN

This section describes the design of this research and methods used to develop this work. It is divided into a literature analysis, context diagnostics, proposal development, test and data analysis. This chapter also describes how the proposal for risk reduction and portfolio optimization for PPM were developed and details of the steps as well as adopted methods, such as multi-criteria decision and multi-objective optimization. A research diagram is presented in Figure 2.1. The explanations of each element of the search structure are presented in the following sections.

Figure 2.1 Diagram of the research structure




## 2.1 Context diagnostics

This section is composed of the R&D projects' data collection from the ANEEL database in addition to a survey with electric power utilities.

### 2.1.1 R&D projects' data collection from the ANEEL database

As mentioned in the Introduction, the Brazilian scenario for R&D projects for the power industry is regulated by the National Electric Energy Agency. The electric utilities are required to invest a percentage of their net operating income (NOI) by Law 9,991/2000. The data collection will be concentrated in the documentation composed by Laws about R&D projects and manuals for R&D projects development and audit. The criteria about risk will be based on the audit criteria because the risk that is considered in this study is the risk of having problems in the audit.

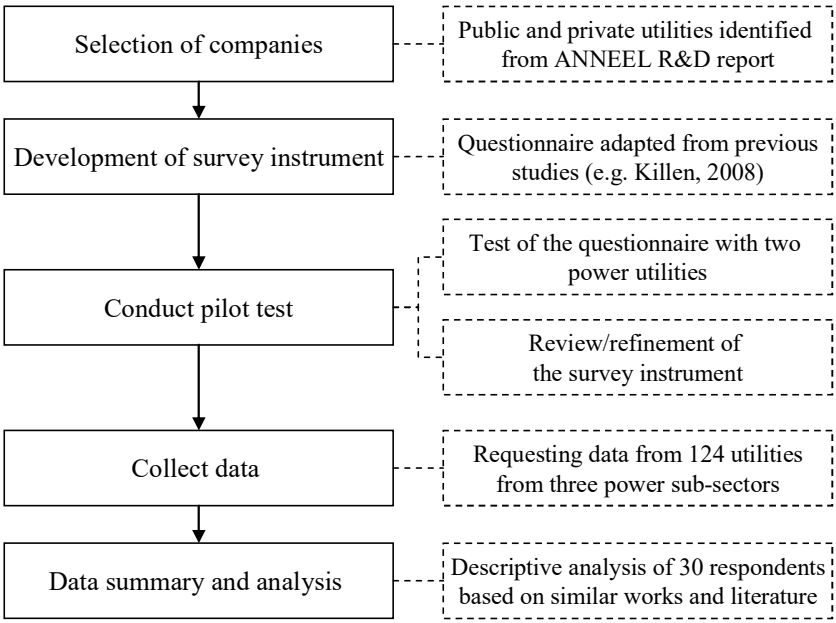
The next section presents the survey methods to diagnose the PPM of electric power utilities.

### 2.1.2 Survey with electric power utilities

By considering the research gaps in the literature presented in Table 1.1 (e.g. Daim et al., 2013), the following opportunity emerged: to assess whether the Brazilian power utilities have been using PPM to reduce risks when planning and conducting R&D projects. Thus, an exploratory survey was carried out based on Forza (2002). For this kind of survey (exploratory), research hypotheses are not required, the sample selection criteria are approximate, the sample size should be sufficient to include a range of the phenomenon of interest, a pre-test can be performed with part of the sample and there is no minimum value for the response rate (Forza, 2002).

A survey instrument was constructed based on Killen (2008c). This survey instrument proposal was considered suitable and was thus adapted for R&D projects, as the original work was designed for companies dealing with new product development. The survey instrument was implemented in Google Drive platform, and respondents could answer through an electronic form (see Appendix 1). Figure 2.2 shows the survey process.

Figure 2.2 Process for carrying out the survey with power utilities in Brazil.




A survey request was sent by email to the person responsible for managing the R&D portfolio for power utilities. The received responses were analysed so that the results could show a general scenario of how the PPM is dealt with in the power utilities; this included the importance given to PPM by utility senior management, whether a formal portfolio process was in place, which kinds of methods of project portfolios the companies used, the difficulties experienced by R&D portfolio managers, etc.

In addition, data on R&D projects was obtained through the ANEEL database (website). Examples of collected information from power utilities were the estimated total cost of the project (before the project execution), the actual total cost of the project, the expected and actual duration of the project, the adequacy of the scope run against the planned scope, products/deliverables obtained from the projects, etc. This information about the developed projects under the ANEEL R&D program could help to verify whether the final results obtained regarding cost, schedule, scope and products were compatible with the expected cost, schedule, scope and products described in the project's contracts by

power utilities. An audit manual for R&D projects (2013 version) was also retrieved from ANEEL to obtain the assessment guidelines.

One hundred twenty-four companies that were conducting or have conducted R&D projects in the past were then targeted. These companies fit within three electric power sub-sectors: 50 from the power distribution, 47 from the power generation and 27 from the power transmission sub-sector. A pilot test of the questionnaire was conducted with two utilities: one with considerable experience in PPM and another one with no established PPM process. The goal of the pilot test was to check the questionnaire for both form and content to enhance it according to the respondent's comments.

The questionnaire was revised, and a final version was then sent by email to all selected power utility companies. An explanation of the research objectives was also provided to the target respondents. The instrument was available to be completed online for up to four weeks. After the second and fourth weeks, emails and telephone contacts were conducted to follow up with the remaining non-respondents in an attempt to increase the response rate. Data were then analysed using descriptive statistical measures.

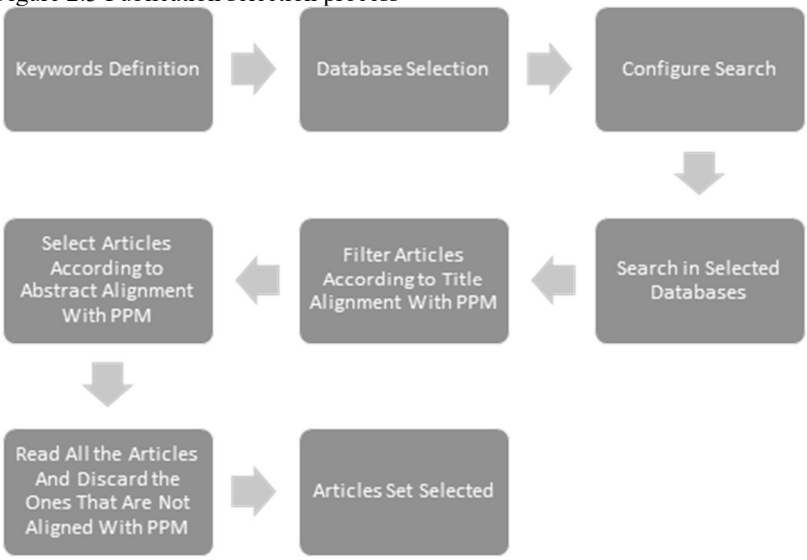
## 2.2 Literature analysis

This section consists of research methods applied to the literature review, including a bibliometry, content analysis, and the identification of research opportunities.

### 2.2.1 Bibliometry

Figure 2.3 shows a diagram of the publication selection process.

Figure 2.3 Publication selection process




To conduct the bibliometry, a search was performed through the portal of the Coordination for the Improvement of Higher Education (CAPES). The accessed databases were the Institute of Electrical and Electronic Engineers (IEEE), ScienceDirect, Scopus, SciELO, ISI Web of Knowledge, Emerald and Google Scholar. Initially, the search was performed using the keyword combination "Project+Portfolio+Management" and its corresponding acronym PPM. This search returned 188 selected articles. Other keywords were identified based on the articles returned from the previous search, such as "R&D+Portfolio", "Innovation+Portfolio", "NPD+Portfolio", "Multi-project+management", "Project+portfolio+selection" and "Project+portfolio+ranking." Thus, they were used for another search.

Initially (in July 2014), no time frame was used in the articles search and 4080 articles were identified. After discarding the duplicates and reading the titles, abstracts and keywords, 285 articles aligned to the research subject (PPM) were obtained. Later, in April 2015, at this time also no time frame used in the articles search, and 17 articles were added to the set, resulting in 302 articles that were read in full and the main information of these articles were registered in a spreadsheet. The software used to organize the publications was EndNote 5.

The set of articles was reviewed considering the PPM components (i.e. elements that are part of the portfolio management, such as project selection, portfolio optimization, etc.). The PPM components may also be known as bundles. Those components have been addressed in the PPM literature (e.g. Archer and Ghasemzadeh, 1999; Amaral and Araújo, 2009; Carvalho et al., 2013; Padovani and Carvalho, 2016). The term "components" was based on the work of Levine (2005). Details of the bibliometric results are shown in Appendix 2.

### 2.2.2 Literature review and content analysis

Content analysis was applied to analyse the publications. It is a research technique for a systematic, qualitative and quantitative description of the literature content in a given area (Harkonen et al., 2015). Structural dimensions and analytic categories for material classification were defined deductively, as suggested by Mayring (2003). As mentioned before, the literature was analysed considering the PPM components. The components were identified by reading the article portfolio to identify the patterns in the PPM content.

### 2.2.3 Identify research opportunities

Research opportunities were identified from reading articles with a detailed analysis of the contributions and the further research suggestions of each article, the methodological and/or application limitations of the articles were identified, and from these limitations the research opportunities were selected, highlighted and used in this work. .

## 2.3 Proposal development

The development of this proposal is described next.

### 2.3.1 Development of the proposal for R&D projects before selection

Projects before selection are projects that were not evaluated by the power utilities' specialist[5] committee; thus, these projects do not compose the R&D project portfolio yet. The first part of this proposal is

[5] The profile of the specialist committee includes the following: (i) they manage R&D projects; (ii) they understand the power utility´s necessities and strategy; (iii) they have technical background and (iv) in many cases have master´s and doctoral degrees in technical subjects.

a ordinal risk calculation stage, where the ordinal risks are calculated for each project and in this case the risks are called relative because they are calculated using the same method and criteria the risks will have values that will be compared between them to have a project ranking regarding these calculated ordinal risksThe proposal will use some multicriteria decision aid method to calculate the ordinal risk based on the ANEEL audit manual (2013) criteria was used.

After the ordinal risk calculation of the financial disallowance of the project is assessed for each project, its alignment with the power utility´s strategy classification is presented in Table 2.1. There is a five-level scale, starting at level 1 that is equivalent to "not aligned with the power utility´s strategy and ending at level 9, which means "fully aligned" with the power utility´s strategy.

Table 2.1 Alignment with the power utility´s strategy and correspondent levels

| **Strategy´s Alignment Level** | **Description** |
|---|---|
| 1 | not aligned with the power utility´s strategy |
| 3 | slightly aligned with the power utility´s strategy |
| 5 | moderately aligned with the power utility´s strategy |
| 7 | strongly aligned with the power utility´s strategy |
| 9 | fully aligned with the power utility´s strategy |

The levels of the project´s alignment with the company´s strategy and descriptions are presented Table 2.2, and these levels of alignment with the company´s strategy were obtained from discussions with customers and with power utility consultants who perform audits for ANEEL. If the project does not have any connection with to the strategy of the power utility, it is assigned to level 1. If the project has a slight connection with the strategy, but its implementation will have no impact on the results of the power utility, it is assigned to level 3. If the project has a slight connection with the power utility strategy and its implementation will have a small impact on the results of the company, it belongs to level 5. If the project has a connection with parts of the power utility strategy and its implementation will have a great impact in implementing the strategy for the company, it is assigned to level 7. If the

project has a strong connection to important parts of the power utility strategy and execution is key to the strategy, it belongs to level 9.

The project portfolio options are generated from the combination of the candidate projects. The project portfolio's budget restriction means that the sum of the project costs in the portfolio cannot exceed the available budget of the power utility for R&D projects. The ideal condition for the power utilities is that all the available budget for R&D projects is spent on the R&D projects in the current cycle. If the entire budget is not spent, the residual value of the budget is corrected by SELIC and returned to the R&D account to be spent in the next cycle.

The next step is to determine the optimal portfolio using PSO for the multi-objective optimization simulation, which was performed using Matlab® software according to three optimization objectives, which are:

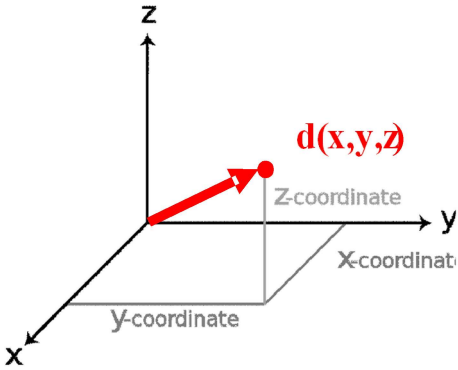
1- to minimize the project portfolio risk;

2- to maximize the alignment to the company's strategy;

3- minimize the amount of the difference between the budget for R&D projects defined by law and the whole cost of the project portfolio.

The optimal portfolio will be the one with the smallest Euclidean distance from the theoretical optimum given by normalized coordinates where the risk of the disallowance of the projects is zero, the difference between the budget for R&D projects defined by law and the whole cost of the project portfolio added is zero and alignment with the strategy is maximum, where in this case the project portfolio cost was used an inverted scale for the maximum alignment with strategy be coincident with the coordinate zero. The Figure 2.4 illustrates an example of optimal portfolio obtained from the optimization using PSO.

Figure 2.4 Euclidian distance in a three-dimensional system.



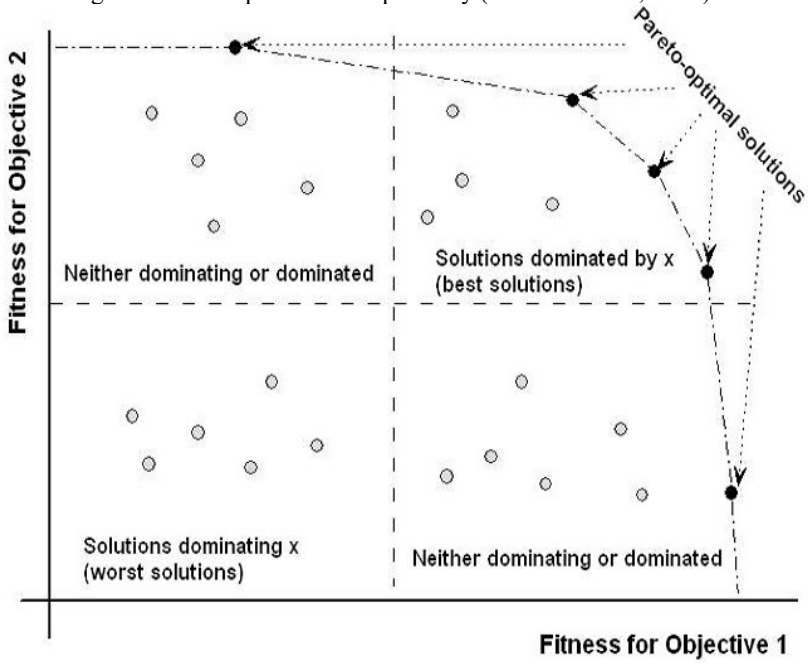
Equation 1 shows the Euclidian distance formula for a three-dimensional system:

$$d(x, y, z) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

Where x is the x-axis coordinate, y is the y-axis coordinate, z is the z-axis coordinate and d represents the Euclidean distance in a three-dimensional system (x,y,z).

The project portfolio data provided by the power utilities were entered into the developed computational tool for simulation. The potential projects ordinal risks were calculated using the MCDA system that is explained in section 3.8 and the financial cost for the project disallowance would cause after the audit to the power utility was used in the multi-objective optimization technique PSO that is explained in Appendix 5 and had been prepared various portfolio options combining the projects and conducted an analysis of the Pareto frontier that are necessary to obtain the conditions best compromise between risk and financial cost. The portfolio with the best compromise is the optimal portfolio under the analysis point of view. This portfolio optimization can be used by utilities to support the decision when there is a need to reduce a number of projects in the portfolio in the development and project selection stage when projects are evaluated and selected to integrate the project portfolio of power utilities. An example with the optimal solutions for a model showing the Pareto optimality concept is shown in Figure 2.5.

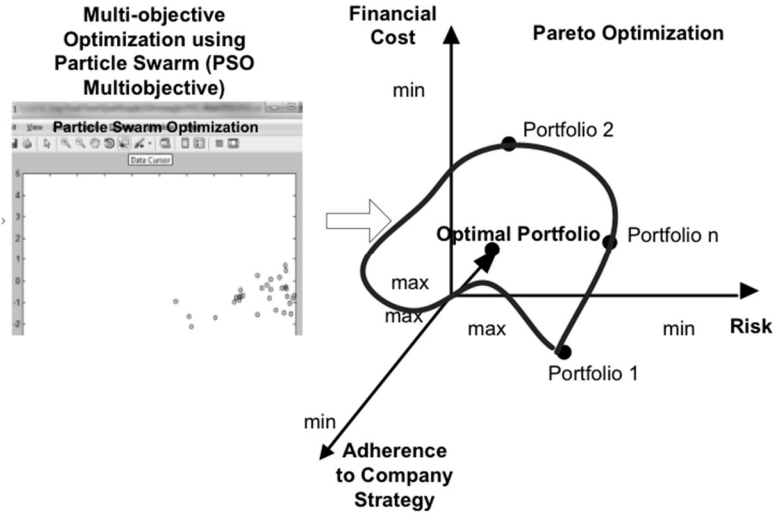
Figure 2.5 Concept of Pareto optimality (Abraham et al., 2004).




It is possible to observe in Figure 2.5 that a solution can be better, worse or indifferent to other solutions (neither dominating or dominated) on the objective values. The best solution means a solution that is not worst in meeting any of the objectives and at least better in meeting one objective than the other. An optimal solution is a solution that is not dominated by any other solution in the search space. Such an optimal solution is called the Pareto optimal, and the entire set of such optimal trade-off solutions is called the Pareto optimal set (Abraham et al., 2004).

Two risk ordinal calculation proposals were developed for risk reduction and the optimization of PPM. These two proposals were implemented in a computational tool using Matlab®, which allows the ordinal risk calculation for each project.

Figure 2.6 Optimal portfolio from multi-objective optimization using PSO.




The optimal portfolio is calculated as the Euclidean distance between the theoretical optimum point (0, 0, 0) and the closest portfolio distance to this point. The portfolio whose Euclidean distance is the smallest about the optimal point is pointed with an arrow. In this work, the optimum point is the point where the project alignment to strategy is maximized, but to illustrate the results, this function is represented as an inverse function or 1/alignment is minimized (or zero), the calculated ordinal risk is minimum (or zero) and the cost of the portfolio minus the available budget is minimum (or zero).

Equation 2 - normalization of ordinal risk calculated values:

$$\left(Z_i^k\right)_N = \frac{Z_i^k - Z_{min}^k}{Z_{max}^k - Z_{min}^k}$$

Where:

$\left(Z_i^k\right)_N$ is the n[th] normalized data

$Z_{min}^k$ is the minimum value for the variable Z

$Z_{max}^k$ is the maximum value for the variable Z

## 2.4 Test and data analysis

The test of the proposals for R&D projects before and after selection is presented in the following sections.

### 2.4.1 Test of the proposal for R&D projects before selection by the specialist committee of the power utilities

The test and data analysis regarding the projects before selection by the specialist committee in the power utilities used actual projects' data from the same power utility to compare with the data generated by computational simulations of the proposal for R&D projects before selection. These projects have already been evaluated by an evaluation commission of the power utility, and the results from this evaluation were compared to those generated by the developed proposal computational simulation.

### 2.4.2 Test of the proposal for R&D projects already selected by the specialist committee of the power utilities

For the projects already selected by the specialist committee in the power utilities, the computational simulations used data from R&D projects that were already finished and that had passed the audit by ANEEL. The objective was to compare the likelihood of the calculated ordinal risk of disallowance calculated by the proposal and the value of real disallowance applied by ANEEL.

This section described the design of this research and the methods used to develop this work. It was divided into the literature analysis, context diagnostics, proposal development, test and data analysis and described how the proposal for risk reduction and the portfolio optimization for PPM were developed. The next section describes the results of the literature analysis, the findings of the content analysis, the main PPM components and the methods to support the decision of PPM components as well as an overview of power utilities' PPM processes described in the literature.

# 3 THEORETICAL BASIS

This chapter presents the results of the literature analysis, starting from the main results from the bibliometry. This is followed by the findings of the content analysis in which the main PPM components are presented. In addition, this chapter describes the methods to support the decision of PPM components as well as an overview of power utilities' PPM processes described in the literature.

## 3.1Bibliometry

The most relevant results of the bibliometry are presented in this section. The full results are presented in Appendix 2. The main findings were as follows:

- The top three industrial sectors where portfolios are applied are the pharmaceutical, followed by the energy sector and information and software technology sector, that are sectors with high investments in R&D.
- Ghasemzadeh Archer (1999) and Cooper, Edget et al. (1999) are the publications with the highest numbers of citations in the literature, with 46 and 34 citations, respectively.
- The PPM publications regarding R&D projects from the 1960s and 1970s to the 2000s had an increase in the number of publications. For new product development (NPD) projects, publications began in the 1980s and grew until the 2000s. Innovation project publications began in the 1990s and had a growing period, and then from 2000 to 2015 published more articles than in previous decades, what shows a growing interest and research in PPM for R&D, NPD and innovation. The PPM publications investigating financial evaluation methods started from 1980s and to the 2015 had an increase the number of publications. The Valuation method had the highest number of articles, specially in the 2000s. The DEA (Data Envelopment Analysis), and the investment evaluation methods (NPV, IIR, ROI) had the second highest number of articles specially from 2010 until 2015.. There were also the financial evaluation methods ROA (Real Option Analysis), Markowitz efficiency frontier, Value creation model, BSC (Balanced Scorecard) and VAR (Value at Risk). The financial evaluation methods are important tools for the companies to select projects and assess the project portfolios performance. If the project does not have a clear financial return it probably will not be selected for the portfolio and if the

financial performance of the project portfolio is not good, the worse projects should be cancelled and better projects should be selected.

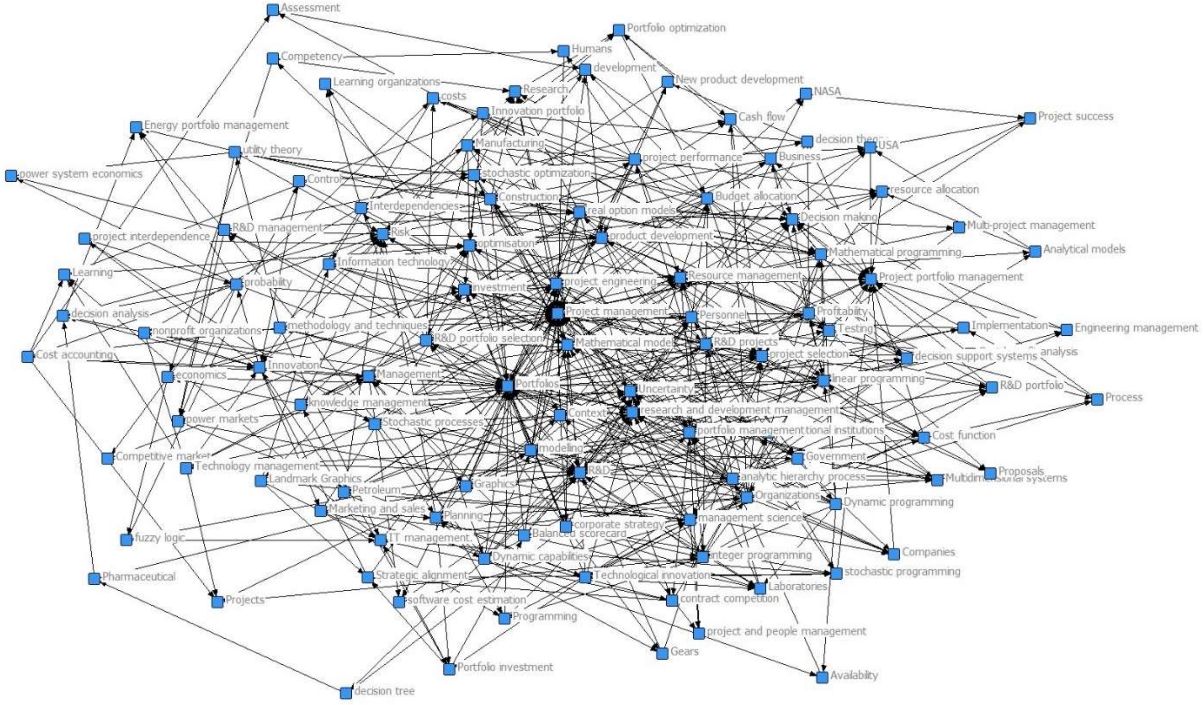
- The methods for decision support applied to PPM with higher occurrence in the article portfolio are the analytic hierarchy process (AHP), multicriteria decision making (MCDM), bubble diagram, organizational decision support system (ODSS), MCDA, analytical network process (ANP), multi attribute decision making (MADM) and multi attribute utility analysis (MAUA). As there are many criteria to select projects and manage the project portfolio, the multiple criteria methods for decision support can be helpful tools for the PPM team.

- The optimization methods and mathematical problem solving to support applied to PPM with a higher incidence in the portfolio items are multi-objective optimizations, integer linear programming, meta-heuristic, stochastic optimization, integer programming, mixed integer programming, linear programming formulation, multi-objective evolutionary algorithms, multi-objective linear programming, simulation-optimization (Sim-opt) and integer multilinear programming. Works with multi-objective optimization, stochastic optimization and multi-objective evolutionary algorithms are more recent, starting from the year 2000. Optimization methods can also be a useful tool for the PPM team to support decisions based on multiple objectives that have to be calculated to find the optimal solution (or solutions).

Considering the results of the bibliometry, the main findings were useful to orientate the options to be considered for use in this work. From the industrial sectors that had the highest incidence in the articles portfolio, the energy industry was chosen because even it having the second position in articles quantity, there are still opportunities to research PPM for the energy industry, so the energy sector was the selected for the application of the developed proposal. The R&D projects were considered as the kind of projects to be analysed in the power utilities. Regarding the methods for decision support applied to PPM, the MCDA was used for ordinal risk calculation and the evolutionary algorithm PSO for portfolio optimization, were used in this work.

The keywords network of the analysed articles is presented at Figure 3.1. The keywords that are presented have appeared in at least two articles. The keywords with higher incidence were “R&D”, “project management”, “portfolios”, “risk”, “project portfolio management”, “investment” and “optimization”.

Figure 3.1 Keywords network diagram



## 3.2 Content analysis

The set of articles was reviewed and the components were identified by reading the article portfolio to identify the patterns in the PPM process bundles that are part of the portfolio management, such as project selection, portfolio optimization, etc. Those components have been addressed in the PPM literature (e.g. Archer and Ghasemzadeh, 1999; Amaral and Araújo, 2009; Carvalho et al., 2013; Padovani and Carvalho, 2016). The term "components" was based on the work of Levine (2005). The PPM components that were found and their respective references are shown in Table 3.1.

Table 3.1 PPM components covered in the set of selected articles

| Components | References |
|---|---|
| Project Selection | [1],[2], [4], [5], [8], [9]-[11], [13], [16], [17], [22], [24]-[29], [31], [35]-[39], [41]-[45], [47], [49], [52], [55], [56], [58], [61], [63], [64], [66], [67], [74], [80]-[82], [84]-[87], [89], [93]-[96], [98]-[103], [107], [108], [112], [114], [115], [118], [119], [127], [129], [139], [140], [148]-[151], [156]-[158], [163], [165]-[170], [173], [175], [179], [180], [184], [185], [188], [190], [192], [193], [195], [196], [199], [200], [201], [203], [204], [212], [214], [215], [219]-[222], [226], [229], [232]-[236], [238], [240], [242], [245], [247], [248], [252]-[255], [263], [266]-[268], [271], [273]-[278], [280], [282], [283] |
| Portfolio Performance Evaluation | [3], [18], [21], [36], [39], [52], [60], [61], [69], [73], [75], [76], [84], [90], [91], [109], [113], [122], [128], [135], [136], [138], [147], [155], [159], [163], [181], [189], [190], [196], [199], [208], [211], [227], [245], [248], [256], [260], [266], [272], [277] |
| Portfolio Optimization | [8], [12], [35], [56], [61], [64], [71], [84], [86], [94], [96], [104], [109], [137], [140], [143], [153], [160], [164], [165], [172], [174], [192], [214], [224], [237], [239], [244], [249], [277] |
| Decision Making | [7], [13], [22], [24], [26], [40], [45], [61], [71], [73], [92], [96], [103], [112], [115], [125], [126], [146], [161], [163], [164], [173], [183], [192], [196], [198], [217], [225], [241], [255], [271], [278], [281] |

| | |
|---|---|
| Project Ranking | [5], [6], [16], [19], [31], [ 47], [49], [61], [64], [67], [79], [110], [112], [140], [163], [171], [180], [186], [192], [195], [196], [199], [204], [212], [223], [232], [238], [239], [268], [273], [274], [277], [282] |
| Resource Allocation | [4], [16], [34], [37], [45], [47], [79], [80], [81], [101]-[103], [111], [134], [135], [143], [146], [161], [167], [169], [181], [194], [209], [216], [236], [239], [241], [265], [282] |
| Risk Management | [30], [50], [59], [61], [76], [96], [116], [137], [152], [194], [205], [217], [223]-[226], [231], [241], [250], [265], [282] |
| Alignment with Strategy | [4], [23], [35], [46], [47], [53], [65], [113], [123], [135], [136], [153], [160], [174], [187], [191], [199], [201], [205] |
| Uncertainty Management | [12], [24], [25], [76], [84], [137], [157], [168], [173], [198], [205], [206], [231], [238], [241], [246], [257], [278] |
| Project Evaluation | [2], [8], [21], [31], [61], [63], [70], [91], [112], [129], [156], [181], [189], [190], [208], [210], [211] |
| Portfolio Balancing | [12], [30], [33], [34], [56], [69], [117], [135], [153], [172], [187], [200], [209], [257], [277] |
| Scheduling | [7], [28], [41], [42], [86], [100], [101], [124], [139], [146], [167], [209], [236], [240], [265] |
| Project Interdependence | [1], [37], [59], [61], [64], [84], [89], [185], [248] |
| Capability | [3], [77], [132], [133], [134], [135], [205], [206] |
| Preparing for the Future | [121], [187], [250] |

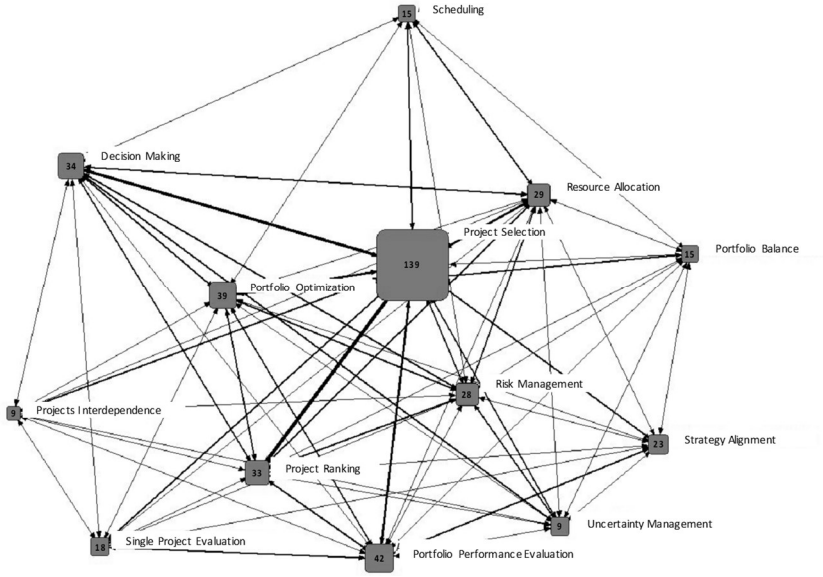
Legend: [1]: Aaker and Tyebjee (1978); [2]: Agresti and Harris (2009); [3]: Albala (1975); [4]: Amaral and Araújo (2009); [5]: Amiri (2010); [6]: Angelou and Economides (2008); [7]: Araúzo et al. (2010); [8]: Archer and Ghasemzadeh (1999); [9]: Baker (1964); [10]: Baker (1974); [11]: Bard et al. (1988); [12]: Beaujon et al. (2001); [13]: Belaid (2011); [14]: Beringer et al. (2012); [15] Beringer et al. (2013); [16]: Betz (2011); [17]: Bhattacharyya et al. (2011); [18]: Biedenbach and Müller (2012); [19]: Bitman and Sharif (2008); [20]: Blichfeldt and Eskerod (2008); [21]: Bohanec et al. (1995); [22]: Bordley (1998); [23]: Buys and Stander (2010); [24]: Büyüközkan and Feyzioglu (2004); [25]: Büyüközkan and Feyzioglu (2004a); [26]: Cabral-Cardoso and Payne (1996); [27]: Calantoneo et al. (1999); [28]: Carazo et al. (2010); [29]: Carlsson et al. (2007); [30]: Caron et al. (2007); [31]: Cauchick Miguel (2008); [32]: Chang and Lee (2012); [33]: Chao and Kavadias (2008); [34]: Chao et al. (2009); [35]: Chiang and Nunez (2012); [36]: Chiara and Anna (2010); [37]: Chien

(2002); [38]: Chiu and Gear (1979); [39]: Cho and Moon (2006); [40]: Christiansen and Varnes (2008); [41]: Coffin and Taylor Iii (1996); [42]: Coffin and Taylor Iii (1996a); [43]: Coldrick et al. (2005); [44]: Cooper (1981); [45]: Cooper (2006); [46]: Cooper and Edgett (1997); [47]: Cooper et al. (1998); [48]: Cooper et al. (1999); [49]: Cooper et al. (2000); [50]: Costa et al. (2007); [51]: Costello (1983); [52]: Cranston (1974); [53]: Crawford et al. (2006); [54]: Daim et al. (2013); []; [55]: Davies and Pearson (1980); [56]: Davoudpour et al. (2012); [57]: Day (2007); [58]: De Almeida and Duarte (2011); [59]: De Maio et al. (1994); [60]: De Oliveira Lacerda et al. (2011); [61]: De Reyck et al. (2005); [62]: Dettbarn Jr et al. (2005); [63]: Dey (2006); [64]: Dickinson et al. (2001); [65]: Dietrich and Lehtonen (2005); [66]: Doerner et al. (2006); [67]: Ebrahimnejad et al. (2012); [68]: Eckhause et al. (2012); [69]: Eilat et al. (2006); [70]: Eilat et al. (2008); [71]: Elfes et al. (2006); [72]: Elfes et al. (2006); [73]: Evans et al. (2009); [74]: Fang et al. (2008); [75]: Faulkner (1996); [76]: Fishelson and Kroetch (1990); [77]: Floricel and Ibanescu (2008); [78]: Frumau (1992); [79]: Gabriel et al. (2006); [80]: Gear and Lockett (1973); [81]: Gear (1974); [82]: Gear et al. (1971); [83]: George and Farid (2008); [84]: Ghapanchi et al. (2012); [85]: Ghasemzadeh and Archer (2000); [86]: Ghasemzadeh et al. (1999); [87]: Ghorbani and Rabbani (2009); [88]: Girotra et al. (2007); [89]: Golmohammadi and Pajoutan (2011); [90]: Graves and Rinquest (1996); [91]: Griffin and Page (1996); [92]: Groenveld (1997); [93]: Grossman and Gupta (1974); [94]: Gurgur and Morley (2008); [95]: Gurgur (2009); [96]: Gustafsson and Salo (2005); [97]: Gutiérrez and Magnusson (2013); [98]: Gutjahr and Froeschl (2013) (Pound (1964); [99]: Gutjahr and Reiter (2010); [100]: Gutjahr (2011); [101]: Gutjahr et al. (2008); [102]: Gutjahr et al. (2010); [103]: Hall and Nauda (1990); [104]: Hannah et al. (2010); [105]: Hansen and Kræmmergaard (2013); [106]: Hartmann and Hassan (2006); [107]: Hassanzadeh et al. (2011); [108]: Hassanzadeh et al. (2012); [109]: Hassanzadeh et al. (2012a); [110]: Helin and Souder (1974); [111]: Hendriks et al. (1999); [112]: Henriksen and Traynor (1999); [113]: Herfert and Arbige (2008); [114]: Hu et al. (2008); [115]: Huang et al. (2008); [116]: Hynuk et al. (2009); [117]: Jerbrant and Gustavsson (2013); [118]: Jiang and Klein (1999); [119]: Jiang and Klein (1999a); [120]: Jolly (2003); [121]: Jonas (2010); [122]: Jonas et al. (2012); [123]: Juiz et al. (2012); [124]: Kao et al. (2006); [125]: Kester et al. (2011); [126]: Kester et al. (2009); [127]: Khalili-Damghan et al. (2013); [128]: Khorramshahgol and Gousty (1986); [129]: Khorramshahgol et al. (1988); [130]: Killen and Kjaer (2012); [131]: Killen and Hunt (2006); [132]: Killen and Hunt (2010); [133]: Killen and Hunt (2013); [134]: Killen et al. (2012); [135]: Killen et al. (2008); [136]: Killen et al. (2008a); [137]: Kira et al. (1990); [138]: Kirchhoff et al. (2001); [139]: Klapka and Pinos (2002); [140]: Koc et al. (2009); [141]: Koh and Crawford (2012); [142]: Kostoff and Schaller (2001); [143]: Kremmel et al. (2011); [144]: Kwon (2010); [145]: Lambertini (2003); [146]: Laslo (2010); [147]: Lauro and Vepsalainen (1986); [148]: Lawson et al. (2006); [149]: Lee et al. (2008); [150]: Lee et al. (1986); [151]: Lengacher e Cammarata (2012); [152]: Leonard e Swanepoel (2010); [153]: Lerch e Spieth (2012); [154]: Lerch e Spieth (2012a); [155]: Lerch and Spieth (2013); [156]: Lieb (1998); [157]: Liesiö and Salo (2012); [158]: Liesiö et al. (2008); [159]: Lin and Chen (2005); [160]: Lin and Hsieh (2004); [161]: Lin and Zhou (2013); [162]: Lin et al. (2005); [163]: Linton et al. (2002); [164]: Litvinchev and López (2008); [165]: Litvinchev et al. (2010); [166]: Litvinchev et al. (2011); [167]: Liu and Wang (2011); [168]: Liu et al. (2012); [169]: Loch e Kavadias (2002); [170]: Loch, Pich et al. (2001); [171]: Lockett e Stratford (1987); [172]: Luo (2012); [173]: Machacha and Bhattacharya (2000); [174]: Macmillan and Mcgrath (2002); [175]: Madey and Dean (1985); [176]: Martinsuo and Lehtonen (2007); [177]: Martinsuo (2012); [178]: Matheson and Menke (1994); [179]: Mathews (2012); [180]: Mavrotas et al. (2008); [181]: Mcdonough Iii and Spital (2003); [182]: Mcnally et al. (2009); [183]: Mcnally et al. (2013); [184]: Meade and Presley (2002); [185]: Medaglia et al. (2007); [186]: Melachrinoudis and Rice (1991); [187]: Meskendahl (2010); [188]: Metaxiotis and Liagkouras (2012); [189]: Mikkola (2001); [190]: Miller and Sage (1981); [191]: Milosevic and Srivannaboon (2006); [192]: Ming and Eliashberg (2002); [193]: Mohanty (1992); [194]: Morcos (2008); [195]: Moreira and Cheng (2010); [196]: Müller et al. (2008); [197]: Oerlemans, Knoben et al. (2013); [198]: Oh, Yang et al. (2012); [199]: Oliveira and Rozenfeld (2010); [200]: Padovani et al. (2012); [201]: Pearson (1974); [202]: Perdue et al. (1999); [203]: Pereira and Veloso (2009); [204]: Pérez-Escobedo et al. (2011); [205]: Petit and Hobbs (2010); [206]: Petit (2012); [207]:

Pilkington (2004); [208]: Pillai et al. (2002); [209]: Platje et al. (1994); [210]: Poh et al. (2001); [211]: Porkolab (2002); [212]: Pound (1964); [213]: Quartel et al. (2012); [214]: Rabbani,et al. (2010); [215]: Rabbani,et al. (2006); [216]: Radosevich and Hayes (1973); [217]: Rajapakse et al. (2005); [218]: Rajapakse et al. (2006); [219]: Ravanshadnia et al. (2010); [220]: Rebiasz (2013); [221]: Ringuest and Graves (1989); [222]: Ringuest and Graves (1990); [223]: Ringuest and Graves (1999); [224]: Ringuest and Graves (2005); [225]: Ringuest et al. (2000); [226]: Ringuest et al. (2004); [227]: Roetheli and Pesenti (1986); [228]: Ruegg (2007); [229]: Rutsch et al. (2006); [230]: Salo et al. (2006); [231]: Sanchez et al. (2008); [232]: Sanna et al. (2008); [233]: Schmidt e Freeland (1992); [234]: Schmidt (1993); [235]: Schniederjans (1993); [236]: Schnittger (1967); [237]: Seider (2006); [238]: Shakhsi-Niaei et al. (2011); [239]: Sharpe and Keelin (1998); [240]: Shou and Huang (2010); [241]: Siddiqi (2000); [242]: Smith-Perera et al. (2010); [243]: Smyth and Morris (2007); [244]: Solak et al. (2010); [245]: Spradlin and Kutoloski (1999); [246]: Stamelos and Angelis (2001); [247]: Strang (2011); [248]: Stummer and Heidenberger (2003); [249]: Subramanian et al. (2003); [250]: Teller and Kock (2013); [251]: Teller et al. (2012); [252]: ThiThanh and Gordon-Brown (2012); [253]: Tian et al. (2002); [254]: Tian et al. (2005); [255]: Tiryaki and Ahlatcioglu (2009); [256]: Tohumcu and Karasakal (2010); [257]: Tritle et al. (2000); [258]: Unger et al. (2012); [259]: Unger et al. (2012); [260]: Urli and Terrien (2010); [261]: Vahaniitty et al. (2010); [262]: Van Bekkum, Pennings et al. (2009); [263]: Van Dyk e Smith (1990); [264]: Vandaele e Decouttere (2013)); [265]: Varma, Pekny et al. (2008); [266]: Vepsalainen and Lauro (1988); [267]: Verbano and Nosella (2010); [268]: Vijoen and Steyn (2007); [269]: Voss (2012); [270]: Voss and Kock (2012); [271]: Walls (2004); [272]: Walsh (2001); [273]: Wang and Hwang (2007); [274]: Wang et al. (2009); [275]: Wei and Chang (2011); [276]: Wind and Mahajan (1981); [277]: Wu et al. (2012); [278]: Young and Hak (1994); [279]: Young et al. (2011); [280]: Yu et al. (2012); [281]: Zapata and Reklaitis (2010); [282]: Zapata et al. (2008); [283]: Zhao et al. (2012); [284]: Ziqi and Greenfield (1998);

The PPM components found in the literature were presented in Table 3.1 and they are ranked according to the number of references using that component. The identified components are related to steps of the PPM process, and in many cases, there was not only one component in the reference, but two or three of them. A social network diagram of PPM components is shown in Figure 3.2, where it is possible to observe the relationship among the components. The nodes correspond to the quantity of articles for each component. The thicknesses of the lines represent the number of articles where the components are addressed together.

Figure 3.2 Network diagram of the PPM components




In the presented network diagram that the component nodes discussed in greater numbers of articles were also the corresponding nodes of the components that were discussed further in conjunction with other components, such as the nodes “project selection”, “performance evaluation portfolio”, “portfolio optimization”, “project ranking”, “resource allocation”, “risk management” and “alignment with the strategy”. There are thirteen nodes corresponding to the fourteen PPM components raised in the portfolio articles. The nodes “project selection”, “resource allocation”, “project prioritization”, “optimizing the portfolio” and “risk management” have twelve connections each with the other nodes, indicating that they were addressed together with all the other components. Then the node “performance evaluation of portfolio” has eleven links to other nodes. The nodes “management of uncertainty” and “decision-making” follow, with ten connections each with the other nodes. The nodes referring to the components "interdependence between projects”, “assessment of individual projects”, “alignment with the strategy” and “portfolio balance” each have nine links with other nodes. The node “schedules” has six connections with other nodes. The node with the highest number of articles addressed together was “project selection”, which has the largest number of lines with greater

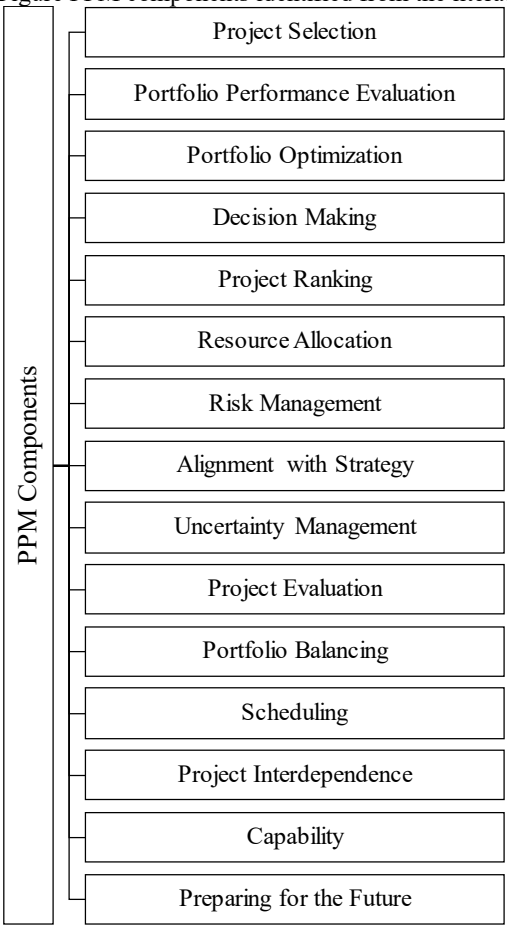
thickness as well as being the component with the highest number of articles addressing it.

The main findings of the literature analysis were the 15 PPM components, the research opportunities that are presented in the next section, either figure out the way of three power utilities use the PPM for their R&D projects management and justify the use of a survey to research whether the power utilities in Brazil had formal PPM processes and the importance of PPM for them.

## 3.3 Definition of PPM components

Figure 3.3 summarizes the main PPM components identified from the literature. Those components are important because they can help to understand the PPM concept in all its dimensions. The PPM components are also important when designing a PPM process as in this work.

Figure 3.3 Figure PPM components identified from the literature




### 3.3.1 Project selection

In the bibliographic search, an investigation considering qualitative and quantitative methods to select R&D projects and new products development projects that used valuation methodologies and post-project selection optimization, multicriteria decision support techniques and artificial intelligence techniques. Articles on project selection were also located through financial analysis techniques. Some observed trends were the sophistication of the proposals, the use of artificial intelligence techniques

and the joint analysis of the selection of projects with one or more PPM components.

The project's selection for the portfolio is based on the financial portfolio theory (Markowitz, 1952). Ot is the initial stage of PPM, and its effectiveness is crucial to the success of companies' R&D programs. If the selection process is too weak many, bad projects will be selected, resulting in a waste of resources; alternatively, if the selection process is very rigorous, many viable projects can be rejected, and good opportunities may be lost (Cooper, 1981).

Because of the importance of this phase in the PPM, inadequate project selection may cause problems for businesses that mainly occur in the selection of projects: a) the projects are not related to the company's strategic objectives, which affects the performance of the organization as a whole; b) low-quality portfolios due to lack of evaluation criteria to select viable projects among project possibilities with low degree of maturity; c) the reluctance to cancel projects because of personal links between members of project teams and projects, which at certain times cause the company to continue to invest their scarce resources in non-viable projects; d) scarce resources due to a lack of focus and management capacity to balance the resources properly by creating pressure for the design team to perform several activities at the same time, contributing to the incidence of unexpected errors and that important project development lessons are not assimilated; e) the selection of short-term projects that are easy to develop, which reduces the potential for companies to thrive and have competitive advantages; f) information overload and a lack of quality of the information, which means that even sophisticated decision processes and high-quality tools lose their effectiveness due to a lack of adequate information for decisions to be made accurately; g) decision-making based on influence to make decisions that are not taken in the light of the future success of the organization, but from the personal opinions of top managers (Cooper et al., 1998 and 2000). An existing quantitative model was identified in the literature on selection including financial models, economic analysis, operations research, mathematical methods, comparative methods, scoring models, earnings ratios, linear programming, integer models, type "checklist", decision theory models, consensus models, utility models, measurement models of benefits and project evaluation techniques (Coffin and Taylor, 1996) and (Chien, 2002).

The bibliographic search resulted in articles on project portfolio selection that used qualitative and quantitative methods to select R&D

projects and new product development (NPD) that used valuation methodologies and post-project selection optimization, multicriteria decision support techniques, such as AHP, ANP MCDA. MCDM, MAUT, MAUA, MADM and ODSs; artificial intelligence techniques, such as fuzzy, genetic algorithm, neural networks, expert systems and particle swarm; and some hybrid systems such as fuzzy AHP and fuzzy MADM. Financial analyses found were real options analysis (ROA), marginal returns, the value creation model (VCM), data envelopment analysis (DEA) and Markowitz efficient frontier. In terms of the activity sectors, there were articles in the energy sector, mining, government agency, software, computer peripherals, automotive, aerospace, aviation, information technology, educational institution, financial institution, pharmaceutical small high-tech companies, toys, recycling non-profit organizations, manufacturing, the chemical industry, petroleum, military, construction and infrastructure. Some trends that were possible to verify were the sophistication of the models, the use of artificial intelligence techniques and the joint analysis of the selection of projects with one or more components of the PPM.

### 3.3.2 Portfolio performance evaluation

The PPM efficiency can be determined by the degree of estimation to which the portfolio fulfils its objectives: strategic alignment, the balance between projects and maximization of the value of the portfolio. To realize the portfolio performance evaluation, it is necessary to define the success criteria (Martinsuo and Lehtonen, 2007). The performance indicator development process or key performance indicator (KPI) should consider the following aspects: a) focus on the critical characteristics of the outputs or results; b) be limited to a manageable number of KPIs without being too complex or consuming too much time and resources; c) using a systematic and consistent approach to all projects; d) data collection should be as simple as possible; e) for the performance measurement to be effective, the measurements and indicators should be accepted, understood and recognized throughout the organization (Chan and Chan, 2004).

The four dimensions of success are design efficiency, the impact on the consumer, business success and project be ready for the future. The project efficiency is a short-term dimension and is related to the constraints of time and budget resources. The impact on the consumer is also a short-term dimension and focuses on consumer demands and meeting these needs. Business success is a long-term dimension and discusses the benefits for the organization to be successful. Project be ready for the future is also a long-

term dimension and considers the creation of markets and products and the development of new technologies (Shenhar et al., 2001).

All the activities of an organization should be reflected in the portfolio and not just on projects. Thus, the portfolio performance does not just happen by adding project performance in the portfolio (Project Management Institute, 2006). The efficiency of individual project management is an important factor, but not sufficient for the portfolio management efficiency (Martinsuo and Lehtonen, 2007).

Performance can be measured through six metrics based on the balance of features, value, time, meeting deadlines, alignment with the strategies of the company and disbursements linked to the company's strategy. Based on the results obtained, the best performances are achieved by organizations implementing more formal approaches to portfolio management with well-defined procedures, the use of these procedures for all projects and management trust (Cooper et al.,1999). The influence of portfolio management techniques in portfolio performance in different contexts can be measured in two ways: the achievement of the desired results of the portfolio and the realization of what was proposed by the project and the program. The results of the projects and the portfolio should not be evaluated independent of each other, as this could lead to inaccurate conclusions. Successful organizations measure their portfolio's performance as the sum of the outputs of the planned results of the projects and the planned purposes (Muller et al., 2008). Project portfolio success can be multidimensional encompassing overall business success, economico success of products and project results, strategic fit, use of synergies and portfolio balance (Voss and Kock, 2013). The involvement of management increases the PPM performance, proposing indicators to measure the performance at each level of management (Jonas, 2010). The project portfolio management offices coordinating and controlling roles on performance regarding PPM quality such as information quality, resource allocation quality and cooperation quality as a predictor of project portfolio success and in the portfolio level the project efficiency should be defined as the average efficiency performance of projects (Unger et al., 2012).

### 3.3.3 Portfolio optimization

The optimization of the portfolio is the process of PPM that creates the best set of projects for all potential candidate projects. Common goals of portfolio optimization are maximizing the potential revenues and strategic

alignment, as well as the minimization of effects of negative synergies between projects selected for a portfolio (Kremmel et al., 2011).

A Pareto Ant Colony Optimization approach was used with artificial ants to construct valid project portfolios and take into account complex project interactions. The consideration of project synergy, the presented good results it has shown in experiments and the possibility of add heuristic information to the algorithm makes Pareto Ant Colony Optimization a valuable approach (Doerner et al., 2004).

There are several differences between the optimization techniques for financial portfolios and the management of the portfolios of R&D projects, with the first being in the realization of returns. For an R&D project, performance time and the variation of project return is dependent on investments, while for financial securities both risk and return time is independent of the amount invested in them (Solak et al., 2010). A second difference is the correlation between project returns; for the theory of financial portfolios, the correlation between returns is assumed to be independent of the way in which these resources are allocated, and for R&D projects, the correlation between project returns is dependent on investment levels because resources spent on a project are diverted from other projects, causing the returns relating to these projects early to often not be realized (Solak et al., 2010). A third difference is how the returns are produced — in financial theory, the cumulative return of two securities purchased is assumed to equal the sum of the individual returns of the securities, but there are dependencies for projects that may have a positive or negative effect on the achievement of returns on all the projects (Solak et al., 2010).

### 3.3.4 Portfolio decision-making

Decision making is a cognitive phenomenon, conceptualized as the end point of a complex process of deliberation, which includes an assessment of consequences and uncertainties (Parkin, 1996). The process of decision making (problem definition, thought, judgment, decision, action) is influenced by the decision maker's history, beliefs, values, social and occupational norms, personality, and environmental constraints (Parkin, 1996). Most organizations think of decision making as an event, not a process. They attach great importance to key decision meetings, but in most cases, the real problems occur before those meetings take place (Ssharpe and Keelin, 1998). The portfolio decision process encompasses some other decision-making processes. It includes periodic reviews of all portfolios of projects, so it is possible to perceive the entire set of projects together,

comparing the projects among themselves. In addition, it involves making decisions go and stop individual projects and developing a new product strategy for the business, supplemented by strategic allocation decisions based on available resources (Cooper et al., 1998).

Decisions related to portfolio management are often described as choices of Go, Hold, or Cancel of individual projects. These decisions are to be executed either at certain process gates or at portfolio management board meetings (Müller et al., 2008). Systematic decision making about single projects has a complex relationship with portfolio management efficiency. Even though the relationship appears to be mediated by project management efficiency, systematic decision-making does not explain project management efficiency, neither directly nor indirectly through reaching of project goals (Martinsuo and Lehtonen, 2007). Some indications for portfolio decision-making style being dependent on the tangibility of the products created by the organization were studied and portfolio managers in industries with tangible outcomes tend to decide as individuals, whereas industries with intangible products often use groups of managers for portfolio decisions (Blomquist and Müller, 2004).

The decision to accept a new project depends mainly on its economic viability, its strategic importance and the term viability. However, the projects that are accepted are affected by other portfolio projects. Once a new project is accepted and incorporated into an existing portfolio, it is necessary to update the schedules of activities of projects and expected return, as well as update the forecasts of acquisitions with the new project needs (Arauzo et al., 2010).

The decision making methods are described in the section 3.4 and include the multicriteria decision aid methods and the financial methods.

### 3.3.5 Project portfolio prioritization

The goal for R&D project prioritization is simply to select winning new projects, and these projects will have a combination of characteristics that are expected to lead to considerable benefits and a high probability of success, and the criteria represent the factors that establish whether or not the goal has been reached (Brenner, 1994). Many factors influence the assignment of priorities for projects in a different way. These are financial benefits, business objectives, intangible benefits and technical importance. Prioritization is the process of prioritizing the selected components based on their scores' evaluation and other management considerations. The prioritization of projects in the portfolio is a component that assists in the

decision-making process that can improve the resource allocation or even stops projects (Project Management Institute, 2013). To realize the prioritization of projects graphical methods can be used, such as the bubbles diagram, multi-criteria decision support methods such as the AHP and MCDA that can be combined with artificial intelligence techniques such as fuzzy, making a hybrid method, such as fuzzy-AHP.

The failures on identifying the projects priority contribute to the waste of scarce resources due to the incorrect perception of suitable projects, or even to the lack of a satisfactory resource strategy (Martino, 1995). It is possible to define R&D project prioritization as a complex decision problem because often, project prioritization involves more than one criterion and the goals to be achieved are not always well explained and also, a basis for project comparison is not, in many cases, perfectly defined (Gomes, 2007).

### 3.3.6 Portfolio resource allocation

PPM is directly related to resource allocation. In a business world concerned about the value to shareholders and doing more with less, technology and market resources are too scarce to be allocated in wrong projects. The consequences of poor portfolio management are visible: you waste resources on the wrong projects and, as a result, leaving no resources the really valuable projects (Cooper and Edget, 1997). Resource allocation seeks how to make a better use of available human resources considering their qualifications and the expected and actual time spent to develop a task in order to reduce the development time and delays (Cheng et al., 2006). One problem about resources allocation is the litigation involving this process. This kind of problem occurs caused by the lack of negotiation with the functional management of the resource to be allocated to projects, and also when resources are shared between many projects and the project manager fails to negotiate the required time for the resource with the other project managers that have projects running (Elonen and Artto, 2003).

Due to the importance of proper resource allocation in the portfolio, articles having different techniques to support the decision and mathematical optimization are used to better allocate resources. This step is called authorization (Project Management Institute, 2013).

### 3.3.7 Portfolio risk management

Regarding risk and return, unlike in financial investments, a higher project risk is not necessarily correlated with a higher potential of project return. The measurement of project risk and return is complex, and some of

the criteria are too generic for the specific business. The risk may be represented by the tangible and intangible impediments that may potentially cause the project to fail. Once the individual risk factors for each project are identified, the project may be weighted against the other portfolio projects for a relative comparison. The return on investment (ROI) is quantified by the tangible and intangible benefits or returns to the business (Sommer, 1998)

PPM and financial portfolio management are similar in terms of the maximization of value and risk management (Chiang and Nunez, 2012). Portfolio risk is an uncertain event, set of events or conditions that, if they occur, have one or more effects, positive or negative in at least one strategic objective of the portfolio (Project Management Institute, 2013). Risk management in the project includes the processes of conducting risk management planning, identification, analysis, response planning and monitoring and control on a project. The objectives of risk management in the project are to increase the probability and impact of positive events and decrease the probability and impact of negative events. Once the risks have been identified through techniques of idea generation or evaluation by experts, they are evaluated using a method involving probability and impact to determine the overall impact on the project. The planning techniques of risk management responses include: (a) Avoid the risk: the project plan can be modified to avoid the risk entirely. (b) The focus is on reducing the probability to zero. This can be done by changing the strategy, better understanding the scope of seeking specific specialties, reducing the number of critical paths to increase the delivery time, etc. (c) The mitigation of risk: This implies reducing the probability and / or impact of the project risk below an acceptable limit. Techniques include improving communication, have a stronger support of the sponsor and paying special attention to specific activities. (d) Risk transfer requires a risk of changing property to a third party. When the impact of risk is primarily financial, insurance can be used to protect the project by paying a fee. An alternative is to outsource some risky activities to a third party. (e) The acceptance of risk is used when it is too expensive or impossible to avoid, mitigate or transfer risk. The consequence may be that the sponsor stops the project if him is not willing to accept the risk. Alternative contingency plans should be prepared in case the risk event occurs, that is, treat the effect rather than the cause (Project Management Institute, 2008a).

### 3.3.8 Portfolio alignment with strategy

Business strategy describes the way in such a firm decides to compete in a market compared to the competitors in this market (Varadarajan and Clark, 1994). Organisations should have clear strategic imperatives in place, properly communicated across all departments, to which the PPM goals are to be aligned to it (Lycett et al., 2004). The problem is that it is more difficult to make the strategy work than to make the strategy (Hrebiniak, 2006). Projects and project portfolio management are powerful strategic weapons as they can be considered as a central building block in implementing the strategy (Shenhar et al., 2001; Dietrich and Lehtonen, 2005). Strategic schemes, strategic flexibility, learning ability, the knowledge management strategy and decision-making strategy are the main features required for an organizational strategy's success (Amaral and Araujo, 2009). Formulating a strategy is difficult, do the strategy work, executing or implementing the same through the organization is even harder (Hrebiniak, 2006). The strategy of a project should not only retain the tactical and operational level but also the institutional level and thus allow a significant interaction design with the environment in which it is undertaken (Artto et al., 2008). There is a positive relation between strategy conform portfolio selection and project portfolio performance (Müller et al., 2008).

Successful organizations have developed a conscious strategy and a closer relationship with the market. The development of the strategic plan seeks to design the organization in a future scenario, defining concrete actions for the achievement of organizational objectives. However, the interaction between the organization and the market works dynamically. Achieving these goals requires the ability to measure market movements, analyse critical information obtained, adjust the strategic plan with the lessons learned and allow some flexibility to respond quickly to the market. The better the development process becomes, the greater the performance achieved by the organization, increasing its results (Makadok and Barney, 2001).

### 3.3.9 Portfolio uncertainty management

Project uncertainty is a degree of precision with which the change in income, resources and work processes can be predicted (Dahlgren and Soderlund, 2010). Project uncertainty is the variation of the items or evidence on which the work is performed and the unpredictable behaviour of people. Some uncertainty measurements are based on the variability of the input, the

number of exceptions found in the work process and the number of major changes in the product concerned (Danilovic and Sandkull, 2005).

The sources of uncertainties can be classified into the following broad categories below (Leifer et al., 2000):

- Technical uncertainties, which include issues related to the completeness and accuracy of the underlying scientific knowledge, the technical specifications of the product, manufacturing, maintenance and so on.
- Market uncertainties include issues related to the needs and desires of consumers, or forms of interaction between the client and the existing or latent product, sales and distribution methods, the relationship with competitors' products and so on.
- Organizational uncertainties refer to the capabilities necessary to form the project team, their relationship with the rest of the organization and the level of management support.
- Financial uncertainties include access to finances for projects, including partnerships.

There are four criteria for decision-making under uncertainty. The first is the criterion of Hurwicz, also known as the maximax criterion, where the decision maker is always optimistic and tries to maximize their profit through a strategy of risking everything. For this strategy, the decision maker will always choose the strategy with maximum profit, which in turn can also lead to a maximum loss. The use of this criterion should be based on how much risk can be taken and how much can be lost. The second criterion is the Wald, or maximin criterion, in which the decision maker is concerned about how much he could lose. A pessimistic view is taken rather than an optimistic with the objective of minimizing the maximum losses. The third criterion is the Savage, or minimax criterion, which seek to minimize the manager´s regret to the fullest. The fourth criterion is the criterion of Laplace, which seeks to transform decision-making under uncertainty in decision making under risk. The criterion makes a Laplace a priori assumption based on Bayesian statistics if the probability of each condition is not known; it can be considered that each state has an equal probability of occurrence (Kerzner, 2011).

### 3.3.10 Individual projects portfolio review

Project management with a large set of success criteria has a strong and significant effect on project portfolio efficiency. Then, the average

success of all projects within the portfolio forms the first dimension of the project portfolio's success (Martinsuo and Lehtonen, 2007).

The compliance with performance objectives, target costs and target quality are taken into account and reflected in the service of projects to product specifications (Griffin and Page, 1996). Success criteria often used to deliver projects on time, within budget and within specifications are complemented with the customer satisfaction dimension (Shenhar et al., 2001).

### 3.3.11 Portfolio balance

Resource constraints and the tendency to develop too many projects for the limited capacity is a common problem for PPM (Blichefeldt and Eskedrod, 2008). Portfolio baloance is a practice that enables the project portfolio be aligned with the organization´s strategy (Chao and Kavadias, 2008). The Theory of Constraints describes the best way to attack multiple constraints. It requires managers to focus until the main restriction is broken. Until this occurs, efforts to resolve minor restrictions will not benefit the company. These principles can be applied to PPM in an organization that is facing restrictions on its ability to perform the job (Seider, 2006). One definition for success in PPM for new product development (NPD) suppose the balance between short-term and long-term benefits that means a combination of small improvements on the existing products and radical changes on new products and services (Chao and Kavadias, 2008; Chao et al., 2009). Criteria for balancing the project portfolio can be composed by project type, risk level and resource adequacy (Killen, 2008).

It is important to have a desirable combination of projects in a balanced portfolio that allows the company to achieve its goals without being exposed to risks without reason (Mikkola, 2001). The project portfolio must be balanced according to dimensions that provide the best value to the organization (Archer and Ghasemzadeh, 1999); (Cooper et al., 2002); (Killen et al., 2008).

### 3.3.12 Portfolio scheduling

Projects have to work and they are generally performed by different resources. Resources are endowed with some capabilities, such as knowledge, labour, etc. that are required to perform the work. Projects require resources over time and resources offer their skills and time available. There are several models of multiple criteria for the selection of R&D projects, but these models typically do not include the scheduling as a

decision criterion. The traditional approach for the selection of R&D projects is first to select a set of projects that meet the economic objectives and resource constraints and then schedule this set of projects through various research centres through rules or scheduling procedures (Arauzo and Pajares et al., 2010). When a conflict occurs, and it is not possible to schedule the selected projects within, the desired projects can be excluded, alternative projects or clusters of projects can be considered, resources can be increased, economic objectives can be reduced or desired terms be increased. None of these alternatives is an approach or logical solution that should provide the best or even a good selection of R&D projects (Coffin and Taylor, 1996).

Project portfolio scheduling (PPS) is supposed to be a reactive decision process, where the listing of projects and the allocation of resources can be revised (Cooper et al., 1998). The result of this process is an effective project portfolio scheduling system (PPSS) and is essential to convert each project into an operating timetable and maintain the performance of the portfolio in a timely format. There are two approaches to deal with unexpected events and uncertainty in scheduling: proactive scheduling that refers to the development of a baseline schedule that incorporates a degree of anticipation of variability during project execution, and reactive scheduling refers to the schedule modifications that should be made during project execution (Herroelen and Leus, 2004).

Scheduling of project activities subject to precedence relationships and resource availability constraints is referred to as the resource-constrained project scheduling problem (RCPSP). Supposing a set of simultaneous projects are contending for scarce resources however, the scheduling problem turns into a resource constrained multi-project scheduling problem (RCMPSP). To resolve cross-project conflicts and consolidate the individual projects, compromises are inevitable in the scheduling decision. According to a given set of priority rules, most scheduling algorithms are performed by resolving resource and/or temporal overlaps in activities (Knotts and Dror, 2003). The potential problems of this scheduling method are mainly due to simplifications since the buffer may fail to act as a real proactive protection mechanism and, management still need to face the trade-offs involved in schedule repair and rescheduling (Herroelen and Leus, 2004). As to the task of scheduling the project portfolio, the manager should identify critical resources in terms of availability and cost to reduce the likelihood of conflicts between projects and for the completion of the portfolio with a minimum cost. Here it is considered the project portfolio scheduling and rescheduling problem by allocating a limited number of resources to projects, where

resources can be classified in two ways: dedicated versus shared and consumable versus reusable (Kao et al., 2006). If the project portfolio is running, the manager monitors its status by tracking how the resources are utilized. When a new event occurs, the scheduling procedure will be repeated. For practical implementation, the scheduling decision framework should be able to represent the hierarchy of activities, provide for temporal relationships between activities, resource usage, arbitrary state attributes, and graphical user interface for viewing and manipulating schedules interactively (Kao et al., 2006).

### 3.3.13 Project portfolios' interdependence

There are several types of interdependence between projects. First, the interdependence due to the overlap in the use of project resources can characterize these projects using common equipment, personal efforts, facilities, etc. The budget for these sets of projects would, therefore, be less than the sum of their budgets to consider individually. Second, the technical interdependencies between projects may appear when the success or failure of a project significantly increases or slows the progress of other projects. Third, the effect of interdependence can arise when projects are such that their contributions value or non-value payments. Projects can have a synergistic effect. A search design of a specific material properties and another developing material processing method could dramatically affect each other if the compensation were successful. Or two projects can develop products that will share production facilities or marketing costs, and therefore, their returns will be quite reinforced if both are successful. Another type of independence is through cannibalization. When two designs seek to develop products that compete, the return of each may be much smaller if both are successful (Aaker and Tyebjee, 1978).

### 3.3.14 Capability

Organizational capabilities are a source of competitive advantage allowing much greater application of organizational resources in a way that is hard to imitate or replace (Barney, 1991).

The PPM capability can provide a broad perspective for making a decision to ensure the project portfolio will align with the company´s strategy and provide better organisational outcomes and the effectiveness of a PPM capability is determined by the level of financial return generated from the project portfolio investments (Cooper, 2001). Another ways to measure PPM effectiveness are a strong of alignment between projects and company´s

strategy, an adequate balance of project types and to have adequate resources to develop the projects. The combination of project management and the PPM capabilities can allow the organization to have the maximum value from project investments (Cooper, 2001). PPM has gained attention as a way to enable organizations to align projects with the strategy and to ensure adequate resources for projects. However, it is necessary to take particular care to ensure the PPM's ability to meet the organizational needs over time (Killen et al., 2013).

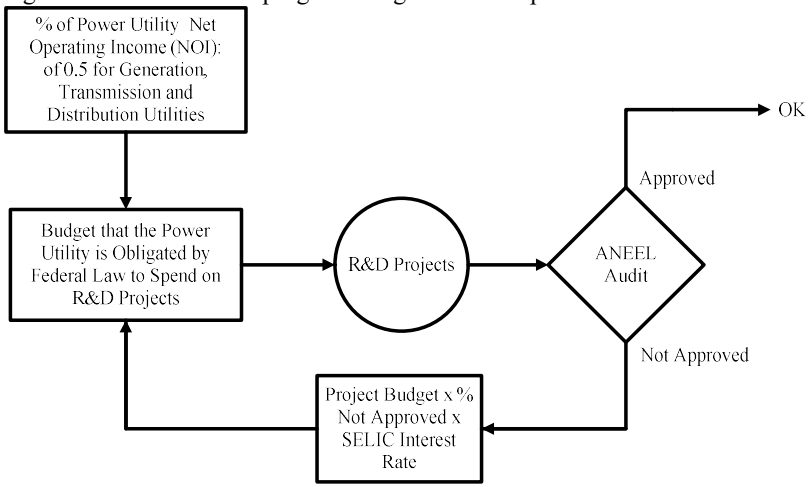
### 3.3.15 Preparing for the future

The preparing for the future assesses the medium and long-term impact on organizations with actions such as creating a new market, a new product line, new technology, knowledge management, historical bases, environmental responsibility and sustainability (Sheenhar et al., 2001; Almeida and Olivieri Neto, 2015). Preparing for the future deals with the long-term aspects and considers the ability to seize opportunities that arise after the projects have been brought to an end (Sheenhar et al., 2001; Teller and Kock, 2013). The dimension preparing for the future addresses the long-term implications of risk management and reflects the ability to quickly react to environmental changes and seize opportunities that arise after the projects have concluded (Shenhar et al., 2001; Meskendahl, 2010). Preparing for the future is the longest-term dimension and addresses the preparation of the organisation and the technological infrastructure for prospect needs (Shenhar et al., 2001; Jonas, 2010). This component examines the long-term benefits and opportunities from the projects, which are mostly indirect and can only be realized long after the projects have been completed.

## 3.4 Data acquisition from ANEEL

From the current period until December 2022, the percentage is 0.5 of the NOI. R&D is managed by electric utilities (governance) and carried out by a research institute, a university or a private company. At the end of a project, electric utilities are compulsory audited by the agency, i.e. ANEEL (2013). The flow of this process is shown in Figure 3.4.

Figure 3.4 ANEEL R&D program budget and audit process



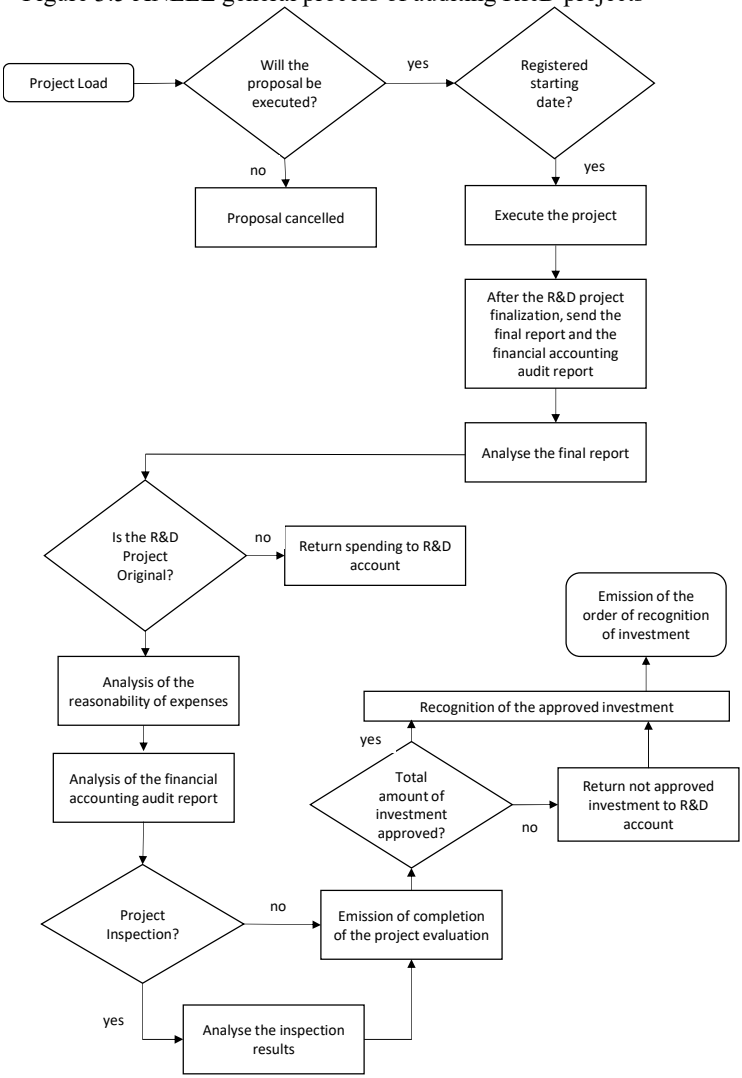

The assessment criteria (auditing) by ANEEL (2013) are:

- Originality: This should be proven through the "search for precedence" in the National Institute of Industrial Property (INPI) and in the ANEEL databases of the R&D projects of previous years. No similar project should have been done previously. This criterion is eliminatory, and in the assessment, if it is considered inadequate, the project is reproved in the auditing.
- Applicability: This is evaluated based on the scope and potential of the application, notably the main product ("deliverable"), including the type of institution that will use the developed deliverable (executing entity, electricity company or electric sector) and its scope (area, segment and number of consumers, etc.). Regardless of the scope, applicability must be justified and demonstrated by quality assurance and control (laboratory tests, field tests, etc.).
- Relevance: This is assessed by the project's contributions ("deliverables") or impacts in scientific, technological, economic, or socio-environmental terms, including all project outcomes. The reasonableness of the costs should be assessed by the confrontation between the investments planned or carried out and the expected or provided benefits.

If originality is not demonstrated or if the reached results are not compatible with the planned results or the financial statements are not

consistent, there is a risk of the total or partial disallowance of the project value by ANEEL. To minimize this risk, a conceptual proposal was developed. This proposal should consider the management of the portfolio taking into account the risks in each phase based on the ANEEL audit criteria. The likelihood of risks and their potential impact should be assessed, and action plans should be prepared to eliminate, mitigate or accept them. The ANEEL auditing process for R&D projects is illustrated in Figure 3.5.

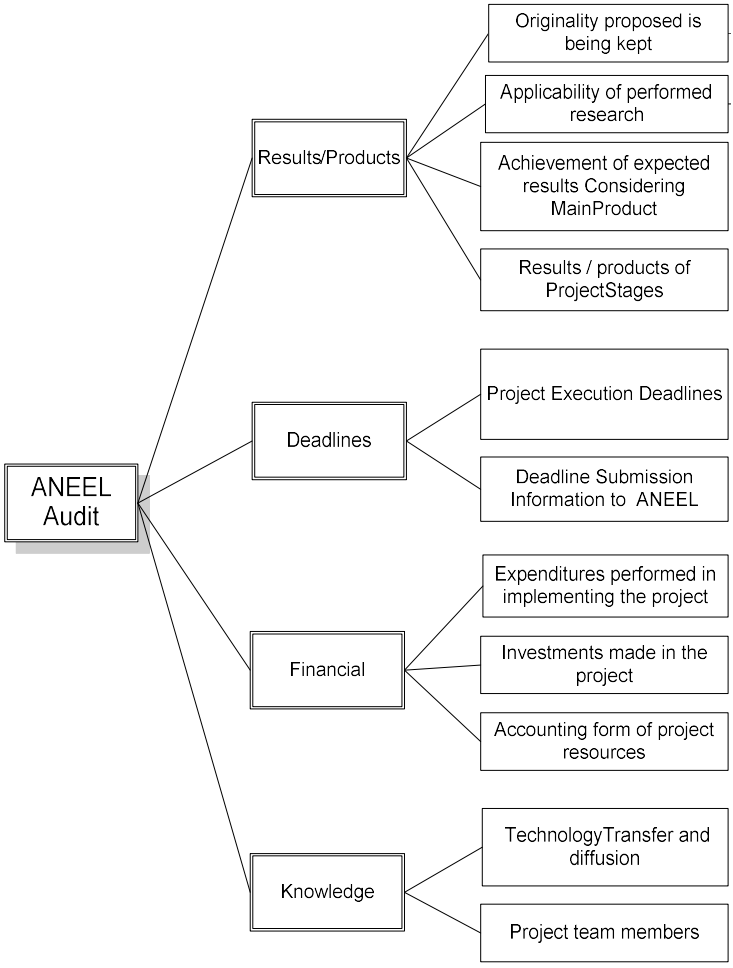
Figure 3.5 ANEEL general process of auditing R&D projects




The items listed in the ANEEL audit manual (2013) are presented in Figure 3.6 and the audit items shown at Figure 3.6 are used as indicators to calculate the ordinal risk of the project have problems in ANEEL Audit and this calculated ordinal risk will be used as one criteria combined to alignment

with strategy and budget to select the projects to compose the project portfolio and this is one of the objectives of this work.

Figure 3.6 Audit items (ANEEL, 2013).

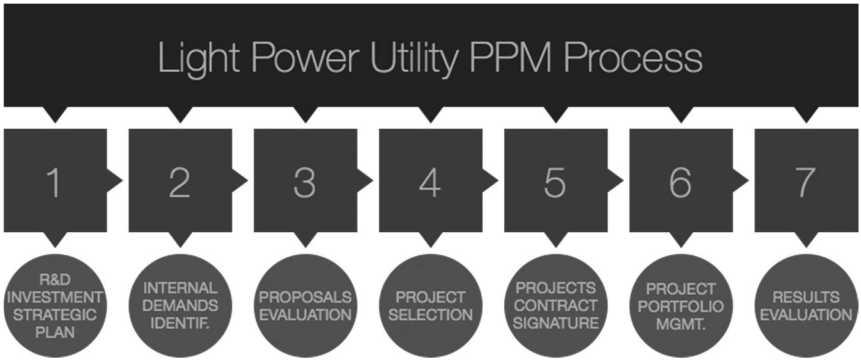



**3.5 Power utilities' PPM processes described in the literature**

Three PPM processes adopted by Brazilian power utilities were identified in the literature. The first process is by a company named Light, a power utility located in Rio de Janeiro. Figure 3.7 illustrates its portfolio

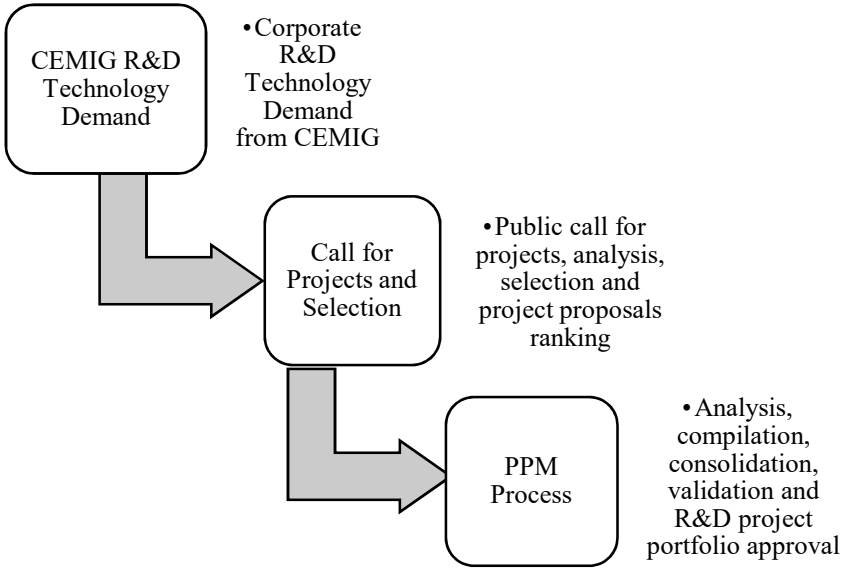
process. It starts with the strategic plan of investment in R&D, which is linked to strategic planning. Then, the internal areas, such as operation, maintenance, planning, regulation, renewable energy and energy efficiency, list their needs in R&D. A call for projects is made and the received project proposals are evaluated by the specialist committee composed of senior engineers from R&D and operational areas. The selected proposals go through the selection process, which then pass through the hiring and signing contracts. The contracted projects are managed by the company's PPM process, and the results are evaluated periodically (Cohen, 2011).

Figure 3.7 Process for the selection and start of an R&D project at Light (Cohen, 2011, p.42).




The second portfolio process was adopted by a Brazilian power utility called Cemig Figure 3.8. It starts with corporate technological demands; the next step is the identification of the specific demands of the board of directors that will provide the strategic direction for the R&D. Then, the call for projects will be held, the projects will be received, analysed and selected according to the strategic direction of the company; the next phase is the management of proposals for R&D and then the analysis, compilation, consolidation, validation and approval of R&D portfolios.

Figure 3.8 PPM process of CEMIG (Soares, 2007).



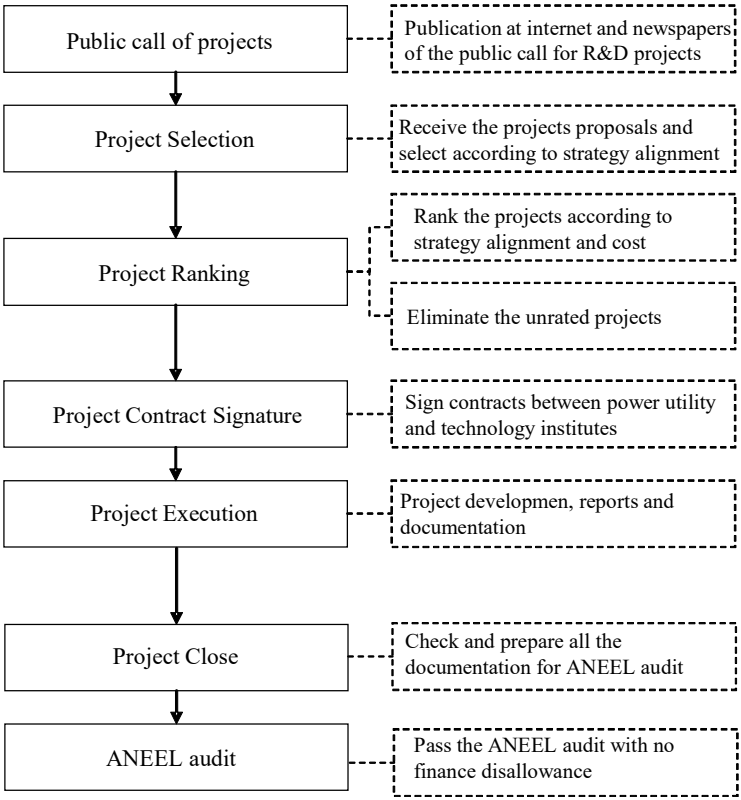

The third portfolio process was used in a power utility called Copel (Figure 3.9). It starts with a strategic benchmarking that uses as inputs the company's operational routine, mission, vision and strategic direction. Then, corporate strategy[6] maps are elaborated; strategic objectives, performance indicators and goals where the strategic initiatives are taken in which the objective of aligning with the operational routine of the projects are analysed. Then, the proposals are prioritized, the portfolio is balanced, then the projects be hired, and finally the project portfolio is monitored.

Figure 3.9 Copel project portfolio management model (Lovato, 2011).

[6] It is a document where the roll out of the strategic planning is described.


Analysing the processes of the three power utilities (Light, Cemig and Copel), a project flow shown in Figure 3.10 was built. Conclusively, the project needs are obtained from the company´s strategic planning and will drive the project demand. The projects will be selected, prioritized, contractors hired, steps executed and monitored and after the projects are finished, they will pass the ANEEL audit.

Figure 3.10 Flow of R&D projects in electric utilities.




The three processes found in the literature have some similarities and could be described as a single process presented in Figure 3.10, which also shows the deliverables for each step. The next section deals with MCDA methods, which for this work is important because for ordinal risk , it is necessary to consider many criteria together that compose the risk.

### 3.7 Multi Criteria Decision Aid methods

To choose an Multi Criteria Decision Aid method, there are some criteria to consider. The most important is to find a method that measures what it is supposed to measure. Different methods generally present different results, so a method that reflects the user's ‘true values’ in the best possible way should be chosen (Loken, 2006). The method is supposed to provide the

decision maker all the information they need, and the method must be compatible with the available data. The method should be as easy to use and understand as possible. If the decision makers do not understand what is happening inside the methodology, they perceive the methodology like a black box and the result may be that the DMs do not trust in the recommendations from the method (Loken, 2006).

There are some possible ways to classify the existing MCDA methods, there are three broad categories or schools of thought (Belton and Stewart, 2002):

- Value measurement models.
- Goal, aspiration and reference level models.
- Outranking models (the French school).

In this work, the MCDA method that will be used is a Value measurement model because there is a necessity of calculate the ordinal risk for each project. When using value measurement methods, a numerical score (or value) is assigned to each alternative. These scores produce a preference order for the alternatives. When using this approach, the various criteria are given weights that represent their partial contribution to the overall score, based on how important this criterion is for the decision makers. Ideally, the weights should indicate how much the decision maker is willing to accept in the trade-off between two criteria (Loken, 2006). The most commonly used approach is an additive value function multiattribute value theory (MAVT) where the partial value function is normalized to some convenient scale. The alternative with the highest value score is preferred. The multiattribute utility theory (MAUT) can be considered an extension of MAVT. MAUT is a more rigorous method for how to incorporate risk preferences and uncertainty into multicriteria decision support methods. When using this approach, multiattribute utility functions where the risk preferences are directly reflected in the values must be established instead of value functions (Loken, 2006). The analytical hierarchy process (AHP) has some similarities to the multiattribute value function approach. AHP also can be describedas an alternative means of eliciting a value function (Belton and Stewart, 2002). However, MAVT and MAUT rest on different assumptions on value measurements, and that AHP is developed independently of other decision theories. Of these reasons, many of the proponents of AHP claim that AHP is not a value function method (Belton and Stewart, 2002). Both MAUT and AHP present their results as cardinal rankings, which mean that each alternative is given a numerical desirability score. Consequently, the results from the two methods are directly comparable (Loken, 2006).

In an MCDA problem, there is usually a better decision, solution or action simultaneously for all the criteria. The decision-making can be defined as the effort to solve the dilemma of conflicting criteria, whose presence prevents the existence of an optimal solution and leads to finding the best compromise (Zeleny, 1982). The MCDA emerged in the second half of the twentieth century as a set of techniques and methods to assist individuals and organizations in decision troubleshooting where various points of view, often conflicting, need to be considered (Vincke, 1992). In this thesis, the MCDA is being used to calculate the possibility of the risk of the financial disallowance of R&D project in the ANEEL audit.

Some multicriteria decision aid methods use the method consisting in comparing pairs of alternatives, in which it seeks to establish relations and aims to classify the alternatives into categories or prescribe any alternatives or get the best alternative according to the decision maker's preference levels. Examples of outranking methods:

- ELIMINATION AND CHOICE TRANSLATING REALITY (ELECTRE): a method that reduces levels of agreement and disagreement to determine relationships of dominance between the alternatives and categorize them (Fulop, 2005).
- PREFERENCE RANKING METHOD FORENRICHMENT EVALUATION (PROMTHEE): a set of methods using reference data to determine the overall intensity preferably between alternatives to obtain a partial or complete categorization. The PROMTHEE implementations described in the literature are:
    - PROMTEE I: where the intersection between flows down a partial over- relationship between the alternative;
    - PROMTEE II: classifies the alternatives, establishing a descending order of the liquid flow, which provides a complete order among the alternatives;
    - PROMTEE III AND IV: developed for the treatment of more sophisticated decision-making problems, in particular with a stochastic component. The PROMETHEE IV involves the case of a continuous set of actions that arises when

the actions are, for example, percentages, dimensions of a product, investments, etc.;
    - PROMTEE V: In this method, after sets up a complete order between the alternatives (PROMETHE II), restrictions are introduced, the problem identified for the selected alternatives, incorporating up an entire optimization philosophy;
    - PROMTEE VI: designed to support the framework when the DM is unable or unwilling to set the weights for the criteria may be specified ranges of possible values rather than a fixed value for each weight
- TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS): is the sorting method preferably similarity based on the principle that the best alternative is the one that is closer to an optimal solution and farther from a non-desired solution according to a different coefficient, which measures the similarity between the alternative (Brites, 2008).
- MEASURING ATTRACTIVENESS BY A CATEGORICAL BASED EVALUATION TECHNIQUE (MACBETH): It is a method in which linear programming problems models are used to describe the degree of preference of the alternatives (Salomon, 2004).
- MULTI CRITERIA DECISION AID – CONSTRUCTIVIST (MCDA-C): All the criteria have the same interest rate through compensation weights and cardinalization process. The interactive method requires the participation and legitimization of all stages by the decision maker, which requires dedication and mental effort part thereof.

To define what multicriteria decision aid method would be used in this thesis several multicriteria decision methods were examined, based on the literature (e.g. Roy, 1991; Fulop, 2005; Brites, 2008; Salomon, 2004; Saaty, 1991). The chosen method was MCDA, as the process is embedded in a broader process of structuring and problem solving, for an initial identification, structuring, construction and use of a model to inform and

encourage analyses to reach a development an action plan (Belton and Stewart, 2002). A summary of MCDA methods can be seen in Appendix 5.

This chapter presented the literature analysis and content analysis, as well as the PPM components and an overview of power utilities' PPM processes described in the literature. The next chapter presents the results of this thesis.

## 4. RESULTS

This section presents the findings of this work. The first section describes the results of the exploratory survey with the power utilities. This is followed by the results obtained using the proposal ordinal risks and portfolio optimization for R&D projects before these projects were selected by the specialist committee of power utilities. The final section presents the results by applying the ordinal risks and portfolio optimization for projects already selected and running in the power utilities.

### 4.1Exploratory survey with power utilities

A survey instrument was constructed based on a doctoral thesis survey instrument (Killen, 2008). This survey instrument proposal was considered suitable and was thus adapted for R&D projects, as the original work was designed for companies dealing with new product development. To select the power utilities to approach for the survey, it was decided to contact all the power utilities that were had R&D projects running. A list of all the power utilities that that had R&D projects running and the people responsible for R&D presenting the names and contacts was available at ANEEL web page. So, the people responsible for R&D were chosen as respondents for the survey. The total number of responses and their percentages by segment are shown in Table 4.1. The percentage of responses was similar for all three sub-sectors, ranging from 22% in electricity transmission to 26% in electricity distribution.

Table 4.1 Numbers of questionnaires sent, responses and percentage of responses

| Sub-sector | Questionnaires Sent | Received Answers | Percentage of Responses Received |
|---|---|---|---|
| Electricity distribution | 50 | 13 | 26% |
| Power generation | 47 | 11 | 23% |
| Power transmission | 27 | 6 | 22% |
| **Total** | **124** | **30** | **24%** |

The respondent power utilities´ kinds were 12 from private companies and 18 from public companies. The name of the power utilities were not disclosed because in the survey research instrument all the respondents chose not to disclosure the power utilities names.

Regarding the respondents' positions, 3 respondents held the post of the superintendent or senior managers of R&D; 12 respondents held the post of the head, manager or supervisor of R&D and 15 respondents had the job analyst, R&D engineer or project manager.

Respondents' perception of the importance of R&D projects' PPM for the business is shown in Table 4.2. The variables and the levels used to capture the respondents´ perception about R&D projects importance were acquired from the survey instrument used in (Killen, 2008). The hierarchies and departments that were used in the doctoral thesis (Killen, 2008) were also important for this work, especially because the power utilities had the same equivalent positions in their organizational structure. The perception of importance of R&D projects for corporate executives and managers from different areas was important for this study because the R&D projects are in many times used to reduce their operational problems and it should be important for all departments because reducing operational problems the productivity is improved, maintenance is reduced, customer satisfaction is improved since the power delivery is not interrupted.

Table 4.2 Respondents' perception of the importance of R&D projects' PPM for different areas of the company.

| Hierarchical / Department | | | | | |
|---|---|---|---|---|---|
| | Not Too Important [1] | Somewhat Important [2] | Quite Important [3] | Very Important [4] | Critically Important [5] |

| | | | | | |
|---|---|---|---|---|---|
| ... by Corporate Executives? | 1 | 6 | 12 | 7 | 4 |
| ... by Senior Managers? | 0 | 7 | 9 | 8 | 6 |
| ... by Technology Managers? | 0 | 2 | 10 | 13 | 5 |
| ... by Marketing/Sales Management Managers? | 4 | 12 | 8 | 2 | 4 |
| ... by Operations or Production Managers? | 0 | 3 | 12 | 9 | 6 |

Table 4.2 shows that the highest averages are attributed to technology managers followed by operation and production managers, then by senior managers and then by senior management executives. The lowest average is related to the perception of the importance of PPM for marketing and sales. The R&D projects, in general, have a greater focus on technological aspects for studies and solutions of operational problems of electric utilities; in addition, these areas are more directly involved in the day-to-day management of portfolios of projects, and therefore, their perception is more positive about the importance of PPM for business. Due to Law No. 9074/1995, in Brazil only consumers with a load of 10,000 kW can choose which power utility will buy electricity for consumption, so only large consumers have the freedom to choose which utility will buy electricity. Other customers should purchase electricity from utilities in the region where they are located. Since there is no competition, marketing and sales sectors have less need for new solutions and technologies for R&D of the areas of operation, production and technology.

The objective of have the variables presented at Table 4.3 was to identify if the companies dealed with projects together as one portfolio, the managers were committed to the PPM method, the method was applied consistently to all projects, rules and procedures were clear, there was a well-established procedure and there is an established PPM and explicit method. This investigation was important to verify if the power utilities already had a PPM process implemented, if the procedures were clear, if the method is consistently applied and if the management buys into it.

Table 4.3 Perceptions of the PPM method.

| | [1] | [2] | [3] | [4] | [5] |
|---|---|---|---|---|---|
| We have an established, explicit method for portfolio management and project selection.<br>1 = not at all; our method is not established.<br>5 = very much so; an established, explicit method | 1 | 5 | 10 | 5 | 9 |
| Our portfolio management method's rules and procedures are very clear; there is a well-defined procedure here.<br>1 = not at all; 5 = very much so. | 1 | 8 | 8 | 6 | 7 |
| Our portfolio management method is consistently applied to all the projects.<br>1 = not consistently applied, many projects "go around" the method.<br>5 = consistently applied to all the projects. | 0 | 8 | 9 | 3 | 10 |
| Management buys into the PPM; through its actions, management strongly supports its use.<br>1 = management does not buy in.<br>5 = management strongly endorses and uses the method | 3 | 2 | 10 | 9 | 6 |
| Our method treats all projects as a portfolio, considers all projects together and compares them against each other.<br>1 = focuses on individual projects, one at a time.<br>5 = looks at all projects together, as a portfolio | 3 | 8 | 5 | 9 | 5 |

As shown in Table 4.3 for PPM methods or procedures, 17 utilities reported having a formal method of management, and 13 reported having an

informal method. However, when asking about the selection of projects, 22 respondents reported using financial methods as criteria for selecting projects, and eight respondents do not use financial methods. That is, if there are financial criteria for selecting projects, there should be a formal method of PPM unless these criteria are not standardized in companies that said they did not have a formal method of management and different criteria are adopted each time the selection is made for the project.

The criteria used in the portfolio assessment process of responding companies are presented in Table 4.4.

Table 4.4 Criteria used in selecting projects

| **Criteria** | **Results** |
|---|---|
| Technology | 27 |
| Strategic Fit/Core Competence | 25 |
| Pay-off | 17 |
| Risk/Probability of Success | 18 |
| Timing | 17 |
| Protectability | 18 |
| Synergy Between Projects | 9 |
| Commercialisation | 2 |

Table 4.4 shows that the criteria technology and strategic fit/core competence are considered the most important for the respondents. These answers could be expected because the projects are R&D projects, so technology and strategic fit are very important drivers. Following this analysis, the other criteria with similar results, such as pay-off, risk/probability of success, timing and protectability, are also important, but considering R&D projects those criteria may be considered less significant in the project selection decision. For power utilities, generally the kinds of projects that they contract many times cannot have synergy with other projects in the portfolio. Regarding the commercialization criterion, most of the time the R&D projects are focused in solving operational problems for power utilities and not to develop a product that is possible to be commercialized.

In an open-end question about the biggest challenges faced by respondents in PPM, seven responses were related to the originality of the projects, which is the main criterion for the evaluation of the audit by ANEEL

and four responses cited directly concern the ANEEL audit directly. The other answers were related to the engagement of the participants' understanding of managers, the lack of role models and standardization, the selection of projects aligned with the organization's strategy, the high complexity of projects, the lack of good projects, the lack of standardization, the lack of time and the lack of qualified research institutions. Concern about the originality of the projects is because this item fails all project expenses are disallowed and, all the money must be returned with interest to the R&D account of the company.

The number of projects currently running in the companies is shown in Table 4.5. As can be seen, the number varied from 1 to 39 projects.

Table 4.5 Project quantities that are currently running the respondent companies.

| # of projects | Frequency | % |
|---|---|---|
| 8 | 4 | 13.30% |
| 11 | 4 | 13.30% |
| 1 | 3 | 10.00% |
| 23 | 3 | 10.00% |
| 2 | 2 | 6.70% |
| 3 | 2 | 6.70% |
| 5 | 2 | 6.70% |
| 7 | 2 | 6.70% |
| 10 | 2 | 6.70% |
| 32 | 2 | 6.70% |
| 4 | 1 | 3.30% |
| 30 | 1 | 3.30% |
| 36 | 1 | 3.30% |
| 39 | 1 | 3.30% |

In Table 4.5, the quantities of projects currently running in the power utilities presented differences due to the size of the companies. The small power utilities at times did not have a team to manage the R&D projects, while the larger companies had departments dedicated to manage the R&D projects; thus, it was possible for these companies to have over 30 projects running at the same time.

The typical duration of projects is shown in Table 4.6. The responses ranged from 18 to 36 months. There was the possibility of having projects 12 months and 48 months in length, but they were not cited by the respondents. For ANEEL, it is possible to have projects lasting up to 60 months. Generally, the R&D projects consider the application of a new technology to improve the power utility operation or to develop a new product based on an already available technology. So, the projects can have a duration of 24 or 30 months, considering that specialized institutions will develop these projects. If the kind of research is basic research, for example, developing a new material or a new technology, it is necessary to have more time, for example 48 or 60 months.

Tabela 4.6 Typical duration of the R&D projects.

| # of months | Incidence | % |
|---|---|---|
| 24 | 23 | 76,70% |
| 30 | 5 | 16,70% |
| 18 | 1 | 3,30% |
| 36 | 1 | 3,30% |

For measuring the overall success of the projects in organizations, the criteria are presented in Table 4.7. The criteria and levels used to verify the overall success of a project in the organizations were also obtained from Killen (2008). These criteria were important to verify how each criteria is perceived as important to indicate if the project was successful or not for the power utilities and in the developed proposal for this work these results were used to support the weighting attribution for the criteria stage at MCDA-C for the compensation rates. The criteria net present value (NPV)/Internal return rate (IRR), return of investment (ROI), payback period and profit are important mainly in the project selection stage by the power utilities. The customer satisfaction criterion is important because every year there is a survey organized by the Brazilian Association of Electric Power Distribution Companies (ABRADEE), that award the power utilities with best customer´s satisfaction results. Another reason for the customer satisfaction criterion be important for the power utilities is that the companies with the best results in the annual customer satisfaction survey organized by ANEEL can have a bonus having a small percentage added in the annual revision of electric energy tariff. The criteria sales volume, market share, growing existing

markets and entering new markets will be important in the near future when the residential customers will have the option to choose from which power utility they will buy the electricity. The criteria degree to which budget is met and degree to which schedule is kept are important for the ANEEL audit and were used in the developed proposal for this work as criteria in the ordinal risk calculation. The criterion time to market is another criterion that is important for the future for the power utilities because when the competition to supply electricity to the residential customers start these companies will have to find another sources of revenue developing new products and services, so time to market may have an important role to keep the companies competitive in the market.

Tabela 4.7 Criteria indicating the overall success of a project in organizations.

| Criteria | [1] very important | [2] | [3] | [4] | [5] Not very important | [0] Not measured |
|---|---|---|---|---|---|---|
| Net Present Value/Internal Return Rate | 7 | 5 | 3 | 3 | 6 | 6 |
| ROI | 12 | 5 | 4 | 4 | 2 | 3 |
| Payback period | 5 | 7 | 7 | 7 | 0 | 4 |
| Profit | 5 | 4 | 5 | 3 | 4 | 9 |
| Customer satisfaction | 9 | 8 | 6 | 0 | 2 | 5 |
| Sales volume / Market share | 1 | 6 | 10 | 0 | 4 | 9 |
| Growing existing markets | 2 | 7 | 7 | 4 | 2 | 8 |
| Entering new markets | 4 | 5 | 8 | 4 | 2 | 7 |
| Degree to which budget is met | 18 | 3 | 6 | 2 | 1 | 0 |
| Degree to which schedule is kept | 17 | 5 | 3 | 4 | 1 | 0 |
| Time to market | 11 | 14 | 0 | 4 | 1 | 0 |

Table 4.7 presents that the criteria identified as most important are related to the project development time, the degree to which the schedule is maintained and the degree to which the budget is maintained, which are the criteria for evaluating the ANEEL audit. As criteria are difficult to measure in R&D projects, such as the entry into new markets, profit, investment payback period and net present value/internal rate of return, they end up not being perceived as important and in many cases, are not used. For the market mode of operation in Brazil of electric utilities, the entry criteria into new markets, market share growth and sales revenue also have no direct relationship with the R&D projects.

From the exploratory survey, it was observed that there is a perception of the importance of PPM by managers mainly from operations, production and technology. It was also observed that most companies treat projects together as one portfolio, the managers are committed to the PPM method, the method is applied consistently to all projects, the rules and procedures are clear and there is a well-defined procedure and an established and explicit PPM method. Most respondents reported having a formal method of management and a few had an informal method. Most respondents said that they used financial methods for project selection criteria and considered the prioritization of projects.

With regard to an open-ended question about the biggest challenges faced by respondents in PPM, 7 responses were related to the originality of the projects, which is the main criterion for evaluation of the audit by ANEEL and 4 responses cited directly concern the ANEEL audit directly. This is a strong and frequent concern of R&D managers of utilities, because in case of failures in the audit of ANEEL, the amount of the project is expected to be partially or completely returned to the R&D budget, as previously explained in section 2.1.1.

The importance of the survey for this thesis are listed as follows:

- The respondents agreed that PPM is vital for the business because it is closely linked to the business strategy, project selection is important to keep the competitive position, keep the resources focused on what is important and maintain the right balance of projects. This result helped to support the justification of this study because it was possible to notice that PPM was important for the companies in the electricity sector.
- About the most significant challenges faced by the respondents in PPM one frequent point is about the ANEEL audit process and audit criteria because if the project is reproved in the audit

part of the invested money (and in some cases all the money) have to be returned to the R&D account plus the SELIC interest of the period. This result presented one research opportunity and an application to focus the development of the proposal, that was the problem with ANEEL audit in the end of the R&D projects by the power utilities.

- The number of projects developed simultaneously by the power utilities had a variation from 1 until 39 projects and the typical development time was 24 months or 30 months. For the companies with several projects being developed simultaneously with a development time between 2 years and 2 years and a half the PPM could be useful to support the R&D process in the power utilities.

## 4.2 Proposal for the PPM process for R&D projects for power utilities

### 4.2.1 Development of the proposal for R&D projects before selection

Each item shown in Figure 3.6 was divided into 5 levels. For example, the item "applicability of performed research" is shown in Table 4.8. Each level represents how good the "applicability" of the project is from the worst (level 1) to the best (level 5).

Table 4.8 Descriptions of the levels for the criteria "applicability of performed research".

| Levels | Description |
|---|---|
| Level 1 | The project has no applicability |
| Level 2 | The results can be applied only in the company, but the application as a whole is unclear |
| Level 3 | The results can be applied only in the company |
| Level 4 | The results can be applied in the company and in a larger geographical context, such as throughout the region, across the country or internationally |
| Level 5 | The results can be applied in the company and in a larger geographical context, such as throughout the region, across the country or internationally or in a sectoral context only in the power utility, the entire electrical industry or in different sectors of the economy |

The next step after the levels definition is to calibrate all the levels according to the consensus among two consultant specialists who are auditors in the ANEEL audit, using the software Macbeth® demo version. The importance judgments between levels could have the following weights: “null”, “very weak”, “weak”, “moderate”, “strong”, “very strong” and “extreme.” In the horizontal comparisons, from the left (level 1) to the right (level 5) the attractiveness differences have to grow. In the vertical comparisons, upwards from the level 5 until the level 1, the importance judgments have to grow as well. An example of the importance judgments is shown in Figure 4.1. After the attractiveness differences are selected, the transformed values from an ordinal scale to a cardinal scale for each level are presented in Figure 4.2. For each level (1 to 5) there is a correspondence value with a cardinal scale that represents the level. Table 2.2 presents the transformed values to cardinal scales for each level description for the criteria applicability of performed research.

Figure 4.1 Attractiveness difference between the criteria levels.

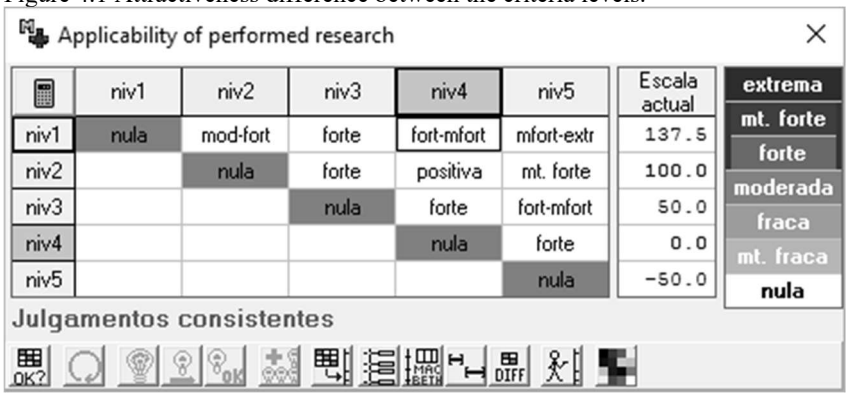


Figure 4.2 Transformed levels from an ordinal to a cardinal scale.

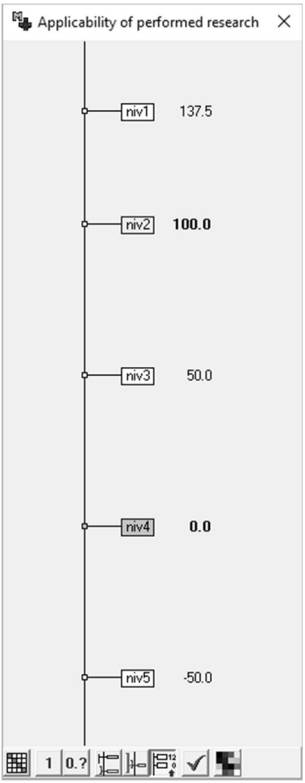



Table 4.9 Transformed values to a cardinal scale for each level description for the criteria applicability of the performed research.

| **Applicability of performed research** | |
|---|---|
| **Cardinal Scale** | **Description** |
| 137.5 | The project has no applicability |
| 100 | The results can be applied only in the company, but the application as a whole is unclear |
| 50 | The results can be applied only in the company |
| 0 | The results can be applied in the company and in a larger geographical context, such as throughout the region, across the country or internationally |

| | |
|---|---|
| -50 | The results can be applied in the company and in a larger geographical context, such as throughout the region, across the country or internationally or in a sectoral context only in the power utility, the entire electrical industry or in different sectors of the economy |

After the process of transforming values to cardinal scales, all the 13 criteria used in the proposal were grouped according to four groups related to the projects (Descriptive, Results and Products, Impacts and Feasibility and Knowledge). For each group of criteria, the values transformed to cardinal scales had the attractiveness differences one criteria to each other to define the compensation rates between the criteria. For the group "Results and Products", the criteria grouped were Results from the Project Stages, Professional Qualification, Applicability of the Research and Originality of Proposal that is shown in Figure 4.3. These criteria (N1 to N4) had the attractiveness differences compared one against other, as shown in Figure 4.4 and the compensation rates are also presented for each group.

Figure 4.3 The group "Results and Products" and its criteria.

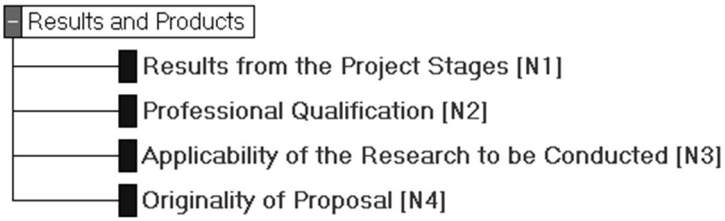


Figure 4.4 Attractiveness differences for the group “Results and Products” and the compensation rate calculation in the “Comp Rate” column.

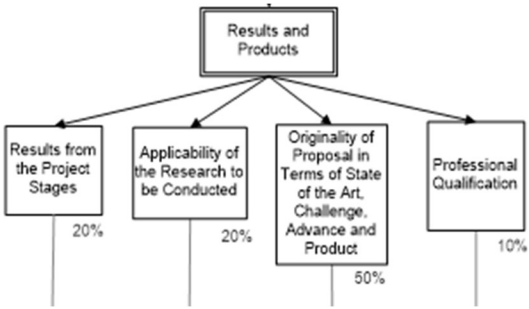
Results and Products

| | [ N4 ] | [ N1 ] | [ N2 ] | [ N3 ] | [ tudo inf. ] | Escala actual |
|---|---|---|---|---|---|---|
| [ N4 ] | nula 0 | forte 30 | forte 30 | extrema 40 | positiva 50 | 50 |
| [ N1 ] | | nula 0 | nula 0 | mfrac-fort 10 | positiva 20 | 20 |
| [ N2 ] | | nula 0 | nula 0 | mfrac-fort 10 | positiva 20 | 20 |
| [ N3 ] | | | | nula 0 | positiva 10 | 10 |
| [ tudo inf. ] | | | | | nula 0 | 0 |

extrema
mt. forte
forte
moderada
fraca
mt. fraca
nula

Julgamentos consistentes

Figure 4.5 The “Results and Products” group with its criteria and compensation rates.



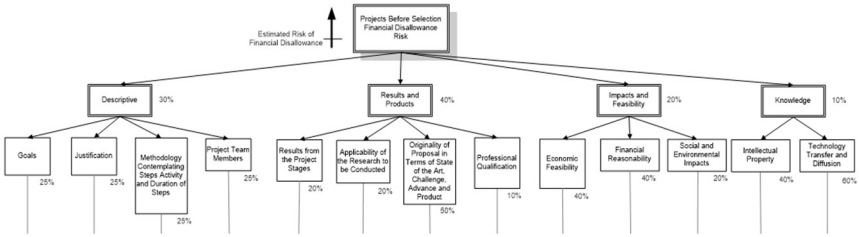

In Figure 4.5, the group “Results and Products” has four criteria with the correspondent compensation rates: Results from the Project Stages (20%), Professional Qualification (10%), Applicability of the Research (20%) and Originality of Proposal (50%). The compensation rates sum in a group is always 100%.

The same process was performed for the four groups created, and they were grouped into one general group “Projects before the selection by the specialists committee of the power utility regarding the finance disallowance risk”, where the groups had their criteria attractiveness differences defined comparing one against other using the Macbeth software and the compensation rates calculated.

### 4.2.2 Development of the proposal for R&D projects before selection

The groups with the calculated compensation rates according to explained before in section 2.3.1 are presented in Figure 4.6.

Figure 4.6 – Projects before the selection of the financial disallowance risk proposal.




The equation for this proposal was developed regarding the sum of all values transformed to cardinal scales of each criterion multiplied by the compensation rate of the criteria and then multiplied by the compensation rate of the group. This is shown in Equation 3. This equation shows the financial disallowance ordinal risk for projects before being selected by the power utility's specialist committee. The Equation 3 is elaborated from the diagram presented in the Figure 4.5 and the criterion cardinal value is multiplied by the weight of each criterion multiplied and by the weight of the criteria group and it is added to the other criteria of the criteria group which are multiplied in the same way. For example for the criteria group”Impacts and Feasibility”, that has a weight of compensation rate of 20%: “Economic Feasibility” x 40% x 20%+”Financial Reasonability” x 40% x 20%+”Social and Environmental Impacts” x 20% x 20%. To compose the complete equation all the Criteria groups are added to each other.

Equation 3 – Financial disallowance ordinal risk for projects before being selected by the power utility´s specialist committee

$$Financial\ Disallowance\ Risk\ For\ Projects\ Before\ Selection = \\ = 0{,}3 \times 0{,}25 \times goals + 0{,}3 \times 0{,}25 \times justification + 0{,}3 \times 0{,}25 \\ \times methodology + 0{,}3 \times 0{,}25 \times team\ members + 0{,}4 \times 0{,}2 \\ \times results\ from\ stages + 0{,}4 \times 0{,}2 \times aplicability + 0{,}4 \times 0{,}5 \\ \times originality + 0{,}4 \times 0{,}1 \times professional\ qualification + 0{,}2 \times 0{,}4 \\ \times economic\ feasibility + 0{,}2 \times 0{,}4 \times financialy\ reasonability + 0{,}2 \\ \times 0{,}2 \times social\ environmental\ impact + 0{,}1 \times 0{,}4 \times intelectual\ property \\ + 0{,}1 \times 0{,}6 \times technology\ transfer\ and\ diffusion$$

### 4.2.3 Development of the proposal for R&D projects already selected

Projects already selected are projects that were already evaluated and approved by the power utilities' specialist committee; therefore, these projects are already part of the R&D project portfolio. The proposal for R&D projects that were already selected is quite similar to the one shown in the previous section. The differences are in the criteria used to estimate risks, which led to a different ordinal risk proposal presented in Figure 4.7 and in the project selection step that in this case does not exist because the projects are already selected.

Figure 4.7 – Proposal for the ordinal risk calculation for already selected projects.

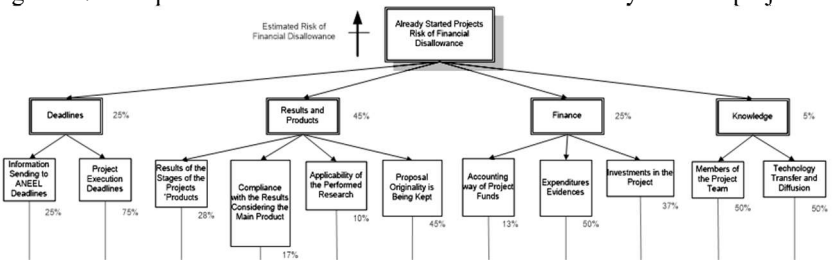



Figure 4.5 presents the four groups of criteria “Deadlines”, “Results and Products”, “Finance” and “Knowledge.” Each group of criteria has a compensation rate (%) that represents the importance of the group for the “Financial disallowance risk for projects that had already started” calculation. For each group of criteria, there are criteria that are used to support the calculation of each risk component with the respective compensation rate (%) regarding the criteria group. The sum of the multiplication of each criteria value by the criteria compensation rate by the group of criteria compensation rate will result in the “Financial disallowance

risk for projects that had already started" calculation, and it is presented in Equation 4. The Equation 4 is elaborated in the same way as explained in the Equation 3.

Equation 4 - Financial disallowance risk for projects that had already started

$$\begin{aligned} &Financial\ Disallowance\ Risk\ for\ Projects\ that\ had\ Already\ Started \\ &= 0{,}25 \times 0{,}25 \times information\ sending\ ANEEL\ deadlines + 0{,}25 \\ &\times 0{,}75 \times project\ execution\ deadlines + 0{,}45 \times 0{,}28 \\ &\times results\ stages\ project\ products + 0{,}45 \times 0{,}17 \\ &\times compliance\ with\ results\ considering\ main\ products + 0{,}45 \\ &\times 0{,}10 \times aplicability\ of\ performed\ research + 0{,}45 \times 0{,}45 \\ &\times proposal\ originality\ kept + 0{,}25 \times 0{,}13 \\ &\times accounting\ way\ project\ results + 0{,}25 \times 0{,}50 \\ &\times expenditures\ evidences + 0{,}25 \times 0{,}37 \\ &\times investiments\ in\ the\ project + 0{,}05 \times 0{,}50 \\ &\times members\ project\ team + 0{,}05 \times 0{,}50 \\ &\times technology\ transfer\ diffusion \end{aligned}$$

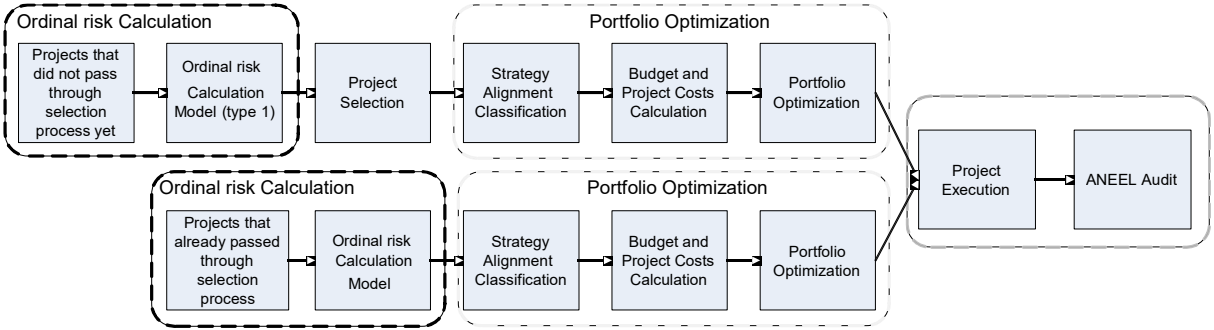
### 4.2.4 Development of the main proposal for R&D project portfolio optimization

The developed proposal result for project portfolio optimization is presented in the at Figure 4.8. Three PPM processes adopted by Brazilian power utilities were identified in the literature and were described at section 3.6. The processes used at the three power utilities can be clusterized in groups and these groups were positioned in a proposed process shown in Figure 4.8.

The ordinal risk calculated for financial disallowance was calculated for each project through a MCDA-C developed for this work. The higher the calculated value ordinal risk of financial disallowance, the greater the theoretical possibility of the project taking a financial disallowance.

The PPM developed proposal is presented in Figure 4.8.

Figure 4.8 PPM developed proposal



There are two kinds of inputs. The first involves projects that have not passed the selection process yet, and for this kind of input, the multicriteria ordinal risk calculation proposal was developed using some specific parameters from ANEEL audit criteria as parameters to calculate each project´s ordinal risk presented in Figure 2.2

The criteria for the projects that did not pass through the selection process yet include the applicability of the research to be developed, the experience and specialization of the researchers who will work on the project, social and environmental impacts, justifications for project execution. The method includes the description of the project stages and their durations, project objectives, proposed originality, potential of intellectual property generation, financial reasonableness, technology transfer forecast, technological diffusion and economic feasibility. After the projects have the ordinal risk risk calculated, they go through the project selection process, and the ordinal risk information can be used to select the projects that will compose the project portfolio.

The calculated ordinal risk will also feed the portfolio optimization proposal, which will use the information about the projects' alignment to strategy and portfolio budget and projects cost. The projects of the optimized portfolio will be executed regarding the auditing criteria ("originality", "performed on time", "budget", "scope" and the "complete, updated documentation"). This would lead to a low-risk project portfolio.

The second kind of input includes projects that have already passed through the selection process; the multicriteria ordinal risk (type 2) model was developed for these, which also uses some other specific parameters from the ANEEL audit criteria as parameters to estimate each project´s risk presented in Figure 2.3. The criteria used in the risk include characteristics related to the progress of projects based on the criteria of evaluation of R&D projects by ANEEL, such as (i) the replacement of the project team members when a team member leaves the project, (ii) technology transfer and diffusion, (iii) a procedure to account for project funds, (iv) expenses control, (v) the control of investments, (vi) timing and continuity of projects, (vii) adequacy of the expected results, (viii) originality of the proposed project is maintained and (ix) results are reached in each project stage.

### 4.3 Results of computational simulations using the proposed models and actual data from the studied power utilities

The utilities that provided the data for the computational simulations were chosen because they were the companies that allowed access to data

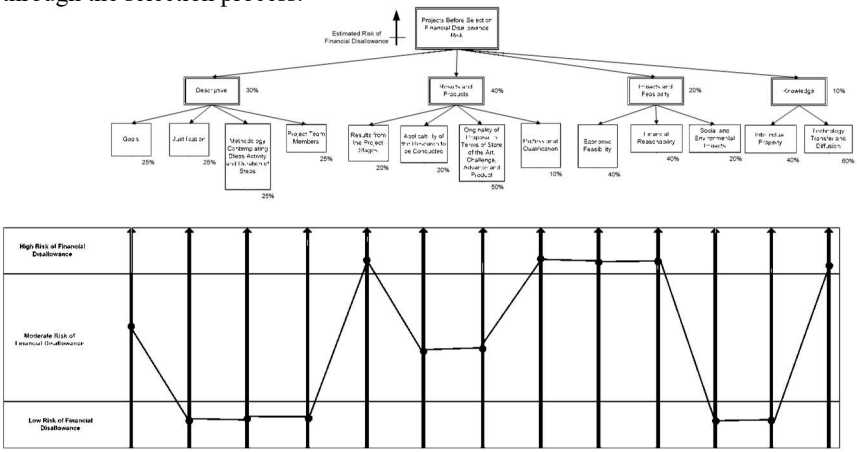
from research projects that were already selected by the power utilities´ specialist committee to compose the portfolio of R&D projects. The analysed projects that were already selected by the power utilities´ specialist committee and in power utilities that provided data about projects that are running and projects that were already audited by ANEEL. It is worth mentioning that no names of power utilities that provided the data will be disclosed.

### 4.3.1 Developed proposal for projects before passing through the selection process by the power utilities´ specialist committee

The ordinal risk proposal was developed using the MCDA-C. Figure 4.6 shows the MCDA-C model developed for the ordinal risk for R&D projects before passing through the selection process by the power utility´s specialist committee. The criteria were chosen using the ANEEL audit manual criteria. The weights were calibrated according to the consensus between two experts[7] who are auditors in the ANEEL audit. The calculation for the ordinal risk is performed using Equation 1 that was presented in Section 2.3.1. The results of the calculation are normalized and represent the ordinal risk for a project that had not passed through the selection process yet.

[7] The profile of the experts entail the following: (i) they have significant experience in managing R&D projects in the ANEEL R&D program; (ii) they understand in detail the ANEEL audit manual; (iii) they have a strong technical background; (iv) they have at least a bachelor degree and five years of professional experience in power electricity companies and (v) they are registered in the respective class council (CREA – Regional Board of Engineering, Architecture and Agronomy).

Figure 4.9 - Ordinal risk model using MCDA-C for R&D projects before passing through the selection process.




Examples of criteria descriptions and their corresponding levels are shown in Figure 4.10 and it was developed according to the method described in section 2.3.1. The full table with all criteria descriptions and corresponding levels is shown in Appendix 3. In the criteria examples presented in Table 4.9 in both cases, it describes the cardinal scale and each description for the criteria used to evaluate the indicator “Applicability of the research to be conducted” and “Professional qualification”. As the objective is to calculate the ordinal risk of problems in ANEEL audit, the highest the value of the criteria, the highest the ordinal risk. For the parameter “Applicability of the research to be conducted” the highest risk is if the developed project has no applicability for the utility, so there result of the project will not be used. On the other hand the lowest risk happens when the results can be applied in the company and in a larger geographical context, such as throughout the region, across the country or internationally or in a sectoral context, such as only the power utility, the entire electrical industry or in different sectors of the economy, so the results of the project have a high potential to be widely applied.

Table 4.10 Example of criteria and values transformed to cardinal scales for each parameter for R&D projects before passing through the selection process.

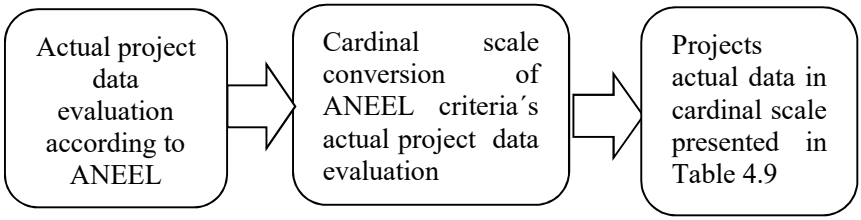
| **Applicability of the research to be conducted** | |
|---|---|
| **Cardinal Scale** | **Description** |
| 137.5 | The project has no applicability |
| 100 | The results can be applied only in the company, but the application as a whole is unclear |
| 50 | The results can be applied only in the company |
| 0 | The results can be applied in the company and in a larger geographical context, such as throughout the region, across the country or internationally |
| -50 | The results can be applied in the company and in a larger geographical context, such as throughout the region, across the country or internationally or in a sectoral context, such as only the power utility, the entire electrical industry or in different sectors of the economy |
| **Professional qualification** | |
| **Cardinal Scale** | **Description** |
| 150 | There will be no professional qualification |
| 100 | There will be a professional qualification at the specialisation level |
| 50 | There will be more than one professional qualification at the specialization level |
| 0 | There will be a professional qualification at the master's level |
| -50 | There will be more than one professional qualification at the doctoral level or masters level |

### 4.3.2Results of the computer simulations using the proposal before the project selection by the R&D specialist committee in the power utility companies

The simulations of projects before the selection by the R&D specialist committee in the power utility companies used the actual data of 37 projects from two power utilities of the same holding (one utility from the distribution sector and another one from the generation sector). These projects have already been assessed by a committee of the power utilities.

The results of the assessment were then compared to the results generated by the developed proposal. The Figure 4.10 illustrates the data from the assessment from the committee of the power utilities are converted to a cardinal scale as presented in the Table 4.10 for all the ANEEL criteria and the results of the project´s data in cardinal scale are presented in Table 4.11. Each project has a standardized text where standardized fields are inserted information about objectives, justification, methodology, project members, results, etc. From these texts, the analyzes are performed to fill in the text that describes each criterion with the cardinalized levels and the corresponding cardinal level is found for each criterion and the table for each project is filled in.

Figure 4.10 – Illustration of actual project data conversion to cardinal




The table 4.10 shows the “ordinal risk value of money disallowance” (i.e. the gross ordinal risk before the normalization) that was calculated using Equation 1 and the “relative value of money disallowance normalized” (i.e. the calculated percentage that the project can be reproved in the ANEEL audit) that was calculated using Equation 4. These ordinal risks were calculated based on the weighted indicators regarding the criteria and the value of the calculated ordinal risk regards these indicators. Thus, each calculated ordinal risk is relative to the adopted indicators, that were based on the criteria of the ANEEL audit manual (2013) and based on the risk values it is possible to obtain a rank of the projects according to the ordinal risks. The table 4.11 presents the projects ranking according to the normalized ordinal risk calculated.

Tabela 4.11 Actual data in cardinal scale for 37 R&D projects before the project selection in a power utility company

| CRITERIA | Project 1 | Project 2 | Project 3 | Project 4 | Project 5 | Project 6 | Project 7 | Project 8 | Project 9 | Project 10 | Project 11 | Project 12 | Project 13 | Project 14 | Project 15 | Project 16 | Project 17 | Project 18 | Project 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goals | 0 | 0 | 57.14 | -57.14 | 100 | 57.14 | 0 | 57.14 | 0 | -57.14 | -57.14 | 57.14 | 57.14 | 0 | -57.14 | 57.14 | -57.14 | 57.14 | -57.14 |
| Justification | 57.14 | 57.14 | 57.14 | -42.86 | 100 | 57.14 | 57.14 | 57.14 | 0 | -42.86 | -42.86 | 0 | 100 | 0 | -42.86 | 57.14 | 57.14 | 100 | 0 |
| Methodology considering stages' activities and duration of stages | 50 | -50 | 100 | -50 | 0 | 100 | 0 | 100 | 0 | -50 | 0 | 100 | 100 | -50 | -50 | 50 | 100 | 50 | -50 |
| Members of the project team | 150 | -50 | 100 | -50 | 50 | 50 | 50 | 100 | 0 | -50 | 50 | 50 | 50 | 0 | -50 | 50 | -50 | 100 | 0 |
| Results products of projects stages | 0 | 0 | 50 | 57.14 | 0 | 57.14 | 0 | 0 | 57.14 | -57.14 | 0 | 57.14 | 57.14 | 57.14 | -57.14 | 57.14 | 100 | 57.14 | 57.14 |
| Applicability of carried out research | -50 | -50 | 50 | -50 | 0 | 100 | 0 | 100 | 0 | -50 | 0 | 50 | 100 | 100 | -50 | 0 | 100 | 100 | 0 |
| Proposed originality in terms of state of the art, challenge, progress and product | -47.06 | -47.06 | 47.06 | 0 | 0 | 47.06 | 0 | 0 | 47.06 | 0 | 0 | 47.06 | 47.06 | 0 | -47.06 | 47.06 | 100 | 47.06 | 0 |
| Professional training | -50 | -50 | 100 | -50 | -50 | 0 | -50 | 150 | 0 | 0 | 100 | 50 | 100 | 0 | 0 | -50 | 150 | -50 | 50 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Economic feasibility | 100 | -42.86 | 100 | 57.14 | 100 | 57.14 | 57.14 | 100 | 0 | -42.86 | 57.14 | 100 | 142.86 | 0 | -42.86 | 142.86 | 57.14 | 100 | 142.86 |
| Financial reasonability | 100 | 150 | 100 | 0 | 100 | 100 | 50 | 100 | 0 | 0 | 0 | 150 | 100 | 0 | 0 | 150 | 100 | 50 | 0 |
| Social and economic impact | 0 | 50 | 50 | 0 | 0 | 50 | 0 | 50 | 50 | -50 | -50 | 150 | 100 | 0 | -50 | 0 | 150 | 0 | 50 |
| Intellectual property | 50 | 0 | 100 | 150 | 50 | 100 | 0 | 100 | 0 | | 50 | 0 | 100 | 100 | -50 | 150 | 150 | 0 | 0 |
| Technology transfer and Diffusion | 50 | 0 | 100 | -37.5 | -37.5 | 100 | 0 | 50 | 0 | -37.5 | 0 | 0 | 100 | 100 | -37.5 | 0 | 100 | 50 | -37.5 |
| **Ordinal risk value of money disallowance** | 24.87 | -8.06 | 72.98 | -8.11 | 32.50 | 66.38 | 14.61 | 62.57 | 15.98 | -31.25 | 4.82 | 61.52 | 82.45 | 18.82 | -42.66 | 57.48 | 76.32 | 57.48 | 9.71 |
| **Ordinal risk value of money disallowance normalized** | 0.48 | 0.25 | 0.82 | 0.25 | 0.54 | 0.78 | 0.41 | 0.75 | 0.42 | 0.08 | 0.34 | 0.74 | 0.89 | 0.44 | 0.00 | 0.71 | 0.85 | 0.71 | 0.37 |

Table 4.11 - Actual data for 37 R&D projects before the project selection in a power utility company - continued

| CRITERIA | Project 20 | Project 21 | Project 22 | Project 23 | Project 24 | Project 25 | Project 26 | Project 27 | Project 28 | Project 29 | Project 30 | Project 31 | Project 32 | Project 33 | Project 34 | Project 35 | Project 36 | Project 37 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goals | -57.14 | -57.14 | 57.14 | 0 | -57.14 | 100 | -57.14 | 0 | 0 | 0 | 0 | 57.14 | 57.14 | -57.14 | 0 | 57.14 | 0 | -57.14 |
| Justification | 0 | 142.86 | 0 | -42.86 | -42.86 | 57.14 | 0 | 57.14 | 0 | 100 | 57.14 | 57.14 | 142.86 | 0 | -42.86 | 100 | 0 | 57.14 |
| Methodology considering stages activities and duration of stages | 0 | 50 | 100 | -50 | 0 | 100 | 0 | 100 | 150 | 50 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 |
| Members of the project team | -50 | 50 | 50 | 0 | 50 | 100 | 150 | 50 | 150 | 50 | 50 | 50 | 50 | 0 | 0 | 0 | 0 | 50 |
| Results products of projects stages | -57.14 | 142.86 | 0 | 57.14 | -57.14 | 0 | 57.14 | 57.14 | 100 | 100 | 0 | 100 | 142.86 | 0 | 0 | 100 | 57.14 | 57.14 |
| Applicability of carried out research | 50 | 50 | -50 | 50 | 0 | 50 | 0 | 0 | 0 | 50 | 0 | 50 | 100 | 0 | 50 | 50 | 0 | 0 |
| Proposed originality in terms of state of the art. challenge. progress and product | 47.06 | 152.94 | -47.06 | 0 | 0 | 47.06 | 100 | 0 | 100 | 47.06 | 0 | 100 | 152.94 | 0 | 100 | 47.06 | 0 | 47.06 |
| Professional training | 150 | 0 | 50 | -50 | -50 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | -50 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Economic feasibility | 0 | 100 | 142.86 | -42.86 | 0 | 0 | 0 | 0 | 57.14 | 100 | 142.86 | 142.86 | 142.86 | 0 | 57.14 | 0 | 0 | 142.86 |
| Financial reasonability | 50 | 150 | 0 | -50 | 0 | 0 | 100 | 0 | 100 | 50 | 50 | 100 | 100 | 0 | 50 | 0 | 0 | 100 |
| Social and economic impact | 0 | 50 | 50 | -50 | 0 | 0 | 100 | 0 | 0 | 150 | 0 | 100 | 100 | 0 | 50 | 50 | 0 | 100 |
| Intellectual property | -50 | -50 | 0 | 50 | 100 | 100 | 0 | 0 | 0 | 0 | 150 | 50 | 100 | 0 | 150 | 0 | 0 | -50 |
| Technology transfer and Diffusion | -37.5 | -37.5 | 0 | -37.5 | -37.5 | 100 | 0 | 100 | 50 | 50 | 0 | -37.5 | -37.5 | 100 | 50 | 50 | 0 | -37.5 |
| **Ordinal rsk value of money disallowance** | 6.56 | 77.70 | 17.55 | -10.07 | -8.57 | 54.20 | 43.54 | 26.11 | 66.07 | 61.41 | 29.46 | 67.50 | 97.70 | 5.46 | 42.36 | 38.20 | 4.57 | 34.91 |
| **Ordinal risk value of money disallowance normalized** | 0.35 | 0.86 | 0.43 | 0.23 | 0.24 | 0.69 | 0.61 | 0.49 | 0.77 | 0.74 | 0.51 | 0.78 | 1.00 | 0.34 | 0.61 | 0.58 | 0.34 | 0.55 |

Table 4.12 Projects ranking according to the normalized ordinal risk calculated.

| Classification regarding ordinal risk normalized | Ordinal risk normalized | Project # |
|---|---|---|
| **1st** | 0.00 | 15 |
| **2nd** | 0.08 | 10 |
| **3rd** | 0.23 | 23 |
| **4th** | 0.24 | 24 |
| **5th** | 0.25 | 2 |
| **6th** | 0.25 | 4 |
| **7th** | 0.34 | 11 |
| **8th** | 0.34 | 33 |
| **9th** | 0.34 | 36 |
| **10th** | 0.35 | 20 |
| **11th** | 0.37 | 19 |
| **12th** | 0.41 | 7 |
| **13th** | 0.42 | 9 |
| **14th** | 0.43 | 22 |
| **15th** | 0.44 | 14 |
| **16th** | 0.48 | 1 |
| **17th** | 0.49 | 27 |
| **18th** | 0.51 | 30 |
| **19th** | 0.54 | 5 |
| **20th** | 0.55 | 37 |
| **21st** | 0.58 | 35 |
| **22nd** | 0.60 | 18 |

| | | |
|---|---|---|
| **23rd** | 0.61 | 26 |
| **24th** | 0.61 | 34 |
| **25th** | 0.69 | 25 |
| **26th** | 0.71 | 16 |
| **27th** | 0.74 | 12 |
| **28th** | 0.74 | 29 |
| **29th** | 0.75 | 8 |
| **30th** | 0.77 | 28 |
| **31st** | 0.78 | 6 |
| **32nd** | 0.78 | 31 |
| **33rd** | 0.82 | 3 |
| **34th** | 0.85 | 17 |
| **35th** | 0.86 | 21 |
| **36th** | 0.89 | 13 |
| **37th** | 1.00 | 32 |

The table 4.12 presents the projects ranking according to the normalized ordinal risk calculated. The sequence of the projects according to the ordinal risk normalized. In this study the calculated project ordinal risks are relative values because they are compared to the other project risks in the same portfolio. In the next step the values of the calculated ordinal risk normalized was used in the multi-objective optimization. As it was explained in the section 2.3.1, to determine the optimal portfolio using PSO for the multi-objective optimization simulation, which was performed using Matlab® software according to three optimization objectives, which are: minimize the project portfolio risk; maximize the alignment to the company's strategy and minimize the amount of the difference between the budget for R&D projects defined by law and the whole cost of the project portfolio. The optimal portfolio will be the one with the smallest Euclidean distance from the theoretical optimum given by normalized coordinates where the risk of the disallowance of the projects is zero, the difference between the budget

for R&D projects defined by law and the whole cost of the project portfolio added is zero and alignment with the strategy is maximum, where in this case the project portfolio cost was used an inverted scale for the maximum alignment with strategy be coincident with the coordinate zero.

The Figures 4.11, 4.12, 4.13 and 4.14 are results of Matlab® software simulation of the developed model and these figures represent all the project portfolio options that were non dominated and from all these possible project portfolio options the one that is the optimal project portfolio has the smallest Euclidian distance from the theoretical minimum that is (0,0,0). The Figures 4.11, 4.12, 4.13 and 4.14 show the same results by different perspectives of visualization. The Figure 4.11 presents a three-dimensional Pareto frontier representation of the portfolios regarding risk, cost-budget and alignment. The optimal portfolio is a small dot indicated by the arrow in the graphic. The optimal point is located at the minimum cost-budget (close to zero), minimum risk (close to zero) and maximum alignment with strategy (the scale is inverted and increases the further it goes down), so this is the point with the smallest Euclidian distance to the theoretical minimum (0, 0, 0).

Figure 4.11 Three dimensional Pareto frontier of portfolios

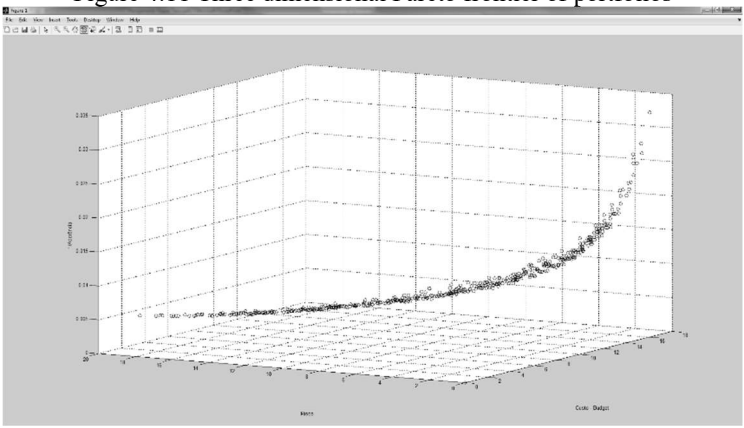


Figure 4.12 presents a two-dimensional Pareto frontier representation showing the optimal portfolio regarding risk versus cost-budget. It shows the optimal portfolio at the minimum point where there is the best trade-off between them, that is the point with the smallest Euclidian distance from the theoretical minimum (0,0).

Figure 4.12 Pareto frontier showing solutions for Risk x Cost-budget.

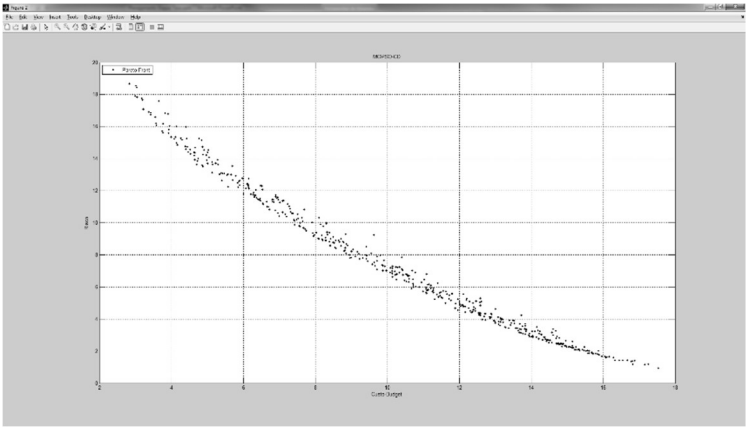


Figure 4.13 presents a two-dimensional Pareto frontier representation showing the optimal portfolio regarding risk versus alignment. It shows the optimal portfolio at the minimum point where there is the best trade-off between them, that is the point with the smallest Euclidian distance from the theoretical minimum (0,0).

Figure 4.13 Pareto frontier for Alignment x Risk.

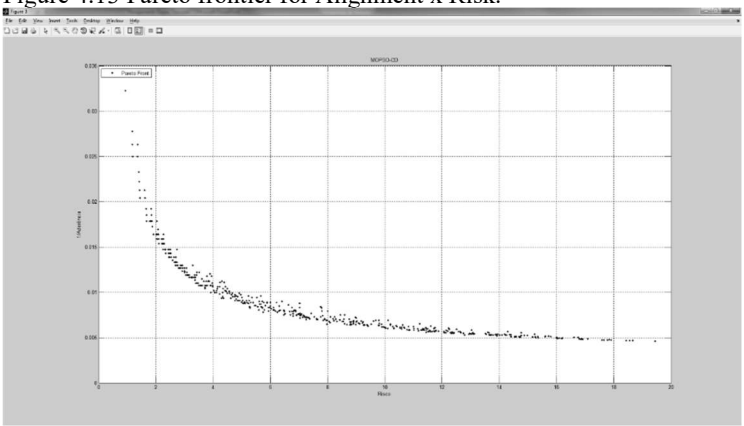


Figure 4.14 presents a two-dimensional Pareto frontier representation showing the optimal portfolio regarding alignment versus cost-budget. It shows the optimal portfolio at the minimum point where there

is the best trade-off between them, that is the point with the smallest Euclidian distance from the theoretical minimum (0,0).

Figure 4.14 Pareto frontier for Alignment x Cost-Budget.

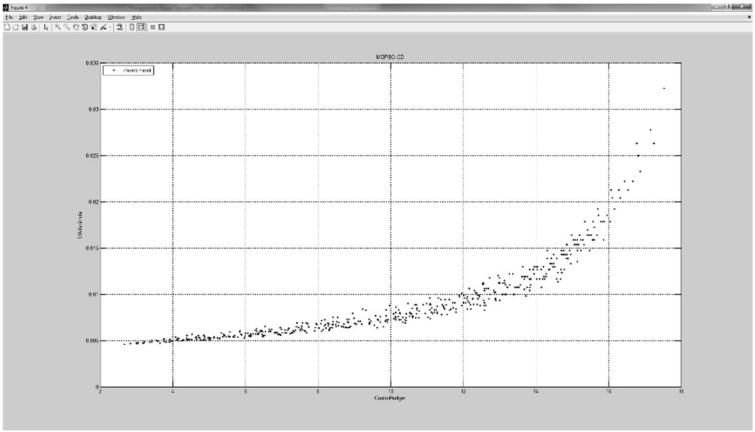


Figure 4.10 is the three-dimensional Pareto frontier representation of the portfolios regarding risk, cost-budget and alignment and Figure 4.11, Figure 4.12 and Figure 4.13 represent Figure 4.10 in two dimensions; the Pareto frontier representation considering two parameters each time shows the optimal portfolio in separate figures. In the three-dimensional Pareto frontier, it is easier to verify that the optimal portfolio is the closest point to the theoretical optimal portfolio is located at coordinate (0, 0, 0) regarding the axes (cost-budget, risk and alignment with strategy). The two-dimensional Pareto frontier views did not make the visualization of the optimal portfolio easier because the optimal portfolio in the two-dimensional visualization is not the point closer to coordinate (0, 0).

Table 4.13 shows the comparison between the project evaluation by the power utility´s specialist committee and the proposed model simulation for optimal portfolio selection. The row "Project" presents the projects identified by the numbers from 1 to 37. The row "Strategy Alignment" shows the results of the alignment with the power utility´s strategy and correspondent levels that were presented at Table 4.13. The row "Cost" presents each project cost informed by the power utility. The row "Normalized Ordinal risk" presents the ordinal normalized risk of money disallowance that was calculated in Table 4.12 for each project. The row "Project Evaluation by the Power Utility" shows the results of the project evaluation by the power utility´s specialist committee, that had three results output possibilities: "Approved" when the project has no potential problems identified by the committee and it is approved, "Review" for the situations where the project has some potential problems identified by the committee regarding ANEEL criteria and the project is supposed to be reviewed by the project proponent and after the project revision it is analysed again by the specialist committee and "Disapproved" for when the project has originality problems or many potential problems regarding ANEEL criteria and it is discarded.

Table 4.13 Comparison between the project evaluation by the power utility´s specialist committee and the proposed model simulation for optimal portfolio selection.

| Project | Strategy Alignment | Cost (x10 MM R$) | Normalized Calculated Ordinal risk | Ranking Regarding Normalized Calculated Ordinal risk | Project Evaluation by the Power Utility | Model Simulation for Optimal Portfolio Selection |
|---|---|---|---|---|---|---|
| Project 1 | 9 | 1.00 | 0.48 | 16th | **Review** | **Not selected** |
| Project 2 | 9 | 1.20 | 0.25 | 5th | **Approved** | **Selected** |
| Project 3 | 5 | 0.80 | 0.82 | 33rd | **Review** | **Not selected** |
| Project 4 | 9 | 0.60 | 0.25 | 6th | **Approved** | **Selected** |
| Project 5 | 7 | 2.00 | 0.54 | 19th | **Review** | **Not selected** |
| Project 6 | 3 | 2.50 | 0.78 | 31st | **Review** | **Not selected** |
| Project 7 | 7 | 0.65 | 0.41 | 12th | **Review** | **Selected** |
| Project 8 | 3 | 0.20 | 0.75 | 29th | **Review** | **Not selected** |
| Project 9 | 7 | 1.80 | 0.42 | 13th | **Approved** | **Selected** |
| Project 10 | 9 | 0.95 | 0.08 | 2nd | **Review** | **Selected** |
| Project 11 | 7 | 0.25 | 0.34 | 7th | **Approved** | **Selected** |
| Project 12 | 5 | 1.10 | 0.74 | 27th | **Review** | **Not selected** |
| Project 13 | 3 | 2.40 | 0.89 | 36th | **Review** | **Not selected** |
| Project 14 | 3 | 0.80 | 0.44 | 15th | **Approved** | **Selected** |
| Project 15 | 9 | 1.35 | 0.00 | 1st | **Approved** | **Selected** |
| Project 16 | 7 | 1.50 | 0.71 | 26th | **Review** | **Not selected** |
| Project 17 | 3 | 2.13 | 0.85 | 34th | **Disapproved for lack of originality** | **Not selected** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Project 18 | 3 | 1.46 | 0.60 | 22nd | Appro-ved | Not selec-ted |
| Project 19 | 7 | 1.17 | 0.37 | 11th | Appro-ved | Selec-ted |
| Project 20 | 5 | 0.87 | 0.35 | 10th | Appro-ved | Selec-ted |
| Project 21 | 5 | 0.87 | 0.86 | 35th | Disappro-ved for lack of originality | Not selec-ted |
| Project 22 | 9 | 1.24 | 0.43 | 14th | Appro-ved | Selec-ted |
| Project 23 | 5 | 1.09 | 0.23 | 3rd | Appro-ved | Selec-ted |
| Project 24 | 7 | 1.12 | 0.24 | 4th | Appro-ved | Selec-ted |
| Project 25 | 5 | 1.95 | 0.69 | 25th | Review | Not selec-ted |
| Project 26 | 7 | 2.58 | 0.61 | 23rd | Disappro-ved for lack of originality | Not selec-ted |
| Project 27 | 7 | 1.61 | 0.49 | 17th | Appro-ved | Selec-ted |
| Project 28 | 7 | 1.24 | 0.77 | 30th | Disappro-ved for lack of originality | Not selec-ted |
| Project 29 | 5 | 0.85 | 0.74 | 28th | Review | Selec-ted |
| Project 30 | 7 | 0.60 | 0.51 | 18th | Appro-ved | Sele-cted |
| Project 31 | 5 | 0.98 | 0.78 | 32nd | Review | Not selec-ted |
| Project 32 | 7 | 2.43 | 1.00 | 37th | Review | Not selec-ted |
| Project 33 | 7 | 1.33 | 0.34 | 8th | Appro-ved | Selec-ted |
| Project 34 | 5 | 1.39 | 0.61 | 24th | Appro-ved | Selec-ted |
| Project 35 | 5 | 0.88 | 0.58 | 21st | Review | Selec-ted |

| | | | | | | |
|---|---|---|---|---|---|---|
| Project 36 | 7 | 1.16 | 0.34 | 9th | **Appro-ved** | **Selec-ted** |
| Project 37 | 7 | 1.12 | 0.55 | 20th | **Review** | **Selec-ted** |

Table 4.13 shows the comparison between the project evaluation by the power utility´s specialist committee and the proposed model simulation for optimal portfolio selection. The row "Project" presents the projects identified by the numbers from 1 to 37. The row "Strategy Alignment" shows the results of the alignment with the power utility´s strategy and correspondent levels that were presented at Table 4.13. The row "Cost" presents each project cost informed by the power utility. The row "Normalized Ordinal risk" presents the ordinal normalized risk of money disallowance that was calculated in Table 4.12 for each project. The row "Project Evaluation by the Power Utility" shows the results of the project evaluation by the power utility´s specialist committee, that had three results output possibilities: "Approved" when the project has no potential problems identified by the committee and it is approved, "Review" for the situations where the project has some potential problems identified by the committee regarding ANEEL criteria and the project is supposed to be reviewed by the project proponent and after the project revision it is analysed again by the specialist committee and "Disapproved" for when the project has originality problems or many potential problems regarding ANEEL criteria and it is discarded.

Table 4.13 Comparison between the project evaluation by the power utility´s specialist committee and the proposed model simulation for optimal portfolio selection.

As presented in Table 4.13, there was only one case in which the project was approved by the power utility, and it was not selected by the developed model simulation for portfolio optimization, i.e. Project 18 (highlighted). The main reason the developed model was not selected in this project is that its alignment to strategy is level 3, which according to Table 4.13 means "little alignment to strategy" and as the system uses an

optimization model, the proposal found another option that was more closely aligned to the strategy, with a smaller cost and with less risk as, for example, Project 10 (highlighted).

Table 4.14 shows the optimal portfolio results from the simulations considering different budgets. For these simulations, Matlab® was used to run the PSO.

Table 4.14 Optimal portfolio results simulations regarding different budgets using Matlab® to run the PSO.

| Budget [R$ million] | Project sequence |
|---|---|
| 5 | 2 4 9 10 15 20 23 |
| 10 | 2 4 7 9 10 15 20 22 23 24 30 36 |
| 15 | 2 4 7 9 10 14 15 19 20 22 23 24 30 35 36 |
| 20 | 2 4 7 9 10 11 14 15 19 20 22 23 24 25 30 34 35 36 |
| 25 | 2 4 7 9 10 11 14 15 19 20 22 23 24 27 29 30 33 34 35 36 37 |
| 30 | 2 4 7 9 10 11 12 14 15 16 19 20 22 23 24 25 27 30 33 34 35 36 37 |
| 35 | 2 4 7 9 10 11 12 14 15 16 19 20 22 23 24 25 27 29 30 31 34 35 36 37 |
| 40 | 2 4 7 9 10 11 14 15 16 18 19 20 22 23 24 25 27 29 30 31 33 34 35 36 37 |
| 45 | 2 4 7 9 10 11 14 15 16 18 19 20 22 23 24 25 27 29 30 31 33 34 35 36 37 |
| 100 | 1 2 3 4 5 7 8 9 10 11 13 14 15 16 18 19 20 22 23 24 25 27 29 30 31 32 33 34 35 36 37 |
| 200 | 2 3 4 5 6 7 9 10 11 13 14 15 16 18 19 20 22 23 24 25 27 29 30 31 32 33 34 35 36 37 |

The power utility that this research had access to for the project portfolio data had a total budget of R$ 25 million, so this is the value that was considered for all the portfolio simulations. The optimal project portfolio for

this budget is shown in Table 4.15. The other simulation scenarios (from R$ 5 to R$ 200 million) were performed just to verify what projects would be selected for those budget values. The projects that were chosen by the simulated proposal when variating the budget value scenarios generally were the same and appear in all the results (Projects 2, 4, 9, 10, 15, 20 and 23); these projects have the best alignment with strategy, smaller risk of financial disallowance and a cost composition that minimizes the residual budget. For budgets equal and larger than R$ 10 million, Projects 22, 24, 30 and 36 also appear in all the optimal portfolio results; as such, these projects have the second best alignment with strategy, a smaller risk of financial disallowance and a cost composition that minimizes the residual budget. For another scenarios with different budgets another projects composed the portfolios and the larger the budget, the greater the number of projects in the optimal portfolio.

Table 4.15 Optimal project portfolio for the R$ 25 million budget.

| | Projects sequence |
|---|---|
| Best Project Portfolio | 2 4 7 9 10 11 14 15 19 20 22 23 24 27 29 30 33 34 35 36 37 |

Table 4.16 shows an example of the output table that lists the project portfolio with the chosen projects.

Table 4.16 Example of the output table of the optimal project simulation that lists the project portfolios with the chosen projects.

| | Project 1 | Project 2 | Project 3 | Project 4 | ... | Project 37 |
|---|---|---|---|---|---|---|
| Portfolio 1 | 1 | 1 | 1 | 1 | ... | 1 |
| Portfolio 2 | 0 | 1 | 0 | 1 | ... | 1 |
| Portfolio 3 | 0 | 0 | 0 | 0 | ... | 0 |
| Portfolio 4 | 0 | 0 | 0 | 0 | ... | 0 |
| Portfolio 5 | 0 | 0 | 0 | 0 | ... | 1 |
| Portfolio 6 | 0 | 0 | 0 | 0 | ... | 0 |
| : | : | : | : | : | ... | : |

| | | | | | | |
|---|---|---|---|---|---|---|
| Portfolio 499 | 0 | 1 | 1 | 1 | ... | 1 |

In Table 4.16 the rows indicate the projects from Project 1 to Project 37, and the lines indicates the portfolio options. The number 1 indicates that the project was selected for the portfolio, and 0 indicates that the project was not selected for the portfolio. A total of 499 different situations were simulated regarding the various projects in the portfolio considering the three objectives: (i) the best alignment with strategy, (ii) a smaller risk of financial disallowance and (iii) a cost composition that minimize the residual budget.

### 4.3.3 Proposal for R&D projects that were already selected by the R&D specialist committee in the power utilities and are already running

The calculated ordinal risk proposal was developed using the MCDA-C. The criteria were chosen regarding the ANEEL audit manual criteria, and the weights were calibrated according to the consensus between two experts who are auditors in the ANEEL audit. The calculated ordinal risk proposal using MCDA-C for the R&D project portfolio for the projects that were already selected by the specialist committee at the power utility and are already running is presented in Figure 4.15.

Figure 4.15 – Calculated Ordinal risk proposal using MCDA-C for the R&D project portfolio for the projects that are already running.

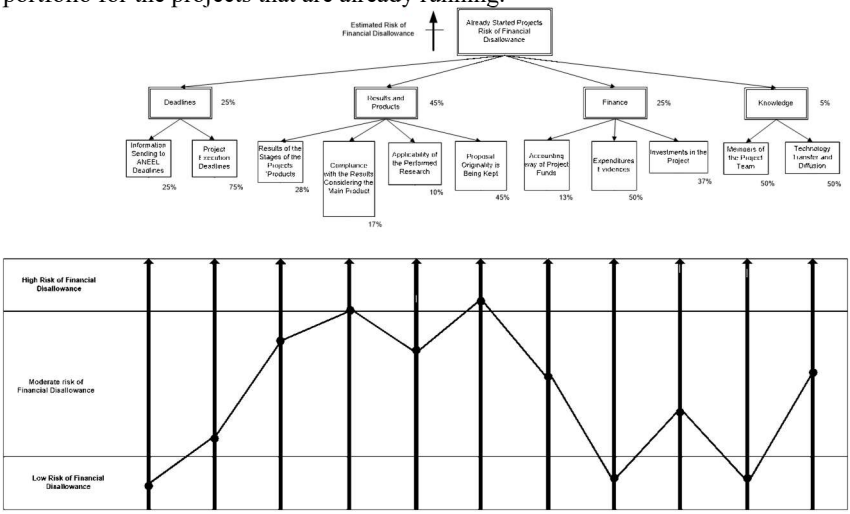


Figure 4.15 shows the MCDA-C model developed for calculated ordinal risk for R&D projects that are already running. The criteria were chosen using the ANEEL audit manual criteria. The weights were calibrated according to the consensus between two experts who are auditors in the ANEEL audit. The calculated ordinal risk for the R&D projects that were already selected by the power utility´s specialist committee for project selection is performed using Equation 2, presented in section 2.3.2. The results of the calculation are normalized and represent the calculated ordinal risk of financial disallowance that is already running. The examples of criteria descriptions and their corresponding levels are shown in Table 4.17. The complete table is presented in Appendix 3.

Table 4.17 Criteria and values transformed to cardinal scales for each parameter projects' risk of finance disallowance for the R&D projects that are already running.

| **Members of the project team** | |
|---|---|
| **Cardinalized Scale** | **Description** |
| 150 | Most members of the project team were replaced by members without equivalent academic degrees in the area of competence, and there are no justifications for them |
| 100 | A minority of the members of the project team were replaced by members with the same academic degree in their area of competence, and there are no justifications for them |
| 50 | Most members of the project team were replaced by members with equivalent academic degrees in their area of competence, and there are justifications for them |
| 0 | A minority of the members of the project team were replaced by members with the same academic degree in their area of competence, and there are justifications for them |
| -50 | All members of the project team were kept or were replaced by members with the same academic degree in their area of competence, and there are justifications for them |
| **Technology transfer and diffusion** | |
| **Cardinalized Scale** | **Description** |

| | |
|---|---|
| 142.86 | There were no meetings, workshops, trainings, etc. for technology transfer and diffusion, and there are no justifications for it |
| 100 | There was an insufficient quantity of meetings, workshops, trainings, etc. for technology transfer and diffusion, with partial justifications for it |
| 57.14 | There was an insufficient quantity of meetings, workshops, trainings, etc. for technology transfer and diffusion, with justifications for them |
| 0 | There was almost a sufficient number of meetings, workshops, trainings, etc. for technology transfer and diffusion, with justifications for them |
| -57.14 | There were sufficient meetings, workshops, trainings, etc. for technology transfer and diffusion of the project |

### 4.3.4Results of the computer simulations using the proposal for already started R&D projects

For the already started projects, the simulation used data from 5 projects from 3 different power utilities that were completed and complied with the audit by ANEEL. The purpose was to compare the chance of the calculated ordinal risk of disallowance calculated by the proposal and the value of real disallowance applied by ANEEL. Table 4.18 shows the results of the simulation compared to the actual results of the ANEEL audit. In this analysis, it was not necessary to elaborate a ranking because the actual intention is to define the possibility of having a money disallowance applicated by ANEEL. Thus, it was calculated the normalized ordinal risk of disallowance for each project and this calculated ordinal risk was compared to the actual disallowance applied by ANEEL.

Table 4.18 Results of the evaluation comparing the actual data of the initiated projects' ordinal risk calculated value and the money disallowance applied by ANEEL

| CRITERIA | Project 1 | Project 2 | Project 3 | Project 4 | Project 5 |
|---|---|---|---|---|---|
| Deadlines to Send Information to ANEEL | -60 | -60 | -60 | -60 | -60 |
| Project Execution Deadlines | -57.14 | -57.14 | -57.14 | 0 | -57.14 |
| Results / Products of Project Stages | -57.14 | 57.14 | 0 | 0 | 0 |
| Compliance with the Expected | -57.14 | 57.14 | 57.14 | 0 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| Results Considering the Main Product | | | | | |
| Applicability of Carried Out Research | 0 | 125 | 125 | 125 | 0 |
| Proposal Originality is Being Held | -57.14 | 0 | 0 | 0 | -57.14 |
| Project Resource Accounting Approach | -66.67 | 0 | 100 | 0 | -66.67 |
| Expenditures Done in the Project Execution | -50 | 0 | 50 | 50 | -50 |
| Investments Made in the Project | 0 | 0 | 42.86 | 0 | -57.14 |
| Members of the Project Team | 0 | 0 | 0 | 50 | -50 |
| Technology Transfer and Diffusion | 0 | 0 | 0 | 0 | 0 |
| Ordinal risk Calculated Value of Money Disallowance | -46.02 | 2.73 | 9.00 | 9.38 | -40.99 |
| Ordinal risk Calculated Value of Money Disallowance Normalized | **5** | **30** | **33** | **34** | **8** |
| Money Disallowance Actually Applied by ANEEL | **0%** | **20%** | **30%** | **70%** | **0%** |

For Project 1, regarding the values captured for each criterion from the project closing report as input for the ordinal risk calculation proposal, the ordinal risk calculated value of money disallowance normalized was 5 and this value does not have a unit and it means that the ordinal risk value is close to the minimum risk of money disallowance, and in this project the money disallowance applied by ANEEL was 0%, what means that for this project there was no problem in the audit and it was not necessary to return money to the R&D budget of the power utility.

In Project 5, the ordinal risk calculated value of money disallowance normalized was 8 and it means that the ordinal risk value is close to the minimum risk of money disallowance, and in this project the money disallowance applied by ANEEL was 0%, what means that for this project also there was no problem in the audit and it was not necessary to return money to the R&D budget of the power utility. In these cases, as the ordinal risk calculated value of money disallowance normalized was relatively low (5 and 8) and these values are both close to the minimum risk of disallowance, that is 0 and also close to the money disallowance applied by ANEEL (0%), thus, it is possible to say that the relative proposal worked for this case.

The possibility of using the calculated ordinal risk to have an approximate value of the actual money disallowance applied by ANEEL is an interesting finding that indicates that it is possible to have a value as output of the proposal simulation as a kind of estimation value close to the actual money disallowance, being an useful tool for the R&D portfolio managers evaluate the projects that are running and have an idea about the money disallowance that ANEEL will apply after the audit.

In Project 2, the ordinal risk calculated value of money disallowance normalized was 30 and means that the ordinal risk value is higher than for the Project 1 and Project 5, and for this project the money disallowance applied by ANEEL was 20% what means that for this project some problems were found in the audit and it was necessary to return 20% of the project money plus the SELIC interest rate for the project time to the R&D budget of the power utility. Similar to what happened for Project 1 and Project 5, the possibility of using the calculated ordinal risk to have an approximate value of the actual money disallowance applied by ANEEL indicates that it is possible to have a value as output of the proposal simulation as a kind of estimation value close to the actual money disallowance and if it is considered that the value of the calculated ordinal risk by the proposal simulation is a value that can be compared to the actual money disallowance applied by ANEEL, that is expressed in percent of the original project budget. The difference between the calculated ordinal risk considering it in percent compared to the actual money disallowance applied by ANEEL can be explained considering that for the proposal used in the computational simulations, the weights used to transform the criteria to cardinal scales were calibrated by two experts who frequently perform the ANEEL audit. As some criteria are subjective, consequently those criteria may have some different

interpretation between the auditors that calibrated the proposal and the auditor that performed the audit on those projects.

In Project 3, the ordinal risk calculated value of money disallowance normalized was 33 and it means that the ordinal risk value is higher than for the Project 2, and for this project and the actual money disallowance applied by ANEEL was 30%, what means that for this project compared to Project 2 more problems were found in the audit and it was necessary to return 30% of the project money plus the SELIC interest rate for the project time to the R&D budget of the power utility. Also it is similar to what happened for Project 1, Project 2 and Project 5, the possibility of using the calculated ordinal risk to have an approximate value of the actual money disallowance applied by ANEEL indicates that it is possible to have a value as output of the proposal simulation as a kind of estimation value close to the actual money disallowance and if it is considered that the value of the calculated ordinal risk by the proposal simulation is a value that can be compared to the actual money disallowance applied by ANEEL, that is expressed in percent of the original project budget, the difference between the calculated ordinal risk considering it in percent compared to the actual money disallowance applied by ANEEL. The difference between the calculated ordinal risk considering it in percent compared to the actual money disallowance applied by ANEEL can be explained regarding that for the proposal used in the computational simulations, the weights used to transform to cardinal scale the criteria were calibrated by two experts in the ANEEL audit and the subjectivity of criteria analysis may result in different interpretations by the experts and the auditors who audited this project.

In the case of Project 4, the power utility had not submitted the technical reports with the final report. For that reason, the information sent to ANEEL was incomplete, thus generating a financial disallowance of 70% of the value, what means that for this project some serious problems were found in the audit (lack of technical data in the final report) and it was necessary to return 70% of the project money plus the SELIC interest rate for the project time to the R&D budget of the power utility. After the power utility be notified of this disallowance, the technical reports were then sent to ANEEL and the money disallowance applied by ANEEL applied to Project 4 was reduced to 30%, which is similar to the result of ANEEL audit for the Project 3 and it means that for this project an equivalent level of problems were found in the audit and it was necessary to return also 30% of the project money plus the SELIC interest rate for the project time to the R&D budget of the power utility, . For the Project 4, the ordinal risk calculated value of

money disallowance normalized was 34.. Also it is similar to what happened for Project 1, Project 2, Project 3 and Project 5, the possibility of using the calculated ordinal risk to have an approximate value of the actual money disallowance applied by ANEEL indicates that it is possible to have a value as output of the proposal simulation as a kind of estimation value close to the actual money disallowance and if it is considered that the value of the calculated ordinal risk by the proposal simulation is a value that can be compared to the actual money disallowance applied by ANEEL, that is expressed in percent of the original project budget, the difference between the calculated ordinal risk considering it in percent compared to the actual money disallowance applied by ANEEL. The difference between the calculated ordinal risk considering it in percent compared to the actual money disallowance applied by ANEEL can be explained regarding that for the proposal used in the computational simulations, the weights used to transform to cardinal scale the criteria were calibrated by two experts in the ANEEL audit and the subjectivity of criteria analysis may result in different interpretations by the experts and the auditors who audited this project. The value of the simulation was  a little bit higher than in the Project 3 and the actual value of the financial disallowance applied by ANEEL was the same 30%. The specialist at the power utility where Project 4 was developed was consulted regarding his perception on the difference between the simulation (34%) and the actual disallowance (30%), who reported that this difference is not so bad because currently they have no system to foresee the disallowance in the ANEEL audit.

For Project 5, the ordinal risk calculated value of money disallowance normalized was 8, and the project has no money disallowance in the ANEEL audit. This difference is another situation that can either be explained by the fact for the proposal the weights used to transform to the criteria to cardinal scales were calibrated by two experts in the ANEEL audit and the subjectivity of criteria analysis may cause different interpretations by the experts and the auditors who audited this project.

The Tables 4.17 and 4.10 are not supposed to be compared to each other because the kind of criteria used to evaluate the projects before the selection and selected projects are different, so the results are not possible to be compared.

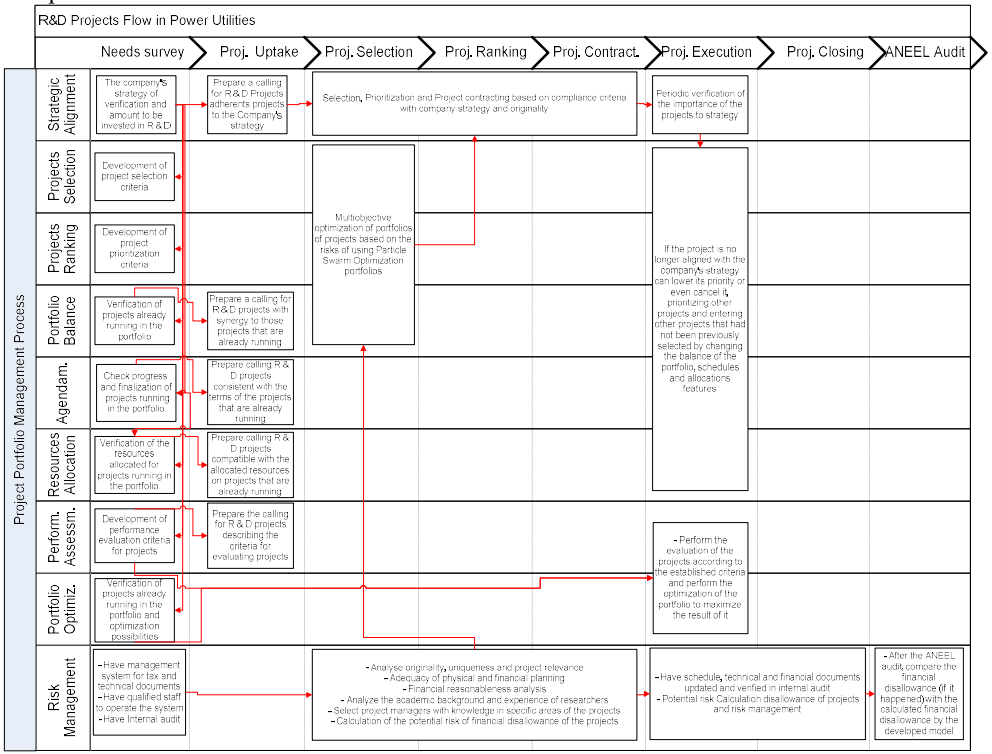
As MCDA-C compensation rates were calculated based on the opinions of two experts who perform audits for ANEEL as external auditors, it is expected that there were some differences, as certain criteria had subjectivity and, therefore, may have a different understanding from one

auditor to another auditor. For all 5 projects the value of the ordinal risk calculated value of money disallowance normalized was higher than the value of the actual money disallowance that was applied in the ANEEL audit; therefore, if the power utilities use the developed proposal, they will have a conservative result and the money disallowance applied in the ANEEL audit will likely be smaller than the calculated value by the developed proposal.

### 4.4 Proposal for governance process for portfolio risks reduction regarding R&D projects flow and PPM process

Additionally to the objectives of this work, a proposal for governance using the components that are more related to a governance process was created. This governance proposal integrates the components “alignment with strategy”, “project selection”, “project ranking”, “portfolio balancing”, “scheduling”, “resource allocation”, “portfolio performance evaluation”, “portfolio optimization” and “risk management” of PPM process with the flow of R&D projects of the power utilities was developed, and it is shown in Figure 4.16 where the relationship of the process steps and actions proposed in the relationship between the steps is presented. The lines represent the PPM process, and the rows represent the R&D projects flow in the power utilities. When the lines cross the rows, the correspondent PPM actions are described in the boxes. For example, when the line “strategic alignment” cross the row “needs from survey”, the actions in PPM process are “company´s strategy verification and the amount of money to be invested in R&D”.

Figure 4.16 Governance model proposal for portfolio risks reduction combining the R&D projects flow at power utilities combined with PPM process



This section presented the results of the exploratory survey with power utilities and the results of computer simulations using the created proposals and real data. The next section presents the discussion of the results of this work.

**4.4 Discussion of the results**

The performed PPM survey showed that most of the companies that responded have an established and explicit method for PPM that is employed to all the R&D projects, being well-accepted by the senior management and executives. This happens mainly in large utilities that have people dedicated to take care of the PPM process, manage the R&D projects and report to the executives. For the small utilities, generally, there was only one person to manage all the R&D projects and/or work with PPM when it exists or in other situations, there were no people to manage the R&D projects and/or work with PPM. In a survey conducted in Brazil with companies from several sectors of economy to verify if the companies had a PPM implemented with standardized process, among the companies that responded the survey in financial services companies five out of eight had PPM, in specialized services three out of seven had PPM, in electro electronics manufacturing companies three out of five had PPM, in telecom companies one out of four had PPM and in pharmaceutical companies two out of two had PPM, thus in financial services companies, electro electronics manufacturing companies and pharmaceutical companies most of companies had a PPM implemented with stardardized process and 87% of the companies had financial methods to assess the portfolio (Castro and Carvalho, 2010). The survey respondents agree that PPM is very important for the business because it is closely linked to the business strategy, which theoretically guarantees that the R&D projects that will be contracted will help to execute the company´s strategy. The project selection is an important process to keep the competitive position by choosing the right projects to be developed and keeping the resources focused on what is important for the company and to maintain the right balance of projects. The criteria net present value (NPV)/Internal return rate (IRR), return of investment (ROI), payback period and profit are important mainly in the project selection stage by the power utilities. The most significant challenges faced by the respondents in R&D projects involve the ANEEL audit process and audit criteria because if the project is reproved in the audit part of the invested money (and in some cases, all the money) have to be returned to the R&D account plus the SELIC interest rate of the period. So, the developed proposal can help the power utilities to estimate risks and

optimize their R&D project portfolio according to the projects' risk, alignment with strategy and use all the budget as much as possible.

A publication gap was observed regarding the models and practices of PPM in companies (Cooper et al., 1997, 1999, 2001; Castro and Carvalho, 2010). In the content analysis, 15 PPM components or elements were identified in the literature analysed. Each component was studied in detail and based on every single definition and the relation of each component with the other components, a set of components was chosen and used to elaborate upon the developed proposal, specifically in the computational implementation of the proposal. Thus, using the developed proposal it was possible to select an optimal portfolio of R&D projects, and this portfolio was composed of projects with the highest alignment to the strategy, the lowest risk of financial disallowance, and the maximum amount of the available budget for R&D projects in the power utility.

One of the main findings of this project is that the ordinal risk calculated for financial disallowance was that the higher the calculated value ordinal risk of financial disallowance, the greater the theoretical possibility of the project taking a financial disallowance of approximately the same calculated percentage.

Portfolio risk management avoids failure and increases the possibility of the project portfolio success (De Reyck et al., 2005; McFarlan, 1981). The overall risk is seen as more than just the sum of individual project risks due to interdependencies between projects (Aritua et al., 2009). Through the application of the developed proposal using actual data to compare the simulation results, it was possible to calculate the relative project risks of financial disallowance with an uncertainty of 10%. So, if the power utility can calculate the project risk of financial disallowance using the proposal and take actions to reduce the risks, it is possible to say that the portfolio risks can be reduced through the developed proposals. Risk management may reduce uncertainty by providing relevant information for decision making (de Bakker et al., 2011). Considering the project selection, the portfolio optimization proposal simulation results show that in most of cases, it was possible to predict whether the project would be approved by the power utility committee. Risk management can significantly enhance the success of research and development projects (Salomo et al., 2010; Wang et al., 2010).

The main contributions of the research can be summarized as follows:

- Survey results explaining how power utilities operate the PPM, the importance of PPM for them and their main concerns about the R&D projects.
- Identification of the fourteen PPM components from the literature to better understand the PPM process and use a set of components to develop the proposal.
- The development of a proposal to calculate the relative project risks through project indicators and to optimize portfolios of projects based on the budget-cost projects, alignment to strategy and risk simulations using real data from utilities

In the present section, the results of the exploratory survey with the power utilities, the identified PPM components, the results obtained using the proposal for ordinal risks calculation and portfolio optimization for R&D projects before these projects were selected and the results are presented obtained using the proposal for ordinal risks calculation and portfolio optimization for projects already selected and running in the power utilities. The results were positive, as the objectives of the developed proposals were reached, as described in the previous discussions.

The next section presents the conclusion of the thesis, the limitations of the research and suggestions for future research.

## 5 CONCLUSIONS

Regarding the research question “how to reduce risk and at the same time optimize the project selection in PPM?”, it is possible to consider that this question was answered thorugh the full achievement of the general objective and the specific objectives in this work. The portfolio risk is reduced because the projects that are chosen for the optimal portfolio are the ones with the smallest risks within the projects that are candidates to become part of the project portfolio. The optimization was also reached through the developed proposal for optimization that regards the ordinal risk value, the alignment with strategy and the budget utilization for R&D projets. The results obtained from the developed proposals was similar to the results obtained from the specialists committee from the power utilities. From the survey, some outputs could be addressed by this work, such as the concern about the ANEEL audit, that the developed model can help to select projects with smaller risks in the audit, the selection of projects aligned with the organization's strategy, that is regarded in the optimization proposal where alignment with strategy is one of the objectives of the optimization and concern about the originality of the project, that is one of the most important criteria in the ordinal risk calculation and if the project has a high risk of lack of originality it will have a high risk score and will not be selected to compose the portfolio.

The general objective of this work was to perform an in-depth exploration of the PPM literature to identify the main PPM components to better understand them and figure out how to use these components to develop a process proposal to optimize the project portfolio according to the ordinal risk or problems in ANEEL audits, maximum budget to be spent and company´s strategy adherence. The calculation of the ordinal risk of problems in ANEEL audits for each project compose a ranking of projects according to project ordinal risk, comparing the results of the computational simulations of the proposal with the actual data from the R&D projects from the Brazilian power utilities to verify if the money disallowance applied by ANEEL had the same ranking for the computational simulation and the actual data. The general objective was fully achieved through the results obtained in all the steps developed to achieve all four specific objectives.

This research investigated the PPM process, starting with the PPM components to better understand them as well as how to use these components to propose a process for the ordinal risk calculation and reduction of problems in R&D projects in the ANEEL audit. During the literature review, it was observed that the interest in PPM was growing year

over year in the literature because the articles with PPM subject were increasing in quantity, tec kind of applications. However, even with the amount of articles regarding PPM is growing, the PPM process definition was still not entirely clear due to the.

For the first specific objectuive, to better understand the PPM process, a systematic search was carried out in the literature with the objective of verifying the publications first on the subject, after reading the abstract and after the reading the complete articles and 15 components were identified. These components in some cases were used individually in the literature and most of times two or more components were used in the PPM processes described in the analysed articles. All the 15 identified components generally can be used before the project portfolio be selected and consolidated as well as after the project portfolio be consolidated and the PPM process start running because the analysis performed in both cases have some similarities with differences in the application. For example, in both cases projects are selected in the first case to compose the project portfolio and in the second case to substitute the projects that are finished or the projects that the importance are not high anymore, the portfolio is optimized in both cases, decisions are made to include some projects that have some strategic importance for the company in the first case or to stop, slow down or speed up a project in the second case, a project ranking is elaborated to pick the projects that will compose the portfolio in the first case or to select the projects that will receive more priority or be stoped in the second case, the resources allocation is evaluated and risk management is used in the first case to list the potential risks and plan the actions to be performed if the risks happen and in the second case to manage risks when they happen and list and plan for new risks that will appear after the project portfolio is running. The component preparing for the future is one of that has more to do with the PPM of R&D projects because these projects are in most of cases for long-term results, create new markets, new technologies, new knowledgements, environmental responsibility and sustainability, addresses the long term implications of risk management and the ability to react to environmental changes and seize opportunities. After a study of the PPM processes of three Brazilian power utilities available in the literature, it was possible to have a better understanding of the PPM process in power utilities; as these processes had several points in common, it was possible to combine the three processes into a single generic process that was useful to develop the proposal for ordinal risk calculation and the optimization for project selection to compose their R&D projects portfolio.

Regarding the second specific objective to determine the existence of PPM in power utilities, a survey was conducted with the Brazilian power utilities to evaluate the importance of PPM for them and determine the evaluation methods used in PPM. A survey was performed with all the power utilities that developed R&D projects in the from the year 2008, where 24% of the consulted companies responded to the survey.Most respondents said that their companies had an implemented PPM process applied to all projects, but this condition generally depends on the size of the power utility, because the larger power utilities tended to have people and money to implement the PPM process, the smaller power utilities did not have sufficient resources to implement the PPM and run the operation and maintenance routine of the companies. The PPM is considered important for the senior management and executives, very important for the technology managers and operation or production managers but somewhat important for the marketing and sales managers. This value perception happens because generally R&D projects for power utilities are more focused on developing a new technology or methodology to support operational areas on solving problems or to test new technologies and solutions and there are just a few R&D projects with subject related to marketing or sales. Regarding the evaluation methods used in PPM, most respondents said that they used to compare projects against each others most of respondent regarded the parameters in descending order: technology, strategic fit, pay-off, risk/probability of success, timing, protectability, synergy between projects and commercialization. The main financial evaluation methods used in the literature were the classical financial methods like net present value, internal return rate, return of investment, payback period and profit. The financial evaluation generally were used to define if the project will go to evaluation or not. If the financial criteria are not reached the project does not go to the evaluation committee, but after the project move forward to be evaluated by the evaluation committee the ANEEL criteria, power utility strategy adherence and budget are used for project selection and ranking of the projects. In the computational simulation these ANEEL criteria were used to calculate the ordinal risk using MCDA. For the project portfolio optimization the strategy adherence, budget and ordinal risk are used as objectives to be optimized.

For the third specific objective, to develop proposal for ordinal risk calculation for the R&D projects, two ordinal risk calculation proposals were developed, one for projects before project selection and another for projects already selected by the power utility´s specialist committee for project selection. Both ordinal risk calculation proposals were developed using the

MCDA-C. The criteria were chosen regarding the ANEEL audit manual criteria, and the criteria weights were calibrated according to the consensus between two experts who are auditors in the ANEEL audit. With the application of the developed proposals using the actual data from power utilities to compare the simulations results for financial disallowance risk made it possible to calculate the ordinal project risks with similar values comparing with the actual value of the financial disallowance applied by ANEEL. The similarity of values can be considered a coincidence at this work because it was tested only for a few cases and to evaluate if this can be used as a risk estimation tool it would be necessary much more tests for evaluation. For the third specific objective, to develop a proposal to select the optimal portfolio of R&D projects based on the three objectives to optimize strategy adherence, ordinal risk and budget utilization, the project portfolio optimization proposal simulation results, in most of cases, made possible to predict whether the project would be approved or not by the power utility´s specialist committee. There was only one case in which the project was approved by the power utility committee and it was not selected by the developed proposal simulation for portfolio optimization, but it could be explained by the difference in the utility committee's understanding of the criterion alignment with strategy, that was considered more adherent to the power utility´s strategy than it was considered in the simulation. As the criteria alignment with strategy, budget utilization and ordinal risk have the same weight in the performed simulation, in this simulation these criteria have the same importance, so if the criteria values for each project are not well defined some differences between the simulation and the actual evaluation results by the specialist committee. Thus, the conclusion for this objective is that the developed proposal simulation worked, for most of the cases tested and when there was a difference, it was possible to understand it and justify. For the power utility, the utilization of this simulation proposal could help them to reduce the committee meetings time or the amount of participants because until when this research was performed there were from 8 to 12 members from different areas of the company with busy agendas to evaluate the R&D project proposals once or twice a month depending on the quantity of the projects to be evaluated in the period and each specialists committee meeting have 4 hours duration to evaluate from 10 to 15 projects. If the simulation proposal could be used by the power utility the specialists committee members could read the projects and fill in the weights for each project, send the information to the R&D analyst that would run the simulation and the specialists committee would be faster because it would be

only to discuss the results of the simulation and mitigate some differences in the projects evaluation or issues with the choosen projects.

The use of artificial intelligence, decision support and optimization methods applied to PPM together with the financial methods are being used in the analysed articles and the application of these methods together will allow the development of computational tools to support the PPM process be more efficient to have better projects selected in an optimized portfolio with the best investment return. An additional contribution from this work, in addition to the objectives of this work, was the proposal a governance process regarding all the steps of the R&D projects process in the power utilities that for each step of this process has some correspondent action in the PPM process from a component that is related to this step. This proposed governance process can be used to manage the R&D projects portfolio to verify if all the documentation and actions to mitigate the project risks are being taken to avoid problems in the audit.

This work led to a better understanding of the definition of the PPM process through its components identified in the literature besides proving that it is possible to have an ordinal risk calculation and a portfolio optimization of projects through a computational model that was assessed through the comparison with actual data provided by electric utilities.

### 5.1 Limitations of the research

There was a 24% return of responses to the survey.. Regarding the companies sizes there were utilities from small companies until larges in the market. Unfortunately, as the quantity of respondents was not statistically representative, it was not possible to conclude that these answers represent the majority opinion of the Brazilian electric power utilities. However, these responses were still quite useful to better understand the PPM process in power utilities and to use this information in the proposals' development.

The MCDA-C criteria weights were calculated based on the opinions of two experts who performed the ANEEL audits as auditors. So, as the experts' opinions have some subjectivity, it was expected that there were some differences between the values from the proposal simulations and the actual values from the power utilities. All the criteria were explained in the ANEEL audit manual, but in some cases the criteria depend on interpretation, so they were subjective and therefore may have a different understanding from one auditor to another auditor.

With the application of the developed proposals using the actual data from power utilities to compare the simulations results for financial

disallowance risk made it possible to calculate the ordinal project risks with similar values comparing with the actual value of the financial disallowance applied by ANEEL, but it is necessary to evaluate if this can be used as a risk estimation tool with more tests for evaluation.

During the development of this work, the power utilities shared some data. However, it was not possible to find a power utility that accepted implementing the proposal to test it and verify whether the risk of having problems in the ANEEL audit could be reduced by the proposal implementation and verify whether the actions taken during the projects' development could reduce the risk of financial disallowance up to a condition in which the possibility of having problems in the ANEEL audit is close to zero.

**5.2 Recommendations for future research**

The following recommendations are made for future research:

- Develop a proposal based on the opinions of more experts to try to reduce the subjectivity effect on the proposal through a more critical discussion of the criteria weights. Conduct a survey with more respondents to have statistical representativeness and be able to have more elements improving the effectiveness of the developed proposal.

- Develop and implement a more generic proposal for project portfolio optimization that can be used in many kinds of companies and not only for R&D projects, but also for new product development projects.

- Develop a comprehensive PPM software that already considers a governance process that can support the documentation and deliverables control to estimate the financial disallowance risk, as this could be quite helpful for the power utilities to minimize the reprove risks in the ANEEL audit.

- Develop a risk calculation proposal using another kind of multicriteria method such as AHP, ANP, MCDM among other methods and a proposal for portfolio optimization using another multi-objective optimization method and compare the results with those proposed in this work and the actual results.

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## Appendix 1 – Survey questionnaire (in Portuguese and English)

The text was written in English and Portuguese because the survey instrument that was sent to the power utilities was in Portuguese. The results of the survey are shown after the questions.

**Survey sobre Gestão de Portfólio de Projetos (Survey on Project Portfolio Management)**

Esta pesquisa foi desenvolvida para determinação de métodos que são utilizados atualmente para a gestão de portfólio de projetos no Brasil. A maioria das organizações apenas utilizam parcialmente métodos e técnicas disponíveis. Algumas organizações têm pouco ou nenhuma prática de gestão aplicada, enquanto outras têm um método documentado e formal. (This research was designed to determine methods that are currently used for project portfolio management in Brazil. Most organizations only partially utilize available methods and techniques. Some organizations have little or no applied management practice, while others have a documented, formal method).

Nós encorajamos você a preencher o questionário da melhor maneira possível e, por favor, não se preocupe se muitos dos itens não são utilizados ou familiares para a sua organização. (We encourage you to fill out the questionnaire in the best possible way, and please do not worry if many of the items are not used or family for your organization).

Identificação (Nenhum nome, informação ou dado será divulgado sem o consentimento do respondente) *( Identification (No name, information or data will be published without the respondent's consente))

Nome da empresa (Company Name)

Setor ou Departamento responsável pela Gestão de Portfólio de Projetos *( Sector or department responsible for Project Portfolio Management)

Nome do responsável pelo preenchimento da pesquisa * (Name of the person responsible for filling out the survey)

Cargo ou função * (Position or function)

Há quanto tempo trabalha na empresa (anos)? (How long have you at the company (years)?

Table A1.1 – Answers about how long the respondents worked in the company

| Anos (Years) | Quantidade (Quantity) | % |
|---|---|---|
| 2 | 2 | 6,7% |
| 3 | 1 | 3,3% |
| 4 | 1 | 3,3% |
| 5 | 2 | 6,7% |
| 7 | 1 | 3,3% |
| 8 | 3 | 10,0% |
| 9 | 1 | 3,3% |
| 10 | 1 | 3,3% |
| 13 | 1 | 3,3% |
| 14 | 2 | 6,7% |
| 15 | 1 | 3,3% |
| 17 | 2 | 6,7% |
| 18 | 1 | 3,3% |
| 19 | 1 | 3,3% |
| 20 | 1 | 3,3% |
| 22 | 1 | 3,3% |
| 23 | 1 | 3,3% |
| 24 | 1 | 3,3% |
| 27 | 2 | 6,7% |
| 28 | 1 | 3,3% |
| 30 | 2 | 6,7% |
| 34 | 1 | 3,3% |

Há quanto tempo exerce esta função (anos)? (How long have you been performing this function (years)?)

Table A1.2 - Answers about how long the respondents have been performing this function

| Anos (Years) | Quantidade (Quantity) | % |
|---|---|---|
| 1 | 3 | 10,0% |
| 2 | 4 | 13,3% |
| 3 | 4 | 13,3% |
| 4 | 5 | 16,7% |
| 5 | 3 | 10,0% |
| 6 | 2 | 6,7% |
| 7 | 2 | 6,7% |
| 10 | 3 | 10,0% |
| 12 | 1 | 3,3% |
| 15 | 1 | 3,3% |
| 25 | 1 | 3,3% |
| 27 | 1 | 3,3% |

Telefone para contato (Contact Phone )*
e-mail para contato (contact email )*

**Quanto ao segmento (About the subsector)**

Table A1.3 – Distribution of answers regarding the subsector

| **Segmento (subsector)** | **Enviados (sent)** | **Respondidos (answered)** | **%** |
|---|---|---|---|
| distribution | 50 | 13 | 26% |
| generation | 47 | 11 | 23% |
| transmission | 27 | 6 | 22% |
| **Total** | **124** | **30** | **24%** |

**Seção A – Contextualização de suas respostas (Contextualization of your answers)**

Seu portfólio de projetos de novos produtos pode dizer respeito a bens físicos ou a serviços ou uma mistura dos dois. Por favor, indique o mix projeto aproximado que se aplica a suas respostas. O nível 1 significa que seu portfólio contem apenas bens físicos, o nível 5 significa que seu portfólio contem um mix de projetos de bens físicos e projetos/serviços e o nível 10 significa que seu portfólio contem apenas projetos/serviços * (Your portfolio of new product projects can be for physical goods or services or a mixture of both. Please enter the approximate mix of projects that applies to your answers. Level 1 means that your portfolio contains only physical assets, level 5 means that your portfolio contains a mix of physical goods projects and projects / services and level 10 means that your portfolio contains only projects / services *)

Table A1.4 – Mix of projects

| Level | Count | % |
|---|---|---|
| 5 | 10 | 33,3% |
| 6 | 1 | 3,3% |
| 7 | 6 | 20,0% |
| 8 | 3 | 10,0% |
| 9 | 4 | 13,3% |
| 10 | 6 | 20,0% |

**Seção B - Algumas questões gerais referentes ao seu Processo de Gestão de Portfólio de Projetos (Some general issues related to its Rules of Project Portfolio Management)**

Até que ponto a gestão de portfólio de projetos considerada uma tarefa vital ou criticamente importante para o seu negócio ... * (To what level project portfolio management is considered a vital task or critically important to your business)

| | Não Muito Importante (Not Very Important) [1] | Pouco Importante (Little important)[2] | Importante (Important) [3] | Muito Importante (Very important)[4] | Criticamente Importante (critically Important) [5] |
|---|---|---|---|---|---|
| ...pelos Executivos da Alta Administração? (by senior management executives?) | | | | | |
| ...pelos Gestores Sêniores? (... By Managers Senior?) | | | | | |
| ...pelos gestores das áreas de Operação e Produção? ... (By area managers Operation and Production?) | | | | | |

| | Não Muito Importante (Not Very Important) [1] | Pouco Importante (Little important)[2] | Importante (Important) [3] | Muito Importante (Very important)[4] | Criticamente Importante (critically Important) [5] |
|---|---|---|---|---|---|
| ...pelos Gestores de Tecnologia? (...technology managers?) | | | | | |
| ...pelos Gestores das áreas de Marketing e Vendas? (... By managers in the areas of Marketing and Sales?) | | | | | |

Table A1.5 - Level project portfolio management is considered a vital task or critically important to the business

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 6 | 20,0% |
| 3 | 12 | 40,0% |
| 4 | 7 | 23,3% |
| 5 | 4 | 13,3% |

Table A1.6 – Importance perceived by senior managers for PPM

| Level | Count | % |
|---|---|---|
| 2 | 7 | 23,3% |
| 3 | 9 | 30,0% |

| | | |
|---|---|---|
| 4 | 8 | 26,7% |
| 5 | 6 | 20,0% |

Table A1.7 – Importance perceived by technology managers for PPM

| Level | Count | % |
|---|---|---|
| 2 | 2 | 6,7% |
| 3 | 10 | 33,3% |
| 4 | 13 | 43,3% |
| 5 | 5 | 16,7% |

Table A1.8 – Importance perceived by managers in the marketing and sales areas for PPM

| Level | Count | % |
|---|---|---|
| 1 | 4 | 13,3% |
| 2 | 12 | 40,0% |
| 3 | 8 | 26,7% |
| 4 | 2 | 6,7% |
| 5 | 4 | 13,3% |

Table A1.9 - Importance perceived by operation and production managers for PPM

| Level | Count | % |
|---|---|---|
| 2 | 3 | 10,0% |
| 3 | 12 | 40,0% |
| 4 | 9 | 30,0% |
| 5 | 6 | 20,0% |

**Por favor, indique o quanto você concorda ou discorda de cada afirmação: (responder de acordo com a perspectiva do que é relevante para o seu negócio atualmente). Gestão de Portfólio é vital em nosso negócio... * (Please indicate how much you agree or disagree with each statement: (answer according to the perspective of what is relevant to your business today). Portfolio management is vital in our business ... *)**

| | Strongly disagree [1] | [2] | [3] | [4] | Fully agree [5] |
|---|---|---|---|---|---|
| ... porque a seleção de projetos está intimamente ligada à estratégia de negócios em nosso negócio (... Because the selection of projects is closely linked to business strategy in our business) | | | | | |
| ... porque a estratégia começa quando você começa a gastar dinheiro (... Because the strategy starts when you start to spend money) | | | | | |

| | Strongly disagree [1] | [2] | [3] | [4] | Fully agree [5] |
|---|---|---|---|---|---|
| - alocação de recursos para projetos é como a estratégia é implementada (allocation of resources to projects is how the strategy is implemented) ... porque a seleção de projetos é importante para manter nossa posição competitiva (... Because the selection of projects is important to maintain our competitive position) | | | | | |

| | Strongly disagree [1] | [2] | [3] | [4] | Fully agree [5] |
|---|---|---|---|---|---|
| ... porque queremos estar focados - não executar projetos demais para os recursos que temos disponíveis (... Because we want to be focused - not run too many projects for the resources we have available) | | | | | |
| ... porque nossos novos recursos de projetos (pessoas, tempo e dinheiro) são muito escassos e não queremos desperdiçá- | | | | | |

| | Strongly disagree [1] | [2] | [3] | [4] | Fully agree [5] |
|---|---|---|---|---|---|
| los com projetos errados (... Because our new project resources (people, time and money) are very scarce and do not want to waste them with wrong projects) | | | | | |

TableA1.10 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 2 | 6,7% |
| 3 | 8 | 26,7% |
| 4 | 9 | 30,0% |
| 5 | 10 | 33,3% |

Table A1.11 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 2 | 6,7% |
| 2 | 5 | 16,7% |
| 3 | 14 | 46,7% |
| 4 | 5 | 16,7% |
| 5 | 4 | 13,3% |

Table A1.12 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 6 | 20,0% |
| 3 | 13 | 43,3% |
| 4 | 6 | 20,0% |
| 5 | 5 | 16,7% |

Table A1.13 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 2 | 6,7% |
| 2 | 7 | 23,3% |
| 3 | 8 | 26,7% |
| 4 | 5 | 16,7% |
| 5 | 8 | 26,7% |

Table A1.14 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 3 | 10,0% |
| 3 | 7 | 23,3% |
| 4 | 13 | 43,3% |
| 5 | 7 | 23,3% |

| | Strongly disagree [1] | [2] | [3] | [4] | Fully agree [5] |
|---|---|---|---|---|---|
| ... porque é importante ter o correto balanceamento de projetos - um balanço entre projetos de longo e curto prazos, de alto e baixo riscos, e assim por diante (... Because it's important to have the correct project balance - a balance between long and short-term projects, high and low risk, and so on) | ○ | ○ | ○ | ○ | ○ |

**Table A1.15 - Answers about the previous statement**

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 2 | 6,7% |
| 3 | 8 | 26,7% |

| | | |
|---|---|---|
| 4 | 10 | 33,3% |
| 5 | 9 | 30,0% |

| | | | | | |
|---|---|---|---|---|---|
| ... porque somos relativamente avessos ao risco, então temos que ser muito cuidadosos na seleção de projetos para não termos falhas (... Because we are relatively risk averse, so we have to be very careful in the selection of projects for not having failures) | ○ | ○ | ○ | ○ | ○ |

Table A1.16 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 2 | 6,7% |
| 3 | 11 | 36,7% |
| 4 | 8 | 26,7% |
| 5 | 9 | 30,0% |

**Seção C - Como a Gestão de Portfólio é Feita e Como Projetos são Selecionados em Seu Negócio (How the Portfolio Management is Made and How Projects are Selected in Your Business)**

**Por favor, pense sobre a maneira como sua empresa determina o seu portfólio de projetos - ou seja, seleciona, atribui valor e classifica os projetos de novos produtos, e aloca recursos para os mesmos. Por favor, responda às seguintes questões para caracterizar a sua abordagem geral de gerenciamento de portfólio. * (Please think about how your company determines its project portfolio - ie, selects, assigns value and classifies the projects of new products, and allocates resources to them. Please**

**answer the following questions to determine their general approach to portfolio management)**

[1] [2] [3] [4] [5]

Nós temos um método estabelecido e explícito de gestão de portfólio e de seleção de projetos. [1]= Não temos; nosso método não está estabelecido. [5]= Realmente temos; um método estabelecido e explícito (We have an established and explicit method of portfolio management and project selection. [1] = we do not have; Our method is not established. [5] = really we have; an established and explicit method)

Table A1.17 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 5 | 16,7% |
| 3 | 10 | 33,3% |
| 4 | 5 | 16,7% |
| 5 | 9 | 30,0% |

Nossas regras e procedimentos do método de gestão de portfólio são muito claras; existe um procedimento bem definido aqui. [1]= Não temos; [5]= Realmente temos (Our rules and procedures of portfolio management method are very clear; There is a well-defined procedure here. [1] = we do not have; [5] = Really we have)

Table A1.18 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 8 | 26,7% |
| 3 | 8 | 26,7% |
| 4 | 6 | 20,0% |
| 5 | 7 | 23,3% |

Nosso método de gestão de portfólio é aplicado consistentemente para todos os projetos onde o mesmo deveria ser aplicado. [1]= não é

consistente aplicado e muitos projetos não seguem o método. [5]= consistentemente aplicado para todos os projetos onde o mesmo deveria ser aplicado (Our portfolio management method is applied consistently to all projects where it should be applied. [1] = is not consistently applied, and many projects do not follow the method. [5] = consistently applied to all projects where it should be applied)

Table A1.19- Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 8 | 26,7% |
| 3 | 9 | 30,0% |
| 4 | 3 | 10,0% |
| 5 | 10 | 33,3% |

Os gestores estão comprometidos com o método de gestão de portfólio; através de suas ações os gestores apóiam fortemente seu uso. [1]= os gestores não estão comprometidos com o método. [5]= os gestores aprovam fortemente e utilizam o método (Managers are committed to the portfolio management method; through their actions managers strongly support their use. [1] = managers are not committed to the method. [5] = managers strongly approve and use the method)

Table A1.20 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 3 | 10,0% |
| 2 | 2 | 6,7% |
| 3 | 10 | 33,3% |
| 4 | 9 | 30,0% |
| 5 | 6 | 20,0% |

Nosso método trata todos os projetos como um portfólio - considera todos os projetos juntos e comparam todos entre si. [1]= foco em projetos individuais - um por vez. [5]= olha para todos os projetos juntos, como um portfólio (Our method treats every project as a portfolio - considers all projects together and compare all together. [1] = focus on individual projects - one at a time. [5] = look at all the projects together as a portfolio)

TableA1.21 - Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 3 | 10,0% |
| 2 | 8 | 26,7% |
| 3 | 5 | 16,7% |
| 4 | 9 | 30,0% |
| 5 | 5 | 16,7% |

Como o Portfólio de Projetos é configurado? * (How is the Project Portfolio is configured?)

[1] Para o Departamento ou Unidade de Negócios Apenas (For the Department or Business Unit Only)

[2] Para Toda a Corporação (For All Corporation)

[3] Para Ambos os Níveis (For Both Levels)

Table A1.22 - Answers about project configuration

| Option | Count | % |
|---|---|---|
| 1 | 11 | 36,7% |
| 2 | 12 | 40,0% |
| 3 | 7 | 23,3% |

Há quanto tempo o método da gestão de portfólio de projetos está estabelecido? *( How long the method of project portfolio management is established? *)

- Menos de Seis Meses [1] (Less than Six Months)
- De Seis Meses a Dois Anos [2] (From Six Months to Two Years)
- De Dois Anos a Cinco Anos [3] (From Two Years to Five Years)
- Mais de Cinco Anos [4] (More Than Five Years)
- Não Aplicável [5] (Not Applicable)

Table A1.23 - Answers about how long the method of project portfolio management is established

| Option | Count | % |
|---|---|---|
| 2 | 4 | 13,3% |
| 3 | 3 | 10,0% |
| 4 | 14 | 46,7% |
| 5 | 9 | 30,0% |

**Seção D - Natureza do Método Utilizado para a Gestão do Portfólio (Nature of Used Method for Portfolio Management)**

1. Qual palavra descreve melhor seu método ou procedimento de gestão de portfólio de projetos? * (What word best describes your method or project portfolio management procedure?)

- [1] Informal
- [2] Formal

Table A1.24 - Answers about what word best describes their method or project portfolio management procedure?

| Option | Count | % |
|---|---|---|
| 1 | 13 | 43,3% |
| 2 | 17 | 56,7% |

2. Qual afirmação descreve melhor seu processo de tomada de decisões * (Which statement best describes your decision-making process)

[1] Decisões de Prosseguir/Cancelar e decisões de investimento em projetos são tomadas em uma reunião de gestão. Eles discutem projetos, utilizam seu melhor julgamento e fazem decisões (Continue / Cancel decisions and investment decisions on projects are taken at a meeting of management. They discuss projects, use your best judgment and make decisions)

[2] Um gestor sênior ou um executivo toma a decisão (A senior manager or executive makes the decision)

[3] Ambos os processos de tomada de decisão são utilizados (Both decision-making processes are used)

[4] Outro (other)

Table A1.25 - Answers about which statement best describes your decision-making process

| Option | Count | % |
|---|---|---|
| 1 | 14 | 46,7% |
| 2 | 2 | 6,7% |
| 3 | 13 | 43,3% |
| 4 | 1 | 3,3% |

3. Você utiliza um método financeiro para a seleção de projetos? Isto significa que você determina a lucratividade, retorno do investimento, retorno ou valor econômico do projeto (por exemplo, retorno do investimento, valor líquido presente, ou alguma outra medida econômica) e julga projetos baseado nestes critérios? * (Do you use a financial method for selecting projects? This means that you determine the profitability, return on investment, return or project economic value (eg, return on investment, net present value, or some other economic measure) and judges projects based on these criteria?)

[1] Sim (yes) [2] Não (no)

Table A1.26 - Answers about use a financial method for selecting projects

| Option | Count | % |
|---|---|---|
| 1 | 22 | 73,3% |
| 2 | 8 | 26,7% |

Como um método financeiro utilizado, qual método você utiliza? * (As a financial method uses what method do you use? *)

[0] Não utiliza (does not use)

[1] Determina a expectativa dos resultados financeiro do projeto ou valor econômico (por exemplo retorno ou lucratividade) e compara este valor com sua taxa de barreira ou critério de aceitação para fazer a decisão de Continuar/Cancelar (Determines the expectations of the financial results of the project or economic value (eg return or profitability) and compares this value with its barrier rate or acceptance criteria for making the decision to Continue / Cancel)

[2] Determinar os resultados financeiros esperados do projeto ou valor econômico e utilizar este valor para classificar os projetos entre eles. Os projetos com melhor classificação (com maiores valores econômicos) são selecionados e incluídos no portfólio de projetos. (Define the expected financial results of the project or economic value and use this value to rank the projects between them. Projects Top rated (with higher economic values are selected and included in the project portfolio.)

Table A1.27 – Answers about what financial method do you use?

| Option | Count | % |
|---|---|---|
| 0 | 8 | 26,7% |
| 1 | 14 | 46,7% |
| 2 | 8 | 26,7% |

4. Você utiliza um método de verificação? Projetos são avaliados através de uma lista de questões do tipo Sim-Não. Cada projeto deve atingir todas as respostas "Sim" (ou um certo número de respostas "Sim") para prosseguir (Do you use a verification method? Projects are evaluated through a list of questions such as Yes-No. Each project must meet all the answers "Yes" (or a number of "Yes" answers) to proceed)

[1] Sim (yes) [2] Não (no)

Table A1.28 – Answers about to use a verification method

| Option | Count | % |
|---|---|---|
| 1 | 6 | 20,0% |
| 2 | 24 | 80,0% |

Utilizando método de verificação, qual método(s) você utiliza? * (Using verification method, which methods) do you use? *)

Fazer decisões Continuar/Cancelar em projetos individuais baseado no número de respostas "Sim" (Making decisions Continue / Cancel on individual projects based on the number of "Yes")

Utilizar as respostas "Sim" para classificar os projetos entre eles. Os projetos com maior quantidade de respostas "Sim" são selecionados para estarem no portfólio de projetos (Using the answers "Yes" to sort the projects between them. Projects with most replies "Yes" are selected to be in the project portfolio)

Aqui todas as 6 respostas foram "utilizar as respostas sim...." (Here all 6 responses were "use the answers yes....")

5. Você utiliza um método de classificação? Projetos tem notas atribuídas ou são classificados baseados em um número de questões, por exemplo Baixo-Médio-Alto, ou em escalas 1-5 ou 0-10. As notas em cada escala são então somadas para compor uma nota total do projeto, cujos critérios são utilizados para tomar uma decisão sobre seleção de projetos. * (You use a classification method? Projects have assigned notes or are classified based on a number of issues, for example Low-Medium-High or scales 1-5 or 0-10. The notes in each scale are then added together to make up a total score of the project, whose criteria are used to make a decision on project selection.)

[1] Sim (yes) [2] Não (no)

Table A1.29 – Answers about use of a classification method

| Option | Count | % |
|---|---|---|
| 1 | 16 | 53,3% |
| 2 | 14 | 46,7% |

Estas notas de classificação são adicionadas juntas em uma forma ponderada ou não ponderada para compor uma classificação global? * (These rating grades are added together in a weighted or unweighted way to compose an overall rating? *)

Ponderada (weighted)

Não Ponderada (not weighted)

Aqui todas as 16 respostas foram "Ponderada" (Here all 16 responses were "weighted")

Caso utilize uma abordagem por atribuição de notas, qual método você utiliza? * (If you use an approach for assigning grades, which method do you use? *)

Comparar o Total ou Nota do Projeto a uma barreira. Projetos que superem esta barreira devem Prosseguir [37,5% marcaram esta opção] (Compare the Total Project or note to a barrier. Projects that overcome this barrier should continue [37.5% marked this option])

Utilizar as notas de projetos para classificar todos os projetos entre si. Os projetos com maiores notas são selecionados para compor o portfólio de projetos [62,5% marcaram esta opção] (Use the project notes to rank all projects together. Projects with higher scores are selected to compose the portfolio of projects [62.5% marked this option])

6. Você utiliza a estratégia do negócio como uma base para alocação de dinheiro para diferentes tipos de novos projetos? Por exemplo, tendo decido a estratégia de negócios, então você aloca dinheiro para diferentes tipos de projetos em "pacotes" ou "envelopes". Projetos são classificados ou avaliados entre estes "envelopes" ou "pacotes" * (You use the business strategy as a basis for allocating money for different types of new projects? For example, having decided business strategy, then you allocate money to different types of projects in "packages" or "envelopes". Projects are rated or evaluated between these "envelopes" or "packages" *)

Sim (yes) [1] Não (no)[2]

Table A1.30 – Answers about use the business strategy as a basis for allocating money for different types of new projects

| Option | Count | % |
|---|---|---|
| 1 | 9 | 30,0% |
| 2 | 21 | 70,0% |

Como a resposta escolhida na questão 6 foi Sim, por favor, liste algumas dimensões e exemplos de categorias, envelopes ou pacotes que você utiliza para dividir financiamentos ou recursos (por exemplo: nós dividimos por mercados, Mercados A, B, C; ou nós dividimos por tipos de projetos - novos produtos, extensões, ajustes, pesquisa, etc) * As the response chosen in Question 6 was yes, please list some dimensions and examples of categories, envelopes or packages that you use to split funding or resources (for example, we divide by markets, Markets A, B, C, or we divided by types of projects - new products,

extensions, settings, search, etc.) *TIPOS DE PROJETOS-NOVOS PRODUTOS (PROJECTS-NEW PRODUCT TYPES)

Baseado na Lei 9991/2000 e resoluções da ANEEL (Based on Law 9991/2000 and ANEEL resolutions)

Dividimos por tipos de projetos. (Classified by types of projects.)

Áreas (áreas)

Projetos que impliquem em ganhos de eficiência operacional, desenvolvimento de novas fontes/ tecnologias de geração de energia e projetos de cunho ambiental. (Projects that result in operating efficiencies, development of new sources / power generation technologies and environmental projects.)

Uma vez que você reserva dinheiro ou recursos em "pacotes" ou "envelopes" para diferentes tipos de projetos, como você atribui notas e classifica projetos entre os pacotes ou envelopes? Por favor marque todos que se aplicam * (Once you reserve money or resources into "packages" or "envelopes" for different types of projects, as you assign grades and ranks projects between packages or envelopes? Please check all that apply *)

☐ Sem método formal: reunião(ões) de gerenciamento [03 marcaram esta opção] (No formal method: meeting (s) management [03 marked this option])

☐ Sem método formal: um gestor sênior decide [03 marcaram esta opção] (No formal method: a senior manager decides [03 marked this option])

☐ Método financeiro [02 marcaram esta opção] (financial method [02 marked this option])

☐ Método de verificação tipo "check list" [01 marcou esta opção] (Verification Method "checklist type " [01 marked this option]

☐ Modelo de classificação [01 marcou esta opção] (classification model [01 marked this option])

☐ Diagrama de bolhas [01 marcou esta opção] (Bubbles Diagram [01 marked this option])

7. Você organiza graficamente os projetos em um diagrama de bolhas ou em um mapa de portfólio e verifica o posicionamento dos projetos em zonas ou quadrantes do diagrama ou mapa? * (You graphically organizes projects on a diagram of bubbles or a portfolio map and check the positioning of projects in zones or quadrants of the diagram or map? *)

[1]Sim (yes) [2]Não (no)

Table A1.31 – Answers about graphically organize projects on a diagram of bubbles or a portfolio map and check the positioning of projects in zones or quadrants of the diagram or map

| Option | Count | % |
|---|---|---|
| 1 | 2 | 6,7% |
| 2 | 28 | 93,3% |

Quantos diferentes tipos de mapas ou diagramas de bolhas X-Y você utiliza para seu portfólio de projetos? (How many different types of maps or diagrams of X-Y bubbles you use for your project portfolio?)

[aqui apenas 01 respondeu afirmando 01 tipo] ([Here only 01 responded by saying 01 type])

Quais são os rótulos dos eixos horizontal e vertical dos diagramas que você utiliza (por exemplo Recompensa x Risco, Esforço x Impacto, etc) * (What are the labels horizontal and vertical axes of the diagrams that you use (eg x Reward Risk, Effort x Impact, etc.))

8.Você utiliza algum método de seleção de projetos que não está descrito nas questões 3 a 7 anteriores? Caso utilize, por favor descreva-o brevemente * (You use a project selection method that is not described in questions 3 to 7 above? If you use, please describe it briefly)

Table A1.32 – Answers about to use a project selection method that is not described in questions 3 to 7 above

| |
|---|
| OS PROJETOS SÃO SELECIONADOS BASICAMENTE PELA APLICABILIDADE NO SETOR, O AVALIAÇÃO FINANCEIRA DO PORTFOLIO E FEITO POR OUTRA SETOR (SELECTED PROJECTS ARE BASICALLY THE APPLICABILITY IN INDUSTRY, THE EVALUATION FINANCIAL PORTFOLIO AND MADE BY OTHER SECTOR) |
| Realizamos reuniões para analisar os projetos, tomada de decisão dos projetos que serão executados. (Held meetings to review projects, decision-making of the projects to be executed) |
| Não (no) |

| |
|---|
| Não (no) |
| Apenas tento ter projetos que fazem parte da expertise de minha equipe. Ou próximo. Assim consigo ter uma rentabilidade melhor, pois o tempo gasto é menor que o realmente vendido.<br>Mas isso se aplica a 100% dos casos. (Just try to have projects that are part of the expertise of my team. Or next. Thus I can have a better yield, since the spent time is less than the actually sold. But this applies to 100% of cases.) |
| É FEITA UMA AVALIAÇÃO POR UMA EQUIPE DE PESQUISADORES QUE CONHEÇAM O PROPÓSITO DO PROJETO. (IT IS MADE AN ASSESSMENT BY A TEAM OF RESEARCHERS KNOW THE PROJECT PURPOSE.) |
| Conceito do Projeto em Função da Nota do Projeto de P&D, numa escala de 1 a 5. (Project concept of the R & D Project Note function, a scale of 1 to 5.)<br><br>Nota do Projeto (N) Conceito do Projeto (Project Note (N) Project Concept)<br>$N \leq 2,0$ Inadequado ($N \leq 2.0$ Unsuitable)<br>$2,0 < N < 3,0$ Insuficiente (Not Enough)<br>$3,0 \leq N < 3,5$ Aceitável (Enough)<br>$3,5 \leq N < 4,5$ Bom (Good)<br>$N \geq 4,5$ Excelente (Excellent) |
| Como distribuidora de energia, devemos, por lei, investir em projetos de P&D e Eficiência Energética. A escolha dos projetos a serem implementados envolve o valor do referido projeto e o aumento na qualidade do serviço prestado, tal qual a melhora de um índice de continuidade, por exemplo. No caso de Eficiência Energética, pensamos no valor do projeto, na eficácia deste e no retorno do valor intangível para a imagem da empresa. (As power distributor, must, by law, invest in R & D and Energy Efficiency projects. The choice of projects to be implemented involves the value of the project and the increase in quality of service, as is the improvement of a continuity index, for example. In the case of energy efficiency, we think the value of the project, the effectiveness of and return on intangible value to the company's image) |
| Há um comitê permanente de avaliação de P&D, composto pelos superintendentes das áreas fins, que é convocado para aprovar as chamadas publicas, e posteriormente escolher os projetos selecionados que serão submetidos à apreciação da alta direção.<br>(There is a permanent R & D evaluation committee, composed of superintendents of the purpose areas, which is called to approve the public calls, and then choose the selected projects that will be submitted to senior management appreciation.) |

| |
|---|
| A seleção de projetos é para buscar a melhoria da qualidade do fornecimento de energia elétrica. (The selection of projects is to seek improvement of the quality of the electric power supply.) |
| Sim, os projetos são selecionados a partir das necessidades oriundas das áreas de negócios da empresa, e são implementados conforme a quantidade de recursos disponíveis. (Yes, the projects are selected from the needs coming from the company's business areas, and are implemented according to the amount of resources available.) |
| Alinhamento às diretrizes estratégicas da organização (Alignment to the organization's strategic guidelines) |
| Os projetos são selecionados internamento por um comitê técnico que após seleção de alguns temas/projetos os selecionam através do ranqueamento de avaliações dos técnicos de áreas responsáveis. O projeto com maior nota é selecionado ser feita sua avaliação externa da empresa. De posse do resultado externo o comitê técnicos aprova ou o projeto por motivos econômicos, técnicos ou de interesse da empresa. (Projects are selected internment by a technical committee that after selection of some topics / projects to select through the ranking assessments of areas responsible technicians. The project with the highest score is selected to be made external evaluation of the company. Having the external result the technical committee approves the project or for economic reasons, technical or company interest.) |

9. Você pode ter indicado mais de um método de seleção de projetos. Qual dos métodos listados abaixo é o dominante no seu processo de tomada de decisão? Por favor selecione apenas um método. Caso seja outro método que não esteja listado abaixo, por favor especificar. *( You may have indicated more than one project selection method. Which of the methods listed below is the dominant in its decision-making process? Please select only one method. If another method that is not listed below, please specify. *)

- (●) Método de atribuição de notas [1] (Notes assignment method)
- ( ) Diagrama de bolhas [2] (Bubble diagram)
- ( ) Método financeiro [3] (Financial method)
- ( ) Método de planejamento estratégico [4] (Strategic planning method)
- ( ) Método de verificação tipo "check list" [5] (another kind of checklist verification method)
- ( ) Outro: [6]

Table A1.33 – Answers about the dominant in its decision-making process

| Option | Count | % |
|---|---|---|
| 1 | 15 | 50,0% |
| 2 | 2 | 6,7% |
| 3 | 3 | 10,0% |
| 4 | 7 | 23,3% |
| 5 | 1 | 3,3% |
| 6 | 2 | 6,7% |

10. Quais fatores são utilizados no processo de avaliação de portfólio de sua empresa nos quais um projeto é comparado com outro para determinar o conjunto final de projetos a ser selecionado? Por favor, marque todos os que se aplicam. * (What factors are used in the process of evaluating your business portfolio in which a project is compared with another to determine the final set of projects to be selected? Please check all that apply. *)

- ☐ Retorno de investimento [19 responderam esta opção] (ROI [19 responded this option])
- ☐ Comercialização [06 responderam esta opção] (Commercialization [06 responded this option])
- ☐ Sinergia entre projetos [07 responderam esta opção] (Synergy between projects [07 responded this option])
- ☐ Aderência à Estratégia / Competência Principal [20 responderam esta opção] (Alignment to Strategy / Main Competence [20 responded this option])
- ☐ Momento [10 responderam esta opção] (Timing [20 responded this option]))
- ☐ Tecnologia [23 responderam esta opção] (Technology [23 responded this option])
- ☐ Projetabilidade [08 responderam esta opção] (Projectability [08 responded this option])
- ☐ Risco / Probabilidade de Sucesso [19 responderam esta opção] (Risk / Probability of Success [19 responded this option])
- ☐ Outro: [02 responderam esta opção com complemento "originalidade"] (Other: [02 responded this option to add "originality"])

11. Quais fatores são considerados mais importantes em uma primeira rodada de análises de escolha entre opções (trade-offs) necessários para otimizar o conjunto de projetos selecionados? Quais fatores são considerados em uma segunda rodada, caso necessário? * (What factors are considered most important in a first round of analysis choice between options (trade-offs) needed to optimize the set of selected projects? What factors are considered in a second round, if necessary? *)

| | Importante na Primeira Rodada (Important in the First Round) | Importante na Segunda Rodada (Important in the Second Round) |
|---|---|---|
| Retorno de investimento (Return of investment) | [17 respostas] ([17answers]) | [13 respostas] ([13answers]) |
| Comercialização (Commercialization) | [2 respostas] ([2answers]) | [28 respostas] ([28answers]) |
| Sinergia entre Projetos (Synergy between projects) | [9 respostas] ([9answers]) | [21 respostas] ([21answers]) |
| Aderência à Estratégia / Competência Principal (Alignment to Strategy / Main Skill) | [25 respostas] ([25answers]) | [5 respostas] ([5answers]) |
| Momento (Timing) | [17 respostas] ([17answers]) | [13 respostas] ([13answers]) |
| Tecnologia (Technology) | [27 respostas] ([27answers]) | [3 respostas] ([13answers]) |
| Risco / Probabilidade de Sucesso (Risk / Probability of Success) | [18 respostas] ([18answers]) | [12 respostas] ([12answers]) |

12. Quais são os maiores desafios que você enfrenta na gestão do portfólio de projetos? * (What are the biggest challenges you face in project portfolio management? *)

Table A1.34 – Answers about biggest challenges in project portfolio management

| |
|---|
| ORGANIZAR E ALINHAR A EQUIPE DE TRABALHO (ORGANIZE AND ALIGN THE WORK TEAM) |
| Tempo. (time) |
| Comparar projetos de diferentes áreas. Engajamento dos diferentes departamentos. Comprometimento dos gerentes de projetos. Aderência dos projetos à estratégia da empresa. Mensuração de resultados. (Compare projects of different areas. Engagement of the different departments. Commitment of project managers. Alignment of projects to business strategy. results measurement.) |
| ENTENDIMENTO DOS GESTORES A RESPEITO DA IMPORTÂNCIA DESTA PRÁTICA (UNDERSTANDING OF MANAGERS ABOUT THE IMPORTANCE OF THAT PRACTICE) |
| Diversidade (Diversity) |
| ORIGINALIDADE (ORIGINALITY) |
| O critério Originalidade o qual é eliminatório para garantir o reconhecimento de investimento por parte do órgão regulador. Portanto, para que o projeto seja aprovado, parcial ou integralmente, na avaliação final este critério deve ter pontuação igual ou superior a 3,0 (The originality criterion which is eliminatory to ensure recognition of investment by the regulator. So for the project to be approved, partially or fully, in the final evaluation this criterion must have scores greater than or equal to 3.0) |
| Falta de modelo (Lack of model) |
| Originalidade e aceitação por parte da Agência Reguladora. (Originality and acceptance by the regulatory agency.) |
| Conseguir projetos que sejam originais e que atendam as necessidades organizacionais. É dificil, ainda, envolver outras áreas da empresa em torno deste objetivo. (Getting projects that are unique and that meet organizational needs. It is difficult also involve other areas of the company around this goal.) |
| Seleção de projetos alinhados com a estratégia da organização. (Selection of projects aligned with the organization's strategy.) |
| O maior desafio é escolher projetos que resultem em melhoria significativa da qualidade do sistema elétrico. (The biggest challenge is to choose projects that results in significant improvement of the quality of the electrical system.) |

| |
|---|
| auditoria Aneel (ANEEL Audit) |
| Complexidade dos projetos. (Complexity of projects.) |
| qualidade projetos originalidade (quality projects originality) |
| faltam gestores (lack of managers) |
| Seleção de projetos alinhados com a estratégia da organização. (Selection of projects aligned with the organization's strategy.) |
| projetos de qualidade (quality projects) |
| falta de bons projetos (lack of good projects) |
| Comparar projetos de diferentes áreas. Engajamento dos diferentes departamentos. Comprometimento dos gerentes de projetos. Aderência dos projetos à estratégia da empresa. Mensuração de resultados. (Compare projects of different areas. Engagement of the different departments. Commitment of project managers. Alignment of projects to business strategy. results measurement.) |
| projetos difíceis de entender (projects that are though to understand) |
| Escassez de recursos humanos para gestão. (Shortage of human resources management.) |
| Falta de entidades de pesquisa devidamente capacitadas (Lack of properly trained research entities) |
| critérios ANEEL (ANEEL criteria) |
| selecionar projetos originais (select unique projects) |
| falta de tempo (lack of time) |
| Padronização (standardization) |
| Tempo. (time) |
| A busca pela originalidade, ou seja, o recohecimento de projetos únicos e inovadores.( The quest for originality, namely the recognition of unique and innovative designs.) |

13. Quais são as oportunidades mais imediatas para melhorar os benefícios que sua empresa obtém da gestão de portfólio de projetos? * (What are the most immediate opportunities to improve the benefits that your company gets the project portfolio management?)

Table 2.35 – Answers about what are the most immediate opportunities to improve the benefits that your company gets the project portfolio management

| |
|---|
| GERAR PRODUTOS DE APLICAÇÃO DIRETA NO NEGOCIO DA EMPRESAS (GENERATING DIRECT APPLICATION OF PRODUCTS IN COMPANIES OF BUSINESS) |
| Melhoria de qualidade de serviços. (services quality improvement.) |

| |
|---|
| Fortalecimento da aderência dos projetos à estratégia da empresa com foco em resulatdos. (Tack strengthening projects to the company's strategy to focus on resulatdos.) |
| DIVERSIFICAÇÃO DE INVESTIMENTOS (INVESTMENT DIVERSIFICATION |
| Estar ligado diretamente a estratégica de negócio da empresa (It is connected directly to the company's business strategy) |
| MELHORIA DA QUALIDADE (QUALITY IMPROVEMENT) |
| Gestores e coordenadores das áreas operacionais apurarem sua percepção para a solução de problemas através da implementação de um projeto de P&D. (Managers and coordinators of operational areas ascertain their perception to solving problems through the implementation of an R & D Project) |
| Administração de projetos (project management) |
| Cumprimento de prazos e otimização de recursos. (Meeting deadlines and resource optimization.) |
| O objetivo mais à vista é cumprir a obrigação legal de destinar 0,5 da ROL em ações de Pesquisa e Desenvolvimento, segundo manual da ANEEL. Eventuais benefícios são considerados, mas a prioridade é o cumprimento da obrigação legal. (The aim else in sight is to fulfill the legal obligation to allocate 0.5 of NOI in research and development actions, according to ANEEL manual. Potential benefits are considered, but the priority is the fulfillment of legal obligation.) |
| Projetos que dão retornos diretos ao pontos de melhorias da organização. (Projects that provide direct returns to the points of organizational improvements.) |
| A oportunidade mais imediata é a maior satisfação dos clientes no fornecimento de energia elétrica. (The most immediate opportunity is the highest customer satisfaction in the supply of electricity.) |
| Melhorar controle (improve control) |
| Aplicação da metodologia. (Methodology application.) |
| mais controle na seleção (more control in selecting) |
| formação de pessoal (staff training) |
| Projetos mais aderentes à estratégia da empresa. (projects more adherent to the business strategy.) |
| satisfazer clientes (satisfy customer) |
| mais parceiros (more partners) |
| Fortalecimento da aderência dos projetos à estratégia da empresa com foco em resulatdos. (Tack strengthening projects to the company's strategy to focus on results.) |

| |
|---|
| métodos mais claros (clearer methods) |
| Não entendi a pergunta. (I did not understand the question.) |
| Melhorar processos e controles para auditorias (Improve processes and controls for audits) |
| critérios assertivos (assertive criteria) |
| melhoria dos critérios (improving criteria) |
| consultores auxiliares (auxiliary consultants) |
| Planejamento (planning) |
| Eficiência (efficiency) |
| Avaliações externas. (external evaluations.) |

**Seção E - Sua Avaliação de Portfólio e Seus Métodos de Seleção de Projetos são Satisfatórios? (Are your Portfolio Evaluation and Its Project Selection Methods satisfactory?)**

Considerar o(s) método(s) principal(is)/dominante(s) que você utiliza na avaliação do portfólio e na seleção de projetos. (Consider (s) method (s) Main (s) / dominant (s) you use in the evaluation of the portfolio and the selection of projects.)

Para os Métodos de Avaliação do Portfólio de Projetos como um Todo *( For Assessment Methods Project Portfolio as a whole *)

[1] [2] [3] [4] [5]

Nosso método é realmente utilizado para tomar decisões de Continuar/Cancelar os projetos. [1] = raramente utilizado; [5] = sempre utilizado (Our method is generally used to make decisions Resume / Cancel projects. [1] = rarely used; [5] = always used)

Table A1.36 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 3 | 10,0% |
| 2 | 5 | 16,7% |
| 3 | 8 | 26,7% |
| 4 | 5 | 16,7% |
| 5 | 9 | 30,0% |

Nosso método é compatível com nosso estilo de tomada de decisão dos gestores. [1] = não é compatível; [5] bastante compatível (Our method is compatible with our decision-making style of managers. [1] = is not compatible; [5] quite compatible)

Table A1.37 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 3 | 10,0% |
| 3 | 10 | 33,3% |
| 4 | 9 | 30,0% |
| 5 | 8 | 26,7% |

Nosso método é entendido pelos gestores. [1] não entendido; [5] bem entendido (Our method is understood by managers. [1] not understood; [5] well understood)

Table A1.38 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 6 | 20,0% |
| 3 | 3 | 10,0% |
| 4 | 7 | 23,3% |
| 5 | 13 | 43,3% |

Nosso método é simples e fácil de usar. [1] Não, complexo e difícil de utilizar; [5] Muito simples e fácil de utilizar (Our method is simple and easy to use. [1] No, complex and difficult to use; [5] Very simple and easy to use)

Table A1.39 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 2 | 6,7% |
| 3 | 8 | 26,7% |
| 4 | 12 | 40,0% |
| 5 | 8 | 26,7% |

Nosso método é realista e captura os pontos chave do problema. [1] Não, o método é simplista; [5] Muito realista (Our method is realistic and captures the key points of the problem. [1] No, the method is simplistic; [5] Very realistic)

Table A1.40 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 2 | 6,7% |
| 2 | 6 | 20,0% |
| 3 | 4 | 13,3% |
| 4 | 13 | 43,3% |
| 5 | 5 | 16,7% |

Our method is perceived by managers as efficient. [1] labor intensive and wastes time; [5] Very efficient

Table A1.41 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 8 | 26,7% |
| 3 | 6 | 20,0% |
| 4 | 8 | 26,7% |
| 5 | 8 | 26,7% |

De maneira geral nós podemos classificar nosso método como excelente. [1] Ruim; [5] Excelente (In general we can classify our method as excellent. [1] Bad; [5] Excellent)

Table A1.42 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 2 | 6,7% |
| 2 | 6 | 20,0% |
| 3 | 10 | 33,3% |
| 4 | 8 | 26,7% |
| 5 | 4 | 13,3% |

Nós recomendamos nosso método para ser utilizado por as empresas como a nossa. [1] Com certeza não; [5] Com certeza sim (We recommend our method to be used by companies like ours. [1] Certainly not; [5] Certainly yes)

Table A1.43 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 7 | 23,3% |
| 3 | 10 | 33,3% |
| 4 | 8 | 26,7% |
| 5 | 4 | 13,3% |

**Para Métodos de Seleção de Projetos Individuais * (For Single Project Selection Methods *)**

[1] [2] [3] [4] [5]

Nosso método é realmente utilizado para tomar decisões de Continuar/Cancelar os projetos. [1] = raramente utilizado; [5] = sempre utilizado (Our method is generally used to make decisions Resume / Cancel projects. [1] = rarely used; [5] = always used)

Table A1.44 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 1 | 3,3% |
| 3 | 10 | 33,3% |
| 4 | 5 | 16,7% |
| 5 | 13 | 43,3% |

Nosso método é compatível com nosso estilo de tomada de decisão dos gestores. [1] = não é compatível; [5] bastante compatível (Our method is compatible with our decision-making style of managers. [1] = is not compatible; [5] quite compatible)

Table A1.45 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 1 | 3,3% |
| 3 | 10 | 33,3% |
| 4 | 15 | 50,0% |
| 5 | 4 | 13,3% |

Nosso método é entendido pelos gestores. [1] não entendido; [5] bem entendido (Our method is understood by managers. [1] not understood; [5] well understood)

Table A1.46 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 4 | 13,3% |
| 3 | 9 | 30,0% |
| 4 | 5 | 16,7% |
| 5 | 11 | 36,7% |

| | [1] | [2] | [3] | [4] | [5] |
|---|---|---|---|---|---|

Nosso método é simples e fácil de usar. [1] Não, complexo e difícil de utilizar; [5] Muito simples e fácil de utilizar (Our method is simple and easy to use. [1] No, complex and difficult to use; [5] Very simple and easy to use)

Table A1.47 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 2 | 6,7% |
| 3 | 9 | 30,0% |
| 4 | 11 | 36,7% |
| 5 | 8 | 26,7% |

Nosso método é realista e captura os pontos chave do problema. [1] Não, o método é simplista; [5] Muito realista (Our method is realistic and captures the key points of the problem. [1] No, the method is simplistic; [5] Very realistic)

Table A1.48 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 4 | 13,3% |
| 3 | 11 | 36,7% |
| 4 | 6 | 20,0% |
| 5 | 9 | 30,0% |

Nosso método é percebido pelos gestores como eficiente. [1] Trabalhoso e desperdiça tempo; [5] Muito eficiente (Our method is perceived by managers as efficient. [1] labor intensive and wastes time; [5] Very efficient)

Table A1.49 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 6 | 20,0% |
| 3 | 8 | 26,7% |
| 4 | 10 | 33,3% |
| 5 | 6 | 20,0% |

De maneira geral nós podemos classificar nosso método como excelente. [1] Ruim; [5] Excelente (In general we can classify our method as excellent. [1] Bad; [5] Excellent)

[1] [2] [3] [4] [5]

Table A1.50 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 4 | 13,3% |
| 3 | 14 | 46,7% |
| 4 | 8 | 26,7% |
| 5 | 4 | 13,3% |

Para Métodos de Seleção de Projetos Individuais [Nós recomendamos nosso método para ser utilizado por as empresas como a nossa. [1] Com certeza não; [5] Com certeza sim] (For Single Project Selection Methods [We recommend our method to be used by companies like ours. [1] Certainly not; [5] Certainly yes])

Table A1.51 – Answers about the previous statement

| Valid | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| 1 | 1 | 3,3 | 3,3 | 3,3 |
| 2 | 4 | 13,3 | 13,3 | 16,7 |
| 3 | 13 | 43,3 | 43,3 | 60,0 |
| 4 | 10 | 33,3 | 33,3 | 93,3 |
| 5 | 2 | 6,7 | 6,7 | 100,0 |
| Total | 30 | 100,0 | 100,0 | |

**Seção F - Resultados de Desempenho dos seus Métodos de Gestão de Portfólio (Performance Results of its Portfolio Management Methods)**

A sua avaliação de portfólio e métodos de seleção de projetos está realmente funcionando? (Its portfolio assessment and project selection methods is really working?)

[1] [2] [3] [4] [5]

Relativo aos competidores em nossa área, nossos programa de novos produtos e serviços é bem sucedido. [1] = é mal sucedido; [5] = é muito bem sucedido (Relative to competitors in our area, our program of new products and services is successful. [1] = is unsuccessful; [5] = is very successful)

Table A1.52 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 3 | 10,0% |
| 3 | 11 | 36,7% |
| 4 | 12 | 40,0% |
| 5 | 4 | 13,3% |

Nós temos o número correto de novos projetos para nossos recursos disponíveis - pessoas, tempo e dinheiro. [1] = Não, temos projetos demais para a quantidade de recursos; [5] = Temos o correto número de projetos para nossos recursos (We have the correct number of new projects for our resources - people, time and money. [1] = No, we have other projects for the amount of resources; [5] = We have the correct number of projects for our resources)

Table A1.53 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 3 | 10,0% |
| 2 | 5 | 16,7% |
| 3 | 6 | 20,0% |
| 4 | 8 | 26,7% |
| 5 | 8 | 26,7% |

Nossos projetos são executados no prazo e no momento oportuno. [1] = não, são realizados lentamente e atrasados; [5]= são realizados no prazo e no momento oportuno (Our projects are implemented on time and at the appropriate time. [1] = not, they are performed slowly and late; [5] = are carried out on time and at the right time)

Table A1.54 – Answers about the previous statement

[1] [2] [3] [4] [5]

| Level | Count | % |
|---|---|---|
| 2 | 4 | 13,3% |
| 3 | 11 | 36,7% |
| 4 | 9 | 30,0% |
| 5 | 6 | 20,0% |

Nosso portfólio de projetos contem somente os projetos de alto valor para nosso negócio - projetos lucrativos, com alto retorno e com sólidas perspectivas comerciais. [1] = Não, muitos projetos pobres, medíocres e de baixo valor; [5] = Com certeza sim, projetos de alto valor para o negócio. (Our project portfolio contains only high value projects for our business - profitable projects with high return and with solid business prospects. [1] = No, many poor designs, poor and low value; [5] = Certainly yes, high value projects for business.)

Table A1.55 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 5 | 16,7% |
| 3 | 9 | 30,0% |
| 4 | 12 | 40,0% |
| 5 | 4 | 13,3% |

Nosso portfólio de projetos tem um excelente equilíbrio em termos de longo prazo versus curto prazo, alto risco versus baixo risco, através de mercados e tecnologias, e assim por diante. [1] = Não, equilibrado e distorcido; [5] = Excelente equilíbrio (Our project portfolio has an excellent balance in terms of long-term versus short-term, high-risk versus low risk through markets and technologies, and so on. [1] = No, balanced and distorted; [5] = Excellent balance)

Table A1.56 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,4% |
| 2 | 8 | 27,6% |
| 3 | 8 | 27,6% |
| 4 | 8 | 27,6% |

| [1] | [2] | [3] | [4] | [5] |
|---|---|---|---|---|
| 5 | 4 | 13,8% | | |

Os projetos em nosso portfólio estão alinhados com nossos objetivos de negócio e nossa estratégia de negócios. [1] = Não, muitos estão desalinhados com os objetivos ou com a estratégia; [5] Estão alinhados com os objetivos e com a estratégia (The projects in our portfolio are aligned with our business objectives and our business strategy. [1] = No, many are out of line with the objectives or the strategy; [5] are aligned with the objectives and the strategy)

Table A1.57 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 1 | 3,3% |
| 2 | 4 | 13,3% |
| 3 | 9 | 30,0% |
| 4 | 10 | 33,3% |
| 5 | 6 | 20,0% |

A divisão de recursos em nosso portfólio de projetos realmente reflete nossa estratégia de negócios. [1] = Não, a divisão de recursos é inconsistente com nossa estratégia de negócios ou não tem estratégia; [5] = a divisão de recursos reflete a estratégia (The resource division in our project portfolio truly reflects our business strategy. [1] = No, the division of resources is inconsistent with our business strategy or has no strategy; [5] = the resources division reflects the strategy)

Table A1.58 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 3 | 10,3% |
| 3 | 12 | 41,4% |
| 4 | 6 | 20,7% |
| 5 | 8 | 27,6% |

| [1] | [2] | [3] | [4] | [5] |
|---|---|---|---|---|

Os projetos em nosso portfólio permitem ao nosso negócio entrar em novos mercados. [1] = não; [5] sim, permite entrar em novos mercados (The projects in our portfolio allows our business into new markets. [1] = no; [5] Yes, allows enter new markets)

Table A1.59 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 8 | 26,7% |
| 2 | 4 | 13,3% |
| 3 | 9 | 30,0% |
| 4 | 3 | 10,0% |
| 5 | 6 | 20,0% |

Os projetos em nosso portfólio desenvolvem nossas tecnologias existentes e nossas competências tecnológicas. [1] = Não; [5] = Sim, frequentemente alavancam as tecnologias existentes e competências (The projects in our portfolio develop our existing technologies and our technological skills. [1] = No; [5] = Yes, often leveraging existing technologies and skills)

Table A1.60 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 2 | 2 | 6,9% |
| 3 | 2 | 6,9% |
| 4 | 15 | 51,7% |
| 5 | 10 | 34,5% |

Os projetos em nosso portfólio trazem novas tecnologias para nosso negócio. [1] = Não; [5] = Sim, sempre utilizam/trazem novas tecnologias (The projects in our portfolio bring new technologies to our business. [1] = No; [5] = Yes, always use / bring new Technologies)

Table A1.61 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 3 | 5 | 16,7% |
| 4 | 15 | 50,0% |

| [1] | [2] | [3] | [4] | [5] |
|---|---|---|---|---|
| 5 | 10 | 33,3% | | |

Os projetos em nosso portfólio levam nossa empresa a novas áreas de atuação (novas áreas não oferecidas há três anos atrás). [1] = Não; [5] = Sim, sempre nos levam a novas áreas (The projects in our portfolio lead our company to new areas (new areas not offered three years ago). [1] = No; [5] = Yes, always lead us to new áreas)

Table A1.62 – Answers about the previous statement

| Level | Count | % |
|---|---|---|
| 1 | 6 | 20,0% |
| 2 | 6 | 20,0% |
| 3 | 10 | 33,3% |
| 4 | 6 | 20,0% |
| 5 | 2 | 6,7% |

**Medição de Desempenho / Fatores de Sucesso (Performance Measurement / Success Factors)**

Quantos projetos estão sendo realizados em sua área atualmente? *( How many projects are being conducted in your area today? *)

Table A1.63 – Answers about number of projects are being conducted in the area today

| # of projects | Count | % |
|---|---|---|
| 1 | 3 | 10,0% |
| 2 | 2 | 6,7% |
| 3 | 2 | 6,7% |
| 4 | 1 | 3,3% |
| 5 | 2 | 6,7% |
| 7 | 2 | 6,7% |
| 8 | 4 | 13,3% |
| 10 | 2 | 6,7% |
| 11 | 4 | 13,3% |
| 23 | 3 | 10,0% |
| 30 | 1 | 3,3% |
| 32 | 2 | 6,7% |
| 36 | 1 | 3,3% |

| | | |
|---|---|---|
| 39 | 1 | 3,3% |

Qual o tempo típico de execução de um projeto de sua área (em meses)? * (What is the typical run time of your area project (in months)? *)

Table A1.64 – Answers about the typical run time the area project (in months)

| Months | Count | % |
|---|---|---|
| 18 | 1 | 3,3 % |
| 24 | 23 | 76,7% |
| 30 | 5 | 16,7% |
| 36 | 1 | 3,3 % |

Do total de projetos iniciados, qual percentual de projetos são abandonados ou cancelados antes do final previsto? * (Of the projects started, what percentage of projects are abandoned or canceled before the expected end? *)

[nesta questão todas as concessionárias disseram que este valor era zero] ([This question all the utilities said that this value is zero])

Para cada um dos indicadores abaixo que sua organização utiliza para medir resultados, por favor indique o quão importante este indicador é para classificar o sucesso do projeto como um todo. Se sua organização não utiliza algum indicador, por favor marque a opção "não utilizado" na última coluna. * (For each of the indicators below that your organization uses to measure results, please indicate how important this indicator is to rate the success of the project as a whole. If your organization does not use any indicator, please check the "not used" option in the last column.) *

[1] = Muito importante (very important) [2] [3] [4] [5] = Não muito importante (not very important) [0] = Não Utilizado (not used)

Valor Presente Líquido / Taxa Interna de Retorno (Net Present Value / Internal Rate of Return)

Table A1.65 – Answers about Net Present Value / Internal Rate of Return

| Level | Count | % |
|---|---|---|
| 0 | 6 | 20,0% |
| 1 | 7 | 23,3% |
| 2 | 5 | 16,7% |
| 3 | 3 | 10,0% |
| 4 | 3 | 10,0% |
| 5 | 6 | 20,0% |

Retorno do Investimento (Return on investment)

Table A1.66 – Answers about re

| Level | Count | % |
|---|---|---|
| 0 | 3 | 10,0% |
| 1 | 12 | 40,0% |
| 2 | 5 | 16,7% |
| 3 | 4 | 13,3% |
| 4 | 4 | 13,3% |
| 5 | 2 | 6,7% |

Período de Retorno do Investimento (Payback Period)

Table A12.67 – Answers about payback period

| Level | Count | % |
|---|---|---|
| 0 | 4 | 13,3% |
| 1 | 5 | 16,7% |

| [1] = Muito importante (very important) | [2] | [3] | [4] | [5] = Não muito importante (not very important) | [0] = Não Utilizado (not used) |
|---|---|---|---|---|---|
| 2 | | 7 | 23,3% | | |
| 3 | | 7 | 23,3% | | |
| 4 | | 7 | 23,3% | | |

Lucro (Profit)

TableA1.68 – Answers about profit

| Level | Count | % |
|---|---|---|
| 0 | 9 | 30,0% |
| 1 | 5 | 16,7% |
| 2 | 4 | 13,3% |
| 3 | 5 | 16,7% |
| 4 | 3 | 10,0% |
| 5 | 4 | 13,3% |

Satisfação do Consumidor (Customer Satisfaction)

Table A1.69 – Answers about profit customer satisfaction

| Level | Count | % |
|---|---|---|
| 0 | 5 | 16,7% |
| 1 | 9 | 30,0% |
| 2 | 8 | 26,7% |
| 3 | 6 | 20,0% |
| 5 | 2 | 6,7% |

Faturamento de Vendas (Sales revenues)

**TableA1.70 – Answers about sales revenue**

| Level | Count | % |
|---|---|---|
| 0 | 9 | 30,0% |
| 1 | 1 | 3,3% |
| 2 | 6 | 20,0% |
| 3 | 10 | 33,3% |
| 5 | 4 | 13,3% |

Crescimento da Participação de Mercado (Market Share Growth)

**Table A1.71 - Answers about Market Share Growth**

| Level | Count | % |
|---|---|---|
| 0 | 8 | 26,7% |
| 1 | 2 | 6,7% |

| | | |
|---|---|---|
| 2 | 7 | 23,3% |
| 3 | 7 | 23,3% |
| 4 | 4 | 13,3% |
| 5 | 2 | 6,7% |

Entrada em Novos Mercados (Entry into New Markets)

**Table A1.72 – Answers about entry into new markets**

| Level | Count | % |
|---|---|---|
| 0 | 7 | 23,3% |
| 1 | 4 | 13,3% |
| 2 | 5 | 16,7% |
| 3 | 8 | 26,7% |
| 4 | 4 | 13,3% |
| 5 | 2 | 6,7% |

Grau em que o Orçamento é Cumprido (Degree to which the budget is Accomplished)

**Table A1.73 - Answers about degree to which the budget is accomplished**

| Level | Count | % |
|---|---|---|
| 1 | 18 | 60,0% |
| 2 | 3 | 10,0% |
| 3 | 6 | 20,0% |
| 4 | 2 | 6,7% |
| 5 | 1 | 3,3% |

Grau em que o Cronograma é Mantido (Degree to which the schedule is Kept)

**Table A1.74 - Answers about degree to which the schedule is kept**

| Level | Count | % |
|---|---|---|
| 1 | 17 | 56,7% |
| 2 | 5 | 16,7% |
| 3 | 3 | 10,0% |
| 4 | 4 | 13,3% |
| 5 | 1 | 3,3% |

Tempo de Desenvolvimento do Projeto (Project Development Time)

**Table A1.75- Answers about project development time**

| Level | Count | % |
|---|---|---|
| 1 | 11 | 36,7% |
| 2 | 14 | 46,7% |
| 4 | 4 | 13,3% |
| 5 | 1 | 3,3% |

Além das opções mostradas acima, alguma outra é utilizada? Por favor especifique. (In addition to the options shown above, some other is used? Please specify.)

[Aderência do projeto a critérios específicos] ([Project Alignment and specific criteria])

[Reconhecimento do valor investido por parte do órgão regulador] ([Value Recognition invested by the regulatory agency])

Para cada um dos indicadores de sucesso abaixo para novos produtos/serviços, como sua organização pode se comparar com os competidores e/ou organizações similares? (For each of the indicators of success down to new products / services, how your organization can compare to competitors and / or similar organizations?)

[1] = melhor que a maioria (better than most) [2] [3] = na média (in average) [4] [5] = pior que a maioria (worse than most) [0] = não tenho conhecimento / não é feita comparação (I do not know / comparison is not performed)

Retorno do investimento em novos produtos/serviços (Return on investment in new products / services)

**Table A1.76 – Answers about return on investment in new products / services**

| Level | Count | % |
|---|---|---|
| 0 | 14 | 48,3% |
| 3 | 14 | 48,3% |
| 4 | 1 | 3,4% |

Outros indicadores financeiros (Other financial indicators)

**Table A1.77 – Answers about other financial indicators**

| Level | Count | % |
|---|---|---|
| 0 | 16 | 55,2% |
| 2 | 1 | 3,4% |

| [1] = melhor que a maioria [2] (better than most) | [3] = na média (in average) [4] | [5] = pior que a maioria (worse than most) | [0] = não tenho conhecimento / não é feita comparação (I do not know / comparison is not performed) |
|---|---|---|---|
| 3 | 12 | 41,4% | |

Número de novos lançamentos de produtos/serviços (Number of new product launches / services)

**Table A1.78 – Answers about number of new product launches / services**

| Level | Count | % |
|---|---|---|
| 0 | 12 | 41,4% |
| 2 | 3 | 10,3% |
| 3 | 12 | 41,4% |
| 4 | 2 | 6,9% |

Satisfação do consumidor com novos produtos/serviços (consumer satisfaction with new products / services)

**Table A1.79 – Answers about consumer satisfaction with new products / services**

| Level | Count | % |
|---|---|---|
| 0 | 11 | 37,9% |
| 2 | 4 | 13,8% |
| 3 | 12 | 41,4% |
| 5 | 2 | 6,9% |

Volume de vendas / Participação de mercado de novos produtos/serviços (Sales volume / Market share of new products / services)

**Table A1.80 - Answers about sales volume / Market share of new products / services**

| Level | Count | % |
|---|---|---|
| 0 | 18 | 66,7% |
| 1 | 2 | 7,4% |
| 3 | 7 | 25,9% |

Crescimento em mercados existentes (Growth in existing markets)

**Table A1.81 – Answers about growth in existing markets**

| Level | Count | % |
|---|---|---|
| 0 | 18 | 62,1% |
| 3 | 7 | 24,1% |
| 4 | 4 | 13,8% |

Entrada em novos mercados (Entry into new markets)

**Table A1.82 – Answers about entry into new markets**

| Level | Count | % |
|---|---|---|
| 0 | 16 | 55,2% |
| 1 | 2 | 6,9% |
| 2 | 1 | 3,4% |
| 3 | 8 | 27,6% |
| 4 | 2 | 6,9% |

Grau em que o orçamento para novos produtos/serviços é executado conforme planejado (Degree to which the budget for new products / services is implemented as planned)

**Table A1.83 – Answers about degree to which the budget for new products / services is implemented as planned**

| Level | Count | % |
|---|---|---|
| 0 | 12 | 41,4% |
| 1 | 2 | 6,9% |
| 2 | 6 | 20,7% |
| 3 | 6 | 20,7% |
| 4 | 1 | 3,4% |
| 5 | 2 | 6,9% |

Tempo de desenvolvimento de projeto (project development time)

**Table A1.84 - Answers about project development time**

| Level | Count | % |
|---|---|---|
| 0 | 10 | 34,5% |
| 1 | 2 | 6,9% |
| 2 | 7 | 24,1% |
| 3 | 5 | 17,2% |
| 4 | 2 | 6,9% |

| | | |
|---|---|---|
| 5 | 3 | 10,3% |

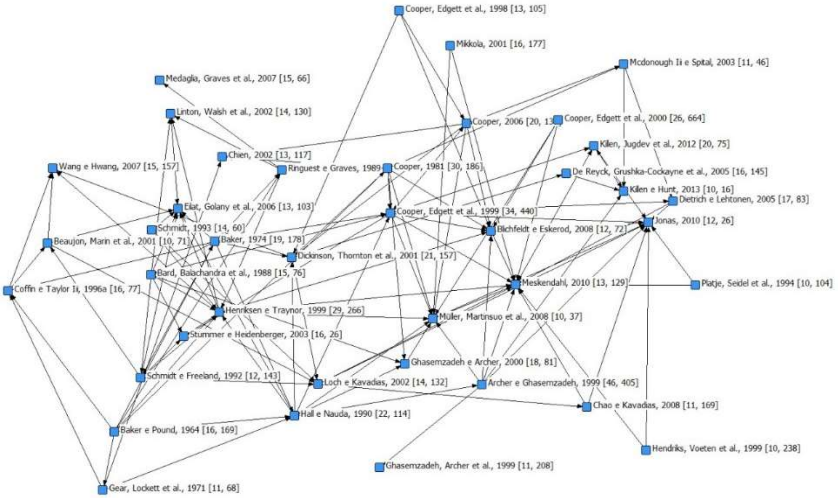
**Appendix 2 – Bibliometry results**

To conduct the bibliometry, a search was performed through the portal of the Coordination for the Improvement of Higher Education (CAPES). The accessed databases were the Institute of Electrical and Electronic Engineers (IEEE), ScienceDirect, Scopus, SciELO, ISI Web of Knowledge, Emerald and Google Scholar. The search was performed using the keyword combination "Project+Portfolio+Management" and its corresponding acronym PPM. This search returned 188 selected articles. Other keywords were identified based on the articles returned from the previous search, such as "R&D+Portfolio", "Innovation+Portfolio", "NPD+Portfolio", "Multi-project+management", "Project+portfolio+selection" and "Project+portfolio+ranking." Thus, they were used for another search.

Initially (in July 2014), 4080 articles were identified (with no time frame). After discarding the duplicates and reading the titles, abstracts and keywords, 285 articles aligned to the research subject (PPM) were obtained. Later, in April 2015, 17 articles were added to the set, resulting in 302 articles that were read in full. The software used to organize the publications was EndNote 5.

Figure  shows the network diagram of bibliographic citations for the portfolio articles analyzed where the numbers in brackets indicate the number of citations for articles within the portfolio and then the total amount of quotes based on Google Scholar. It shows the items that got more than ten citations by articles of the analyzed literature portfolio.

**Figure A2.1 - Network diagram for the citations of portfolio articles.**




Note: numbers by brackets indicate the number to the left of article citations by other portfolio articles analyzed and right the total amount of article citations by Google Scholar

Software UCINET 6® was used to build the network diagram of PPM components and the network diagram of citations of portfolio articles. Table shows articles with ten or more citations within the articles set studied while setting some citations in Google Scholar for these items. Observing the number of citations of articles within the articles set and the number of citations in Google Scholar is possible to see cases, where the amount of article quotes within the portfolio, exceeds 50% of total citations in Google Scholar, as the article by Killen and Hunt (2013) with 10 citations in the portfolio of articles, corresponding to 62.5% of article citations in Google Scholar with 16 citations. Moreover, occur cases where the amount of article citations in the portfolio is less than 5% of total citations in Google Scholar, as an example, the article Cooper et al. (2001) with 26 citations in the portfolio of articles, corresponding to 3.9% of total citations in Google Scholar with 664 citations.

**Table A2.1 - Citations of articles in the articles of studied portfolio and Google Scholar, considering articles with more than ten citations in studied portfolio articles.**

| Article | Citations within the portfolio | Citations in Google Scholar |
|---|---|---|
| Archer and Ghasemzadeh (1999) | 46 | 405 |

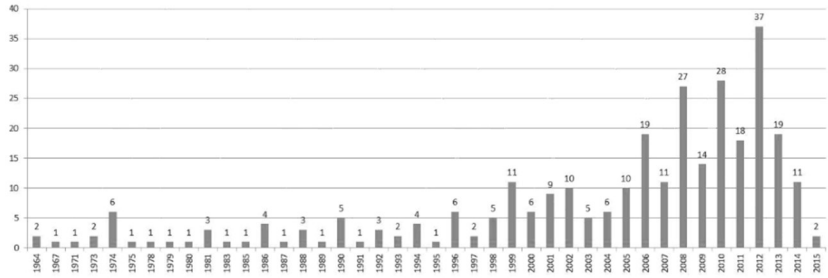
| | | |
|---|---|---|
| Cooper et al. (1999) | 34 | 440 |
| Cooper (1981) | 30 | 186 |
| Henriksen and Traynor (1999) | 29 | 266 |
| Cooper, Edgett et al.( 2000) | 26 | 664 |
| Martinsuo (2012) | 26 | 79 |
| Hall and Nauda (1990) | 22 | 114 |
| Dickinson et al. (2001) | 21 | 157 |
| Cooper (2006) | 20 | 138 |
| Killen et al. (2012) | 20 | 75 |
| Baker (1974) | 19 | 178 |
| Ghasemzadeh and Archer (2000) | 18 | 81 |
| Dietrich and Lehtonen (2005) | 17 | 83 |
| Baker and Pound (1964) | 16 | 169 |
| Coffin and Taylor Iii (1996a) | 16 | 77 |
| De Reyck et al. (2005) | 16 | 145 |
| Mikkola (2001) | 16 | 117 |
| Stummer and Heidenberger (2003) | 16 | 26 |
| Bard et al. (1988) | 15 | 76 |
| Medaglia et al. (2007) | 15 | 66 |
| Wang and Hwang (2007) | 15 | 157 |
| Linton et al. (2002) | 14 | 130 |
| Loch and Kavadias (2002) | 14 | 132 |
| Schmidt (1993) | 14 | 60 |
| Chien (2002) | 13 | 117 |
| Cooper et al. (1998) | 13 | 105 |
| Eilat et al. (2006) | 13 | 103 |
| Meskendahl (2010) | 13 | 29 |
| Blichfeldt and Eskerod (2008) | 12 | 72 |
| Jonas (2010) | 12 | 26 |
| Schmidt and Freeland (1992 ) | 12 | 143 |

| | | |
|---|---|---|
| Chao and Kavadias (2008) | 11 | 69 |
| Gear et al. (1971) | 11 | 68 |
| Ghasemzadeh et al. (1999) | 11 | 208 |
| Mcdonough Iii and Spital (2003) | 11 | 46 |
| Beaujon et al. (2001) | 10 | 71 |
| Hendriks et al. (1999) | 10 | 238 |
| Killen and Hunt (2013) | 10 | 16 |
| Müller et al. (2008) | 10 | 37 |
| Platje et al. (1994) | 10 | 104 |

Table A2.1 shows that some authors that had more than one articles with citations within the articles portfolio, indicating that their articles can be considered relevant for the project portfolio management theme such as Archer and Ghasemzadeh (1999), Cooper et al. (1999), Killen et al. (2012), Henriksen and Traynor (1999) Meskendahl (2010) , Martinsuo (2012), and Jonas (2010).

Regarding the articles in the articles set from 2010 until the current days the articles with authors with more than one article in the articles set more citations, indicating that these articles can be considered the new relevant articles about PPM were Martinsuo (2012), Killen et al. (2012), Meskendahl (2010), Jonas (2010), Gutjahr et al (2010), Unger et al (2012), Teller (2012), Lerch (2012) and Litvinchev (2010). In 2012, there was a special issue of the journal International Journal of Project

**Figure A2.3 – Number of articles per year**




Management on project portfolio management, and this year there were 11 publications on the subject in this journal. Table A2.2 presents the ten journals with the largest number of publications and citations within the selected set of articles. The period 2005-2015 concentrates 195 articles of 302 total selected

articles set. These 195 articles were published in 110 different journals. The ten journals with the highest number of published articles and citations include 87 articles in the same period a total of 195 items, or 44.6% of the total.

**Table A2.2 - The ten journals with the highest number of publications in the articles selected set 2005-2015**

| **Journals with more publications in the period of 10 years** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| International Journal of Project Management | | | 2 | | 3 | 1 | | 3 | | 11 | **3** | 23 |
| European Journal of Operational Research | | 1 | | 2 | 1 | 3 | | 3 | | 1 | | 11 |
| Engineering Management, IEEE Transactions on | 1 | | | | | 2 | 1 | 1 | | 4 | **1** | 10 |
| Project Management Journal | | | | 2 | | 2 | | | 1 | 2 | | 7 |
| Expert Systems with Applications | | | | | | | | 2 | 2 | 2 | | 6 |
| Research Technology Management | 1 | | 1 | 2 | | 1 | | | | | | 5 |
| Technovation | 1 | 1 | 1 | 1 | | 1 | | | | | **1** | 6 |
| Omega | | | | | 1 | 2 | | | 1 | | | 4 |
| Journal of Product Innovation Management | | | | | | | 1 | | 1 | | **1** | 3 |
| Management Science | | | | | 1 | 1 | 1 | | | | | 3 |
| Total Journals top 10: | 3 | 2 | 4 | 7 | 6 | 13 | 3 | 9 | 5 | 20 | 6 | 78 |
| Total in all the 110 journals in the portfolio | 5 | 6 | 10 | 19 | 11 | 27 | 14 | 28 | 17 | 37 | 15 | 189 |
| Percentual [%] | 60,0 | 33,3 | 40,0 | 36,8 | 54,5 | 48,1 | 21,4 | 32,1 | 29,4 | 54,1 | 40,0 | 41,3 |

Regarding the types of PPM projects Table A2.3 shows the distribution of different periods, and it´s possible to notice that most of the publications

regarding R&D projects from the 1960s and 1970s to the 2000s with an increase in the number of publications. For new product development projects, publications began in the 1980s and grew until the 2000s to the innovation projects publications began in the 1990s and had a growing period, and then from 2000 to 2015 have been published more articles than in previous decades. As for the technological development project management, publications began in the 1990s and remained in a constant amount to the current period.

**Table A2.3 – Articles distribution by the kind of PPM projects**

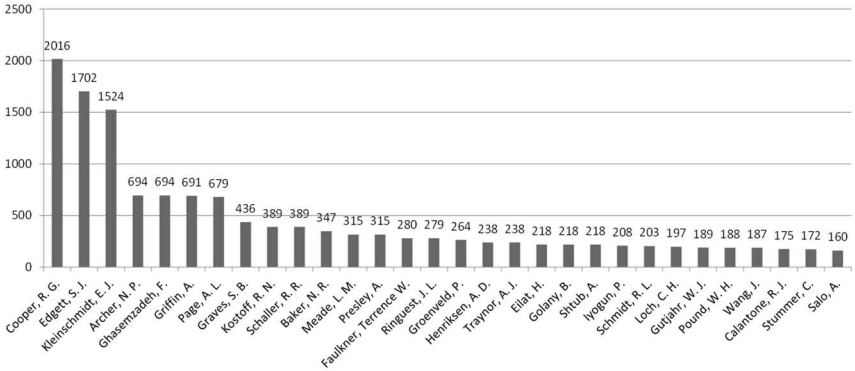
| Years | Articles Quantity in Portfolio | R&D Projects | New product develop-ment projects | Innovation projects | Technology management development projects |
|---|---|---|---|---|---|
| 1960 a 1979 | 15 | 13 | 0 | 0 | 0 |
| 1980 a 1989 | 15 | 11 | 1 | 0 | 0 |
| 1990 a 1999 | 41 | 27 | 5 | 1 | 1 |
| 2000 a 2009 | 117 | 46 | 9 | 4 | 1 |
| 2010 a 2015 | 115 | 19 | 5 | 5 | 1 |
| **Total** | 302 | 116 | 20 | 10 | 3 |

The ten activities sectors with the highest incidence in the portfolio are shown in Table A2.4 The pharmaceutical segment appeared first in the publication quantity starting in the 1980s and grew until the 2000s, followed by the energy sector, where the first publications started in the 1990s and grew in the 2000s the areas of information and software technology comes next and publications in these areas began in the 2000s and the 2010-2015 period is growing and already have equal or greater number of publications from the previous period. The telecommunications sector was the first publication in the 1990s and grew in the 2000s Public organizations have more recent publications starting in the 2000s The other sectors showed publications in the 1960s, 1970s, and 1980s did not show publications in the 1990s and returned to present publications after the 2000s.

**Table A2.4 - Activities segments with higher incidence in the portfolio of PPM articles**

| Years | Articles Quantity in the Portfolio | Pharmaceu-tical | Energy | Information Technology | Software | Telecom | Public Orga-nizations | Oil | Aerospace | Finan-cial Institu-tion | Che-mical In-dus-try |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 to 1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 1980 to 1989 | 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 1990 to 1999 | 41 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 2000 to 2009 | 115 | 12 | 4 | 2 | 3 | 4 | 3 | 2 | 2 | 0 | 1 |
| 2010 to 2015 | 98 | 4 | 2 | 5 | 3 | 0 | 1 | 1 | 0 | 2 | 1 |
| **Total** | 284 | 19 | 8 | 7 | 6 | 5 | 4 | 4 | 3 | 3 | 3 |

**Figure A2.4 - Thirty authors with highest number of articles in the portfolio**




In the set of 302 articles, it was found 566 authors. The 30 authors with a highestr number of articles in the set are shown in Figure A2.3.

The 10 authors appearing in the largest number of articles and citations in the selected set are Archer, N. P., Cooper, R. G., Edgett, S. J., Ghasemzadeh, F., Graves, S. B., C.P., Kleinschmidt, E. J., Ringuest, J. L., Salo, A., Stummer, C. e Wang, J. In the analyzed articles, several methods were found related to decision

support, optimization, artificial intelligence, and financial analysis to support the components of the PPMin its processes.

**Table A2.4- Methods for decision support, and with the highest incidence in the portfolio of articles**

| Years | Articles amount in the portfolio | AHP | MCDM | Bubble Diagram | ODSS | MCDA | ANP | MADM | MAUA |
|---|---|---|---|---|---|---|---|---|---|
| 1960 to 1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 to 1989 | 15 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 2 |
| 1990 to 1999 | 41 | 3 | 5 | 2 | 2 | 0 | 0 | 0 | 0 |
| 2000 to 2009 | 115 | 6 | 8 | 1 | 4 | 2 | 1 | 2 | 0 |
| 2010 to 2013 | 98 | 4 | 1 | 2 | 0 | 2 | 3 | 0 | 0 |
| Total | 284 | 17 | 16 | 6 | 6 | 4 | 4 | 2 | 2 |

Methods for decision support applied to PPM with higher occurrence in the articles portfolio are AHP (*Analytic Hierarchy Process*), MCDM (*Multicriteria Decision Making*), bubble diagram, ODSS (*Organizational Decision Support System*), MCDA (*Multicriteria Decision Aid*), ANP (*Analytical Network Process*), MADM (*Multi Attribute Decision Making*) and MAUA (*Multi Attribute Utility Analysis*). Publications with AHP, MCDM and diagram bubbles started up in the 1980s and continue to occur until the current period. Publications with ODSS were more concentrated in the decades of 1990 and 2000. The amount of publications with ANP started in the 2000s and had been growing after 2010. But the MAUA had publications only in the 1980s.

**Table A2.5 - Optimization methods and support for solving mathematical problems**

| Years | Articles amount in the portfolio | Multi-objective optimization | Integer linear programming | Meta Heuristics | Stochastic optimization | Integer programming | Mixed integer programming | Linear programming formu- | Evolutionary algorithms | Zero One Linear GP Goal Programming | Multi objective linear programming | Sim-Opt | Multi integer linear pro-gram- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 to 1979 | 15 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1980 to 1989 | 15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1990 to 1999 | 41 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 2000 to 2009 | 115 | 4 | 5 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 0 | 2 | 0 |
| 2010 to 2013 | 98 | 3 | 0 | 3 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| Total | 284 | 7 | 6 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |

The optimization methods and mathematical problem solving to support applied to PPM with a higher incidence in the portfolio items are a multi-objective optimizations, integer linear programming, meta-heuristic, stochastic optimization, integer programming, mixed integer programming, linear programming formulation, multi-objective evolutionary algorithms, multi-objective linear programming, Sim-opt (Simulation-Optimization) and integer multilinear programming. Works with multi-objective optimization, stochastic optimization, and multi-objective evolutionary algorithms are more recent starting from the year 2000. The multi-integer linear programming has only articles after 2010. Articles with integer linear programming began in the 1990s increasing in the next decade, however after 2010 were not found new jobs using this technique. The other techniques presented some work in the decades up to the 2000s and jobs were not located after 2010 relating to them.

**Table A2.6 - Artificial intelligence methods combined or without combination with other methods most frequently found in the articles portfolio**

| Years | Articles amount in the portfolio | Fuzzy | Genetic algorithms | fuzzy AHP | fuzzy weighted average | fuzzy pay-off method | Antscolony | Neural Network | Expert systems | Particle Swarm | Multi agent system | Bee colony |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 to 1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 to 1989 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1990 to 1999 | 41 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 to 2009 | 115 | 5 | 3 | 3 | 2 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2010 to 2013 | 98 | 8 | 6 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 |
| **Total** | 284 | 14 | 9 | 4 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |

In some Works, the artificial intelligence techniques that are applied together or not with other techniques are presented in Table 8. The works are about fuzzy logic, genetic algorithms, fuzzy AHP, fuzzy weighted average pay-off fuzzy, ant colony, neural network, expert systems, particle swarm, multi-agent systems and bee colony. The only work with expert systems is the 1980s. Works with fuzzy logic started in 1990 and were increasing every decade with several works after 2010. The other methods have publications after 2000 and in some cases as a fuzzy pay-off, swarm particles, multi-agent systems and colony of bees have jobs only after 2010.

**Table A2.7- Financial valuation methods most frequently found in the articles portfolio**

| Years | Articles amount in the portfolio | Valua-tion | DEA | Invest-ment evalua-tion (NPV, IRR, ROI) | ROA Real Op-tion Analy-sis | Marko-witz effici-ency frontier | Value Creation Model | BSC Balan-ced Score Card | Value at Risk |
|---|---|---|---|---|---|---|---|---|---|
| 1960 to 1979 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 to 1989 | 15 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1990 to 1999 | 41 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2000 to 2009 | 115 | 7 | 3 | 2 | 5 | 1 | 3 | 3 | 1 |
| 2010 to 2013 | 98 | 2 | 6 | 4 | 1 | 2 | 0 | 0 | 0 |
| Total | 284 | 10 | 9 | 9 | 7 | 3 | 3 | 3 | 1 |

The financial valuation methods applied to the PPM that most occur in the articles of portfolio are shown in Table A.2.7 and are in descending order of articles found *Valuation*, DEA (*Data Envelopment Analysis*), Investment evaluation (NPV, IIR, ROI), ROA (*Real Option Analysis*), Markowitz efficiency frontier, Value creation model, BSC (*Balanced Scorecard*) and VAR (*Value at Risk*).

**Appendix 3 - Descriptors for model regarding projects before pass for the selection process by the power utility´s specialists committee from Macbeth Software**

**Table A3.1 – Criteria and values transformed to cardinal scales for each parameter for R&D projects before pass through the selection process**

| **Applicability of the research to be conducted** | |
|---|---|
| **Cardinalized Scale** | **Description** |
| 137,5 | The project has no applicability |
| 100 | The results can be applied only in the company, but the application as a whole is unclear |
| 50 | The results can be applied only in the company |
| 0 | The results can be applied in the company and, also, they can be applied in a larger geographical context, as throughout the region, across the country or internationally |
| -50 | The results can be applied in the company and, also, they can be applied in a larger geographical context, as throughout the region, across the country or internationally or sectoral context only the power utility, the entire electrical industry or in different sectors of the economy |
| | |
| **Professional qualification** | |
| **Cardinalized Scale** | **Description** |
| 150 | There will be no professional qualification |
| 100 | There will be a professional qualification in specialisation level |
| 50 | There will be more than one professional qualification in specialisation level |
| 0 | There will be a professional qualification in master's level |
| -50 | There will be more than one professional qualification at the doctoral level or masters |
| | |
| **Social and environmental impacts** | |
| **Cardinalized Scale** | **Description** |

| | |
|---|---|
| 150 | No potential social and environmental impacts |
| 100 | Potential social and environmental impacts one of a kind |
| 50 | Potential social and environmental impacts of two types |
| 0 | Potential social and environmental impacts of three types |
| -50 | Potential social and environmental impacts of four types |
| | |
| **Justification of the project execution** | |
| **Cardinalized Scale** | **Description** |
| 142,86 | It is not explained why the project should be developed and are not explained the reasons for the solution proposed by the project and points impacted by the realisation of the project |
| 100 | The reason the project should be developed is explained, but not clearly, the rationale for the solution proposed by the project is not displayed or impacted points for carrying out the project |
| 57,14 | It explained why the project should be developed, the rationale for the proposed solution is made explicit but is unclear, and the impacted points are not spelt out |
| 0 | It is explained why the project should be developed, are explained the reasons for the proposed solution, the affected points for carrying out the project are explained but are unclear |
| -42,86 | It is explained why the project should be developed, explaining the reasons for the solution proposed by the project and the points affected by the realisation of the same |
| | |
| **Project team members** | |
| **Cardinalized Scale** | **Description** |
| 150 | The project team does not have qualified for the project |
| 100 | The project team has some skilled professionals in training, but lack experience in the project theme for most team |
| 50 | The project team has the most qualified professionals in training, but many professionals have no experience with the project theme |

| | |
|---|---|
| 0 | The project team includes all qualified professionals in training, but not all members have experience in the project theme |
| -50 | The project team includes all qualified professionals regarding training and experience and the activities to be performed by each are well defined |
| | |
| **Methodology contemplating steps activity and duration of steps** | |
| **Cardinalized Scale** | **Description** |
| 150 | The methodology does not present the project stages or their explanations |
| 100 | The methodology presents the project stages, however, without explanations of them, does not describe the duration of each step and activities and it is not clear that they are consistent with those presented costs |
| 50 | The methodology presents the project stages explaining each, but does not describe the duration of each step and activities, and it is not clear that they are consistent with those presented costs |
| 0 | The methodology presents the project stages explaining each, describes the length of time of each step and activities, but it is not clear that they are consistent with those presented costs |
| -50 | The methodology presents the project stages explaining each, describes the length of time of each step and the steps and activities are compatible with those presented costs |
| **Goals** | |
| **Cardinalized Scale** | **Description** |
| 157,14 | The goals are not clear and do not describe what will be accomplished in the project |
| 100 | The overall goal is unclear, and the specific goals do not describe what will be accomplished |
| 57,14 | The overall goal is clear though the specific goals do not describe what will be accomplished |
| 0 | The overall goal is clear, though the specific goals are unclear, not objectively explaining what will be accomplished |
| -57,14 | The general and specific goals are clear and describe accurately what will be accomplished in the project |

| | |
|---|---|
| **Originality of proposal regarding state of the art, challenge, advance, and product** | |
| **Cardinalized Scale** | **Description** |
| 152,94 | The project is not original |
| 100 | The originality of the project is not clear since it is not clear what the project has compared to the innovative projects already carried out |
| 47,06 | The originality of the project is evident regarding what the project presents innovative compared to the projects already made, but there are not clear advances, the improvements that will be delivered and product features being developed |
| 0 | The originality of the project is evident regarding what the project presents innovative about those already made, the advances, improvements to be implemented in the product to be developed and the product characteristics are not evident |
| -47,06 | The originality of the project is evident regarding what the project presents innovative forward to already made the progress of the project, the improvements offered by the same and product features being developed |
| | |
| **Intellectual Property** | |
| **Cardinalized Scale** | **Description** |
| 150 | There are no products that can be patented |
| 100 | There is a product that can be patented |
| 50 | There are two products that can be patented |
| 0 | There are three products that can be patented |
| -50 | There are three or more products that can be patented |
| | |

| **Financial reasonability** | |
|---|---|
| **Cardinalized Scale** | **Description** |
| 150 | The values are not indicated or justified |
| 100 | The amounts related to expenses of each resource are pointed in a general way and are not justified |
| 50 | The amounts related to expenses of each resource are pointed and justified generically |
| 0 | The amounts related to expenses of each resource are pointed but are justified in a generic way |
| -50 | The amounts related to expenses of each resource are pointed and justified properly |
| | |
| **Results from the Project stages** | |
| **Cardinalized Scale** | **Description** |
| 142,86 | Outcomes and outputs of the stages are not defined and is not explained how products will work and or the project as a whole |
| 100 | Results and products from the stages are unclear, and there is no guarantee that the product project or the project as a whole will work |
| 57,14 | Outcomes and outputs of the stages are clear, but there is no guarantee that the product project or the project as a whole will work |
| 0 | Outcomes and outputs of the stages are clear, and the evidence of the functionality of the products, however, there is no guarantee that the whole project will work |
| -57,14 | Outcomes and outputs of the stages are clear, and the evidence of the functionality of the product and the project as a whole |
| | |
| **Technology transfer and diffusion** | |
| **Cardinalized Scale** | **Description** |
| 150 | There are planned technological diffusion events and publications |
| 100 | It is not planned to carry out technological diffusion events. It is expected publication of articles in relevant conferences |
| 50 | Is planned to hold technological diffusion events between development project entity and power utility |

| | |
|---|---|
| 0 | Is planned to hold technological diffusion events between developer entity design and power utility and are provided for articles published in relevant conferences |
| -37,5 | Is planned to hold of technological diffusion events between developer entity design and power utility and are provided for articles in journals and publications relevant congresses |
| | |

| **Economic feasibility** | |
|---|---|
| **Cardinalized Scale** | Description |
| 142,86 | The economic feasibility study shows that the project has no economic return |
| 100 | The economic feasibility study shows that the project does not return in the maximum period adopted by the power utility |
| 57,14 | The economic feasibility study shows that the economic return provided by the project to be developed and the value of the return time invested in the project and these parameters are the minimum acceptable levels of the power utility |
| 0 | The economic feasibility study shows that the economic return provided by the project to be developed and the value of the return time invested in the project and these parameters are within acceptable levels of the power utility |
| -42,86 | The economic feasibility study shows that the economic return provided by the project to be developed and the turnaround time of the amount invested in the project and these parameters are much better than the acceptable levels of the power utility |

**Appendix 4 - Descriptors for model regarding projects that already passed for the selection process by the power utility´s specialists committee and already started from Macbeth Software**

**Table A4.1 – Criteria and and values transformed to cardinal scales for each parameter projects risk of finance disallowance for R&D projects that are already running**

| **Members of the project team** | |
|---|---|
| **Cardinalized Scale** | **Description** |
| 150 | Most members of the project team were replaced by members without equivalent academic degree in the area of competence, and there are no justifications for them |
| 100 | A minority of the members of the project team were replaced by members of the same academic degree in the area of competence, and there are no justifications for them |
| 50 | Most members of the project team were replaced by members with equivalent academic degree in the area of competence, and there are justifications for them |
| 0 | A minority of the members of the project team were replaced by members of the same academic degree in the area of competence, and there are justifications for them |
| -50 | All members of the project team were kept or were replaced by members with the same academic degree in the area of competence, and there are justifications for them |
| **Technology transfer and diffusion** | |
| **Cardinalized Scale** | **Description** |
| 142,86 | There were no meetings, workshops, training, etc. to transfer and technology diffusion and there are no justifications for it |
| 100 | There was insufficient quantity of meetings, workshops, training, etc. for technology transfer and diffusion, with partial justifications for it |
| 57,14 | There were insufficient in quantity meetings, workshops, training, etc. for technology transfer and diffusion, with justifications for them |
| 0 | There were in close enough amount of meetings, workshops, training, etc. for technology transfer and diffusion, with justifications for them |
| -57,14 | There were enough meetings, workshops, training, etc. for technology transfer and diffusion of the Project |

| **Accounting way of project funds** | |
|---|---|
| **Cardinalized Scale** | **Description** |
| 150 | The accounting was not performed according to the ODS and the MCSE, and there are no justifications for it |
| 100 | The accounting was not performed according to the ODS and the MCSE, and there are partial justifications for it |
| 50 | The accounting was not performed according to the ODS and the MCSE, and there are justifications for it |
| 0 | The accounting was partially performed according to the ODS and the MCSE, and there are justifications for it |
| -66,67 | The scoring was performed according to the ODS and the MCSE |
| **Expenditures evidences** | |
| **Cardinalized Scale** | **Description** |
| 137,5 | There is no evidence of expenditures and disbursements were not conducted as expected and there are no justifications for them |
| 100 | Lack of most expenditures evidence and disbursements were not made as planned and there are partial justifications for them |
| 50 | Missing a few pieces of evidence of expenditures and disbursements occurred most as expected and there are justifications for them |
| 0 | There is evidence of all spending, and few disbursements occurred in a manner not expected, and there are justifications for them |
| -50 | There is evidence of all costs, and all disbursements were performed as planned |
| **Investments in the project** | |
| **Cardinalized Scale** | **Description** |
| 142,86 | The investments were not performed as planned and approved by ANEEL and there are no justifications |
| 100 | Most of the investments were not performed as planned and approved by ANEEL and there are partial justifications |
| 42,86 | Most of the investments were not realized as planned and approved by ANEEL and there are justifications |

| | |
|---|---|
| 0 | The minority of investments made were not conducted as planned and approved by ANEEL and there are justifications |
| -57,14 | Investments were all performed as planned and approved by ANEEL |
| **Information Sending to ANEEL Deadlines** | |
| **Cardinalized Scale** | **Description** |
| 140 | Many deadlines were missed and not justified |
| 100 | Many deadlines were missed and partly justified |
| 60 | Few deadlines were missed partially justified |
| 0 | Few missed deadlines totally justified |
| -60 | All deadlines met as planned |

| **Execution Deadlines** | |
|---|---|
| **Cardinalized Scale** | **Description** |
| 128,57 | Many execution deadlines were missed and not justified |
| 100 | Many execution deadlines were missed and partially justified |
| 57,14 | Few execution deadlines were missed and partly unjustified |
| 0 | Few execution deadlines were missed, and they were completely justified |
| -57,14 | All the execution deadlines were completely met as planned |
| **Applicability of the Performed Research** | |
| **Cardinalized Scale** | **Description** |
| 125 | There will not be performed subsequent R&D projects in continuity to research conducted |
| 100 | There is a small probability to be performed a subsequent project |
| 50 | It is being written a subsequent project that is adherent to the company's strategy |
| 0 | A subsequent project will be performed and is already written and hiring |
| -50 | There is already a subsequent ongoing project |
| | |
| **Compliance with the results considering the main product** | |
| **Cardinalized Scale** | **Description** |
| 142,86 | Failure to comply with most major and minor products justifications and the results are not in use in the power utility |
| 100 | Failure to comply with most major and secondary products with partial justification and results are not in use in the power utility |
| 57,14 | Failure to comply with most major and minor products fully justified and the results are in use in the power utility |
| 0 | Failure to comply with the minority of primary and secondary products fully justified and the results are in use in the power utility |
| -57,14 | Full compliance of the primary and secondary products and they are in use in the EEA |

| | |
|---|---|
| **Proposal originality is being kept** | |
| **Cardinalized Scale** | **Description** |
| 142,86 | Originality was totally changed, and there is no justification |
| 100 | Originality was quite changed, and there is partial justification |
| 57,14 | Originality was significantly amended, but there is justification |
| 0 | Originality was little changed, but there are justifications |
| -57,14 | Originality was fully kept |
| | |

| Results of the stages of the projects´ products | |
|---|---|
| **Cardinalized Scale** | **Description** |
| 142,86 | Total non-compliance of the activities, results, and products without justification |
| 100 | Failure to comply with most of the activities, results, and products with partial justification |
| 57,14 | Failure to comply with most of the activities, results, and products with justification |
| 0 | Failure to comply with the minority of the activities, results and products fully justified |
| -57,14 | No activity, results or product failed to comply |

## Appendix 5 – Multi-criteria decision methods, multiobjective optimization and metaheuristics

This appendix described the multicriteria methods, the outranking methods, the multicriteria decision aid constructivist (MCDA-C), the metaheuristics to solve problems, the particle swarm optimization theory and the particle swarm optimization used in this work.

An actor in a decision-making process is an individual or a group of individuals that influence directly or indirectly in the decision. The decision maker is assuming responsibility for the problem and influence the process of the decision according to the value judgment that is or relationships that are established and can not participate in the decision process, but influence due to its veto power. The facilitator is an experienced leader who should focus their attention on solving the problem and coordinate the views of decision-makers. The analyst is responsible for the analysis, assisting the decision-maker and facilitator in structuring the problem and identify the environmental factors that influence the development, solution, and problem setting (Roy, 1996). The expert can be considered an actor in the decision-making process, although the expertise not very cited in the MCDA literature, is present in the Decision Theory literature (Almeida, 2011). The expert has considered in the decision-making process is the situation that occurred in the development of this work, as two experts who are auditors in ANEEL's audit process helped in the development of assessment criteria for projects already started.

The process in which the decision is adopted as a modeling integrated between the subjective and objective systems to help in making the decision and these two systems will always be present in the decision-making context. So if there is a decision, it must be conducted some clear and logical steps, from one stage to another (White, 1975). There are, at least, two options presented simultaneously to the decision maker; it is unable to choose one of them immediately. The decision requires that there is, at least, one Heuristics (Ensslin, 2007). Heuristic it is a set of rules in the inventive reflection, whose first logical and methodologies were presented by Descartes in Regulae ad Directionem Ingenii (Kaufman, 1968). The purpose of the decision is to select a composite strategy for a preferred set of consequences, and which process comprises three steps (Simon, 1979):

- List all possible strategies;
- Determine the consequences of each strategy;
- Evaluate and compare the consequences groups.

Due to the presence of subjectivity in the fundamentals emphasized, it is possible to identify the legitimacy of a decision-making methodology will be

based on results achieved, i.e., if in fact built knowledge to decision-makers and the community science will be responsible for validating the tools used and certification suitability of the employee process. There is no universal scientific method, as there are no universal criteria for the validation of models already its construction and validation are not only cognitive activities, but also activities social, and they may not be judged only according to the criteria of cognitive nature (Landry, 1993).

After the identification of the limits of objectivity in decision-making due to lack of knowledge, understanding is needed of how the process occurs judgment of value systems in the human mind so that the evaluation process performance is built considering the limitations and how the brain performs the values judgments. The preparation of judgments is a process cognitive, with an amalgamation of standards and purposes to be achieved subjective in nature own the values of actors and characteristics of the shares of objective nature systems (Bana e Costa, 1993a).

There are three types of judgments that are part of decision-making and in need first be clearly marked:

- What will be judged?
- What are the preferences?
- What are the odds?

Identify what will be judged means recognizing that the concerns are the values and goals. Are these elements that our mind will use as points of reference when making judgments. The realization of judgment expresses the people value system, what are the preferences considered and identification is to determine how much you want to achieve a certain goal.

Finally, to perform judgments are performed prognostic or forecasts about the context, which reflects expectations as to what is expected to happen. Developing a support tool for decision making should consider these three forms of judgment that the human mind uses in decision making.

Due to the limitation of processing capacity, the brain acts selectively on the information it receives. The number of stimuli which require responses is greater than the number of responses that could be put in place. The human mind works this way to avoid saturation with information that will not be used, since, to process those that have been selected; information Additional are generated. Thus, the perception of information is selective to the mind deems relevant (Simon, 1979).

Also as a result of the limitations of the brain, the nature of the processing the selected information is sequential. In this case, the order of sequencing will check the different degree of value to the information, a fact that is very important in making the prognosis of the shares. To reduce the mental stress on the capacity of the processing, the mind prioritizes simple procedures

such as rules and heuristics. But in so doing, details of information of context of interrelations are lost, which may lead to consequences undesirable or contradictory choice. The American School was influenced by the positivist paradigm, the postulates of the rational decision maker, the great and the quantitative (Bana e Costa, 1993a). In this school, decision aid is directed to the outlet of the Decision, as it seeks to develop a model mathematician would help identify the optimal solution, independent of the actors. Your foundation is in technical multicriteria aggregation with only criterion synthesis (Lacaze, 2003). A methodology that stands out in this approach is the MultiCriteria Decision Making (MCDM).

The European School has developed around the constructivist paradigm, considering that the decision aid should recognize that decision-making is an attitude human permeated by the notion of value and supports the aggregation no single criterion synthesis. With this, the European School is oriented Decision Support. By incorporating the paradigm Constructivist to develop their tools, Decision Support enables generation knowledge about the context, and thus MultiCriteria Decision Aid (Methodology Multi-Criteria Decision Aid - MCDA) now has the best conditions supporting complex situations. The purpose of the Decision Support is used as a guide on paths where there ambiguities, uncertainties and plenty of bifurcations, leading to a final solution created, and not to the discovery of a solution (Roy, 1990).

The Decision Support should play the role of support communication between actors and guide for the preparation, justification and/or processing of your judgmental (Bana e Costa, 1993a). Not only is the application of tools for treatment of complex problems, but in an activity carried out by someone who progressively clarifies a decision-making process initially ill-structured, with the help methodologies and tools (Bana e Costa et al., 1999). Decision Support It is, above all, help to clarify how preferences are formed, transformed and argued (Roy; Bouyssou, 1993). And because of the fuzzy border inset alternatives, they cease to exist and become potential shares, which comparison is gives based on the indicators of their impacts.

On Decision Support, the models are intended to generate knowledge to the actors, to the decision is by their interests and thus should be considered appropriate to the problem. As the model construction can not be totally objective, if expected to evolve throughout the process. These response elements aimed at bringing understanding the consequences of actions by increasing the coherence between the evolution of process and goals of the decision maker (Roy; Bouyssou, 1993). The difference between the Decision Making (MCDM) and Decision Support (MCDA) lies primarily in the approach to subjectivity, the first following the vision Descriptivist / prescriptive and the second, the constructivist view. That is the degree of incorporating the values of the actors

in the valuation models. Adopting an approach Prescriptive means describing the system preferences and, based on assumptions regulations, carry out the prescriptions (Bana e Costa, 1993a).

Four perspectives were identified under which aid decision can be made, according to what you want to achieve. They are the Issues Q:

• Pα: selects the best action, whether good or satisfactory; measuring performance; clarifies the decision by choosing a subgroup as restricted as possible to final choice;

• Pβ: fits every action in a predefined category, based on what one wants to reach; provides a classification, an order;

• Pγ: Sorts the actions from the more satisfactory, based on a pre-order in whole or partial; establishes a classification;

• Pδ: clarifies the decision by describing the actions and consequences; supplies alternatives actions (Roy and Bouyssou, 1993)

The problem of identification brings an understanding of what the problem is in the perspective of the decision maker or the customer, and its essence is in the setting in which the study could contribute (Bana e Costa, 1998).

The MCDA is proposed to be prescriptive and constructivist vision problems. The prescriptive vision is a vision of the world as it presents itself, therefore under this concept models after ready are presented to the decision-maker who chooses to use them or not. A prescriptive model describes primarily modeling preferences and then make prescriptions based on normative assumptions that are validated by the reality described. The constructivist vision is a vision of the world through idealized processes, and the models built using the decision-making process, allowing the participation of actors at all stages of the decision support process (Roy, 1985).

### A5.2Multi criteria decision aid – constructivist (MCDA-C)

For Decision Support, the actors and their values, goals and standards, added to actions and their characteristics, are elements that structure the decision-making context (Bana e Costa, 1993a). This set of activities that aims to generate knowledge to decision makers, based on their value system, it is called structuring. The decision context is structuring that will empower the decision maker to reach better a broad understanding when dealing with problems (Miller, 1970). The structuring is constituted in phase whose preparation is the most critical success factor in the decision support; it aims to the understanding of the problem and the entire context in which it is inserted. In the MCDA-C, the popup held in Structuring is an activity that Operational Research (OR) Classical failed to do by restricting the formulation, which is to turn Structuring (description and

goals) in mathematical equations. On Decision Support, the formulation can not be separated from research idea and whose progress happens simultaneously for the two approaches (Roy, 1993). The problem Structuring may change during the process due to individual perceptions of reality of the actors interact with the real situation contributing to modify it (Roy, 1994). Thus, the purpose may change periodically, and evolve, with changes of knowledge and consider, and remain united to some point by a global criterion of choice (Simon, 1979). Sometimes, the change can be such that it is necessary certification if you are still dealing with the same problem since constantly additional information and formulations are added, data can cease to be relevant, and new questions can replace the original (Roy, 1993).

The structuring phase is divided into three stages the first focuses on the definition of the problem, which, in turn, is divided into three sub-steps, which are the identification of stakeholders and decision makers, creating a label that describes the problem and a summary to contextualize the problem. In the second stage, they are identified and built Fundamental Viewpoints, which are the aspects considered by the makers, critical to evaluate potential actions. The third step is the construction of descriptors (ordinal scales) (Ensslin et al., 2005).

The phase of the evaluation is the development of a process to determine the preferences between the consequences, conducted by comparing the alternatives according to with value indexes (Simon, 1979). Compare two actions regarding preference is output when faced with conflicting aspects that are in the minds of different actors (Roy; Bouyssou, 1993). And this is through an interactive, iterative approach, recursive and constructive learning. Because the evaluation is limited in its accuracy power monitor the various elements of value in consequence imagined, previous experience It allows making inferences (Simon, 1979). At this stage, the levels are quantified impacts of descriptors and Fundamental Viewpoints (PVFS). This is done by building value functions and determining compensation rates for PVFS.

The recursion in the model building process makes the MCDA-C more versatile and flexible, to allow feedback to the actors at any stage of the process (Bana e Costa et al., 1999). This gives players the power to review their concepts any time they want, as more knowledge is getting the problem. Present in the construction of the model is sensitivity analysis, which provides vision how robust the model is built to change the criteria for value judgments. The sensitivity analysis helps to evaluate the influence of weight conferred by the decision maker as to its robustness to the results. This is due to the multiplicity of variables or factors preclude its complete control, since organizational and human discrepancies imperceptible may be present in the problem formulation, the purpose of the decision and certain aspects of the consequences (Roy, 1993).

In this work the multicriteria model for risk relative used the MCDA-C until the phase "identification of the substitution rates." The PVFs are the ANEEL audit criteria. MCDA-C was chosen because it was necessary to have a calculated risk relative value, that is a function of the criteria, that had to have the same interest rate through compensation weights.

### A5.3Multiobjective optimization (MO)

#### A5.3.1MO introduction

The real applications have several multiple conflicting objectives. Even though some real-world problems can be reduced to a matter of a single objective very often, it is hard to define all the aspects regarding a single objective. Defining multiple objectives often gives a better idea of the task. In single-objective optimization, the search space is often well defined. As soon as there are several possibly contradicting objectives to be optimized simultaneously, there is no longer a single optimal solution but rather a whole set of possible solutions of equivalent quality (Abraham et al., 2004). When trying to optimize several objectives at the same time, the search space also becomes partially ordered. To obtain the optimal solution, there will be a set of optimal trade-offs between the conflicting objectives. A solution could be best, worst and also indifferent to other solutions (neither dominating or dominated) on the objective values. The best solution means a solution not worst in any of the objectives and, at least, better in one objective than the other. An optimal solution is a solution that is not dominated by any other solution in the search space. Such an optimal solution is called a Pareto-optimal, and the entire set of such optimal trade-offs solutions is called a Pareto-optimal set (Abraham et al., 2004).

Some stochastic optimization techniques such as simulated annealing, tabu search, ant colony optimization, etc., could be used to generate the Pareto set. Just because of the working procedure of these algorithms, the solutions obtained very often tend to be stuck at a good approximation, and they do not guarantee to identify optimal trade-offs. An evolutionary algorithm is characterized by a population of solution candidates, and the reproduction process enables the combination of existing solutions to generate new solutions. This enables finding several members of the Pareto-optimal set in a single run instead of performing a series of separate runs, which is the case for some of the conventional stochastic processes. Finally, natural selection determines which individuals of the current population participate in the new population (Abraham et al., 2004).

### A5.3.2Metaheuristics to solve multiobjective problems

In recent years, a group of approximate optimization techniques, known as metaheuristics, have become an active research area. Although there is no commonly accepted definition of metaheuristics, they can be considered as high-level strategies that guide a set of simpler techniques in the search for an optimum. Multi-objective optimization (MOP) seeks to optimize several components of a cost function vector. Contrary to single-objective optimization, the solution of a MOP is not a single solution, but a set of solutions known as a Pareto optimal set, which is called a Pareto border or a Pareto front when it is plotted in the objective space (Talbi et al., 2011).

When approximate techniques such as metaheuristics are applied, the goal becomes to obtain a set of solutions having two properties: convergence to the true Pareto front and homogeneous diversity (Coello et al. 2002).

Although most metaheuristics designed to solve MOPs are evolutionary algorithms, there exist other techniques that can be used for the resolution of these problems (Talbi et al., 2011). Those techniques are listed as follow and explained at Appendix 1 :Simulated Annealing, Local Search, Tabu Search, Scatter Search, Path relinking, Genetic Algorithms, Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO): is a bio-inspired metaheuristic based on the flight of a flock of birds when they search for food (Kennedy and Eberhart, 1995). Compared with evolutionary algorithms, PSO is also a population-based technique with a population of random solutions aimed at finding an optimum by successive generations (Reyes-Sierra and Coello, 2005).

In a comparative work between five evolutionary algorithms techniques, the PSO technique was chosen because PSO method performs better than other algorithms in terms of success rate and solution quality (Elbeltagi et al., 2005)

### A5.3.3Particle swarm optimization

The Particle Swarm Optimization (PSO) algorithm is a biologically-inspired technique originally proposed by James Kennedy and Russell Eberhart. PSO was successfully used as an optimization technique and has become increasingly popular mainly due to its simplicity regarding its implementation, its relatively low computational cost and its good performance (Kennedy & Erbhart, 2001).

The use of Particle Swarm Optimization algorithms - PSO has been widespread over the last decade, because of its main features, which are as follows: (a) incorporation of social characteristics; (b) strength; (c) flexibility; (d) ease to deal with complex problems and (e) performance (Eslami *et al*., 2012).

The Swarm Intelligence SI is inspired by nature, the fact that the various members of a group contribute their experiences to the group, making it stronger

to others, i.e., it is based on the finding that the capacity the group are beyond the capacities that members can achieve individually. One of the concepts of SI is the composite systems of property elements "dumb" exhibit intelligent collective behavior (Liu e Passino, 2000) e (Meng *et al*.,2010). The IE in nature can be based on three basic principles: the evaluation, comparison, and imitation. The rating is the ability to analyze what is positive or negative, attractive or repulsive in nature. Even the smallest living beings possess this ability, such as bacteria, which have the ability to realize the medium in which they are is harmful or not. Learning can not occur unless the body can assess attractive and repulsive characteristics of the environment (Johnson, 2004). The comparison is the way beings use other beings as a standard to measure themselves. The results of these comparisons may prove to be a motivation to learn and change. Imitation, in turn, is a more effective way of learning. However, few animals in nature can perform imitations. The three mentioned principles can be combined in a simplified manner in computer programs so as to be adapted to solving complex problems. In other words, it can be said that SI is a set of inference techniques that uses the collective behavior of a population consisting of simplified computational agents that have the ability to understand and modify the local environment influence the global behavior of the entire the population. One of the techniques included in SI is the PSO algorithm, which arose from the development of computer simulations related to the movement of birds and schools pack. PSO is mainly based on the control of the distances between the birds (particle) of the population (swarm) and birds of effort to maintain a distance between them (Engelbrecht, 2005). This algorithm is based on the control of the distances between the particles of the cluster where the timing behavior of colonies was perceived as the particles to maintain a distance PSO therebetween. Theoretically, each particle can get information about the discoveries experience previously held by all other particles of the swarm in search of his goal. Thus, the PSO is based on an exchange of information between particles to provide an evolutionary advantage (Kennedy et al., 2001) and (Huang and Wang, 2007). In this sense, the PSO technique that has some similarities with genetic algorithms, these constituents of evolutionary computation. PSO is based on a swarm / population, and each element of this swarm is called particle / individual, and every particle of the swarm is a potential (Kennedy and Eberhart, 1995).

The metaheuristics for system optimization have been studied and developed because of their ability to solve complex problems that often traditional methods fail to address or have satisfactory results. Thus, the PSO algorithm, since its creation, earned interest compared with other techniques of CN because it has a promising performance in a variety of applications and potential for creating new approaches and hybridizations (Engelbrecht, 2005), (Sierra and Coello, 2006) and (Das et al., 2011). The optimization problems are

widely found in science and technology; there is a need to seek algorithms that can be efficient and robust to its resolution of the computational form using mathematical models. The most popular algorithms already developed, can be cited: Optimization by Particle swarms (PSO) (Kennedy and Eberjart, 1995), these are IE constituents (Beni, 1988), genetic algorithms (GA) (Holland, 1992), differential evolution (DE) (Storn and Price, 1995) and cultural algorithms (CA) (Reynolds, 1994). The PSO algorithm is an optimization technique based on population/cluster that aims to solve global optimization of complex problems (Kennedy and Eberhart, 1995). In its structure, the PSO algorithm has candidate solutions that work together. Each solution called particle "flies" in the search space looking for the ideal location for "land." A particle during their generations or iterations, you can refine your search by exchanging information with your neighbor and their experience. So the algorithm combines a local search for the experience of a particle, and a global search for the experience of other particles, to balance the exploration and exploitation of the search space (extrapolation). Several studies and applications for the PSO have been presented.

### *A5.4.1Particle swarm optimization algorithm*

According to Multiobjective optimization deals with generating the Pareto front which is the set of non-dominated solutions for problems having more than one objective. A solution is said to be non-dominated if it is impossible to improve one component of the solution without worsening the value of at least one other component of the solution. The goals of multiobjective optimization are: (1) to guide the search toward the true Pareto front (non-dominated solutions) or approximate the Pareto optimal set, and (2) to generate a well-distributed Pareto front (Raquel and Naval, 2005).

The Multiobjective Particle Swarm (MOPSO) algorithm used is shown next:

1. For i = 1 to M (M is the population size)
    a. Initialize P[i] randomly
    (P is the population of particles)
    b. Initialize V[i] = 0 (V is the speed of each particle)
    c. Evaluate P[i]
    d. Initialize the personal best of each particle
    PBESTS[i] = P[i]
    e. GBEST = Best particle found in P[i]
2. End For
3. Initialize the iteration counter t = 0
4. Store the nondominated vectors found in P into A
(A is the external archive that stores nondominated
solutions found in P)

5. Repeat

a. Compute the crowding distance values of each nondominated solution in the archive A

b. Sort the nondominated solutions in A in descending crowding distance values

c. For i = 1 to M

i. Randomly select the global best guide for P[i] from a specified top portion (e.g. top 10%) of the sorted archive A and store its position to GBEST.

ii. Compute the new velocity:

V[i] = W x V[i] + R1 x (PBESTS[i] – P[i]) +

R2 x (A[GBEST] – P[i])

(W is the inertia weight equal to 0.4)

(R1 and R2 are random numbers in the range [0..1])

(PBESTS[i] is the best position that the particle i have reached)

(A[GBEST] is the global best guide for each nondominated solution)

iii. Calculate the new position of P[i]: P[i] = P[i] + V[i]

iv. If P[i] goes beyond the boundaries, then it is reintegrated by having the decision variable take the value of its corresponding lower or upper boundary and its velocity is multiplied by -1 so that it searches in the opposite direction.

v. If (t < (MAXT * PMUT), then perform mutation on P[i].

(MAXT is the maximum number of iterations)

(PMUT is the probability of mutation)

vi. Evaluate P[i]

d. End For

e. Insert all new nondominated solution in P into A if they are not dominated by any of the stored solutions. All dominated solutions in the archive by the new solution are removed from the archive. If the archive is full, the solution to be replaced is determined by the following steps:

i. Compute the crowding distance values of each nondominated solution in the archive A

ii. Sort the nondominated solutions in A in descending crowding distance values

iii. Randomly select a particle from a specified bottom portion (e.g. lower 10%) which comprise the most crowded particles in the archive then replace it with the new solution

f. Update the personal best solution of each particle in P. If the current PBESTS dominates the position in memory, the particles position is updated using

PBESTS[i] = P[i]

g. Increment iteration counter t

6. Until maximum number of iterations is reached (Raquel and Naval, 2005)

**Appendix 6 – References used only in the bibliometric analysis and content analysis to extract the PPM components**

In the following, the references used only in the bibliometric analysis to elaborate the graphics and tables and the content analysis to extract the PPM components table and elaborate the social network diagram for the components.

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