Universidade do Minho
Escola de Engenharia

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Modeling the project portfolio risk considering interactions among risk factors and their impacts on project portfolio success dimensions

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Work performed under the supervision of:
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June 2022

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MODELING THE PROJECT PORTFOLIO RISK CONSIDERING INTERACTIONS AMONG RISK FACTORS AND THEIR IMPACTS ON PROJECT PORTFOLIO SUCCESS DIMENSIONS

Abstract

Project Portfolio Risk Assessment (PPRA) is oriented to provide information on the risk composition at the portfolio level in supporting of the risk response plan. While diverse aspects to be considered for PPRA have been recognized in literature, a comprehensive PPRA incorporating both risk factor interdependency and the impact on portfolio success from a practical perspective remains scarcely explored. This thesis aims to develop knowledge to guide the PPRA design in a way that risk factor interdependency and their impacts on the project portfolio success dimensions can be considered.

Based on a systematic literature review, 80 papers were analyzed by conducting conventional content analysis. The analysis led to define and characterize four constructs associated with PPRA, namely, 'components for PPRA', 'PPR categories', 'project portfolio success dimensions', and 'risk assessment method'. The integration of these constructs resulted in a literature-based framework for PPRA design. Based on this framework, twenty-eight semi-structured interviews were conducted with Colombian professionals with experience related to project portfolio management in organizational development project portfolios. Thus, a conceptualization of a comprehensive PPRA in portfolios of organizational development portfolios is proposed. It integrates six interdependent themes through which practitioners' perspective can be represented and four propositions that emerged from discussion of the findings. In the last research phase, an analytical model to put in practice the conceptualization of PPRA is proposed. The model is based on a network-based approach and ISM-MICMAC method. The analytical model for PPRA was applied to a project portfolio case study to evidence its practical use.

The present study makes several contributions: extending the conceptualization of the type of impact derived from risk factors; adopting organizational capabilities to be generated by the portfolio as a construct for PPRA; posing a risk assessment orientation towards portfolio success dimensions associated with project portfolio effectiveness; and introducing an analytical PPRA model. From a practical perspective, the PPRA conceptualization proposed represents a comprehensive view of characteristics and aspects to be considered for conducting PPRA in practice, which can be operationalized following the analytical PPRA model proposed.

Key words: project portfolio risk, risk assessment, project portfolio success, portfolios of organizational development projects, risk factor interdependency.

MODELAÇÃO DO RISCO DE PORTEFÓLIOS DE PROJETOS CONSIDERANDO A INTERAÇÃO ENTRE FATORES DE RISCO E O SEU IMPACTO NAS DIMENSÕES DE SUCESSO DO PORTEFÓLIO

Resumo

A avaliação do risco dos portefólios de projetos (PPRA) está orientada no sentido de fornecer informações sobre a composição do risco a nível do portefólio, em apoio ao plano de resposta ao risco. Embora tenham já sido reconhecidos diversos aspetos para consideração na PPRA na literatura, uma PPRA abrangente em que tanto a interdependência dos fatores de risco como o impacto no sucesso do portefólio sejam considerados numa perspetiva prática, continua a ser pouco explorada. Esta tese destina-se a desenvolver conhecimentos para orientar a conceptualização e operacionalização da PPRA de modo que a interdependência entre os fatores de risco e os seus impactos sobre as dimensões de sucesso do portefólio de projetos possam ser considerados.

Com base numa revisão sistemática da literatura, 80 artigos foram analisados através de análise de conteúdo convencional. A análise levou à definição e caracterização de quatro constructos relativos à PPRA, nomeadamente, 'componentes para PPRA', 'categorias de riscos dos portefólios de projetos', 'dimensões de sucesso dos portefólios de projetos', e 'método de avaliação de risco'. A integração destes constructos resultou numa estrutura para o desenho da PPRA. Com base nesta estrutura, vinte e oito entrevistas semiestruturadas foram realizadas com profissionais colombianos com experiência em gestão de portefólios de projetos de desenvolvimento organizacional. Assim, uma conceptualização de uma PPRA abrangente em portefólios de projetos de desenvolvimento organizacional é proposta. A conceptualização integra a representação da perspetiva dos profissionais entrevistados e quatro proposições que emergiram da discussão dos resultados. Na fase final da investigação um modelo analítico para pôr em prática a conceptualização da PPRA é proposto. O modelo fundamenta-se numa abordagem baseada em redes e no método ISM-MICMAC. O modelo de PPRA foi testado num caso de estudo representado por um portefólio de projetos para evidenciar a sua utilização prática.

O presente estudo faz várias contribuições: alargando a conceptualização do tipo de impacto derivado dos fatores de risco; adotando capacidades organizacionais a serem geradas pelo portefólio como um constructo para a PPRA; orientando a avaliação de risco para as dimensões de sucesso associadas à eficácia do portefólio de projetos; e introduzindo um modelo analítico de PPRA. A conceptualização proposta, numa perspetiva da prática profissional, representa uma visão abrangente dos aspetos a ser considerados para a implementação da PPRA, que pode ser operacionalizada seguindo o modelo de PPRA proposto.

Palavras-chave: risco de portefólios de projetos; avaliação do risco; sucesso dos portefólios de projetos; portefólios de desenvolvimento organizacional; interdependência entre fatores de risco.

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List of Abbreviations

CA – Content Analysis

ISM - Interpretive Structural Modeling

MICMAC - Matrice d' Impacts Croices Multiplication Appliquée a un Classement

MNA – Meta Network Analysis

MPT – Modern Portfolio Theory

PPM – Project Portfolio Management

PPR – Project Portfolio Risk

PPRA – Project Portfolio Risk Assessment

PPRM – Project Portfolio Risk Management

PMO – Project Management Office

SLR – Systematic Literature Review

SRT – Social Representation Theory

TA – Thematic Analysis

PART I. RESEARCH SCOPE

1. INTRODUCTION

Risk management has been cited as a key element of project management, evidencing positive impacts on project success (Teller, Kock, and Gemünden, 2014). However, given the multi-project environment in which projects are frequently executed and their strategic relevance, researchers and organizations have complemented the project management approach with a Project Portfolio Management (PPM) approach (Ahmadi-Javid, Fateminia, and Gemünden, 2020; L. Wang, Kunc, and Jianping, 2020). The adoption of a management view oriented to project portfolios expanded the nature of project management leading to the recognition that risk management approaches have to evolve in the same direction, i.e., toward Project Portfolio Risk Management (PPRM) complementing project risk management (Breault and Cleveland, 2020; Hofman, Spalek, and Grela, 2017). Thus, recent studies show that risk management applied to the project portfolio level positively influences project portfolio success (Teller et al., 2014).

This research was oriented to study and develop a quantitative model for Project Portfolio Risk Assessment (PPRA), recognizing PPRA as a PPRM element. In this chapter, the general background that motivated this research is described. Then, the problem outline is presented, discussing the risk planning approaches applied to project portfolios and their implications for PPRA. Next, the definition of the research question and the objectives pursued. At the end of this chapter, a general description of the thesis structure is presented.

1.1 Motivation

Using projects and programs to implement new information systems, new products, new or improved processes, among other changes within organizations, has grown and consolidated in the last decades (Richard, Pellerin, Bellemare, and Perrier, 2021; Teller et al., 2014). A project is a temporary endeavor undertaken to create a unique product, service, or result (PMI, 2017a). Both practitioners and academics recognize projects as a structured way to implement business changes (PMI, 2017a; Serra and Kunc, 2015), increasing the number of projects to be carried out in each strategic period (Hopmere, Crawford, and Harré, 2020; Richard et al., 2021). A program is a set of projects managed collectively to optimize or integrate, schedule, effort, or other parameters, seeking to obtain benefits and control not available by managing projects individually (PMI, 2017b). Consequently, project and program management gained

greater attention in organizations, which has increased human and financial resources' allocation to projects, revealing a higher strategic relevance (Annosi, Marchegiani, and Vicentini, 2020; Clegg, Killen, Biesenthal, and Sankaran, 2018; L. Wang et al., 2020).

Hence, the project management scope has expanded to cover both the inter-relations between projects and the relationship between the organization's strategy and projects (Clegg et al., 2018; Neumeier, Radszuwill, and Garizy, 2018; L. Wang et al., 2020). In this regard, organizations seek to invest their financial, technical, and human resources in the most effective and efficient combination of projects that deliver the greatest value for the business strategy (Clegg et al., 2018; Martinsuo and Geraldi, 2020; Serra and Kunc, 2015). Thus, organizations have adopted project portfolio approaches to support the execution of their business strategies, enabling project portfolios to become a key element in implementing intended strategies (Meskendahl, 2010; Richard et al., 2021).

A project portfolio is "a collection of projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives" (PMI, 2017b, p. 3), which represents the bridge between the projects and the organization's strategic objectives (Clegg et al., 2018; Sanchez and Robert, 2010b). In this context, PPM has been associated with managing resources, risk, and stakeholders to operationalize the organization's strategy (Annosi et al., 2020; de Oliveira Lacerda, Ensslin, and Ensslin, 2011). PPM allows developing the decision-making process toward balancing value added linked to the organizational strategy against risk level assumed, guiding the portfolio to achieve strategic benefits (Martinsuo, 2013; PMI, 2017b; L. Wang et al., 2020). In other words, PPM is defined as the overall organizational ability to strategically manage the project portfolio, orienting it toward the organization's success (Clegg et al., 2018).

In this regard, a positive influence of project portfolio performance on business-level results has been evidenced (Meskendahl, 2010). However, the expected results may not be achieved due to, e.g., project and Project Portfolio Risk (PPR) as well as the inherently dynamic nature of projects, portfolios, and parent organizations (Meskendahl, 2010; Voss and Kock, 2013). Hence, risk management has been established as one key aspect of successful PPM (Kock, Schulz, Kopmann, and Gemünden, 2020; PMI, 2017b; Teller et al., 2014), and, consequently, project portfolio success (Teller, 2013; Teller and Kock, 2013).

The literature recognizes that risk management approaches at project, program, and portfolio levels are required for managing the risk of project portfolios (Ghasemi, Sari, Yousefi, Falsafi, and Tamošaitienė, 2018; Sanchez, Robert, Bourgault, and Pellerin, 2009). Also, it has been identified that

integrating these risk management levels leads to greater benefits from both project portfolio and organizational perspectives (Arena, Azzone, Cagno, Silvestri, and Trucco, 2014; Teller et al., 2014; L. Wang et al., 2020). From this background, this research project is focused exclusively on studying risk management applied at the project portfolio level, i.e., PPRM. Therefore, risk management at the project and program level and the integration between risk management levels fall out of the scope of this research.

The PPRM must focus on maximizing the value delivered to the company through risk analysis and management, reducing the negative impacts and potentiating opportunities while considering project interdependencies and balancing the organizational capabilities required to the project portfolio execution (Ahmadi-Javid et al., 2020; Clegg et al., 2018; Hofman et al., 2017; Teller et al., 2014). When the PPR is analyzed and managed, the project portfolio has a better success probability (D. Guan, Guo, Hipel, and Fang, 2017; Teller and Kock, 2013; Q. Wang, Zeng, and Tu, 2017). Therefore, risk and success at the portfolio level are linked.

PPRM is constituted by several elements, being PPRA one of them. Other PPRM elements include risk identification and responses. PPRA is oriented to provide information on, for example, the importance of risks and risk trends, supporting risk response decisions (PMI, 2017b). PPRA should accurately depict reality and its associated risks to give decision-makers a clear overview of the PPR (Ahmadi-Javid et al., 2020; Hofman and Grela, 2018). By recognizing the strategic relevance of project portfolios and the positive relationship between risk management and project portfolio success, this research is oriented to deepen the understanding about PPRA as a PPRM element oriented to contribute to project portfolio success.

1.2 Problem Outline and Key Concepts

Being recognized as an element of the PPRM, PPRA cannot be understood independently. Thus, PPRA is underpinned by the PPRM approaches adopted. On this subject, two traditional risk planning approaches can be recognized in the project portfolio-related literature (Ahmadi-Javid et al., 2020): (i) risk planning in general management and (ii) risk planning in project management.

The first one derives from the Modern Portfolio Theory (MPT) posed by Markowitz for portfolios of financial investment instruments (Ahmadi-Javid et al., 2020). This theory was later adopted for project portfolios, which formalized the research problem around project portfolio selection with risk considerations, now well-established in the literature (Tang, Zhou, and Cao, 2017; Yousefi, Haji,

Saparauskas, and Kiani, 2018). In this approach, both the risk contribution from every single project and the influence of interdependencies between the risk of the projects within the portfolio, or inter-project risk, are considered (Tang et al., 2017). In addition, by analogy with portfolios of financial investment instruments, variations of financial success measures have been considered for risk assessment at the project portfolio level, leading to an approach based on the financial risk of the investment made by the organization in the project portfolio (Tang et al., 2017).

In other words, the PPR is assessed according to the impact on a financial success measure of the organization, i.e., a unidimensional business success measure of risk. Hence, this risk assessment orientation represents the business level rather than the portfolio level. In this regard, the literature provides evidence that, although related, business success and portfolio success represent two different levels (Meskendahl, 2010). Moreover, the business success is also dependent on results from other initiatives undertaken by the parent organization, i.e., it cannot be exclusively associated with the project portfolio outputs (Serra and Kunc, 2015).

In addition, limiting the project portfolio value to financial terms leads to ignoring its strategic contribution, which hampers a full view of the portfolio's relevance for the organization (Abbasi, Ashrafi, and Ghodsypour, 2020; Sanchez, Robert, and Pellerin, 2008). Consequently, complementary measures that better and more completely represent the portfolio strategic relevance and the stakeholders perspective, or in other words the value delivered to the parent organization, should be considered (Kaiser, El Arbi, and Ahlemann, 2015; Sanchez et al., 2008; Wu, Wu, Shi, and Chou, 2021). The above implies that, although financial measures may be adequate to assess investment risk, a PPRA focused on the project portfolio should lead to assessing risk according to the strategic relevance of the portfolio (Abbasi et al., 2020).

The second traditional risk planning approach, i.e., risk planning in project management, derives from risk management applied at the project level, in which each project was initially considered as an independent element (Ahmadi-Javid et al., 2020). However, the multi-project environment led to the recognition that interdependencies between projects could affect the projects' performance and success (Neumeier et al., 2018; Zou, Yang, and Wang, 2021). Consequently, shared resources, shared risk factors, input-output relationships, or bilateral information between projects, among others, have been incorporated into this second risk planning approach (Ahmadi-Javid et al., 2020; Bai, Zhang, Shi, An, and Han, 2020; Ghasemi et al., 2018).

Accordingly, the PPRA framed in this second risk planning approach is characterized by incorporating the project risk factors derived from the projects and considering the impact of project interdependencies (Neumeier et al., 2018; Q. Wang et al., 2017; Zou et al., 2021). For this purpose, the risk is based on project success measures, such as time or cost of each project within the portfolio (see for instance Neumeier et al., 2018), or an aggregation of some of those measures (see for instance Ahmadi-Javid et al., 2020). Thus, the risk of the projects comprising the portfolio is evaluated considering interdependencies derived from the multi-project environment in which they are executed, i.e., during the execution of the projects within the portfolio.

However, the literature recognizes that PPR is more than just a circumscribed view of success of the projects within a portfolio (Hofman et al., 2017; Teller et al., 2014). In this regard, Hofman et al. (2017) identified some specific phenomena that can negatively affect portfolio success, being these negative phenomena caused by PPR factors. Building on this, Hofman and Grela (2018) assessed a set of project portfolio-level risk factors based on the likelihood and the impact on project portfolio goals. Similarly, Ghasemi et al. (2018) identified new risk factors caused by interactions between projects which impact the project portfolio result. They also established a set of risk factors stemming from the project portfolio level that could negatively impact portfolio success factors and portfolio management objectives. The PPR was represented as the project portfolio probability of failure, being PPR an aggregated measure oriented to assess the impact of risk factors on the project portfolio result as an aggregated unit.

Thus, the analysis of both risk planning approaches led to recognize that PPR should be assessed based on expected project portfolio results rather than on measures related to the business success or success of the projects within the portfolio. This is aligned with considerations evidenced from a more general PPM perspective, such as "even though often neglected, the continuous evaluation of running projects, using the same criteria as for their selection, is paramount for stringent PPM" (Kaiser et al., 2015, p. 129). The above exemplified how currently there is a gap in portfolio decisions, where project portfolio selection is mainly addressed based on business-level criteria while the monitoring of the project portfolio is addressed considering project-level criteria.

The above does not discredit either of the two traditional risk planning approaches. On the contrary, it suggests that approaches based on business success or project success risk measures, although related to the project portfolio, support decision-making at other complementary management levels in the organization. Even though the conclusions above might seem obvious, it has been only a little over a decade since the portfolio strategic relevance and the value provided for the project portfolio started to

be considered as part of PPRM (Bai, Han, Wang, Zhang, and Sun, 2021; Sanchez et al., 2009; L. Wang et al., 2020). Thus, both risk planning approaches, and consequently the PPRA approaches, have sought to adopt a strategic view based on the portfolio level itself.

Thus, risk representation ranges from traditional project success- or business success-based approaches to ones associated with the direct expected impact on the strategic or the portfolio objectives. These multiple approaches have led to PPR representation being currently, but not always explicitly, discussed. This discussion also takes into consideration how portfolio risk is generated and how it impacts the portfolio results. On one hand, the risk and complexity stemming from projects and project interdependencies cannot be ignored, as evidenced in the literature (Ahmadi-Javid et al., 2020; Bathallath, Smedberg, and Kjellin, 2019; Neumeier et al., 2018). On the other hand, the risk generated directly from the portfolio level itself, as identified by Hofman et al. (2017), must also be recognized in the risk assessment. In addition, it is suggested that portfolio risk can also derive from the delivery of portfolio value to the organization (L. Wang et al., 2020). Thus, the debate about how the PPR should be represented and assessed remains open. Therefore, this debate and its actuality frame the present research project.

From a theoretical perspective, the risk construct is associated with outcomes of known probability (Peters and Verhoef, 2008), representing both positive and negative impacts on the expected results (Hopkin, 2018). Then, it may be defined based on the exposure concept, which indicates the amount or measure of impact on expected results, or the volatility or variability of results, due to changes in risk factors (Crouhy, Galai, and Mark, 2014; Yousefi et al., 2018). In this regard, risk factors are considered as the different variables that generate, directly or indirectly, exposure (Crouhy et al., 2014; Yousefi et al., 2018).

Thus, PPR could be conceptualized as the amount or measure of impact on the project portfolio expected results due to changes in risk factors. This conceptualization raises two pivotal issues to establish the representation of PPR and its assessment: (i) how the project portfolio results are represented, and (ii) how risk factors impact those expected results.

Concerning the first issue, different impact levels have been stated to assess the PPR, being these levels mainly associated with the expected project portfolio results/objectives in their entirety (see Ghasemi et al., 2018; or Hofman and Grela, 2018) and the parent organization's strategic objectives impacted by the project portfolio (see Bai et al., 2021), considering these levels as impact strategic levels under a project portfolio perspective. In addition, from a wide PPM perspective, recognizing that project

portfolios serve multiple objectives, scholars have adopted a multi-dimensional construct related to portfolio success dimensions based on project, portfolio, and company levels (Unger, Gemünden, and Aubry, 2012; Voss, 2012). These dimensions have been defined as a second-order construct, which is mainly, but not exclusively, derived from the four PPM goals posed by Cooper, Edgett, and Kleinschmidt (2002): (1) maximize the value of the portfolio, (2) balance portfolio or right mix of projects, (3) achieve a strategically aligned portfolio, and (4) achieve the right number of projects for the limited resources available.

Project portfolio success and its relation with the PPM objectives is a well-established construct and widely used in the literature (Unger et al., 2012; Voss, 2012). In addition, a positive relationship between risk management and portfolio success has also been identified (Teller, 2013; Teller and Kock, 2013). Then, considering the above, and by analogy to project risk assessment and investment portfolios risk assessment, in which project success and monetary success respectively have represented the expected results, project portfolio success can be posed as the representation of the portfolio expected result which frames the PPRA. In this concern, by considering the project portfolio success as the representation of the project portfolio expected results, the PPR to be assessed would correspond to a multi-dimensional risk measure.

Regarding the second issue, associated to how risk factors impact project portfolios, previous studies show that risk factors could be generated from the project level, but also from interdependencies between projects within the portfolio, and explicitly derived from the project management level (Hofman and Grela, 2018; Zou et al., 2021). In addition, by adopting a wide project portfolio perspective, recent studies call to recognize that project portfolios interact with the parent organization, as well as with the stakeholders (Martinsuo and Geraldi, 2020). In terms of risk, the above implies that those interactions can affect the expected results, so that, they could represent risk factors for the project portfolio. Thus, various risk factors of different nature and implications contribute to the PPR. Furthermore, the literature suggests that the evaluation of interdependencies between risk factors allows identifying the risk factors of greater influence on the project portfolio. And this can be achieved not only through direct impact but also due to indirect impacts that any risk factor generates on other risk factors (Ahmadi-Javid et al., 2020; Cooley, Galik, Holmes, Kousky, and Cooke, 2012; Q. Wang et al., 2017).

Considering both the diversity of risk factors that influence the project portfolios, as well as their interaction would allow PPRA to focus efforts and resources on the factors that are particularly relevant for the project portfolio success, contributing to the improvement of the PPRM decision-making process.

In this regard, for instance, Hofman and Grela (2018) assessed risk factors derived from the project portfolio level, Ghasemi et al. (2018) pose an integral risk assessment with some considerations about risk factor dependencies and impact at portfolio level, Ahmadi-Javid et al. (2020) incorporate risk interdependencies at project level to planning the risk response in an aggregated way from a portfolio perspective, Q. Wang et al. (2017) assess the entropy between risk factors derived from the projects within a portfolio, Bai, Zhang, Shi, An, and Han (2020) conducted a risk assessment based on the resource risk factors for the project portfolio, and Yang, Zou, Ye, and Yao (2022) put forward a proposal to evaluate the influence of risk propagation derived from shared technologies among product development projects within a portfolio.

However, the influence of the variety of risk factors of different nature on project portfolios have not been addressed in an integrated manner from a wide-portfolio perspective, which does not allow a comprehensive view of the PPR or an appropriate understanding of the relevance of these risk factors. Hence, due to the evolution of this field of knowledge, several studies suggest that a project portfolio-wide risk assessment approach is required, through which inherent project portfolio characteristics would be recognized (Ahmadi-Javid et al., 2020; Ghasemi et al., 2018; Zou et al., 2021).

For that, according to what has been exposed previously, PPRA should provide information about the risk factors' importance considering not only the direct effect of each risk factor and the different ways it impacts on the project portfolio, but also the interactions between risk factors and their impact on the project portfolio success. Therefore, this research is focused on studying the knowledge gap associated with that a conceptualization that allows the integration of risk factor interdependency at the project portfolio level and their impact on the project portfolio success.

1.3 Research Question and Objectives

This research project contributes to the PPRA body of knowledge by addressing the gap identified in the literature related to: how to assess the project portfolio risk considering interactions among risk factors and their impact on the project portfolio success dimensions? Thus, this research project sought to answer the research question posed by fulfilling the following main objective:

> *To develop a project portfolio risk assessment model considering interactions among risk factors and their impacts on the project portfolio success dimensions.*

The main research objective is operationalized through the attainment of the following four specific objectives:

Specific objective 1: To identify the components that must be considered for the project portfolio risk assessment.

Several studies have explored different aspects or conditions that influence PPRM, such as considerations associated with the competitive environment of the parent organization (Arena et al., 2014; Floricel and Ibanescu, 2008; Olsson, 2008; Sanchez et al., 2008). Being PPRA one of the PPRM elements, these aspects or conditions should be considered for its design. In a similar way, recent proposals for PPRA have also stated specific considerations and characteristics required for an adequate project portfolio-wide risk assessment (Ahmadi-Javid et al., 2020; Ghasemi et al., 2018; Hofman et al., 2017; Sanchez and Robert, 2010b). Although those studies have been conducted considering different types of projects portfolios, such as research and development, infrastructure, software development, or internal development project portfolios, establishing common or transversal components that can be generalized from those studies could help represent a framework for PPRA.

According to the Cambridge dictionary, "a component represents a part that combines with other parts to form something bigger". In this regard, bearing in mind the wide range of labels and nature of possible components that can be identified for a PPRA, it is worth mentioning that aspects, characteristics, conditions, attributes, and considerations were all understood as 'components for PPRA'. Thus, the first specific objective is associated with the components for PPRA.

Specific objective 2: To define project portfolio risk categories in order to support an adequate risk-based decision process.

Efficient risk management depends on the information obtained from adequate risk identification and categorization processes (Hofman et al., 2017; Sanchez et al., 2008). In this regard, empirical results show a positive relationship between risk identification and project portfolio success (Teller and Kock, 2013), as well as the identification of a variety of risk factors that could impact the project portfolio in different manners and extents (Ghasemi et al., 2018; Q. Wang et al., 2017). This implies that PPRA should recognize the different ways and extents in which risk factors impact the portfolio success, as well as provide information for risk response planning.

In addition, an adequate risk categorization contributes to the effectiveness and quality of risk assessment and leads to an adequate risk-based decision process (PMI, 2017b). In this regard, studies are required to broaden the approaches used for risk assessment, in order to reach results that allow establishing risk factor categories that, feasible in practice, support the decision-making process (Costa, Barros, and Travassos, 2007; Ghasemi et al., 2018; Hofman and Grela, 2015). For the reasons

mentioned above, the second objective is related to categorization as a critical input and output for PPRA to support an adequate risk-based decision-making process.

Specific objective 3: To design an approach to assess project portfolio risk taking into account the risk factors interactions.

Evaluating the interdependencies and the correlation between risks allows to identify the risks that have a greater impact on portfolio objectives, not only because of their direct impact but also due to their indirect effect (Cooley et al., 2012; X. Li, Zhong, Zhang, and Wang, 2017). Despite their importance, the identification, qualification, and quantification of the interdependencies between risk factors from a project portfolio perspective, have been explored in a limited manner (Ahmadi-Javid et al., 2020; L. Wang et al., 2020). Moreover, generic frameworks not adapted to inherent project portfolio characteristics have dominated PPRA. Then, it is required that PPRA incorporates the impact of risk factors' interactions to obtain a more accurate and complete representation of their impacts on project portfolios (Ghasemi et al., 2018; Neumeier et al., 2018). Therefore, the third specific objective is associated with the importance of incorporating the risk factor interactions in PPRA.

Specific objective 4: To propose an approach allowing to incorporate the impacts of risk factors and their interactions on project portfolio success dimensions.

Project portfolios represent part of the strategic deployment of organizations (Hofman et al., 2017; PMI, 2017b; Richard et al., 2021). The literature suggests that PPR can influence the project portfolio objectives, the parent organization's strategic objectives, and the PPM objectives (Ghasemi et al., 2018; Sanchez and Robert, 2010b; Teller, 2013). In this regard, project portfolio success dimensions were defined as the level at which PPR can be assessed. This leads to the assessment of risk factor impacts on project portfolio success and, therefore, the need to incorporate it into multiple project portfolio success dimensions. Thus, the PPR represents a multi-dimensional measure of impact on the project portfolio success due to changes in risk factors. Accordingly, the fourth specific objective focuses on the importance of evaluating the impact of risk factors on project portfolio success. The achievement of this specific objective represents, in turn, the main contribution of this research project.

1.4 Research Methodology Overview

For this research two outputs were established as landmarks in the path to answer the research question: (i) a comprehensive PPRA conceptualization and (ii) a PPRA model. Consequently, these outputs underpin the research design.

For the first research output, a qualitative research design was adopted as the same is based on exploratory literature review and interview strategies. For that, two research Phases were established. Phase I is associated with the literature review process, while Phase II is associated with the conduction and analysis of semi-structured interviews. In Phase I, a Systematic Literature Review (SLR) was conducted. Specifically, conventional content analysis was performed to analyze literature in PPRM field and portfolio success dimensions resulting in a literature-based framework for PPRA design. Phase II was designed to conceptualize PPRA from the practitioners' perspective. For that, focusing on portfolios of organizational development projects, Social Representation Theory (SRT) was adopted to analyze the empirical evidence from twenty-eight semi-structured interviews conducted with Colombia project portfolio practitioners. The finding analysis and discussion resulted in a comprehensive PPRA conceptualization recognizing different type of risk factors, diverse extent of risk factors impact, organizational capabilities generated by the portfolio, and impact on the success dimensions linked to portfolio effectiveness. Hence, the proposed comprehensive PPRA conceptualization derives from qualitative analysis of both literature and empirical data.

The second research output, named as PPRA model, represents a proposal to put the proposed PPRA conceptualization in practice. Then, in the last phase – Phase III, it is proposed a quantitative model through which the comprehensive PPRA conceptualization derived from the previous research phases can be operationalized. Thus, for modeling the risk transfer path which represents how risk factor impacts the project portfolio success dimensions a network-based approach was adopted. And the relationship between risk factors was modeled following an integration of Interpretive Structural Modeling (ISM) and Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC – acronym in French that stands for Matrice d'Impacts Croisés Multiplication Appliquée à un Classement). A case study was conducted to seek evidence that the PPRA model can be applied in practice. The project portfolio case study used is from a Colombian company. It is composed by 18 projects and 31 risk factors.

1.5 Thesis Structure

This document is structured in four Parts grouping nine chapters: Research scope (Part I), research development: a comprehensive PPRA conceptualization (Part II), research development: PPRA proposed model (Part III), and research contributions (Part IV). Figure 1.1 clarifies the contents of each part, illustrating the organization of this thesis.

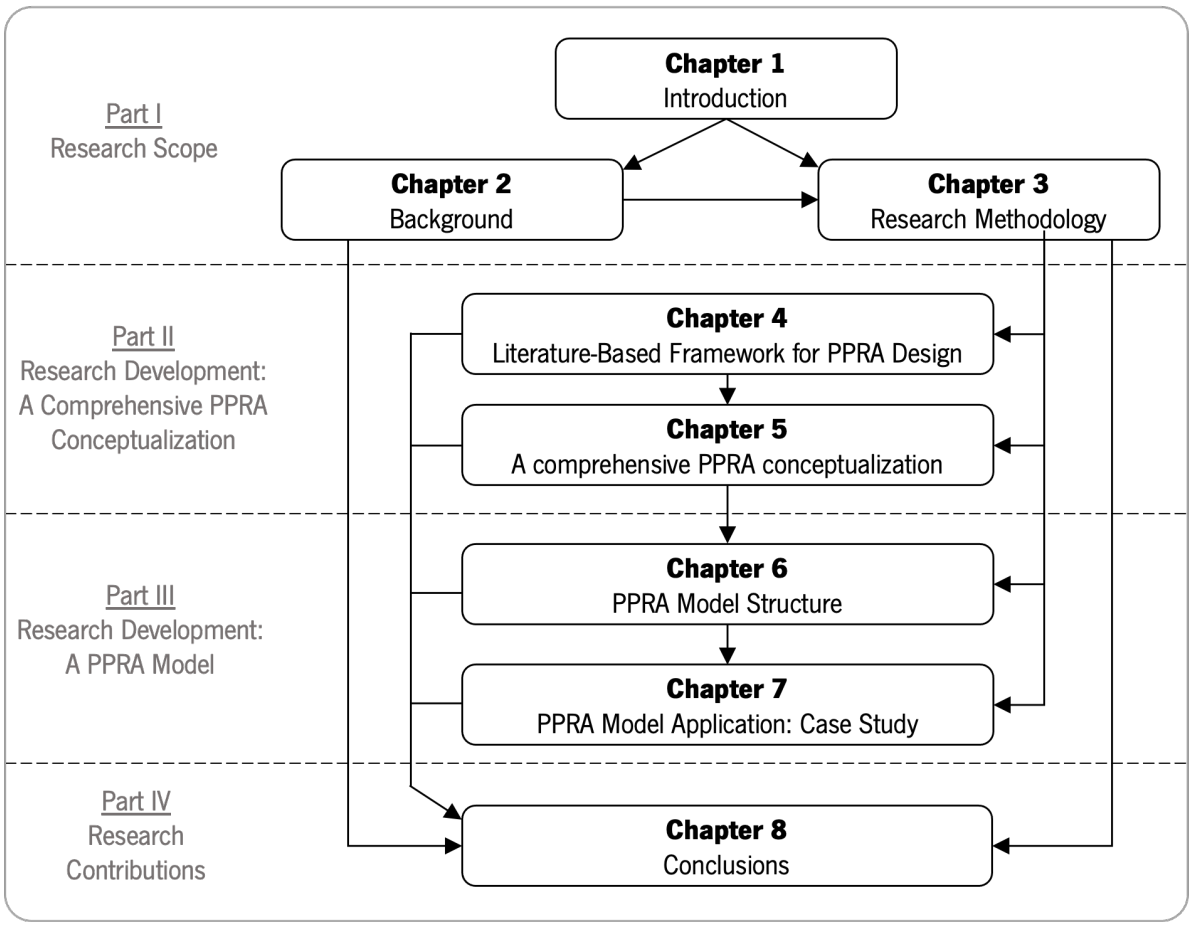


Figure 1.1. Thesis Structure

In Part I, the research scope is stated by describing the research problem and objectives, the literature background in the topic, and the adopted research methodology. Therefore, three first chapters compose **Part I**:

Chapter 1 is the introduction chapter. Consequently, it contains the motivation and the research problem identification, which lead to the research question and objectives definition.

Chapter 2 presents the body of knowledge in which this research is framed, describing the current literature available concerning PPRA proposals and the relationship between portfolio risk and portfolio success. This background establishes the baseline for defining the research methodology and the expected outputs.

Chapter 3 concerns the research philosophy and the research design defined to fulfill the research question and objectives. As a result of the research design, three sequential phases were determined. The methods used in each phase, as well as data collection and data analysis strategies, are described in a sub-section for each phase.

Once established the research scope, the results are presented in Part II and Part III. The conceptualization of a comprehensive PPRA is presented in Part II, while the mathematical representation of the proposed PPRA model is covered in Part III. The results derived from a SLR process carried out in Phase I and the qualitative analysis of interviews conducted with project portfolio practitioners in Phase II, are described in Part II. Thus, two chapters compose **Part II**:

Chapter 4 focuses on the characterization of the constructs: 'components for PPRA', 'PPR categories', 'project portfolio success dimensions', and 'risk assessment method'. They were described based on a SLR process where conventional content analysis was conducted, i.e., based on Phase I results. Finally, considering the constructs characterized, Chapter 4 presents a literature-based framework for PPRA design.

Chapter 5 is centered on reporting the qualitative analysis of interviews conducted with Colombian project portfolio practitioners. Drawing on SRT, a conceptualization of comprehensive PPRA is proposed. It does not discredit the literature-based framework proposed, on the contrary, it complements and reconfigures it by taking it towards an organizational view of the project portfolios.

In Part III, an analytical model to operationalize the comprehensive PPRA conceptualization, which was obtained in research Phase II, is proposed, exemplified, and tested. Thus, the results of Phase III are reported in **Part III**, which is organized in two chapters:

Chapter 6 presents the proposed model for the PPRA operationalization. Therefore, a PPRA model overview, as well as the definition and description of a set of steps for PPRA implementation, are offered. Furthermore, the mathematical representation of the proposed model is presented along with an illustrative example.

Chapter 7 shows the application of the proposed PPRA model to a project portfolio case study. The case study illustrates key aspects of the model application, such as the parameters required, the characterization of the risk profile based on the PPRA model application, and the scenario analysis carried out.

In Part IV theoretical and practical contributions are discussed, and the conclusions attained within this research are presented. Chapter 8 composes **Part IV**.

Chapter 8 is focused on discussing the main findings of this research project. As a result of that discussion, both theoretical and practical contributions are provided, leading to the identification

of the main contributions. Conclusions, research limitations, and suggestions for future research are also outlined in this chapter.

Finally, **references** and **appendices** are presented at the end of the document. A folder containing Nvivo and Microsoft Excel files is attached to the online version of this document. The Nvivo file contains the transcripts of the interviews in the original language and the coding performed. The Microsoft Excel file provides evidence regarding the application of the mathematical formulation described in Chapter 7.

2. BACKGROUND

This chapter introduces the pivotal concepts that create a basis for the research development and reported in the following chapters. It presents fundamental theoretical concepts and relevant approaches to risk management and PPM, besides framing the present study in these current approaches. More specifically, Chapter 2 outlines how the PPRA can be understood as an element of the PPRM and how PPRA have been incorporated into the risk planning approaches identified in the literature.

For this purpose, the conceptualization of PPM and project portfolio on which this research rests are presented in Section 2.1. Next, Section 2.2 presents the two main risk approaches identified in the literature under which the concept of 'risk' can be understood. Then, the conceptualization of 'risk' adopted to conduct this research is presented, leading to the definition of what would be understood as PPR over the course of this research project. Section 2.3 contains the description of PPRA, which is supported by the conceptualization of risk management and PPR management. Based on the above, PPRA is conceptualized as an element of the PPRM. Then, the risk management approaches adopted in the literature that framed the PPRA are described and discussed in Section 2.4. This section highlights the main strengths and weaknesses of current risk planning approaches adopted to support project portfolio decisions.

2.1 Project Portfolio Management

PPM is one of the disciplines associated with the project management field (Clegg et al., 2018; Hansen and Svejvig, 2018). PPM seeks to align with the strategy of the organization through the identification and selection of appropriate components, allocating resources according to needs, and supervising the execution of components. It seeks to generate value for the organization by supporting the achievement of strategic objectives and increasing the success rate of projects (Hadjinicolaou and Dumrak, 2017; Laursen and Svejvig, 2016; PMI, 2017b). The importance of PPM lies in its impact on attaining competitive advantages for the organization, as it is considered a strategic weapon that represents the investment priorities of the organization to achieve its strategic objectives (Carvalho, Lopes, and Marzagão, 2013; Clegg et al., 2018; Hansen and Svejvig, 2018).

Carvalho et al. (2013) highlight the existence of works that expose how an adequate PPM generates better projects performance and higher strategic alignment. Since the project portfolio constantly faces risks, organizational conflicts and internal and external influences may affect its performance, project portfolios must be continuously analyzed and updated to achieve the expected

results (Bathallath et al., 2019; Carvalho et al., 2013; PMI, 2017b). This continuous improvement and monitoring cycle has led to establishing three generic, interdependent, and recursive main phases for PPM: i) portfolio structuring, ii) resource management, and iii) portfolio steering. However, firms may not necessarily accomplish all phases to the same extent and quality (Beringer, Jonas, and Kock, 2013; Kopmann, Kock, Killen, and Gemünden, 2017). Each phase is defined as follows (Beringer et al., 2013; Jonas, Kock, and Gemünden, 2013):

> Portfolio structuring is associated with the strategic planning cycles, in which a set of project investments are defined according to the organization's structure, processes, and goals. This phase links the business strategy to the project portfolio of the organization. Strategic portfolio planning, evaluation of project proposals, and project portfolio selection are processes developed in this phase.
>
> Resource management refers to initial resource assignment and permanent reactive redistribution of assigned resources, being focused on the effective and efficient management of resources across the portfolio.
>
> Portfolio steering phase is the stage in which the permanent execution and coordination of the portfolio are carried out. Monitoring the strategic alignment, resource utilization, and coordination of projects across organizational units represent key activities of this phase. The information collected in this phase is used to exploit synergies, identify deviations from the project portfolio expected results, and define corrective and preventive measures. Within this phase, some projects can be canceled or temporarily suspended.

Some publications, such as Jonas (2010) or Unger et al. (2012), establish a fourth phase known as (iv) organizational learning and portfolio exploitation, which is defined as follows:

> Organizational learning and portfolio exploitation cover "tasks that cater to projects at the end of their life-cycle, which are concerned with post-project reviews and lessons learned." (Unger et al., 2012, p. 612).

Although PPM is largely dominated by rational and controllable assumptions and processes, the business environment is characterized by rapid changes (Clegg et al., 2018; Hansen and Svejvig, 2018). Likewise, most of the current PPM approaches fail to recognize that portfolios pursue different types of strategy depending on what is strategically important and valuable to each firm concerning its context and stakeholder expectations (Martinsuo and Geraldi, 2020). This has led to pursuing a conceptualization of PPM from a broader perspective (Hansen and Svejvig, 2018; Neumeier et al., 2018).

Hansen and Svejvig (2018) classify the PPM development by extending two complementing perspectives derived from project management, namely, Classical project management and Rethinking project management, to analyze the PPM literature. The first perspective corresponds to the classical view based on assumptions and rational processes that focus on aspects such as executability, linearity and simplicity, controllability, instrumentality, and temporarity (Hansen and Svejvig, 2018). While the second one focuses on a broader perspective based on aspects such as learnability, multiplicity, complexity, uncertainty, sociability, valuability, and temporarity.

An interesting fact is that, although temporarity is evaluated in both perspectives, its meaning varies significantly. From a classical project management perspective, which is based on PMI (2017a), Hansen and Svejvig (2018, p. 7) pose that "a project is a temporary endeavor undertaken to create a unique product, service or result". While the rethinking project management perspective poses that "a project is a temporary organization established by its base organization to carry out an assignment on its behalf" (Hansen and Svejvig, 2018, p. 7). In the same vein, the literature on project portfolios also proposes, on one hand, a classical perspective, in which the project portfolio represents a collection of projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives. On the other hand, an alternative perspective conceptualizes a project portfolio as an organization (temporary or permanent) hosting temporary organizations (projects and programs) that are managed together (Martinsuo and Geraldi, 2020; Turner and Müller, 2003).

Conceiving the project portfolio as an organization has important implications for PPM and its study. The organizational lenses help recognize how a project portfolio interacts with the parent organization and its strategy and with the portfolio environment and stakeholder expectations (Martinsuo and Geraldi, 2020). In this regard, Martinsuo and Gerarli (2020, p. 442) propose "the move from PPM to the management of project portfolios", which in turn positions the project portfolio as the main unit of analysis. Thus, following what is proposed in the rethinking project management perspective, this research considers the project portfolio as an organization.

2.2 Project Portfolio Risk

From a theoretical perspective, the risk is associated with a set of outcomes with known probability (Peters and Verhoef, 2008), which can represent both positive and negative impacts on the expected results (Hopkin, 2018). Thus, the risk corresponds to the deviation range that the expected results could have (Tang et al., 2017; Yan and Ji, 2017; Yousefi et al., 2018). However, two different approaches for

risk analysis have been proposed in the literature leading to an important distinction between risk and uncertainty (Hofman et al., 2017).

In line with the above, Yousefi et al. (2018, p. 170) mention that the risk could be evaluated following two different approaches: "1) Uncertainty, which shows the change in the factors leading to the occurrence of risk and the uncertainty of the occurring event; 2) Exposure, which indicates the amount of exposure due to changes in risk factors". In the first one, the risk is a consequence of uncertainty (Yousefi et al., 2018). Uncertainty represents the input for risk analysis, while the risk is the output that shows how the expected results could be affected (Hofman et al., 2017; Yousefi et al., 2018). In this regard, from a project perspective, the Association for Project Management (2006, p. 156) defines risk as "an uncertain event or set of circumstances that, should it occur, will have an effect on the achievement of the project's objectives". The second risk approach can be associated with conceptualization made in 1920 by the economist Frank Knight, in which the risk is expressed as a quantifiable variability, while the non-quantifiable variability is defined as uncertainty (Crouhy et al., 2014; Hofman et al., 2017). Risk and uncertainty represent independent outcomes, so uncertainty analysis opens up another independent research line regarding risk analysis (Hofman et al., 2017). A common characteristic of the first and second approaches is that risk is characterized as an output with measurable attributes (D. Guan et al., 2017; Hofman and Grela, 2015; Smalley, Begg, Naylor, Johnsen, and Godi, 2008; Zou et al., 2021).

Although both approaches coexist among studies in the field of PPM, the adopted approach is not always explicitly or clearly stated, as risk and uncertainty are used as equivalent terms in some studies. In the studies carried out by Panadero, Doering, Kizys, Juan, and Fito (2020) and Yan and Ji (2017), it is adopted the first risk approach, i.e., risk as a consequence of uncertainty. In the frame of the second risk approach, the study conducted by L. Wang et al. (2020) is an example of uncertainty analysis, while the study conducted by Ahmadi-Javid et al. (2020) is focused on risk analysis.

In the research here reported, the first risk approach is adopted. Considering that in this risk approach risk and uncertainty represent independent analysis and outcomes (Hofman et al., 2017), uncertainty analysis is out of the scope of this research. Thus, as mentioned in Chapter 1, PPR is associated with the exposure concept, which indicates the amount or measure of impact on the project portfolio expected results due to changes in risk factors. Risk factors represent the variables that, directly or indirectly, generate exposure (Crouhy et al., 2014; Yousefi et al., 2018) or, in other words, the variables that impact the risk of the project portfolio.

2.3 PPRA as an Element of Project Portfolio Risk Management

The focus of this research is the study of PPRA. In this regard, it is relevant to establish what PPRA encompasses and how it is embedded in the major concepts to which it is circumscribed. To this end, this section starts with the conceptualization of risk management from a broad perspective. Then, it describes PPRM, represented as a PPM element. Finally, PPRA is presented, in turn, as a PPRM element that provides information to support the management of the project portfolio.

2.3.1 Risk Management

"Risk in the widest sense is not new to business. All companies are exposed to traditional business risks: earnings go up and down as a result of such things as changes in the business environment, in the nature of competition, in production technologies, and in factors affecting suppliers" (Crouhy et al., 2014, p. 37). Although the risk construct is not particularly new, risk management has gained relevance over the last few decades, both for practical and academic purposes. It has been already applied in a wide range of contexts, such as environmental and nuclear, banking, insurance, hospitals, and industrial safety sectors. It is considered one of the most important innovations of the 20th century, even though some concepts supporting risk management are much older (McNeil, Frey, and Embrechts, 2005).

Risk management is associated with coordinated activities to direct and control an organization concerning risk (ISO, 2018). Developments in the topic have focused on more sophisticated analytical tools to measure and quantify risk. However, the use of measured and risk quantification tools cannot be overvalued, because this can lead to ignoring the risk management process as a main and global objective (Coleman, 2011). Risk management is not only a continual process of risk reduction, nor is it about passive measurement, monitoring of risk, and defensive strategies. The latter can lead organizations towards a passive approach to measurement and monitoring that does not propose actions that prepare the organization to face future risks (Coleman, 2011; Crouhy et al., 2014).

In this regard, a relevant concept related to risk management is risk transparency. Risk transparency is associated with the ability to provide decision-makers and stakeholders with objective and in context information (Crouhy et al., 2014; Teller and Kock, 2013). Thus, identifying the risk composition becomes a fundamental aspect of risk management (Coleman, 2011; Crouhy et al., 2014). For this, cataloging risk factors and their typology in each specific context, as well as determining their impacts, are essential steps to obtain an adequate representation of the risk composition (Coleman, 2011; Crouhy et al., 2014).

From a general perspective, the categorization of risk in market risk, credit risk, liquidity risk, operational risk, legal and regulatory risk, business risk, strategic risk and, reputation risk represents an example of a risk typology (Coleman, 2011; Crouhy et al., 2014), which can be further divided into subcategories (Crouhy et al., 2014). Also, regarding risk composition, Coleman (2011) highlights the importance of differentiating between systematic and idiosyncratic or non-systematic risk, because the sources of risk and the impact level on the organization are different between them. The no-systematic risk is under the control of the firm and its managers, while the systematic risk is the result of exogenous events that affect the whole context. Similarly, Coleman (2011) defines idiosyncratic risk as a risk specific to a particular firm and systematic risk as widespread across the system.

In addition, identifying the risk composition is important because the risk management of each risk category requires different capacities, techniques and tools (Coleman, 2011; Crouhy et al., 2014). However, special attention is necessary to avoid converting risk management into the management of each isolated risk category, since risk management must be characterized by the information integration to achieve global and systemic results in the organization (Arena et al., 2014; Crouhy et al., 2014). Thus, risk management is focused on making choices concerning the risk, the risk composition, and the possible reward of each decision and its success possibility through managing people, processes, data, and projects (Coleman, 2011; Crouhy et al., 2014).

2.3.2 Project Portfolio Risk Management

The effect of risk management at the project level has been studied, evidencing positive impacts on the success of each individual project. However, the literature also shows that managing risks only at the level of projects is not enough (Breault and Cleveland, 2020; Teller et al., 2014). As such, PPRM has been identified as one of the areas of PPM and a fundamental topic for project portfolio success (Ahmadi-Javid et al., 2020; Hofman and Grela, 2018; PMI, 2017b). The PPRM complements the risk management applied at the project level by considering the interactions between the management levels related to the project portfolio and their information exchange (PMI, 2017b; Teller et al., 2014). Therefore, the domain of PPRM consolidates risk management activities at the project portfolio level, avoiding duplication of efforts and resources and allowing higher effectiveness in risk management (Ahmadi-Javid et al., 2020; Carvalho et al., 2013; Hofman et al., 2017).

As illustrated in Section 1.2, two traditional risk planning approaches can be recognized in the project portfolio-related literature: (i) Risk planning in general management and, (ii) Risk planning in project management (Ahmadi-Javid et al., 2020). The first one is strongly associated with the seminal

conceptualization of project portfolios derived from the MPT proposed by Markowitz (Brester, Ryzhikov, and Semenkin, 2017; Tang et al., 2017; Yousefi et al., 2018). In this regard, that approach has been mainly focused on the project portfolio selection with risk considerations problem by the analogy with financial portfolios (Tang et al., 2017). The second one is derived from risk management applied at the project level, focusing on incorporating the impact of interdependencies between projects into the risk of each project or cumulative measures associated to project success (Ahmadi-Javid et al., 2020; Neumeier et al., 2018).

An approach without risk considerations at the portfolio level neglects the relevance of a broader scope for managing risks of project portfolios (Bai et al., 2020; Ghasemi et al., 2018; Teller et al., 2014). It may also influence the project portfolio success and, therefore, contribute to an organization being ill-prepared for the future (Ghasemi et al., 2018; Teller et al., 2014; L. Wang et al., 2020). Thus, traditional approaches, like the ones described in Section 1.2, have converged to the need for having a view that is more centered on the project portfolio level itself, i.e., on a third risk planning approach focused explicitly on the project portfolio level. Thus, expected project portfolio results, rather than business success or project success measures, could be used to represent the risk impact level.

Hence, the PPRM must focus on the identification and balance of the PPR throughout the project portfolio life cycle, seeking to maximize the value delivered to the company through the impact achieved on strategic goals (Bai et al., 2021; PMI, 2017b) while considering and managing the stakeholder expectations and the capabilities of the parent organization (Hofman and Grela, 2018; PMI, 2017b). In addition, although PPRM is an integral part of PPM, based on Sanchez et al. (2008), Teller et al. (2014, p. 69) mention that "research on integrating risk management into the PPM process has been relatively scarce". In this regard, the literature posits that risks at the project portfolio level can be separated at a moderately unified level of detail (Hofman and Grela, 2015; Hofman et al., 2017) and that integration of risk management at the portfolio level impacts positively the project portfolio success (Teller et al., 2014). Along these lines, the research reported herein adopted a view of risk management integrated into portfolio management, whereby portfolio risk is conceptualized explicitly at the project portfolio level rather than at the project or business levels.

2.3.3 Framing PPRA into Project Portfolio Risk Management Research [1]

The literature associated to PPRM address the topic from different perspectives. Then, PPRM literature was consolidated in four research perspectives: (i) PPRM as part of organizational risk management, (ii) Risk management, success dimensions and strategic impact, (iii) Mechanisms for PPRA, (iv) PPRM as a complex and dynamic system. These four perspectives are not exhaustive; in fact, different or complementary perspectives may be identified by other researchers. However, they are intended to provide an overview of trends into PPRM and on how this research project frames itself therein. Therefore, the focus of the research project here reported is framed within the research perspective oriented to establish mechanisms for PPRA.

(i) PPRM as part of organizational risk management

A risk management system at the project portfolio level should generate high visibility of the state of the project portfolio for top management, and it should allow planning and execution of threats/opportunities management in an integrated and coordinated manner throughout both the project life cycle and the project portfolio life cycle (Bolos, Sabau-Popa, Scarlat, Bradea, and Delcea, 2016; Olsson, 2008). However, there is a lack in the PPRM literature regarding the liaison between risk management processes, the requirements of a project portfolio threats/opportunities management, and the strategic management of threats and opportunities (Arena et al., 2014; Olsson, 2008). In this sense, the integration of PPRM into the project and program level and into the organizational level using Enterprise Risk Management systems, and other methodologies that allow a global and dynamic view, should be explored, both in a theoretical sense and in its practical dimension. As a complement to this, risk visualization systems - the relationship with performance variables, with decision variables and their behavior over time, need to be explored. Indeed, the proposal by Silva et al. (2017) and Wang et al. (2017) can be seen as an example of this.

Risk management skills as management and dynamic capabilities according to the dynamic and changing environment of current organizations, and according to the culture and competitive environment of each organization, can be considered a relevant topic in the decision-making process (Arena et al., 2014; Floricel and Ibanescu, 2008). However, descriptions of how to incorporate dynamic

[1] This Section was partially the object of the paper: Micán, C., Fernandes, G., & Araújo, M. (2020). Project portfolio risk management: a structured literature review with future directions for research. *International Journal of information systems and project management*, 8(3), 67-84. https://doi.org/10.12821/ijispm080304

capabilities in practice are rare, for which reason empirical studies on this topic are needed (Petit and Hobbs, 2010).

(ii) Risk management, success dimensions and strategic impact

Different levels associated with the impact of PPRM have been explored. Thus, future research could focus on establishing hierarchies between the identified levels, as well as interrelations between levels and intra-relations within each level, which, in turn, would allow the impact of the risk factors in each decision level to be established. To pursue this, empirical studies, historical information analysis and expert judgment, among other means, can be used to obtain methods, methodologies and indicators that allow for the identification and evaluation, both qualitatively and quantitatively, of the relationships between each level and the effect of the threats/opportunity factors on each of the decision levels. As such, conceptual frameworks have been proposed to determine the impact of the risks and opportunities on strategic and operative aspects that allow the performance of the portfolio to be monitored from a strategic perspective (Sanchez and Robert, 2010b; Sanchez et al., 2008; Teller and Kock, 2013). The extension of these proposals to practical applications that allow for their validation in the real context of each organization is necessary (Hofman et al., 2017; Sanchez and Robert, 2010b).

From another perspective, research focused on the evaluation of RM, riskiness, or the interdependencies between projects as contingent factors between PPM and project portfolio success will allow for the importance of PPRM to be qualified and quantified, as well as identifying which conditions, environment characteristics or project portfolio characteristics represent aspects to be considered for adequate PPRM (Floricel and Ibanescu, 2008; Kock, Heising, and Gemünden, 2016; Rank, Unger, and Gemünden, 2015). Additionally, to identify and underline the time effects, longitudinal studies would have to be employed (Kock et al., 2016), which could allow for assessment of the time effect between RM and project portfolio success. Likewise, the identification and characterization of moderating or contingent factors between RM and project portfolio success has been and should continue to be a focus of attention. Thus, empirical studies based on practice and those methodological proposals oriented to establishing the influence of different moderating factors must be developed. Identification of these factors allows for spotting RM capabilities and establishing strategies to deal with threats and opportunities (Arena et al., 2014; Sanchez et al., 2008; Teller and Kock, 2013).

(iii) Mechanisms for PPRA

Different categories of risk factors have been proposed in the literature. However, additional studies are required to broaden the sample size and expand upon the approaches used to obtain results

that can be generalized and that determine that the categories defined are feasible in practice (Costa et al., 2007; Ghasemi et al., 2018; Hofman and Grela, 2015). PPR categorization should be developed based on practice and expert judgment.

PPRA raises the need to integrate different dimensions (Broilo and Nazarova, 2016; Chatterjee, Hossain, and Kar, 2018). In this regard, the definition of the weight for each of the risk dimensions is a determining factor that can generate major differences in the final result (Costa et al., 2007; Razi and Shariat, 2017). Thus, two aspects should continue to be explored. The first is associated with the types of methods and risk measures to be implemented according to the context and information available for each project portfolio, taking into account the differences established in the literature between risk measures (Kettunen and Salo, 2017; Sefair, Méndez, Babat, Medaglia, and Zuluaga, 2017).

Another aspect to be considered is associated with the use of methods that allow for the incorporation of multidimensionality. The Multi-Criteria Decision-Making models and methods support the decision-making process when there are conflicting objectives. The Multi-Criteria models and methods are grouped in two categories: (1) Multi-Objective Decision-Making methods are focused in obtaining optimized solutions based on multiples objectives, and (2) Multiple-Attribute Decision-Making methods are focused in making a discrete comparison of alternatives based on different attributes associated with each alternative (Dobrovolskiene and Tamošiuniene, 2016; Heydari, Hosseini, and Makui, 2016). In this regard, since the incorporation of risks into project portfolios is considered a multi-criteria problem from the project selection perspective, both optimization approaches and multi-attribute approaches should continue to be explored (Dobrovolskiene and Tamošiuniene, 2016; Drake and Byrd, 2006; Heydari et al., 2016). Also, in the perspective of seeking to consolidate the risk inherent to the project portfolio, a measure or a subset of measures at project portfolio level could be explored more than just considering impacts on each project expected results or business level expected results (Ghasemi et al., 2018).

(iv) PPRM as a complex and dynamic system

It is generally assumed that projects are independent, with dependencies considered only when related to the sequence between projects, rarely exploring other types of dependencies (Ghasemi et al., 2018; Heydari et al., 2016; Neumeier et al., 2018). The gaps in the literature regarding these issues, mainly associated with generic frameworks not adapted to the characteristics of the PPM environment, require that risk identification and RM go beyond this, considering the complexity associated with risks

generated by the interaction between projects, risks at the project level and at strategic levels (Ghasemi et al., 2018; Neumeier et al., 2018).

Exploring alternatives to the traditional process-based approach is necessary. In the literature there are approaches to project portfolios, such as networks, knowledge networks, biological networks or complex and adaptive systems (Ghasemi et al., 2018; Neumeier et al., 2018; Sanchez and Robert, 2010b; Q. Wang et al., 2017), and it is necessary to deepen the analysis of these alternative approaches and their application. The identification and exploration of other alternative approaches that allow a systemic, non-linear and dynamic representation, which supports the decision-making process, should also be considered (Neumeier et al., 2018; Q. Wang et al., 2017).

Approaches such as those proposed by Q. Wang et al. (2017), which look at finding the balance between project portfolio efficiency and risk through the identification of project subgroups, have great theoretical and practical importance. They make it possible to reduce not only the complexity of the decision-making process, but also to reduce the risk associated with interdependencies, generating a globally positive impact on PPR. In addition to this, approaches based on the concept of learning from information in projects and portfolios that have already been executed, such as artificial neural networks, can also help to understand the relationship between variables that make up the decision-making process (Costantino, Di Gravio, and Nonino, 2015).

2.3.4 Project Portfolio Risk Assessment

At the portfolio level, the risk is managed within a comprehensive risk strategy in which both internal and external considerations are addressed (Hofman et al., 2017; PMI, 2017b). Thus, covering the whole project portfolio life cycle, PMI (2017b) defines four PPRM elements, namely, (i) risk management planning, (ii) risk identification, (iii) risk assessment, and (iv) risk response. These four elements are represented in two groups: Project risk management plan and managing portfolio risk. The first one is composed of risk management planning only, while risk identification, assessment, and response belong to the second group. Therefore, risk identification, assessment, and response elements, collectively, aim at providing information to support decision making associated with managing portfolio risk, which leads to continuous feedback to the risk management plan (PMI, 2017b).

This research project is centered on risk assessment as a PPRM element. PPRA provides information on the importance of risks and risk trends supporting risk response decisions, which are oriented towards managing the portfolio risk through a comprehensive risk strategy (Ahmadi-Javid et al., 2020; PMI, 2017b). As mentioned in Chapter 1, PPRA should generate better approximations of reality

and give decision-makers a clear overview of the portfolio risk. For that, inherent project portfolio characteristics should be recognized and taken into consideration in the PPRA (Ahmadi-Javid et al., 2020; Ghasemi et al., 2018; Hofman et al., 2017; Paquin, Gauthier, and Morin, 2016). Then, in the research here reported, PPRA is understood as a PPRM element oriented to provide information to manage the portfolio risk.

According to the above, and considering that: First, the project portfolio is conceptualized as an organization (see Section 2.1); second, risk management focuses on making choices considering the risk composition (see Section 2.3.1); and third, a PPRM view in which portfolio risk can be conceptualized explicitly at the project portfolio level (see Section 2.3.2), for this research project, risk assessment was established as a PPRM element that provides information on the risk composition at the portfolio level, helping the decision-makers manage portfolio risk and supporting decisions throughout the project portfolio life cycle. For this, it recognizes the project portfolio as an organization composed of temporary organizations (projects and programs) that interact with the parent organization and its strategy as well as recognized inherent project portfolio characteristics.

2.4 Conceptualizing PPRA into Risk Planning Approaches

According to Ahmadi-Javid et al. (2020), two main traditional risk planning approaches have been applied to conduct studies considering a project portfolio perspective. As illustrated in Introduction Chapter, these approaches have led to considering a third risk planning approach in project portfolio studies. Those three risk planning approaches are described in the following three sub-sections. The aim of this section is twofold: To show the state-of-art of the PPRA framed in these three risk planning approaches and explain in which of them this research seeks to build knowledge. Hence, the presented information introduces how portfolio risk assessment is theoretically addressed from each risk planning approach rather than describes the analytical tools, methods, or techniques used to perform the risk assessment.

2.4.1 General Management Approach

The problem of creating an optimal risk-reward portfolio has been actively considered in the literature (Sefair et al., 2017; Tamošaitienė, Yousefi, and Tabasi, 2021; Wu et al., 2021; Yan and Ji, 2017). The difficulty associated with an inadequately balanced portfolio and its risks mean that organizations cannot achieve optimal portfolios for strategic deployment, even more so when the strategic objectives are also subject to risks (Sharifighazvini, Ghezavati, Raissi, and Makui, 2018). However, uncertainty and risk increase the complexity of the project portfolio selection process since, in investment decisions, the

decision-makers have insufficient and inaccurate information (Mavrotas and Makryvelios, 2021; Mohagheghi, Mousavi, and Vahdani, 2016). Additionally, the impact of external factors such as market conditions, government regulations, or technical difficulties adds uncertainty to each project of the portfolio, leading to the need to incorporate the assessment of unknown or vague circumstances (Mohagheghi, Mousavi, and Vahdani, 2015; Tamošaitienė et al., 2021).

One aspect that is generally ignored is that the risk is usually asymmetric. Nevertheless, investors would like to maximize the asymmetry because this could imply greater benefits, so that this aspect should be included in the analysis (Xu, Liu, Li, and Luo, 2017). Also, from a decision-makers' perspective, Kettunen and Salo (2017, p. 1852) pose that "in the case of underestimation, the decision-makers will be exposed to greater risks than what was expected. In the case of overestimation, the decision-makers may unnecessarily abstain from starting risky projects in the expectation that possible risk constraints would be violated, although this would not be the case".

From the investors perspective, PPR has been mainly associated with the expected economic results. In this regard, the portfolio risk has been measured as (i) the sum of the individual risk of each selected project (Tofighian, Moezzi, Khakzar Barfuei, and Shafiee, 2018); (ii) the sum of the covariances multiplied by the cost of the respective pair of projects (Panadero et al., 2020); (iii) the variance of project portfolio present value (Dobrovolskiene and Tamošiuniene, 2016; Yan and Ji, 2017); and (iv) the variance of Net Present Value considering inter-project risk or covariance among projects (Mazelis and Solodukhin, 2015; Mazelis, Solodukhin, Tarantaev, and Chen, 2016; Tang et al., 2017). In this concern, risk measures derived from financial project portfolios have been mainly used to assess the PPR. Thus, expected shortfall, tail conditional expectation, standard deviation, semi-standard deviation, value at risk, and conditional value at risk have been identified as project and PPR measures, with the value at risk method being widely used in risk management literature (Molina, Contreras, and Rudnick, 2017; Tamošaitienė et al., 2021; Yousefi et al., 2018).

Considering that multiple risk measures have been explored, the literature highlights the importance and implications of selecting the appropriate measure of PPR (Paquin et al., 2016; Yousefi et al., 2018). Authors have found that adopted risk measures generate changes in the portfolio composition, i.e., changes on selected projects. An adequate risk measure must recognize that, generally, projects have a high probability of low profits and a low probability of high profits, and that managers and investors have a strong bias against underperforming portfolios, whereas decision-makers prefer downside-risk measures (Sefair et al., 2017).

The lower semi-variance of projects' returns is a widely accepted downside risk measure. It only measures negative deviations from the expected return. Besides, it is being considered a direct, efficient, and clear downside risk measure that can provide greater explanatory power than variability, as a risk measure (Heydari et al., 2016; Mohagheghi et al., 2016; Mohagheghi et al., 2015). However, Kettunen and Salo (2017) show that downside-risk measures might have significant negative implications because of optimism bias and strategic misrepresentation as not all projects can be selected. Then, this type of measure leads to a systematically biased risk estimation. In this concern, an adaptation of the semi-variance which incorporates the cash flow asymmetry in the decision-making process is proposed by Xu et al. (2017). Also, the lower semi-variance of projects' returns used due to the downside potential of projects is essential to help the managers by finding potential negative circumstances (Mohagheghi, Mousavi, Vahdani, and Shahriari, 2017).

However, even though coherent risk measures have been widely applied, generally, these measures ignore the effect of the target since the main objective of the majority of companies is not to maximize the return but to obtain an objective or balanced return from the decision-makers perspective (Hall, Long, Qi, and Sim, 2015). Based on the above, a general risk measure called 'underperformance riskiness index' is proposed for the project portfolio selection problem, which incorporates the risk aversion of the decision-maker, and a second risk measure, called 'entropic underperformance riskiness index', which incorporates the effects of the interaction between projects, is also proposed (Hall et al., 2015).

In addition, an alternative approach can be found in the literature. It is associated with mean-risk-third parameter models, which incorporates one additional criterion to risk-return models. This new criterion is associated with sustainability because it generates an impact on the expected result of two other criteria. However, this impact is still the subject of academic debate (Dobrovolskiene and Tamošiuniene, 2016). Although it represents a complementary alternative to traditional project portfolio selection, this alternate proposal remains aligned with the conventional approach for risk assessment. Moreover, complementary approaches that have been proposed arise from two main propositions. First, to incorporate the strategic perspective and the stakeholder perspective in the portfolio management decisions. And second, to represent the portfolio risk from a wide perspective in which non-monetary risk can be incorporated into the assessment along with monetary aspects (Abbasi et al., 2020; Wu et al., 2021).

Thus, this risk planning approach has been largely dominated by a view focused on the business level, evidencing the relevance of investment in project portfolios for organizations. Therefore, the risk represents the financial risk resulting from the investment in the portfolio, which is highly relevant to achieving financial sustainability in the organization's short, medium, and long term. This type of risk assessment has sought to recognize the risk appetite of decision-makers (Mohagheghi et al., 2017; Xu et al., 2017). For instance, if the organization is oriented towards an expansion strategy, it might be willing to accept more risk in its project portfolio than when oriented towards a sustaining or recovery strategy. This implicitly recognizes that the strategic orientation influences the portfolio composition as stated by Meskendahl (2010).

The balance between strategic orientation, risk appetite, and PPR is precisely one of the elements that PPRM pursues. At the portfolio level, the risk is balanced against the value proposition according to strategic expectation and not necessarily maximized or minimized (PMI, 2017b). "For example, within a portfolio, threats may not be minimized if there is potential for value by taking on additional negative risks" (PMI, 2017b, p. 87). However, assessing risk only in monetary terms does not recognize the diversity of strategic goals that comprise the strategic orientation (Bai et al., 2021; Sanchez and Robert, 2010b; Sanchez et al., 2008). In addition, it also neglects to acknowledge how the project portfolios deliver value to the parent organization (L. Wang et al., 2020).

The strategic orientation of the parent organization is composed of various strategic goals and sub-goals that are influenced by the project portfolio (Abbasi et al., 2020; Bai et al., 2021; Sanchez and Robert, 2010b). The strategic goals pursued may represent different commitments that complement each other, generating differentiated risk expectations regarding each component or group of components (Bai et al., 2021; Haghighi Rad and Rowzan, 2018; Richard et al., 2021). This suggests that risk appetite is not homogeneous among the projects within the portfolio, which could not be represented from a unidimensional risk assessment based solely on monetary terms, as it is traditionally addressed.

The above does not mean risk planning from the general management approach is irrelevant, but, from a PPRM perspective, it does not provide a clear view of the PPR composition against portfolio value proposition. In other words, although assessing the financial risk derived from the investment in the portfolio, it does not assess the risk at the portfolio level in a manner that provides information to support the management of the portfolio risk. As illustrated above, the information provided by the risk assessment should support the decision-making involved in the balance between risk and value to be

delivered by the portfolio. Another important consideration is that the literature in this field describes two stages over which the PPR should be evaluated. The first one is the technical or operational risk associated with the result of the project portfolio execution. The second one is the commercial or business phase risk that is generally associated with the market, economic, or organizational factors of the business phase. Both stages contribute to the PPR composition (Hall et al., 2015; Paquin et al., 2016).

Some differences between these phases are described by Paquin et al. (2016), who mentions that, for instance, the project portfolio diversification in the investment or selection phase does not imply that the operational project risks of the project portfolio are also diversified. The above implies that risk composition between phases is different, so a wide view of the portfolio risk requires providing information about the risk composition in each one of these phases.

2.4.2 Project Management Approach

Q. Wang et al. (2017) and Neumeier et al. (2018) highlight that integration and cooperation between projects can increase efficiency but requires greater risk management efforts since it increases the risk. For instance, failures in a project can cause negative impacts to other projects within the portfolio, which can lead to not achieving the portfolio objectives (D. Guan et al., 2017). Therefore, considering only the risks of each solo project is not enough, requiring that the interactions between projects and their effects on the projects' performance be also considered (Sanchez and Robert, 2010b). In this regard, Neumeier et al. (2018) mention that, although the interactions between projects are common, most of the risk approaches do not consider dependencies, and the existing literature is insufficient on this topic.

Thus, some studies have been oriented to incorporate the complexity related to project interdependencies and their effects (Neumeier et al., 2018; Zou et al., 2021). In the specific field of resources interaction, the common utilization of labor and the common utilization of infrastructure are identified as subtypes of resources interaction that generate the risk of projects within the portfolio (Heinrich, Kundisch, and Zimmermann, 2014). The authors indicate that the impact of resources interaction on risk management has been less well investigated than on projects cost. Also, engaged in identifying critical projects by considering interdependencies between projects and shared risk factors, Neumeier et al. (2018) assess the risk as the potential cost loss that each project can cause on the project network.

The strategic interactions are also highlighted as sources of complexity but simultaneously as a determining factor for the relationship between projects and strategic objectives (Sanchez and Robert, 2010a; Sanchez et al., 2009). In this regard, Sanchez and Robert (2010b) state that project portfolios

could be understood as complex and adaptive systems from an organizational perspective. In a similar vein, Q. Wang et al. (2017) argue that the traditional approach needs to be updated to integrate a more comprehensive risk analysis in which interactions and complexity can be represented. For this reason, they propose a biological network approach for portfolio and portfolio risk representation. Thus, considering an information technology project portfolio, an efficiency-risk balance model based on the entropy concept was proposed by Q. Wang et al. (2017). In this regard, the authors argue that if the group of projects is highly homogeneous, the risk is easily spread among projects when it occurs randomly.

The incorporation of opportunities is another aspect mentioned in the literature. Although opportunities realization is a key factor for project portfolio value maximization, the literature does not have an orientation towards the opportunities exploitation and management (D. Guan et al., 2017; Sanchez and Robert, 2010b). Consequently, the positive results are rarely quantified and compared to the negative ones (D. Guan et al., 2017). In this concern, D. Guan et al. (2017) propose a model for assessing the impact on project portfolio monetary loss expected due to opportunities generated by interdependencies between projects. The expected monetary loss is calculated based on the Net Present Value obtained from each project within the portfolio.

From a risk score perspective, Sharifighazvini et al. (2018) propose the integration of time, cost, and quality risk influences to establish a project risk score, defining PPR as the weighted sum of each individual project risk score. Razi, Eshlaghy, Nazemi, Alborzi, and Poorebrahimi (2015) focus on the exchange rate risk, for that, they assess the occurrence, detectability, and severity of risk factors to prioritize them. Moreover, in the context of oil and gas project portfolios, political risk is measured through a qualitative scale assigned to political, socio-economic, and commercial petroleum risk factors, using the weighted average method to calculate the portfolio risk index (Lopes and Almeida, 2015).

Another situation is associated with considering that risk factors among projects are not independent, which is linked to how a risk factor can affect the probabilities and impacts of other risk factors (Namazian and Yakhchali, 2018). For instance, risk factors considered to have a low impact on a specific project may be correlated with another risk factor in other projects within the same portfolio as well as the materialization of other risk factors in the same project (Cooley et al., 2012). In line with the above, under the context of construction projects, the assessment of schedule delay and cost overruns probabilities takes place by considering a network of risk factors (Namazian and Yakhchali, 2018). In addition, Costa et al. (2007) suggest that not all risk factors have the same weight in the PPR

quantification. For this reason, they used expert judgment through pairwise comparison to estimate the impact of each risk factor on the portfolio.

Therefore, issues regarding risk derived from project interdependencies and the effects of risk factors interdependency on the projects within the portfolio have been the main subjects of discussion. Project outcome measures, such as Net Present Value and project management performance measures (e.g., time and cost), have been used to assess the risk. Also, by adopting the view of portfolios as a group of projects, other studies have explored the aggregation of these individual project measures into overall measures.

Thus, this approach has focused on projects and the interdependencies between them. Portfolio risk has been associated with both outputs at the level of project execution and outcomes related to the business phase. Another aspect that derives from this approach is the representation of the project portfolio as a network to incorporate the influence of project interdependencies on the risk. Similarly, risk factors have been represented as a network to incorporate the impact of the interdependencies between them on the portfolio risk. However, some types of risk factors identified in the literature have not been incorporated, such as those associated with PPM (see Hofman and Grela, 2018).

The focus on the project level has led to recognizing that the strategic relationship of project portfolios has not been explored from the perspective of portfolio risk nor its impact on portfolio success. In this concern, the literature recognizes that risk management at the project level positively impacts project success. However, additional aspects should be considered when a portfolio management approach is adopted (Bai et al., 2020; Ghasemi et al., 2018; Hofman et al., 2017).

2.4.3 Project Portfolio Management Approach

The works developed by Ghasemi et al. (2018) and Hofman et al. (2017) are focused on the risk at a PPM level from an explicit perspective, identifying risks inherent to the level of the project portfolio. Hofman et al. (2017) identify some specific phenomena that can negatively affect portfolio success. These factors, designated as negative phenomena, are caused by the PPR factors identified. Although their proposal provides important information about the relationship between PPR and negative phenomena, it does not represent a PPRA model that allows assessing the impact of risk factors on project portfolio success dimensions. Later, Hofman and Grela (2018) assess a set of project portfolio-level risk factors based on the likelihood and the impact on project portfolio goals. Based on that, the risk factors categorization is proposed based on both risk likelihood perspective and impact perspective.

Ghasemi et al. (2018) identify risk factors caused by project interactions, and they also define risk factors at the project portfolio level as causes that could generate negative consequences on portfolio success factors and portfolio management objectives. The authors also consider the risks derived from not achieving the economic objective and not achieving the success in time, cost, quality, and customer satisfaction objectives of each project within the portfolio. This assessment is carried out considering risk precedence interdependencies. PPR is represented as the project portfolio probability of failure, being this high or low. Also, by focusing on the influence of resource interdependency between projects, Bai et al. (2020) find that poor communication and cooperation among projects and lack of sharing technology are part of the leading factors of the PPR. In all these studies, PPR is presented as an aggregate measure and the proposals do not allow to identify the impact on project portfolio success.

From another angle, more specifically, from an uncertainty-based perspective, other proposals have been developed to represent the uncertainty impact on the value delivery or the expected strategic goals. Thus, Bai et al. (2021) suggest an index, namely 'strategic loss rate', to assess possible project portfolio configurations and the uncertainty associated with achieving the organizational strategic objectives in each configuration. For this, they conceive the project portfolio as a network considering a perspective in which project portfolio selection is based on strategic goals. Another perspective is adopted by L. Wang et al. (2020), who study the uncertainty associated with the realized value of projects and their interdependency. They establish that a strategic perspective is required for portfolio coordination, in contrast to the traditional project-based control to improve the overall strategic benefits. Also, Shafi, Elsayed, Sarker, and Ryan (2017) pose another approach in which they focus on the optimization of capabilities that are required to face strategic risks. For this, the authors adopted a capability-based planning approach that was applied to the case of national defense project portfolios.

Thus, risk associated with portfolio expected results such as portfolio goals, strategic goals, and capabilities to be generated, as well as the incorporation of risk factors explicitly derived at the project portfolio level, are being explored by project portfolio level approaches. Accordingly, the research project here reported is framed in this risk management approach.

2.5 Summary

This chapter frames the broad context of Project Portfolio Management (PPM) and project portfolio risk assessment (PPRA) and identifies the approaches adopted in this research study. PPM is framed in four interdependent and recursive phases (Carvalho et al., 2013; Clegg et al., 2018; Hansen and Svejvig,

2018; Unger et al., 2012): i) portfolio structuring, ii) resource management, iii) portfolio steering, and iv) organizational learning and portfolio exploitation. These phases encompass the PPM scope and therefore frame the studies related to it. The literature shows PPM studies are largely dominated by rational and controllable assumptions and processes (Clegg et al., 2018; Hansen and Svejvig, 2018), usually based on the conceptualization of project portfolios as a collection of projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives (Martinsuo and Geraldi, 2020). However, an alternative perspective has been posed, where projects portfolios are conceptualized as an organization (temporary or permanent) hosting temporary organizations (projects and programs) that are managed together (Martinsuo and Geraldi, 2020). This research project was conducted under the conceptualization of project portfolios as an organization. Recognizing project portfolios as organizations help recognize how a project portfolio interacts with the parent organization and its strategy and with the portfolio environment and stakeholder expectations.

Two main approaches under which Project Portfolio Risk (PPR) is conceptualized were identified. The main distinction between these approaches is about how risk and uncertainty are defined. In the first one, the risk is a consequence of uncertainty (Hofman et al., 2017; Yousefi et al., 2018). In the second approach, risk and uncertainty represent independent outcomes (Hofman et al., 2017). This research adopts the second approach, therefore PPR was defined as the amount or measure of impact on the project portfolio expected results due to changes in risk factors, where risk factors represent the variables that, directly or indirectly, generate exposure.

Risk management at the project portfolio level has been identified as one of the areas of PPM and a key topic for project portfolio success, avoiding duplication of efforts and resources and allowing higher effectiveness in risk management (Ahmadi-Javid et al., 2020; Hofman and Grela, 2018; PMI, 2017b). That relevance has aroused the interest of academics as evidenced in the current literature in the field. Four interdependence research perspectives were posed based on the literature analysis: (i) Project Portfolio Risk Management (PPRM) as part of organizational risk management, (ii) Risk management, success dimensions and strategic impact, (iii) Mechanisms for PPRA, and (iv) PPRM as a complex and dynamic system. This research project is framed into the third research perspective, i.e., it seeks to deepen on how to conduct PPRA.

PPRA is defined as a PPRM element. Risk identification, assessment, and response elements, collectively, aim at providing information to support decision making associated with managing portfolio risk (PMI, 2017b). Thus, PPRA is understood as an element that receives information from risk

identification and provides information to help managing the portfolio risk through a comprehensive risk response strategy. For this research project, PPRA was established as a PPRM element that provides information on the risk composition at the portfolio level, helping the decision-makers manage portfolio risk and supporting decisions throughout the project portfolio life cycle.

As a PPRM element, PPRA cannot be understood in isolation from risk planning approaches adopted to conduct studies considering a project portfolio perspective. Three main risk planning approaches were identified and discussed: (i) PPRA under a general management approach; (ii) PPRA under a project management approach; and (iii) PPRA under a PPM approach.

The general management approach is strongly related with project portfolio selection problem considering the optimal risk-reward in monetary terms for the parent organization due to the investment made in the portfolio. In this approach, it is adopted the perspective of the parent organization. Project management approach is derived from risk project management focusing on assessing the impact of interdependencies between projects on the project's metrics. In this approach, it is adopted a perspective based on the projects. These two first risk planning approaches, although related to the project portfolio, support decision-making associated with the risk at the parent organization level and at the project level rather than at the project portfolio level itself. Also, both risk planning approaches led to recognize that PPR should consider the strategic relationship of project portfolios and the inherent characteristics at portfolio level such as risk factors derived at the portfolio level. Thus, both risk planning approaches, and consequently the PPRA, have sought to adopt a strategic view based on the portfolio level itself.

The third approach seeks to recognize the strategic nature of portfolios and characteristics derived from the portfolio level itself (Ghasemi et al., 2018; Hofman et al., 2017). In this regard, a PPRA that considers the PPR based on the strategic nature of project portfolios, risk factors at the portfolio level, and effects of risk factor interdependency on the portfolio results remains scarcely explored. Accordingly, the research project here reported is framed in this third risk planning approach.

3. RESEARCH METHODOLOGY

This chapter describes the methodological aspects that support the development of this research project. In Section 3.1, the research philosophy and the paradigms of knowledge development underlying this research and a tailored research design are presented. The research design led to define the three research Phases illustrated in Figure 3.1. Finally, the procedures and methods implemented for data collection and analysis in each Phase are described in Sections 3.2, 3.3, and 3.4.

3.1 Research Philosophy and Design

Research philosophy and research approach are aspects that orient the adoption of specific procedures and assumptions within the research frame. In other words, they influence the way knowledge is developed and, in consequence, how research results are analyzed and interpreted (Collis and Hussey, 2013; Saunders, Lewis, and Thornhill, 2019).

This thesis sought to deepen the understanding of PPRA, specifically, how to assess the PPR considering interactions among risk factors and their impact on the project portfolio success dimensions. To achieve this, PPRA is seen as a PPRM element, through which information is provided to support decision-making processes oriented to obtain the project portfolio expected results. Therefore, this research project aims to contribute with practical and informed solutions to future PPRA practices.

By considering the project portfolio as an organization (see Section 2.1), PPRM can be established as an organizational process, where PPRA corresponds to one of its elements. In this regard, the literature shows that organizational studies have been mainly enclosed in a classic functionalistic approach (Burrell and Morgan, 2019). However, several limitations and inadequacies have been identified in both organizational studies and project portfolio studies when only functionalistic and objectivist approaches are adopted (Avenier, 2010; Martinsuo and Geraldi, 2020). For instance, the inadequacy to represent an organization as a system shaped by human intentions and embedded in the environment in which it evolves as described by Avenier (2010). Also, reductionism, determinism, and inadequacy in recognizing the way in which each project portfolio delivers value to the company and stakeholders as well as the interaction with the parent organization are some of the limitations mentioned by Martinsuo and Geraldi (2020) when an objectivist approach is adopted.

In addition, as evidenced in the studies developed by Namazian and Yakhchali (2018), Ghasemi et al. (2018), Hofman and Grela (2015), among others, quantitative information regarding PPRM is scarce in organizations. Additionally, the literature in this field is still subject to debate and both subjective

interpretations and measurable phenomena can be considered sources of acceptable knowledge in the PPRM field. Then, the *constructivism-founded scientific paradigm for organization research* posed by Avenier (2010) was adopted as the research paradigm for this research project. In the constructivist view of organizational design science, both constructivist epistemologies and organizational design science complement each other to further generate knowledge (Avenier, 2010).

As in organizational design science, the goal of the research is to develop knowledge to guide design processes, i.e., knowledge that is oriented to support the design and implementation of organizational artifacts having desired properties (Avenier, 2010; Mohrman, 2007). In this regard, this research aims to develop knowledge to guide the PPRA design process in a way that interactions among risk factors and their impacts on the project portfolio success dimensions can be considered. In this paradigm, goal-directedness and dependency upon the environment represent the two specific properties of any organization. Therefore, a concrete and objective reality, as posited in positivism (Schutt, 2019), cannot be defined. In contrast, it is proposed that the process design must fit the situation and work properly when put into use. In this concern, in-depth field research conducted under a constructivist view is useful (Avenier, 2010). However, "the constructivist view of organizational design science confronts researchers with the issues of generalizing local knowledge and justifying generalization" (Avenier, 2010, p. 1240).

In constructivism, knowledge is developed in the understanding that reality corresponds to a shared view which the researcher tries to obtain from discovering what the participants think (Schutt, 2019). Hence, knowledge developed in field research represents local knowledge. In this regard, the generalization of local knowledge, such as in the constructivism paradigm, could take the form of consistent propositions, design rules, design methods, or knowledge artifacts such as generic frameworks or models. Through those generalized knowledge forms, the researchers seek to transcend the singularities of local knowledge (Avenier, 2010). According to Saunders et al. (2019), generalizing from the interactions between the specific and the general to generate or modify theory is associated with an abductive approach. Therefore, an *abductive research approach* suits this research project.

Concerning research strategy and research design, the main considerations relate to defining the method or methods that enable credible and reliable data to be collected to achieve the research objectives. Thus, for this research, two outputs were established as landmarks in the path to answer the research question. These two outputs are sequential, i.e., the subsequent output builds on the previous

one. The research outputs were defined as (i) a comprehensive PPRA conceptualization and (ii) a PPRA analytical model. Consequently, these outputs underpin the research design.

In abductive approaches "data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth" (Saunders et al., 2019, p.153). In this case, both literature and empirical data were collected and analyzed to propose a conceptualization of a comprehensive PPRA, the first research output. Hence, the proposed conceptualization of a comprehensive PPRA is based on a set of propositions derived from literature and empirical data analysis. In addition, enabling the practical use of knowledge is both a goal of knowledge generation in organizational design science and a means of its legitimation (Avenier, 2010). Thus, the second research output, labeled as PPRA model, represents a proposal to put the proposed PPRA conceptualization in practice and its legitimation.

The adoption of the research strategy and methods must occur based on the research question and objectives and considering information and knowledge availability, and time and resource constraints (Saunders et al., 2019). Even though no research strategy is ultimately better than another, there are research strategies that better fit the characteristics and requirements of each research (Collis and Hussey, 2013; Saunders et al., 2019). Qualitative research, for instance, can be supported with an approach to build theory or to develop a richer perspective based on existing literature (Saunders et al., 2019). Thus, for the first research output, a qualitative research design was adopted as the same is based on exploratory literature review and interview strategies. For that, two research Phases were defined. Phase I is associated with the literature review process, while the second one is associated with the conduction and analysis of semi-structured interviews. Hence, the proposed conceptualization of a comprehensive PPRA derives from qualitative analysis of literature and empirical data. The second output (PPRA model) is based on the proposed conceptualization of a comprehensive PPRA. Then, a quantitative strategy through which the PPRA can be implemented was defined in Phase III. Each Phase is described in the following sub-sections. Figure 3.1 shows an overview of the research design.

Furthermore, this research is characterized by its *descriptive and exploratory nature*. It requires incorporating aspects of a descriptive nature since, prior to the model definition, it is necessary to understand the general components and characteristics of PPRA as an element of PPRM. Descriptive studies can be precursors of and stimulate exploratory studies (Schutt, 2019). In addition, the exploratory nature allows a flexible research structure, which begins with a broad focus that gets adjusted as the research advances and new data is obtained (Saunders et al., 2019). Finally, this proposal considers a

cross-sectional study since it seeks to explore and delve into a specific phenomenon at a particular moment in time.

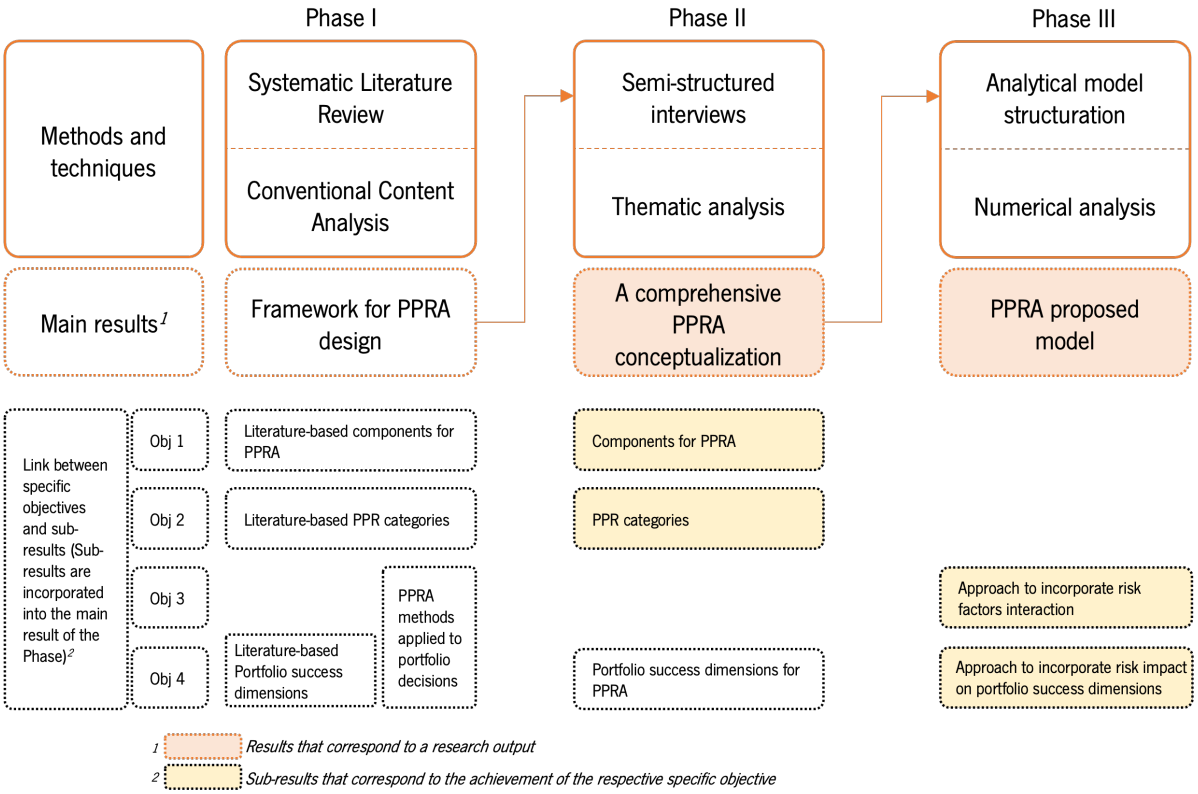


Figure 3.1. Overview of the research design

3.2 Phase I: Establishing a Framework for PPRA Design

"Literature reviews examine and critically assess existing knowledge in a particular problem domain" (Boell and Cecez-Kecmanovic, 2014, p. 258) allowing summarize and synthesize earlier relevant publications related to the research problem and leading to identify, among others, theoretical perspectives or theoretical foundations in the existing body of knowledge. The literature review process can be understood as the earlier research identification, analysis, assessment, and synthesis (Boell and Cecez-Kecmanovic, 2014). Literature review processes have been used by different authors to induce theoretical or conceptual frameworks in the PPRM context, through which a better understanding of a phenomenon or system is provided. In this regard, Petit and Hobbs (2010), for instance, defined a conceptual framework to study uncertainty sources and sensing mechanisms from a project portfolio perspective. Teller and Kock (2013) defined a conceptual framework that describes the relationship between PPRM and project portfolio success, and Heinrich et al. (2014) illustrated resource interaction effects in IT project portfolios through a theoretical framework.

Particularly, a literature review approach defined as Systematic Literature Review (SLR) was employed herein. It was originated in medical health care fields in the context of meta-analysis to define policy decisions. However, SLR has been later adopted in other fields such as engineering and management fields (Aarseth, Ahola, Aaltonen, Økland, and Andersen, 2017; Boell and Cecez-Kecmanovic, 2014). Thus, an SLR was conducted in Phase I of the research project to get a wider understanding of aspects considered for PPRA design. In some works, SLR was also associated with a structured literature review (see for instance Hansen and Svejvig, 2018; or Laursen and Svejvig, 2016). As a planned strategy for literature search and analysis, reporting the findings, discussion, and conclusions about a specific topic, it targets the replicability of research (Laursen and Svejvig, 2016; Saunders et al., 2019).

In comparison to other approaches, SLR is considered to be superior in terms of transparency (Aarseth et al., 2017; Müller, Pemsel, and Shao, 2014). In this regard, rigor, replicability, and objectivity are fundamental characteristics of an SLR (Boell and Cecez-Kecmanovic, 2014; Svejvig and Andersen, 2015). However, these characteristics have generated some criticism as formalistic literature searches can decrease academic curiosity and critical analysis required for an adequate literature review (Boell and Cecez-Kecmanovic, 2014). Thus, a successful literature review requires integrating both a replicable research setup and interpretation, questioning, and critical analysis skills (Müller et al., 2014; Saunders et al., 2019).

Therefore, the five steps illustrated by Svejvig and Andersen (2015) to conduct a replicable literature review were followed in this Phase of the research project. They are: (i) planning and scope definition; (ii) conceptualization of topic; (iii) searching, evaluating, and selecting literature; (iv) literature analysis; and (v) reporting and dissemination. The SLR process designed for this stage is summarized in Figure 3.2.

An important consideration about the literature review process is the continuous and interactive nature of this process, so the literature review can be seen as a set of hermeneutic circles (Boell and Cecez-Kecmanovic, 2014) or as an upward spiral (Saunders et al., 2019; Svejvig and Andersen, 2015). In other words, as a cycle of literature collection and analysis is conducted, it might be identified that an additional cycle is required to achieve the literature review objective. In this research, two cycles of literature selection and analysis (Cycle 1 and Cycle 2) were identified as necessary and conducted in this Phase. The following sections describe all the choices and procedures adopted.

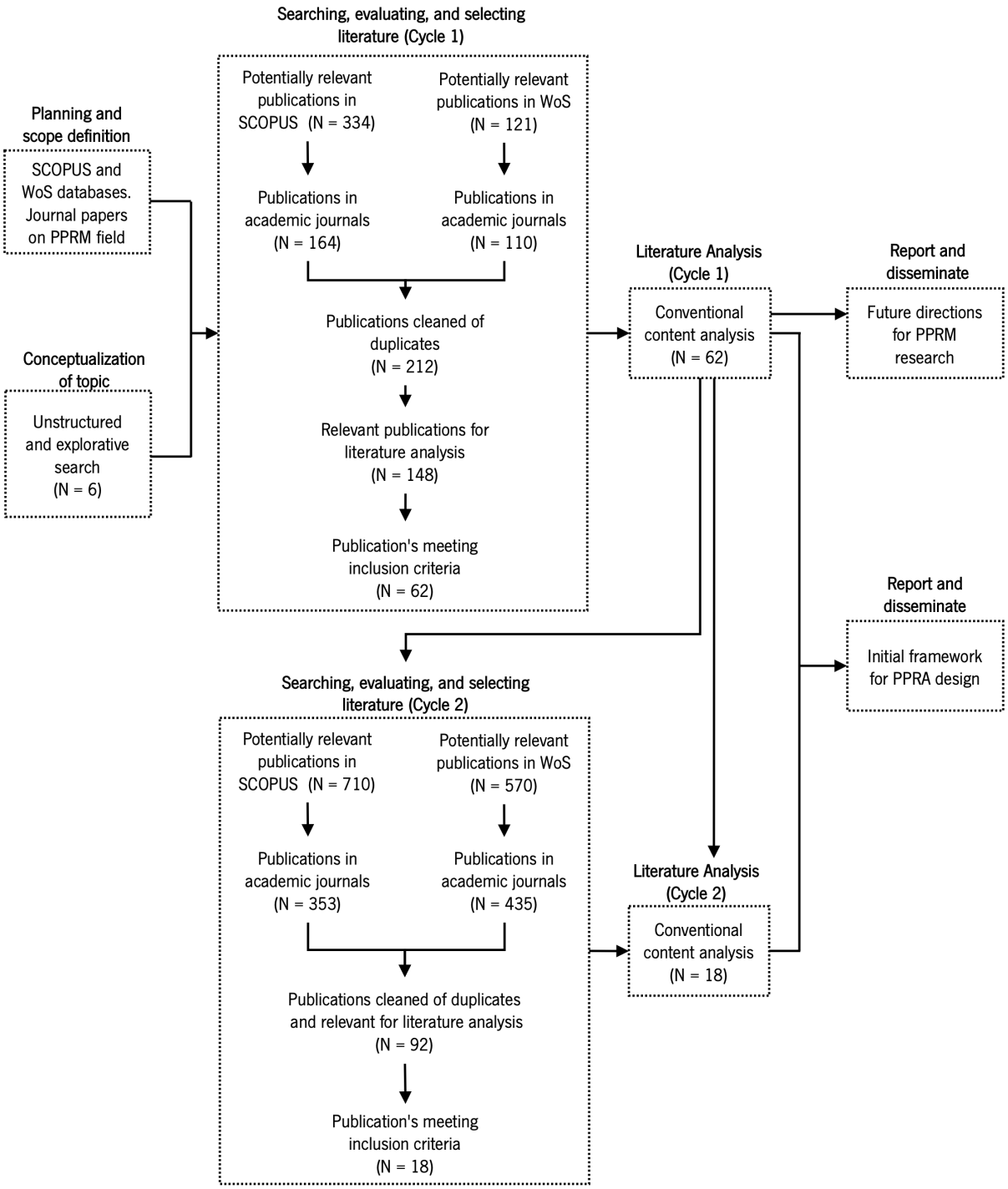


Figure 3.2. Summary of the SLR conducted in phase I

3.2.1 Planning and Scope Definition

Concerning the inclusion criteria, it was defined that only articles published in scientific journals would be considered. According to Rowley and Slack (2004), in professional disciplines, articles in scholarly and research journals should form the core of the literature review since this literature source has been peer-refereed prior to acceptance for publication and contains critical treatment of concepts and models. Literature reviews based on scientific journals have also been adopted in the project management area

by, for instance, Derakhshan et al. (2019), Prater et al. (2017), and Xia et al. (2018). Hällgren (2012) and Söderlund (2011) carried out their literature review process focused explicitly on the most relevant journals related to project management and management and organization journals outside the conventional project management publications, respectively. However, similarly to Laursen and Svejvig (2016), the literature review performed in this study had the goal to include a wider range of publications to establish a framework for PPRA design so that the scope of the search process was not restricted to specific journals. It was also defined that the literature search would be carried out using the SCOPUS and Web of Science (WoS) databases, given that they cover a wide-ranging peer-reviewed and high-quality scientific journals.

The fact that PPRA is defined as a PPRM element was a key aspect to define the scope of the literature review since the PPRA conceptualization should not be isolated and independent of the other PPRM elements. Hence, the literature to be selected and analyzed should cover PPRM or any of its elements rather than focus exclusively on PPRA. Even if a paper did not cover PPRA specifically but another of the elements of the PPRM instead, the analysis of that paper could lead to the identification of valuable information related to PPRA. For example, content derived from how other elements of the PPRM influence PPRA and vice versa could provide valuable input to establish the framework for PPRA design.

Based on the above, the included literature should have PPRM or some of the PPRM elements as main topic. When the main topic was not PPRM, their main objective should show a specific and explicit relationship with PPRM. In addition, considering the abductive approach underlying this research (see Section 3.1), it was defined that the literature analysis strategy should follow a descriptive rather than a prescriptive orientation.

Literature analysis was based on Content Analysis (CA). CA allows for the interpretation of the meaning or usage of written data, organizing information into relevant categories for each specific research work and establishing an understanding of the topic being studied (Hsieh and Shannon, 2005; Leung and Chung, 2019). Three main approaches can be used to conduct CA: conventional, summative, or directed (Leung and Chung, 2019). Summative CA is the most quantitative approach, which seeks to explore the contextual use of words, and whose findings may be explained using descriptive statistics associated with the frequency of use of particular words or phrases in specific contexts. Directed CA requires that data codes and categories are defined to be applied deductively to code the data. As a fundamental purpose, it adds credibility to a theoretical framework or conceptually extends a theory.

Conventional CA "provides a much more comprehensive picture of the phenomenon, through new insights exclusively grounded in the data, than the other two types" (Leung and Chung, 2019, p. 830).

In this regard, conventional CA was chosen to conduct the literature analysis herein. Conventional CA is the most descriptive type of CA (Leung and Chung, 2019). In this approach, preconceived categories are not defined, conversely, categories and new insights emerge from critical and reflexive analysis (Hsieh and Shannon, 2005; Leung and Chung, 2019). Findings are structured to establish conceptual meanings or general statements (Leung and Chung, 2019).

3.2.2 Conceptualization of Topic

The objectives of this step are twofold. On one hand, it aims at conceptualizing key concepts such as risk management, PPM, and PPRA, as well as the identification of risk and uncertainty approaches that had been adopted in the project portfolio context. This conceptualization led to the initial version of the literature background. As is natural in research processes, these antecedents were updated as the research progressed, leading to the final background presented in Section 2 of this document. On the other hand, this step also targeted obtaining information to support the next step of the SLR, the literature selection. Thus, an unstructured and exploratory literature search was carried out in addition to the conceptualization of the key concepts previously conducted.

Exploratory search and analysis of the literature have been recommended as input for more advance literature searches. For instance, Svejvig and Andersen (2015) and Laursen and Svejvig (2016) implemented the first cycle of data collection and analysis composed of an unstructured and preliminary literature search. Similarly, as part of the SLR process, Müller et al. (2014) defined a step associated to appraise primary studies and extract data. The unstructured search conducted in this research project was focused on publications with specific relation to the PPM and PPRM topics, which were published published in the three years previous to the search, 2016, 2017 or 2018. SCOPUS database was used for this unstructured search. Among the publications identified, the articles developed by Hansen and Svejvig (2018), Hofman and Grela (2017), Guan et al. (2017), Clegg et al. (2018), Hofman et al. (2017), and Paquin, Gauthier, and Morin (2016) were selected.

Based on these six publications, it was found that the incorporation of risk considerations into project portfolio selection is a research topic that has important developments and represents the beginning of RM applied to project portfolio decisions. In this vein, the MPT proposed by Markowitz in 1952 for financial investment is the seminal theory in the area. This theory was later adopted for project portfolios by McFarlan in 1981 and became the seminal work for PPM (Guan et al., 2017). Thus, this

line of research has been explored systematically for more than three decades. In contrast, research associated with risk incorporation in project execution from a portfolio perspective and an explicit view of the risk management at the portfolio level have been less explored (Hofman and Grela 2017). In this regard, it was found that this subject has systematically had publications only since 2008, one of the reasons why literature in the field remains scarce (Paquin et al., 2016; Hofman et al., 2017), as pointed by Hofman et al. (2017, p1), who mentioned that "project portfolio risk management constitutes a relatively new study area".

In addition, these six publications allowed identifying the main keywords related to PPRM, which could be used in the next step of the literature review process. 'Risk', 'risk management', 'project portfolio', 'project portfolio risk management', and 'portfolio risk management' were the main keywords identified.

3.2.3 Searching, Evaluating, and Selecting Literature (Cycle 1)

Iterative analysis of different search strings based on the keywords identified in the previous step was carried out. Possible search strings were tested in SCOPUS database. Table 3.1 presents the main search strings tested and the resulting number of publications identified. In addition, Table 3.1 shows a brief comment for each result regarding its PPRM field representability or relevance compared to the other search strings. The string search that best grouped the publications related to PPRM field was the query "project portfolio" and "risk" in articles' keywords, title, and abstract.

Table 3.1. Main search strings tested in SCOPUS

Search string (SS)	**Result (nº publications)**	**Comment**
SS1: "project portfolio risk management"	3	The result is not representative of the PPRM field.
SS2: "Project portfolio risk" or "risk of Project portfolio"	53	The works found seem to be related to the PPRM field. All of 53 works are included in SS4 results.
SS3: "portfolio risk" or "portfolio risk management"	1359	Most of the works correspond to financial portfolio risk more than the PPRM field.
SS4: "project portfolio" and "risk"	334	The works found seem to be related to the PPRM field.
SS5: "portfolio project management" and "risk"	82	The works found seem to be related to the PPRM field. All 82 works are included in SS4 results.

Therefore, 334 publications were identified in SCOPUS. The 334 publications correspond to 298 works that met the search string plus 36 works identified as secondary papers by SCOPUS, i.e., works that met the search string but were not indexed to SCOPUS. The list of secondary papers was initially composed of 51 publications. However, 4 papers were already included in the primary list of 298 works,

6 papers were duplicated, and 5 papers were in the Chinese language. Then, these 15 papers were discarded, so the secondary list was composed of 36 publications. The total of publications identified in SCOPUS was 334, 298 in the primary list and 36 in the secondary list. 164 of these 334 works were articles, articles in the press, or review articles, i.e., 164 works corresponded to publications in academic and scientific journals. In the search carried out in the WoS database, 121 publications were identified. Eleven of them have been published in conferences proceedings, so they were discarded. Thus, 110 publications in academic and scientific journals were identified in WoS. Comparing the results of SCOPUS and WoS, 62 publications were included in both databases. Once the duplicates were cleaned, the total of publications identified in SCOPUS and WoS databases corresponded to 212.

By reading the abstract and introduction of the 212 articles, it was perceived that only 148 of the 212 papers had PPRM as the main topic or had an explicit relation with PPRM. In this regard, even though the 64 papers discarded included the terms risk, project portfolio, or risk portfolio in their abstract, keywords or title, these articles were focused on project risk management, project evaluation, or PPM without the incorporation of risk. These articles, for instance, can be focused on project risk but mention project portfolio in the abstract only as part of the context in which the projects are executed.

It was identified that 32 of the 148 publications were associated with risk incorporation in project execution considering a portfolio perspective or the adoption of an explicit view of risk management at the portfolio level. Since this is a strain of PPRM with a limited number of publications, inclusion criterion associated with the publication year was not applied. The remaining 116 publications were associated to project portfolio structuration considering risk. For the publications that composed this group associated with portfolio structuration, the year filter was 2015 onwards (up to the end of December 2018) since this is a topic with a large number of publications and, according to Dobrovolskiene and Tamošiuniene (2016), earlier works are generally included in the latest research. Then, 30 publications met this inclusion criterion. Therefore, a total of 62 papers were selected for the literature analysis, 30 related to project portfolio selection and 32 associated with PPRM applied to project portfolio execution.

Table 3.2 shows the journals in which more than one of the selected papers had been published, representing a total of 20 of the 62 papers selected. The remaining 42 papers were each published in a different journal, such as ‘Operations research’, ‘Omega (United Kingdom)’, ‘Production and operations management’, ‘International journal of fuzzy systems’, among others.

Table 3.2. Journals with more than one paper published

Journal	Number of publications
Project Management journal	6
International Journal of Project Management	5
Sustainability (Switzerland)	3
International Journal of Managing Projects in Business	2
International Journal of Information Systems and Project Management	2
International Journal of Project Organisation and Management	2

3.2.4 Literature Analysis (Cycle 1)

The conventional CA of the 62 selected publications was conducted to establish the PPRM recurrent overarching topics and trends, looking for identified aspects on which PPRA could be framed. In line with the descriptive nature of conventional CA, preconceived categories for PPRM recurrent overarching topics and trends were not defined but emerged from the analysis of the literature. Then, a sequential cumulative process was implemented based on a chronological analysis of the publications, from oldest published papers to most recent papers. For each analyzed publication, one or more preliminary categories associated with recurrent PPRM topics or trends were identified. To the extent that publications were analyzed, the categories identified from each paper were contrasted with categories identified in previously analyzed publications, defining a preliminary set of categories, their composition, and attributes. An important fact to be considered is that each publication could have contributions to one or more categories. For instance, the publication made by Ghasemi et al. (2018) evidenced contributions regarding PPR categories and methods for PPRA, which were two of the categories identified as recurrent PPRM topics.

To carry out this process, a set of five papers were analyzed at each time, and, once the preliminary categories were established for them, the analysis of the next group of papers was carried out. The analysis of each group of five papers was labeled an analysis round so that 13 rounds were required. As publication analysis progressed, it was necessary to define, add, merge, divide, or reconstruct the categories in accordance with the new information obtained from each new analysis round forthwith until a final categorization was reached. Once a new analysis round was concluded, in light of the new insights or adjusted categorization structure, it was sometimes necessary to re-analyze some papers from previous rounds to confirm, extend, or redefine the information derived from those papers regarding the new categorization structure.

Regarding recurrent topics in PPRM, for each publication the following issues were analyzed: The general problem that framed each study, the specific research question or research objective documented, and the background reported. Then, the method, approach, or methodology developed or applied, and the results of each study were also analyzed. The research problem and the specific research questions or research objectives were also considered for the identification of PPRM trends. Thus, research problems, results analysis, discussion, future directions, and conclusions of each paper were analyzed. Based on that information, a categorization of future directions for PPRM was generated.

The conventional CA leads to the identification of four current PPRM topics and four interdependent future directions. The recurrent topics identified were 'Influence of risk management on project portfolio success', 'Risk and project interdependencies', 'PPR identification and categorization', and 'PPR assessment'. The four future directions were defined as 'PPRM as part of organizational risk management', 'Risk management, success dimensions and strategic impact', 'Mechanism for PPRA', and 'PPRM as a complex and dynamic system'. These results helped frame this research project into current PPRM knowledge and trend and provided information to support this research proposal. A brief description of the four future directions identified for PPRM was reported in Section 2.3.3.

Based on the literature review carried out, a framework for PPRA design could be established. According to the research objectives (Section 1.4), four constructs for PPRA design were established. Thus, the constructs 'components for PPRA', 'PPR categories', and 'project portfolio success dimensions' were built from the research objectives number one, two, and four, respectively. Besides, objectives three and four are oriented towards proposing an approach to PPRA, and the literature shows a variety of approaches and methods applied to incorporate PPRA into project portfolio decisions. Thus, a fourth construct, namely 'risk assessment method', was defined. Table 3.3 shows the relationship between specific objectives and constructs.

It was considered that the recurrent topic labeled as 'PPR identification and categorization', which had been defined from the conventional CA carried out, allows conceptualizing the construct 'PPR categories'. Likewise, it was considered that the recurrent topic 'PPR assessment' allows conceptualizing the construct 'risk assessment method'. Although the construct 'components for PPRA' did not fit directly to any of the categories identified from the conventional CA, it was considered that the literature reviewed would allow the identification of categories associated with it. Thus, an additional content categorization was carried out to identify possible 'components for PPRA', and an iterative process was conducted once again. For instance, one of the first CA categories was labeled as 'PPR contextualization and

conceptualization', but later this category was split into 'risk and uncertainty approach', 'risk interdependences', and 'project interdependencies' categories.

Table 3.3. Relationship between specific objectives and constructs

Specific objectives	Constructs	
1. To identify the **components** that must be considered for the project portfolio risk assessment	**Components for PPRA**: Common or transversal aspects that could be considered to PPRA design. Thus, aspects related to specific considerations which can modify the PPRA are labeled as 'components for PPRA'	
2. To define **project portfolio risk categories** in order to support an adequate risk-based decision process	**PPR categories**: Risk categorization contributes to the effectiveness and quality of risk assessment as well as leading to a risk-based decision process (Hofman et al., 2017; Sanchez et al., 2008). A 'PPR category' corresponds to a set of risk factors with common characteristics in terms of source or type of impact.	
3. To design an **approach to assess** project portfolio risk taking into account the risk factors interactions		**Risk assessment method**: A method oriented to assess the risk impact on a project portfolio's expected results. Risk assessment method emerges as an analytical integration of risk factors as input with portfolio expected results as the output of PPRA.
4. To propose an **approach allowing to incorporate the impacts** of risk factors and their interactions on **project portfolio success** dimensions	**Project portfolio success dimensions**: The literature recognizes a set of project portfolio success dimensions; these dimensions are mainly based on the PPM objectives proposed by Cooper et al. (2002).	

Concerning the construct 'project portfolio success dimensions', some primary information was identified especially from the recurrent topic of 'Influence of risk management on project portfolio success'. However, it was considered that this construct had not been fully covered in the literature selected. Based on the above, a second cycle of literature selection and analysis particularly focused on this construct was required.

3.2.5 Searching, Evaluating, and Selecting Literature (Cycle 2)

The second cycle was focused on the identification of the 'project portfolio success dimensions' and its characteristics. The attributes defined in the planning and scope definition step were not modified. Consequently, only articles published in academic journals were included, no year filter was applied, and only SCOPUS and WoS databases were considered.

The search string used was: project portfolio success. This search string identified 710 works in SCOPUS, 353 of which were articles in academic journals. In WoS, 570 publications were identified, however, only 435 corresponded to publications in academic journals. The set of identified publications was limited to publications with at least one of the following keywords: Project portfolio management, risk management, portfolio management, portfolio analysis, and risk analysis. Thus, once duplicate publications were removed, 92 papers were identified as possible relevant publications for literature

analysis. Based on the abstract analysis, it was observed that 23 of the 92 papers were relevant as for the scope of this literature search cycle. In addition, 5 of the selected publications were discarded because they had already been included in the previous cycle. Thus, 18 publications were selected.

3.2.6 Literature Analysis (Cycle 2) and Report

This cycle focused on analyzing the content regarding the definition or description of dimensions of success. 'Project portfolio success dimensions' were already categorized in the literature, and no overlap between categories from the different papers was identified. Then, merging, and splitting categories during the analysis process was not required. The results obtained from this literature analysis cycle were integrated into the first analysis cycle.

As mentioned previously, the results associated with future directions were reported in 2.3.3 to frame the focus of this research into PPRM research. The results associated with recurrent topics from the first and the second cycles were used to support the conceptualization of the four constructs proposed to aid the PPRA design. The conceptualization of the four constructs is provided in Chapter 4.

3.3 Phase II: Incorporating the Practitioners' Perspective into PPRA

This Phase had a twofold objective: (i) to identify, from a practical perspective, possible complementary or alternative categories associated with the constructs identified in the previous Phase; (ii) to conceptualize an approach to support the operationalization of PPRA in a practical context. Social Representation Theory (SRT) was adopted as the theoretical lens, adhering to a sociogenetic model for SRT operationalization (Rateau, Moliner, Abric, and Moliner, 2012). Social representations can be defined as systems of cognitive elements – opinions, knowledge, and beliefs – particular to a culture, a social category, or a group, concerning objects in the social environment (Bergquist, Ansolabehere, Carley, and Konisky, 2020; Rateau et al., 2012). In the purview of this research, the social environment corresponds to the organizational environment, or, more specifically, the project portfolio environment. In this regard, Joia and Melon (2020) mentioned that the adoption of SRT has grown in different areas of knowledge, including the management field.

SRT was originally developed to analyze the relationship between individuals and society for psychological studies. However, SRT can be equally applied to understanding the relationship between a subject and an object (Joia and Melon, 2020; Rateau et al., 2012). For this research Phase, the constructs 'components for PPRA', 'PPR categories', and 'project portfolio success dimensions' were defined as objects. Project portfolio practitioners were established as subjects to understand the

relationship between the practitioners and their notion of what constitutes these constructs. The construct 'risk assessment method' was not included in the empirical Phase of the study since it was expected that the practitioners would not be able to contribute to this construct, due to their lack of in-depth technical knowledge of the different methods proposed in the literature for carrying out a PPRA.

Furthermore, three main orientations can be identified within the SRT, they are (Rateau and Lo Monaco, 2013): The sociogenetic model, the sociodynamic model, and the structural model. This research adheres to a sociogenetic model. According to this model, a social representation involves two distinct but complementary processes: Anchoring and objectifying. Anchoring is defined as the process by which new information is interpreted by linking it with familiar knowledge. Objectification is defined as the process by which the object is reproduced and described in a concrete and selective manner (Bergquist et al., 2020; Rateau et al., 2012).

In this research Phase, social representation focused on describing the objectification of the three constructs under analysis: 'components for PPRA', 'PPR categories', and 'project portfolio success dimensions'. Specifically, objectification can be understood as "the way in which a new object, through communication about it, will be rapidly simplified, imaged, and diagrammed" (Rateau et al., 2012, p. 6). By collectively generalizing this schematization of the object, the reality of the object itself is naturalized (Bergquist et al., 2020; Rateau and Lo Monaco, 2013). This schematization is composed of different aspects of the object, which configure what is defined as the figurative core (Rateau et al., 2012).

In the sociogenetic model, monographic and qualitative approaches to data collection and analysis constitute the main methodological framework (Rateau et al., 2012), and researchers have mainly opted for observation or interviews (Rateau and Lo Monaco, 2013). Thus, for SRT operationalization, one of the research strategies implemented in this project has been interviews (Bergquist et al., 2020). The interview strategy helps to obtain relevant, contextualized, and reliable information regarding the subjects studied and led to achieving a broader understanding of it (Saunders et al., 2019). In addition, Saunders et al. (2019) stated that managers are more likely to agree to be interviewed, especially when the interview topic is seen to be interesting and relevant to their current work.

From this background, an exploratory qualitative research process was undertaken by adopting a research strategy based on interviews conducted with project portfolio practitioners.

3.3.1 Interviews Scope

Research interview is a general term for several types of interviews. The interview type depends on the formality and structuration level, being categorized as structured, semi-structured, and unstructured or in-depth interviews (Bryman, 2016; Saunders et al., 2019). Sometimes, the term qualitative interview is used to semi-structured and unstructured interviews, and quantitative interviews to structured interviews (Bryman, 2016). Structured interviews are usually conducted to gather data, which will then be analyzed using quantitative analysis. Structured interviews employ questionnaires with specific sets of questions filled by the researcher according to the interviewee responses. All interviewees answer the same questions. Semi-structured and unstructured interviews are implemented to gather data that will be analyzed qualitatively (Saunders et al., 2019). Semi-structured interviews are based on a list of topics and key questions, but their order may vary from interview to interview. Unstructured interviews are the most informal type of interview. There is no predetermined question list, only the general topic to be explored is predefined (Bryman, 2016; Saunders et al., 2019).

Considering the exploratory and qualitative nature of this Phase, as well as a set of predefined topics associated with the three constructs under analysis, a semi-structured interview approach was adopted. Semi-structured interviews have been conducted as part of the research methodology by different authors in the project management field, such as Awojide, Hodgkinson, and Ravishankar (2018), Bos-de Vos, Volker, and Wamelink (2019), Van der Hoorn and Whitty (2019), and Willumsen, Oehmen, Stingl, and Geraldi (2019). Semi-structured interviews allow exploring the answers of the interviewees about specific issues that were previously defined (Bryman, 2016; Saunders et al., 2019). In this regard, this strategy can also provide additional data to other data collection strategies (Collis and Hussey, 2013; Saunders et al., 2019). Therefore, the description and categories of the three constructs under analysis in this Phase were used to guide the design and scope of the semi-structured interviews.

An aspect to consider when semi-structured interviews are adopted to collect data is the data quality. Table 3.4 describes five issues posed by Saunders et al. (2019), which may influence the quality of data gathered by using this type of interview. These issues were established as transversal aspects that frame the protocols for interview design and application, sample definition, and data analysis protocol.

Table 3.4. Issues that may influence the data quality in semi-structured interviews

Issue	Description
Reliability or dependability	Since the circumstances to be explored are complex and dynamic, semi-structured interviews are not necessarily meant to be repeatable. However, the lack of standardization in semi-structured interviews can lead to concerns about reliability/dependability. In this regard, it is necessary to implement a standardized design and provide detailed information about the implemented protocol to ensure and provide evidence that data is obtained and analyzed adequately.
Forms of bias	Interviewer bias: Comments, tone, or non-verbal behavior of the interviewer can create bias in the interviewee's responses. In addition, the interviewer must not impose his own beliefs or frame of reference in the questions. Interviewee bias: An interviewee could provide only partial responses to some questions because he/she may be sensitive to the exploration of specific topics. Usually, it is associated with topics on which the interviewee considers he/she would intrude in sensitive information or on which he/she does not feel empowered or comfortable. Participation bias: It is related to the nature (profile and organization) of the individuals who agree to be interviewed. This may generate bias in the sample.
Cultural differences	Cultural differences may affect what the interviewee is willing to say. It is about how the interviewer asks the questions, and how the researcher interprets the interviewee's words and meanings. Cultural differences may be associated with cultural background or linguistic differences.
Generalizability and transferability	The extent to which the findings apply to other settings is abridged under this issue. The generalizability/transferability of the results must be consistent with the sample characteristics and scope of the generalization (provide specific insights, develop a theory, or develop statistical generalizations).
Validity or credibility	It refers to how the researcher has gained access to a participant's knowledge and experience. This issue is interrelated to the issues 'forms of bias' and 'cultural differences'.

Source: Based on Saunders et al. *(2016)*

3.3.2 Interviewees Profile

Due to the professional and cultural background of the researcher, the interviews were conducted with Colombian practitioners. Also, the selection of only Colombian professionals to participate in the study came about due to previous contacts with project portfolio practitioners and other professionals through whom the researcher could gain access to portfolio practitioners. As in studies carried out by Tam (2020) and Hofman et al. (2017), this study was focused on the professional experience of the interviewees. The above enabled the researcher to obtain insights into the interviewees' portfolio management experience with project portfolios both in their current and previous organizations. Then, the interviews target was Colombian professionals with experience related to PPM.

To conduct this study, the focus was on portfolios of organizational development projects, also acknowledged as internal development projects (Elonen and Artto, 2003). This type of project portfolio embraces a mixed set of projects directly related to the firm's strategy or corporate-level goals and organizational strategic impacts (Elonen and Artto, 2003). They aim to achieve a mid or long-term

organizational outcome and, consequently, impact on the business model and processes of the company (Richard et al., 2021). A portfolio of internal development projects can be composed of a mix of business processes development, information technology development, organizational change or re-engineering, and investments in new equipment, major software, and other capital projects (Elonen and Artto, 2003).

This decision was made after considering three aspects: (i) focusing on a single type of portfolio would allow establishing a common language to be used by the interviewees; (ii) this type of project portfolio was closest to the researcher's experience, which also helped to establish a common language between interviewees and interviewer as well as gain access to portfolio practitioners with experience related to that type of portfolios; and (iii) the focus on portfolios of internal development projects allowed both the interviewer and the interviewees to clarify the focus of the interview, avoiding confusion with other specific types of portfolios such as IT, R&D, or operational portfolios in project based-organizations. This decision also recognizes that the diverse types of portfolios have specific attributes and particularities. Thus, the professional experience of the interviewees was established as portfolio management experience related to portfolios of internal development projects.

It is worth mentioning that the diversity of the sample is not given by the diversity of portfolio types but by the diversity of business sectors of the parent organizations in which the interviewees gained professional experience. With this, it was expected to get a sample with a broad representation of organizational development project portfolios across different business sectors to capture data for establishing the figurative core of the constructs under analysis. Also, it is clear that empirical results cannot be directly extended to other types of portfolios. However, the results could open the path for future research to contrast empirical results from similar studies based on different types of portfolios.

Consequently, the interviewees' target profile was defined as: Colombian professionals with experience related to PPM in portfolios of organizational development projects regardless of the business sector of the parent organization.

3.3.3 Interviews Design

Important background or contextual material can be obtained to design semi-structured interviews (Saunders et al., 2019). In this type of interview, an interview guide protocol is prepared in advance comprising a list of questions about specific topics, but there is a considerable level of flexibility in the protocol implementation. The interviewee has a great deal of leeway or latitude in how to reply, the order of questions may be varied depending on the flow of the conversation, and additional questions that are

not included in the interview guide may be required from interviewee to interviewee (Bryman, 2016; Saunders et al., 2019).

An interview guide can refer both to the list of areas to be covered and to a more structured list of issues to be addressed (Bryman, 2016). The guidelines to formulate an interview guide suggested by Bryman (2016) and the interview guides or protocols implemented by Duarte (2009), Fernandes (2014), and Miroslava (2018) were used as references to design the interview guide adopted in this research. Figure 3.3 illustrates the process conducted to define the interview guide.

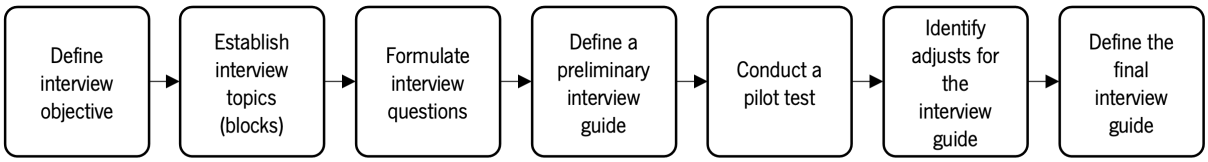


Figure 3.3. Protocol for interview design

The *general objective* of the interviews is twofold: To obtain empirical data based on interviewees' experiences and perceptions and gather information that allows comparing and complementing the literature review findings about 'components for PPRA', 'PPR categories', and 'project portfolio success dimensions'. In line with the twofold objective defined for this Phase, two specific objectives were associated with the interviews' general objective: (i) to identify complementary or alternative categories associated with the three constructs under study; and (ii) to establish the figurative core of the three constructs under analysis to support the operationalization of PPRA in a practical context.

Based on the general objective, it was defined that the core of the interview would be the constructs 'components for PPRA', 'PPR categories', and 'project portfolio success dimensions'. Therefore, each construct would represent an *interview topic*, i.e., they represent three *interview blocks*. In addition, following the structure of the interview guide implemented by Duarte (2009), Fernandes (2014), and Miroslava (2018), two additional interview blocks were added. These additional blocks are associated with an introductory block and an interview closing block. The introductory block is focused on ensuring the scope of the interview is clear and making the respondent and interviewer feel comfortable. Regarding the interviewer, previous studies mention that this strategy helps diminish anxiety and increase the feeling of control, which, in turn, avoid influencing the interviewee's answers with researcher's anxiety (Fernandes, 2014; Miroslava, 2018). Concerning the interviewees, introductory questions about professional background help them feel more confident and comfortable, which is important to encourage openness (Bos-de Vos et al., 2019).

The other additional block, the interview closing block, is oriented to allow interviewees to give additional comments about any topic addressed during the interview or other topics that they consider relevant. Table 3.5 shows the five blocks defined and their respective objective.

Table 3.5. Interview blocks

Blocks	**Block objective**
1: Introduction	Clarify the interview scope and the interviewee's background
2: Components for PPRA	Identify perceptions about components for PPRA that should be considered for design and conduct PPRA.
3: PPR categories	Identify perceptions about categories in which the project portfolio risk can be analyzed.
4: Project portfolio success dimensions	Identify perceptions about dimensions that could be associated to project portfolio success.
5: Closing interview	Obtain additional information considered important from the interviewee's perspective about PPR assessment.

Then, following the process illustrated in Figure 3.3, questions were defined for each block in accordance with the block's objective. Table 3.6 shows the questions defined in this process.

Table 3.6. Questions established for each interview block

Block	**Questions**
1	Do you want to know more about the research project or the interview? Do you authorize the recording of this interview? Can you give me a short introduction of your professional background regarding project management and portfolio management?
2	Could you identify the main aspects or components that should be considered for an adequate PPRA? Do you perceive <<name of a PPR component identified in the literature>> as a component of project portfolio risk assessment?
3	Could you identify types of risks, groups of risks, or categories of risks that should be considered at the project portfolio level? Do you perceive <<name of a PPR category identified in the literature >> as a relevant category for project portfolio risk assessment?
4	What criteria/dimensions might represent project portfolio success dimensions? Do you perceive <<name of a project portfolio success dimension identified in the literature>> as relevant for project portfolio risk assessment?
5	Do you consider other aspects should be measured or considered as part of PPRA? Do you want to add anything? Do you have any suggestions regarding the interview?

Looking to minimize the interviewer bias, it was planned that specific categories of 'components for PPRA', 'PPR categories', and 'project portfolio success dimensions', previously identified in the

literature, would only be introduced in the respective interview block after interviewees had communicated and clarified their opinion regarding each construct from an open perspective. Thus, blocks two, three, and four consisted of, first, asking about the construct and, only after that, asking about the specific category that compounds each construct in the literature-based framework for PPRA design.

Then, the preliminary interview guide was designed. In the first part, the guide contains the definition of the PPM, 'components for PPRA', 'PPR categories', and 'project portfolio success dimensions'. For each interview block, the questions defined in Table 3.6 were posed. The list of categories identified in the literature for each construct was added to each interview block. As part of the preliminary interview guide, it was established that a briefing document must be previously sent to interviewees. The briefing document outlines the scope of the research project, the scope of the interview (main questions), and key terms adopted in the study. The briefing document is shown in Appendix A1.

For the pilot test, two professionals were invited. Participant one is a professor in project management topics at the University of Valle (Colombia) with, respectively, fifteen and seven years of practical experience in project management and PPM field. Participant two is a professional with a background in PPM with more than seven years of experience in the project management field and around four years as a project portfolio manager in service and manufacturing industries. As established, the briefing document was sent previously to each participant. The two interviews were conducted by video-call using 'Skype' because at that moment the interviewer was out of Colombia. These interviews were conducted in September 2019.

In both cases, the interview duration was around 60 minutes. This duration was considered appropriate to conduct future interviews so that changes in the interview guide associated to reduce its content or extension were not necessary. However, it was identified that, when the first question of block two was asked, the word 'components' generated some difficulties in its interpretation by the participant. This realization took place at the first interview as the participant mentioned general aspects associated to change management and human resources as a source of portfolio risk in response to the first question. Although useful, the information provided by the participant did not allow accomplishing the block's objective. This situation forced the researcher/interviewer to clarify the meaning of 'component for PPRA' and to give some examples. In this regard, it was considered that this situation could generate interviewer bias as the interviewer could impose his own frame of reference, i.e., impose some of the components previously identified in the literature.

Then, the 'project portfolio success dimensions' block was moved up to second place, and 'components for PPRA' block was down to fourth place in the interview guide. 'Introduction', 'PPR categories', and 'interview closing' blocks remained in their initial position. This modification helped the researcher collect information about interviewees' language and experiences before asking about 'components for PPRA'. So, when necessary, previous information mentioned by the interviewee in the first three blocks could be used by the researcher to provide a meaningful explanation or exemplification of this construct. This change was tested with the second participant, and the results were satisfactory.

The pilot test was also used to obtain feedback regarding the interview process. Then, once the interview was finished, the participants were asked to provide feedback regarding the interview carried out. In this regard, participant one mentioned that "*I think the interview was very well guided*", and participant two posed "*I liked to talk with a very knowledgeable person*". Asking them about the briefing document, participant two stated "*the document was very clear, and I liked it so much [...] a very small space was very well used*", and participant one mentioned that "*information was very well encapsulated, and it was very accurate*". Finally, about if they felt some influence or bias by the interviewer, interviewee 2 affirmed "*I do not feel I have been led to give a certain type of response, in truth it did not happen*".

Then, the interview guide was adjusted only in terms of the order of initial blocks two and four. Thus, blocks in the final interview guide were defined as follows: Block 1 – introduction; Block 2 – Project portfolio success dimensions; Block 3 – PPR categories; Block 4 – Components for PPRA; and Block 5 – Closing interview. The interview guide is shown in Appendix A2.

3.3.4 Interviews Process

Convenience sampling was used to identify an initial group of possible interviewees, while snowball sampling provided additional participants for the study. This sampling strategy is also reported in later published studies such as that by Mac Donald, Rezania, and Baker (2020). Initial contact with professionals was established following three strategies: (i) calling professionals that the researcher already knew and fit into the interviewee profile; (ii) speaking with professionals previously known to the researcher that could indicate professionals in charge of project portfolios in different Colombian organizations; and (iii) presenting the research project and interview scope in one of the "Valle del Cauca (Colombia) PMO director's group" meetings to invite participants to engage in the study. As usual, in the snowball strategy, some participants provided information about other professionals they knew who could fit the interviewee profile.

The initial contact with each potential participant was conducted by e-mail, call, or WhatsApp according to the information available. The researcher provided information regarding the research project, interviewee's profile, and interview scope in the initial contact. Also, questions about the interview and interviewee's profile were responded to. Once confirmed that the potential participant matched the interviewee's profile and he/she agreed to participate in the study, the interview date was defined. Most of the time, the briefing document was sent once the potential interviewee accepted participating in the study. However, in some cases, it was required to send the briefing document to the potential participant before he/she accepts his/her participation. In those cases, the confirmation was obtained in a second contact once the potential participant had read the briefing document. Thus, the day, hour, and location to conduct the interview was defined and usually confirmed by email or WhatsApp.

In such a way, the initial contact was carried out with forty-two professionals. However, this initial contact led to identifying, by mutual agreement, that seven of the contacted professionals did not fit the interviewee's profile. In these cases, professionals usually provided the researcher with information regarding people within their organization that possibly matched the profile. Thus, thirty-five project portfolio practitioners initially accepted to participate in the study. However, with six of them, a date for conducting the interview could not be defined. In these cases, they asked to be contacted later to confirm their availability and define the data and hour for the interview. Still, they did not respond to the consecutive attempts made to contact them or continuously asked to be contacted later again. Therefore, twenty-nine interviews were scheduled between October and December 2019.

Three interviews were canceled by the interviewees and could not be rescheduled within the proposed timeframe. One interviewee was canceled and could not be rescheduled because the person informed health problems that led her to be off work for the next few months. Two other interviews could not be conducted because the practitioners asked to change the date. Although this type of requirement was usual during the process, in these two cases, new interviews could not be scheduled before the established interview period, i.e., before the end of 2019. As it was defined in the interview design, the interviews were recorded with the previous authorization of each interviewee. Additionally, hand notes were also taken during interviews. No modifications to the interview content or guide were necessary throughout the interviews. Hence, the interview protocol established was followed without changes. All these interviews were conducted in person. The interviews were conducted in the Spanish language, which is the native language of both researcher/interviewer and interviewees. Twenty-four interviews were conducted in the offices of the interviewees, and two interviews were conducted outside of interviewees' organizations, upon their own request. Only three interviews were interrupted by external

situations, however, those interruptions lasted less than 5 minutes and the interviews continued undisturbed.

A summary of the interview was made and sent to each interviewee by email or WhatsApp according to the preference of each interviewee. Based on the summary, interviewees were asked if they considered it appropriate to adjust some interpretations, expand answers, or add new information.

3.3.5 Sample

Twenty-six interviews were conducted in person between October and December 2019. Since the interview's content was not modified as a result of the pilot test, the two interviews conducted in the pilot test were also included in the final sample. Thus, the sample was composed by twenty-eight interviews. Most of the interviews lasted between 45 minutes and 75 minutes with exception of two of them that were particularly brief, around 30 minutes. In both cases, it was because, at the time of the interview, the participants had less time availability than agreed due to other commitments. However, the interview guide was fully addressed in both cases, so they were included in the sample.

The interviewees had high levels of project and portfolio management experience: 68% had more than 7 years of project management experience; 22% had more than 7 years of PPM experience; 56% had between 3 and 6 years of PPM experience, and all participants seemed to be well qualified to provide valuable information on the topic. 68% of the participants were project portfolio managers, 18% were head of Project Management Office (PMO), while the remaining 14% were executive directors, heads of improvement offices, or project managers with experience in PPM. All of them had at least one undergraduate degree, while 46% of them held a post-graduate qualification, and 86% had some form of academic qualification related to the PM field. Most of the interviewees were male (64%). Considering the classification of organizations proposed by Müller et al. (2019), 50%, 28%, and 22% of the interviewees had their primary experience in process-oriented, project-oriented, and project-based organizations, respectively. Table 3.7 shows the detailed characterization of the interviewees.

Previous studies stated that 12 interviews should be sufficient when the aim is to understand commonalities within a homogenous group. However, such a sample size is insufficient when interviewees are heterogeneous, the focus of the research question is wide-ranging, or comparisons between interview groups are required (Guest, Bunce, and Johnson, 2006; Michael, 2014; Saunders et al., 2019). In this concern, Creswell (2014) suggested that, for a general study, the expected sample size is between 5 and 30 interviews, whereas Saunders (2019) suggested between 5 and 25 interviews. However, sample size increases when the participant group is heterogenous (Saunders et al., 2019; Guest et al., 2006; Patton, 2014).

Table 3.7. Interviewees' characterization

No.	Label	Duration (min)	Project Management experience (years)	PPM experience (years)	Primary experience (Type of organization)	Current role
1	I1	60	10	7	Project-based	Project portfolio manager
2	I2	59	6	4	Project-based	Project portfolio manager
3	I3	49	4	2	Project-based	Project portfolio manager
4	I4	50	20	3	Project-oriented	Project manager
5	I5	47	8	4	Project-based	Project portfolio manager
6	I6	61	9	1	Project-based	Project portfolio manager
7	I7	60	11	4	Process-oriented	Project portfolio manager
8	I8	56	10	2	Process-oriented	Project portfolio manager
9	I9	73	15	5	Project-oriented	Project portfolio manager
10	I10	45	11	5	Project-oriented	Project portfolio manager
11	I11	50	10	3	Project-based	Project portfolio manager
12	I12	57	8	3	Process-oriented	Head of improvement office
13	I13	48	5	2	Project-oriented	Project portfolio manager
14	I14	60	13	10	Process-oriented	Project portfolio manager
15	I15	51	20	8	Project-oriented	Head of PMO
16	I16	66	7	3	Project-oriented	Project portfolio manager
17	I17	46	12	1	Process-oriented	Project portfolio manager
18	I18	31	20	5	Process-oriented	Executive director
19	I19	73	15	5	Process-oriented	Head of PMO
20	I20	46	3	1	Process-oriented	Project portfolio manager
21	I21	59	4	1	Process-oriented	Project portfolio manager
22	I22	41	15	7	Process-oriented	Project portfolio manager
23	I23	49	7	3	Project-oriented	Executive director
24	I24	47	15	10	Process-oriented	Head of PMO
25	I25	42	7	3	Process-oriented	Head of PMO
26	I26	32	7	3	Process-oriented	Project portfolio manager
27	I27	47	10	4	Process-oriented	Project portfolio manager
28	I28	73	18	7	Project-oriented	Head of PMO

As the interviewees' profile was exclusively oriented towards Colombian portfolio practitioners with experience in portfolios of organizational development projects, the participant group can be considered homogeneous. Therefore, it was expected between fifteen and thirty interviews. In this regard, the sample size of twenty-eight interviews conducted in this study was considered adequate for understanding commonalities within the interviewees' group, i.e., identifying the figurative core regarding the constructs

under study. In addition, once performed the interview analysis, it was considered that no additional interviews were required. The above is in line with the saturation concept. The point in data collection and analysis when new information produces little or no change in the results - codes, themes, ideas representation (Guest et al., 2006; Saunders et al., 2019).

3.3.6 Interviews Data Analysis

In-depth analysis of qualitative data sets produces well-grounded explanations (Saunders et al., 2019). For this purpose, fragmenting these data sets and rearranging them into analytical categories associated with the research question is generally accepted (Saunders et al., 2019). Therefore, although during the SLR a conventional CA was carried out, for the empirical data, a Thematic Analysis (TA) approach was employed. TA has a shared history with CA and thereby TA and CA have been often used interchangeably ignoring their similarities and differences (Braun, Clarke, Hayfield, and Terry, 2019; Vaismoradi, Turunen, and Bondas, 2013). However, while TA is defined as an adequate technique for theory building purposes, which is focused on analyzing patterns or themes (Braun et al., 2019; Vaismoradi et al., 2013), CA is tailored to describing the characteristics of the data set content (Vaismoradi et al., 2013).

Thus, the qualitative analysis of the answers was geared towards identifying the aspects which compound the figurative core of the constructs under analysis and the main arguments for interviewees considering each theme relevant or not relevant. It involves, therefore, identifying the qualitative arguments which establish that a theme is a part, or not, of the figurative core. To this end, all interviews were fully transcribed by the same researcher (interviewer) and subjected to a TA.

TA allows for full and analytic analysis, aims to identify, in accordance with the research question, patterns or themes across qualitative data sets, and leads to a rich seam of results, explanations, and theorizing (Saunders et al., 2019; Terry, Hayfield, Clare, and Braun, 2017). According to Terry et al. (2017), TA approaches can be classified as coding reliability approaches, codebook approaches, or reflexive approaches, which differ in the way themes are conceptualized. In the coding reliability and codebook approaches, a theme is conceptualized as analytic inputs related to domain summaries. However, while in coding reliability, themes are totally predefined, in the codebook approach, themes can be modified during the data analysis process. In contrast with coding reliability and codebook, in a reflexive approach, a theme is conceptualized as analytic outputs that represent shared meaning-based patterns, organized around a core concept or idea (Braun et al., 2019). For this research, a reflexive TA was adopted. Thus, the set of themes for a PPRA, or themes derived from interviews, correspond to the analytic output of the qualitative data analysis process conducted.

Based on Braun et al. (2019), a six-step procedure was carried out to implement the reflexive TA: (i) familiarization; (ii) generating codes; (iii) constructing themes; (iv) revising; (v) defining themes, and (vi) producing the report.

The familiarization step was carried out based on listening to a sample of interview records and reading all the interview transcriptions and handwritten notes. As a result of this step, and considering that "in practice, any researcher will approach the data with preconceived ideas based on their existing knowledge and viewpoints" (Braun et al., 2019, p. 853), it was defined that the qualitative data should initially be grouped according to the nine 'components for PPRA', four 'PPR categories', and five 'project portfolio success dimensions' identified in the literature. In turn, this initial grouping served to identify whether the interviewees mentioned new or complementary components, risk categories, or success dimensions. In this concern, these possible new elements would complement the literature-based PPRA framework for PPRA design derived from the SLR.

Based on the fact that TA steps represent "a reflexive and recursive, rather than strictly linear, process" (Braun et al., 2019, p. 852), it was established that the analysis process would be carried out in blocks of four interviews at a time. Thus, in the generating codes step, based on the information grouped in the components, risk categories, and success dimensions, a first possible set of codes derived from the analysis of the first block of four interviews was pre-defined. Consequently, the codes were updated in each cycle of analysis; to do so codes were merged, added, or split according to each new group of data. For this step, a sentence was defined as the unit of data analysis. Finally, the data was coded into 26 codes related to the construct 'components for PPRA', 6 codes related to 'PPR categories' – three of them are shared with the construct 'components for PPRA', and 7 codes related to 'project portfolio success dimensions'. Table 3.8 shows an example of codes derived from the analysis of two 'components for PPRA'. The coding process was supported by NVIVO software.

Table 3.8. Examples of codes for two 'components for PPRA'

Components for PPRA	**Codes**
Portfolio operational risk and risk in the portfolio business phase	Organizational view Risk factor sources Risk assessment points Other factors
Impact on higher levels	Organizational strategy Capabilities generated Impact representation

The constructing themes, revising themes, and defining themes steps were carried out recursively to obtain the final set of PPRA themes which are integrated into the results derived from the qualitative analysis of empirical information regarding the constructs under study. To this end, two strategies were considered, either the analysis of codes as building blocks could lead to a possible PPRA theme or a code could be directly promoted to a PPRA theme. After conducting the analysis, no single code was promoted to a PPRA theme. A specific definition of candidate PPRA themes and a test of candidate PPRA themes against the dataset were strategies of analysis implemented as part of the recursive process. This process was oriented to ensure that each PPRA theme was related to a central meaning, PPRA themes comprise the whole dataset and do not overlap, and to analyze how themes are related between themselves. For this reason, thematic maps were developed from the candidate PPRA themes. Figure 3.4 shows an example of how reflexive TA implementation led to the definition of the PPRA themes.

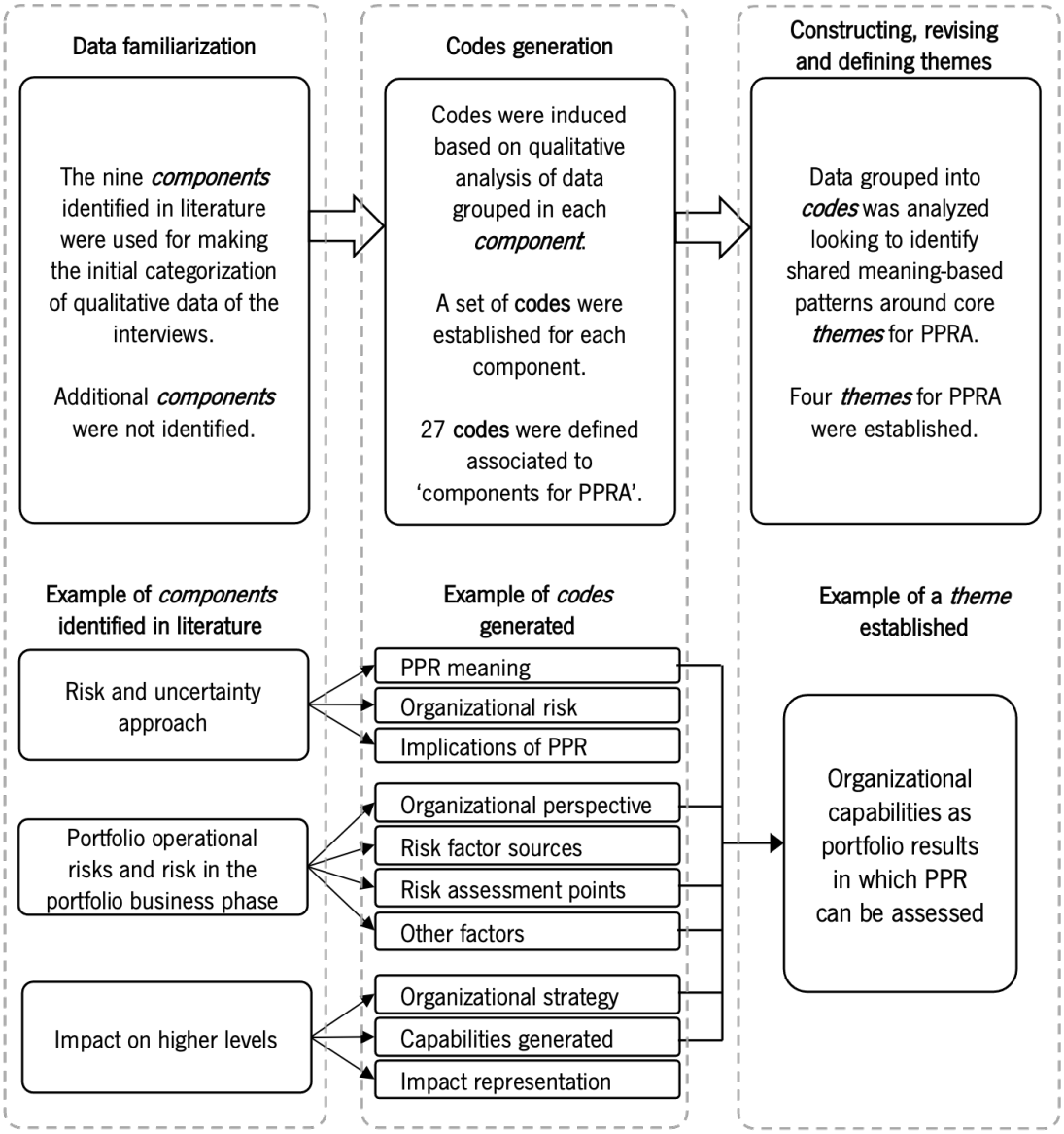


Figure 3.4. Sample illustration of themes identification for 'components for PPRA'

Figure 3.4 gives an example of how the interview data associated with the construct 'components for PPRA' were classified into, first, the components identified in the literature and then into codes produced based on qualitative analysis of each group of data. Finally, based on the analysis of shared meanings between codes, the PPRA themes were established. According to the analysis of shared meanings between codes, six themes were identified as themes through which the figurative core of PPRA can be represented, namely: 'Organizational capabilities as portfolio results in which PPR can be assessed'; 'Project portfolio levels as risk sources for PPRA'; 'Project portfolio as the organizational unit for PPRA'; 'Balance between project portfolio attributes and complexity'; 'Impact extent of risk factors on project portfolio'; and 'Portfolio results based on portfolio effectiveness'.

These six themes represent the figurative core for PPRA in portfolios of organizational development projects from Colombian practitioners' perspectives. In other words, these six themes correspond to the objectification of PPRA, which was obtained from the analysis of how the interviewees represent it. The six themes identified are described in Chapter 5, which corresponds to the sixth step of TA, *producing a report*. Table 3.9 exemplifies the relationship between the nine 'components for PPRA' identified from the literature review and the codes for information classification derived from them, and categorizes the codes according to the four PPRA themes that are directly related to these groups of codes. For this reason, two PPRA themes are not reported in Table 3.9 as they were not related to the codes derived from 'components for PPRA', but rather to the codes derived from 'PPR categories' and 'project portfolio success dimensions'. A comprehensive description of the codes is provided in Appendix B.

The discussion of the findings against the conceptualization of the constructs identified in Phase I and existing literature led to proposing the conceptualization of a comprehensive PPRA in organizational development projects. This proposed PPRA conceptualization represents how risk factors impact the project portfolio success. That impact is represented based on a risk transfer path in which risk factors, projects, capabilities, and success dimensions denote the comprising entities. It also identifies other elements that influence PPRA. The conceptualization of a comprehensive PPRA is presented in Section 5.2.

Table 3.9. Structure for PPRA themes identification

Components for PPRA	Codes	PPRA themes*			
		T1	T2	T3	T4
Risk and uncertainty approach	PPR meaning	X			
	Organizational risk			X	
	Implications			X	
Opportunities incorporation	Relevance				X
	Complexity				X
Portfolio operational risk and risk in the portfolio business phase	Organizational perspective	X			
	Risk factor sources		X		
	Risk assessment points	X			
	Other factors	X			
Impact on higher levels	Organizational strategy	X			
	Capabilities generated	X			
	Impact representation				X
Project interdependency	Interdependencies as risk				X
	Source of complexity				X
	Organizational issues		X		
Risk factor interdependency	Relevance and complexity				X
	Second level				X
Relation of risk among portfolio levels	Interaction between levels		X		
	Projects and programs		X		
	Portfolio		X		
	Organization		X		
Environment characteristics	Strategic management			X	
	Technological context			X	
	Organizational culture			X	
Project portfolio and organizational processes	Risk management process			X	
	Processes influence			X	

** **T1**: Organizational capabilities as portfolio results in which PPR can be assessed; **T2**: Project portfolio levels as risk sources for PPRA; **T3**: Project portfolio as the organizational unit for PPRA; **T4**: Balance between project portfolio attributes and complexity.*

3.4 Phase III: Designing a PPRA Model

As mentioned in Section 3.1 enabling the practical use of knowledge is both a goal of knowledge generation in organizational design science and a means of its legitimation (Avenier, 2010). In this Phase an analytical model to put in practice the proposed conceptualization of a comprehensive PPRA derived from conducting Phase II, is structured. As part of the legitimation of the PPRA conceptualization in practice, the analytical model is applied in a project portfolio belonging to a Colombian organization. Thus, this Phase is composed by: (i) analytical model structuration, and (ii) a numerical analysis of the proposed PPRA model.

3.4.1 Analytical Model Structuration

The proposed PPRA model was developed considering four inputs: (i) the conceptualization of a comprehensive PPRA proposed as results of conducting Phase II, (ii) the requirement that risk interactions must be incorporated, (iii) the methods adopted in previous studies related to PPRA, (iv) alternative methods identified in the literature applied to project risk assessment.

(i) the conceptualization of a comprehensive PPRA proposed as results of conducting Phase II posed that PPRA must allow incorporating entities of different nature through which risk impacts is transferred from risk factor to portfolio success. It means, the PPRA should represent a sequence of entities comprised by multiple sub-entities such as projects or success dimensions (see Section 5.2).

(ii) the requirement that risk factor interactions must be incorporated is derived from the scope of this research project. In this regard, interaction between risk factors was identified as pivotal issue to establish the representation of PPR and its assessment, so that incorporation of risk factor interactions was included in the scope of the research project (see Section 1.3).

(iii) the methods adopted in previous studies related to PPRA were described as part of the literature analysis conducted in Phase I; specifically, they were described covering the construct 'risk assessment method' defined in the first cycle of literature analysis (see Section 3.2.4). The methods applied to PPRA are reported in Section 4.4.

(iv) alternative methods identified in the literature applied to project risk assessment were identified to complement the possibilities of risk representation. Methods applied to project risk assessment were studied considering that project risk analysis could offer additional options to risk assessment possibilities obtaining a wider range of alternatives rather than only considering the methods already proposed at the PPRA level.

The two first inputs represent requirements to be covered by a PPRA model. Thus, the method for PPRA should allow incorporating a sequence of entities of varied nature comprised by multiple sub-entities through which risk impacts are transferred and represented. It should also incorporate the impact of risk factors interdependency on expected results. In contrast, the two last inputs correspond to strategies or methods through which those requirements could be covered.

Consequently, methods in which risk is represented as a unidimensional measure were discredited, such as those derived from MPT in which risk is assessed in accordance with economic profitability. Also, methods as Data Envelopment Analysis or similar, were discredited because, although they can incorporate multiple entities, the entities are represented only as inputs or outputs which does not allow a representation of the sequential influence between entities. Then, it was identified that network-based approaches presented a suitable fit with the requirements. Bayesian Networks, Complex Networks, Meta-Networks Analysis (MNA), Interpretive Structural Modeling (ISM), and Matrice d' Impacts Croices Multiplication Appliquée a un Classement (MICMAC) represent common methods applied in the literature for risk assessment.

In this concern, it was considered that methods based on MNA capture better the representation of a sequence of entities of varied nature which are comprised by sub-entities. Also, MNA allows to represent the final and partial results based on multiple outputs (see for instance T. Wang, Gao, Liao, Ganbat, and Chen, 2021). And finally, it is possible to incorporate different configurations of interdependency for each group of sub-entities and for the relationship between entities (see for instance Y. Li, Lu, Li, and Ma, 2015), i.e., it has a high flexibility. A meta-network can be conceptualized as a multi-node and multi-link network composed of different node entities and connections among them (Y. Li et al., 2015; T. Wang et al., 2021). According to T. Wang et al. (2018), MNA has been used in diverse fields such as supply chains, e-commerce, knowledge networks, and public health systems. Then for modeling the risk transfer path which represents how risk factor impacts the portfolio success dimensions a MNA was adopted. Specifically, the proposed structure for PPRA was based on publications made by T. Wang et al. (2018) and T. Wang et al. (2021). The general structure for PPRA based on MNA is reported in Chapter 6.

MNA allows specific representation of interaction between sub-entities of each entity. Then, a structure based on the integration of ISM and MICMAC was adopted for modeling interactions between risk factors. ISM and MICMAC have been used in an integrated way widely in the literature (Dandage, Mantha, and Rane, 2019; L. Guan, Abbasi, and Ryan, 2020). An ISM-MICMAC model helps identify all possible pairwise relations and the dependence and drive power of the elements comprising the system studied (Dandage et al., 2019; L. Guan et al., 2020). ISM-MICMAC models have been conducted for risk prioritization of international projects (Dandage et al., 2019), and for analyzing the project interdependency in green building projects (L. Guan et al., 2020), among others. The details regarding ISM-MICMAC incorporation into the proposed PPRA model are reported in Section 6.2.

3.4.2 Numerical Analysis

The project portfolio case study used is from a Colombian company framed in the retail sector (detailed information regarding the project portfolio is provided in Section 7.1). The head of the PMO provided information regarding the portfolio structure and risk factors. Four meetings were carried out with the PMO leader. These meetings lasted between one and two hours. The meetings took place online. The following were the main meetings held:

- Initial contact to provide a brief description of the research project. Explore the possibility of obtaining information from the organization's project portfolio to conduct the case study.
- Presentation of the general structure of the PPRA model and type of specific information required. Explanations regarding some specific elements incorporated within the model were made to clarify the model's scope.
- Presentation of the portfolio information in terms of the projects within the portfolio, strategic orientation, risk factors, qualifications of the risk factors. Also, information regarding the entities represented in the PPRA model was provided.
- Representation of the information provided in terms of the specific PPRA model structure. Discussion and adjustments.

A detailed description of the application of the model is provided in Chapter 7. The results are reported specifically in Section 7.2.3.

3.5 Summary

This chapter outlines the research philosophy and design adopted in addressing the research question and objectives. The *constructivism-founded scientific paradigm for organization research* posed by Avenier (2010) was adopted as the research paradigm for this project research. As in organizational design science, the goal of the this research paradigm is to develop knowledge to guide design processes, i.e., knowledge that is oriented to support the design and implementation of organizational artifacts having desired properties (Avenier, 2010; Mohrman, 2007).

The main goal of this research is to develop knowledge to guide the PPRA design process in a way that interactions among risk factors and their impact on the project portfolio success can be considered. For this research, two outputs were established: (i) A comprehensive PPRA conceptualization, and (ii) a PPRA model. To achieve these research outputs three research phases were conducted, the first two associated with the conceptualization of a comprehensive PPRA, and the last phase associated with the PPRA model.

Phase I is based on a Systematic Literature Review (SLR) which was conducted in two cycles. The literature search was carried out using the SCOPUS and WoS databases. In the first cycle the query "project portfolio" and "risk" was used, being selected 62 papers. In the second cycle the query "project portfolio success" was used and 18 papers were selected. The selected papers were analyzed conducting conventional Content Analysis (CA). The analysis led to define and characterize four constructs associated with PPRA, namely, 'components for PPRA', 'PPR categories', 'project portfolio success dimensions', and 'risk assessment method'. A detailed description of the findings derived from Phase I are reported in Chapter 4.

Phase II was designed to conceptualize PPRA from the practitioners' perspective. For that, a semi-structured interview was designed based on the four constructs identified in the previous phase and Social Representation Theory (SRT) was adopted as the theoretical lens. Specifically, the Phase II was focused on identifying the objectification of PPRA. Objectification is defined as the process by which the object is reproduced and described in a concrete and selective manner (Bergquist et al., 2020; Rateau et al., 2012). Twenty-eight interviews were conducted with Colombian professionals with experience on PPM. Interview data analysis was conducted based on reflexive thematic analysis (TA), following six steps: (i) familiarization; (ii) generating codes; (iii) constructing themes; (iv) revising; (v) defining themes, and (vi) producing the report. The analysis was supported by NVIVO software. This research phase led to identify that practitioners' perspective can be represented in six interdependent themes. Four propositions emerged from the discussion of the results. Then, based on the six themes and four propositions, a comprehensive PPRA conceptualization is proposed. A detailed description of the findings derived from Phase II is reported in Chapter 5.

In Phase III an analytical model to put in practice the comprehensive PPRA conceptualization is proposed. For that end, it was identified that network-based approaches presented a suitable alternative to modeling PPRA. Specifically, for modeling the risk transfer path that represents how risk factor impacts the project portfolio success dimensions, a Meta Network Analysis (MNA) was adopted. The relationship between risk factors was modeled following an Interpretive Structural Modeling – Matrice d' Impacts Croices Multiplication Appliquée a un Classement (ISM-MICMAC) method. The proposed model is described in Chapter 6. The proposed PPRA model was applied to a project portfolio of a Colombian company. According with organizational design science, enabling the practical use of knowledge is both a goal of knowledge generation in organizational design science and a means of its legitimation (Avenier, 2010). A detailed description and analysis of the application of the PPRA model in the project portfolio case study is presented in Chapter 7.

PART II. RESEARCH DEVELOPMENT: A COMPREHENSIVE PPRA CONCEPTUALIZATION

4. LITERATURE-BASED FRAMEWORK FOR PPRA DESIGN

Risk assessment converges diverse attributes and considerations derived from the portfolio management phases and the risk management approaches on which risk assessment at the portfolio level has been grounded. Literature analysis helps examine the existing body of knowledge and obtain a richer perspective (Saunders et al., 2019). A SLR was then conducted to establish the attributes and considerations underlying PPRA design. Certain attributes, such as project interdependency or the existing risk approaches, have already been mentioned in previous chapters. However, the literature review sought to obtain a wide view of those attributes and considerations scattered across the literature in the PPRM field, which have implications for PPRA design. As described in Section 3.2, a conventional CA was conducted during the SLR, i.e., in the research Phase I.

This chapter presents the results of Phase I. The first four sections are organized according to the four constructs defined in the methodological design of Phase I (see Section 3.2): 'components for PPRA', 'PPR categories', 'project portfolio success dimensions', and 'risk assessment method'. Thus, 'components for PPRA' are described in Section 4.1, 'PPR categories' in Section 4.2, and 'project portfolio success dimensions' in Section 4.3. Findings regarding 'risk assessment method' are described in Section 4.4. Section 4.5 describes the framework for PPRA design which is based on the integration of results obtained in the previous Sections. However, the characterization of the construct 'risk assessment method' was not incorporated into the framework because the different methods attend to considerations and characteristics that are not generalizable. Information regarding 'risk assessment method' was considered an input for Phase III of this research project.

4.1 Components for PPRA

Bearing in mind that risk assessment is not isolated from other elements of risk management, the characterization of the 'components for PPRA' identified in the literature covers those that are representative for designing a PPRA by considering a broader PPRM perspective. This means that decisions regarding the components are not exclusive to the PPRA element, but, being framed in the PPRM, they influence the PPRA design.

Nine components represent the different aspects to consider when designing a PPRA. Thus, a PPRA should integrate the decisions made concerning each component. This notion is in line with the conceptualization of component as a part that combines with other parts to form something bigger (see Section 1.4). Therefore, these components and the decisions related to them frame the scope and characteristics of a PPRA. The nine components were classified into three groups, namely conceptual, technical, and organizational components. These three groups do not correspond to a specific classification identified in the literature, but they were introduced to establish common types of considerations between components. Figure 4.1 depicts the nine components identified and their classification.

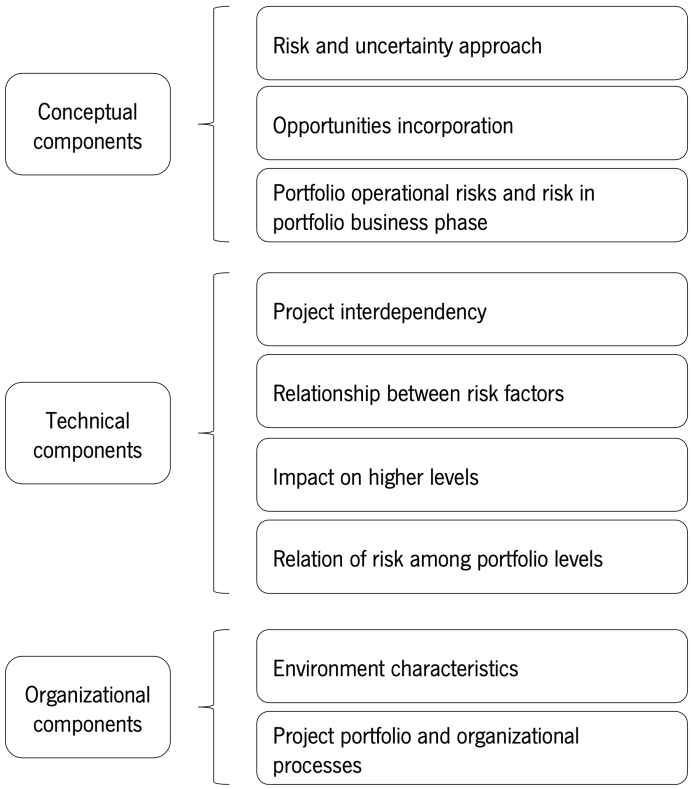


Figure 4.1. Components for designing a PPRA

Conceptual PPRA components concern aspects related to theoretical or conceptual approaches' definitions or decisions within the risk assessment's conceptual scope, for instance, the definition of the risk approach in which the PPRA proposed is framed. This, in turn, would define what is meant by risk and uncertainty as well as whether the proposed PPRA covers both concepts. Then, conceptual components define what is understood by PPR under the PPRA to be proposed. Technical PPRA components are related to decisions as to the PPR representation into the PPRA. Thus, technical PPRA components define the attributes to be represented into the PPRA as well as the scope and depth to which they are considered. For instance, regarding project interdependency component, decisions are

not just about whether dependencies between projects are considered but also what kind of dependencies and what level of detail are contemplated. Finally, organizational PPRA components are concerned with aspects of the organizational environment (both internal and external) related to the project portfolio and the processes that should be considered as part of the definition or design of the PPRA.

4.1.1 Conceptual Components

Three components for designing PPRA constitute the conceptual components category: (i) risk and uncertainty approach, (ii) opportunities incorporation, and (iii) portfolio operational risk and risk in portfolio business phase.

i) Risk and uncertainty approach:

The literature coincides in that, beyond its denomination, there are two types of events or factors that impact the project portfolio performance and the project portfolio expected results. On one hand, there are events that can be recognized and measured qualitatively or quantitatively, and on the other hand, there are events or factors that cannot be previously known or measured with certainty (Hofman et al., 2017; Teller, 2013). However, based on the definitions of risk and uncertainty, several conceptual approaches have been posed to establish how to represent them and how they relate to each other (Hofman and Grela, 2018).

Thus, the literature reported two approaches through which risk and uncertainty are conceptualized. In the first one, risk is a consequence or a measure of uncertainty impact (Hofman et al., 2017). In this regard, uncertainty is the input for risk assessment and is represented by events of uncertain nature that have an impact on expected results (Costa et al., 2007; Tofighian et al., 2018). Therefore, effort is directed towards representing uncertain events due to contextual conditions of projects within the portfolio and the portfolio itself. In this approach, risk is the representation of the impact on expected results, and different risk measures can be explored according to the decision maker's risk aversion (Tofighian et al., 2018; Yan and Ji, 2017; Yousefi et al., 2018). It was identified that this risk and uncertainty approach underlies the literature on project portfolio selection with risk considerations problem.

The second risk approach has been conceptualized from two different perspectives. According to the first perspective, risk is the uncertainty's foreseeable component as uncertainty is composed of foreseeable and unforeseeable or unexpected events (Smalley et al., 2008; Teller, 2013). In this

perspective, the focus is on how to represent risk events and their impact on expected results while, because of their own nature, unexpected events are not included in the risk assessment (see for instance D. Guan et al., 2017). Thus, risk is usually represented as an output affected by specific risk factors or events, which represent the inputs for the assessment, and uncertainty is associated to the environment of the different project's types within the portfolio or the portfolio itself (Ghasemi et al., 2018; D. Guan et al., 2017).

In a second perspective of the second risk approach, risk and uncertainty are defined independently (Hofman and Grela, 2015). Here, both risk and uncertainty represent outputs of risk and uncertainty analysis, respectively. Thus, from a risk assessment perspective, this perspective adopts a similar focus to the first perspective concerning how to represent the impact of risk factors on the expected results. Regarding uncertainty, the analysis is usually focused on the representation of imprecise or incomplete information (Chatterjee et al., 2018), as well as on the uncertainty assessment and their impact on the decisions related to the project portfolio (Panadero et al., 2020; Tofighian et al., 2018).

Then, defining the risk and uncertainty approach determines the PPRA scope. In this regard, supporting the PPRA in accordance with one or another approach defines what is the focus of the assessment as well as what is included and what is not in the assessment to be conducted.

ii) Opportunities incorporation:

Opportunities or positive impacts' analysis can help to identify benefits and positive impacts and generate compensatory effects in relation to risk, however, it also adds complexity to the analysis (D. Guan et al., 2017). Factors like resource interactions and exposition to the same external variables could generate both positive and negative effects so that opportunities analysis should be incorporated as part of risk management in a project portfolio context (Hofman and Grela, 2015; Olsson, 2008; Sanchez and Robert, 2010b; Sanchez et al., 2008; Smalley et al., 2008; Teller et al., 2014).

In this concern, approaches based on the first risk and uncertainty approach tend to incorporate both negative and positive impacts derived from uncertainty, which are represented in the variation measures associated to each project within the portfolio (Yousefi et al., 2018). This incorporation is derived directly from the MPT, in which the estimation of the financial assets value incorporates both positive and negative variations to optimize the risk-return relationship. Thus, by itself, uncertainty represents possible positive and negative risk consequences (Yan and Ji, 2017; Yousefi et al., 2018). Given that, this risk approach is usually associated to the first PPM phase, i.e., portfolio structuration,

where main considerations associated to the business phase of projects within the portfolio are established as uncertainty sources.

However, from the other two risk approaches, opportunities and threats represent specific events or factors. Risk factors associated to the business phase of projects as well as to the execution of projects are considered for both project portfolio selection and project portfolio execution perspectives (see for instance Chatterjee et al., 2018; and Neumeier et al., 2018). However, only negative impacts are assessed in these approaches. In this regard, D. Guan et al. (2017) mentioned that negative impacts or threats are widely analyzed, whereas opportunities or positive impacts on the project portfolio are rarely analyzed.

Then, the way to represent opportunities is linked to the risk and uncertainty approach adopted – the first identified component for PPRA. Therefore, whether the impact of opportunities on portfolio risk is incorporated or not, and how opportunities are represented must be in line with the risk and uncertainty approach adopted. The above, in turn, also delimits the PPRM scope and the PPRA scope because it is considered a PPRM element.

iii) Portfolio operational risk and risk in portfolio business phase:

Another consideration is that the literature in this field describes two stages over which the PPR should be evaluated. The first one is the technical, or operational, risk associated with the result of project portfolio execution. The second one is the commercial, or business phase, risk generally associated with market, economic, or organizational factors of the business phase of projects. Both contribute to the PPR composition but in different ways (Hall et al., 2015; Paquin et al., 2016).

Some differences between these stages were described by Paquin et al. (2016), who mentioned that, for instance, the project portfolio diversification in the investment phase does not imply that the operational project risks of the project portfolio are also diversified. This indicates that the risk composition between both phases is different so that a wide view of the portfolio risk requires providing information about the risk composition in both phases. For instance, when portfolio risk is assessed considering only the business phase of projects, it has been implicitly assumed that the execution of projects would deliver the product or expected results to the organization (Hall et al., 2015).

However, operational risk must also be incorporated to obtain a comprehensive PPR view. When projects within the portfolio do not achieve their expected objectives under the desired conditions, the expected results of the business phase are directly impacted, and, in some occasions, it does not allow

reaching and executing the business phase (Hall et al., 2015; Paquin et al., 2016). In this regard, when a project portfolio perspective is adopted, operational or technical risk derived from projects within the portfolio should be understood as consequences over the entire project portfolio life cycle due to events that occurred in the investment phase, that is, during the execution of the projects within the portfolio (Hall et al., 2015; Paquin et al., 2016).

Thus, although a PPRA may be focused on the risk derived from one of the phases, it should not fail to recognize the project portfolio as the level at which risk is assessed. In this regard, the PPRA scope is also framed in terms of whether it covers one or more phases and the assumptions each phase implies for the PPRA.

4.1.2 Technical Components

Four components for PPRA constitute the technical components category: (iv) project interdependency, (v) risk factor interdependency, (vi) impact on higher levels, and (vii) relation of risk among portfolio levels.

iv) Project interdependency:

Interdependencies between projects are one of the issues that allow researchers to argue that risk management at the project level is not enough to ensure the success of projects within a portfolio and, consequently, the project portfolio success (Ghasemi et al., 2018; Heinrich et al., 2014; Hofman et al., 2017; Neumeier et al., 2018; Olsson, 2008). Interdependencies between projects are common either in technical aspects related to project execution, or in commercial aspects associated with business issues. They can bring positive or negative contributions to the expected benefit and to the project portfolio as a whole (Ghasemi et al., 2018; Hall et al., 2015; Neumeier et al., 2018; Olsson, 2008).

Ignoring the interdependencies between projects and their effects may lead to several projects not achieving planned results and, consequently, the project portfolio not attaining its expected results (D. Guan et al., 2017). For instance, failures in a project can cause negative impacts to other projects in the portfolio, which can lead to not achieving the portfolio objectives (D. Guan et al., 2017). However, most of the risk approaches do not consider dependencies, and the existing literature is insufficient on this topic (Neumeier et al., 2018). In this regard, although the integration and cooperation between projects in a portfolio can increase efficiency, it also influences the PPR (Neumeier et al., 2018; Q. Wang et al., 2017). In this concern, it is important to note that an interaction that produces a positive effect is generally called synergy (Hall et al., 2015).

In the literature, the relationships between projects have been addressed from different perspectives. They can be addressed in terms of the type of interaction and temporality. In temporal terms, two types of relationships between projects have been defined: Inter-temporal or dependencies, which are related to outputs expected from previous projects or previous phases of projects within the portfolio; and intra-temporal or interdependencies, which are related to the common aspects between projects required to be managed simultaneously (Ghasemi et al., 2018; Heinrich et al., 2014; Olsson, 2008). Thus, for instance, Neumeier et al. (2018) studied the impact of risk derived from resources shared between projects on projects' success also considering the technical dependency between projects. In this respect, shared resources represent an intra-temporal relationship, while technical dependency represents an inter-temporal relationship.

In this regard, shared resources and technical dependences are two types of interactions between projects. So, from a PPR perspective, these types of relationships between projects could be represented by resources interaction or shared resources, technology and knowledge relationship, technical or outcome dependencies, value interaction, accomplishment interaction, and strategic or benefits interaction (Ghasemi et al., 2018; D. Guan et al., 2017; Heinrich et al., 2014; Neumeier et al., 2018; Sanchez et al., 2008). The first three types of interdependencies can be associated with relationships that impact the performance of projects within the portfolio, i.e., they could be represented as risk derived from project portfolio inputs. In contrast, the remaining three types of relationships between projects are related to what the portfolio produces, i.e., they could be represented as risk derived from project portfolio outputs.

Resources relationship is associated with sharing resources between projects; technology and knowledge relationship refers to using a specific and common technology or knowledge in several projects; technical or outcome dependencies are related to using the end or partial result, and knowledge or capabilities gained from other projects; value interaction happens when the total value of two or more projects is greater or less than the sum of their values; accomplishment interaction is associated to increasing or decreasing the success probability of a project due to undertaking another project; and, strategic or benefits interaction represents the relationship between projects regarding how they impact the company strategic objectives (Ghasemi et al., 2018; Mohagheghi et al., 2016; Sanchez et al., 2008). Thus, depending on the PPRA focus, one or several types of relationships between projects could be incorporated into PPRA.

v) Risk factor interdependency:

Another technical component, risk factor interdependency, is associated with the consideration that risks among projects are not always independent, so it represents how one risk factor can affect the probabilities and impacts of other risk factors (Namazian and Yakhchali, 2018). In this regard, an aspect identified in the literature is the difference between correlation and interaction, since their effects on PPR are significantly different in each case (Hall et al., 2015).

On one hand, correlation establishes the influence that an external factor can have over a specific set of variables, representing the relation between the behavior of two risk factors. From a project-centered perspective, correlation is associated to the fact that two or more projects are affected by the same risk factor or set of risk factors. Besides, risk factors considered as having a low impact on a project may be correlated with the same risk factor in other projects within the portfolio. Also, it could be correlated with other risk factors in the same project or other projects (Cooley et al., 2012). On the other hand, interdependence refers to the relationships and influences one variable has over another, which could be considered as events generating threats or opportunities (Hall et al., 2015). The dependencies between risk factors can be unidirectional or bidirectional, i.e., they could be represented as dependencies or interdependencies (Ghasemi et al., 2018; Q. Wang et al., 2017). In this regard, this type of relationship between risk factors is usually represented as a network of risk factors. Then, these networks can help to describe the impact of risk factors on an expected result (Ghasemi et al., 2018; Q. Wang et al., 2017). For instance, Ghasemi et al. (2018) assessed the impact of risk factors on the project portfolio considering the dependency between them.

Accordingly, these characteristics allow incorporating both inter-temporal and intra-temporal effects derived from the relationships between risk factors. In addition, incorporating interdependence and correlation between risk factors allows identifying those with the most significant impact on the project portfolio objectives by considering both their direct and indirect impact (Cooley et al., 2012; Q. Wang et al., 2017). Thus, a PPRA could include the relationship between risk factors or not. Therefore, the decision on including correlation, dependencies, or both in PPRA has to be made beforehand.

vi) Impact on higher levels:

From a PPRM perspective, different levels associated with project portfolio expected results have been proposed for assessing the portfolio risk. These levels are mainly linked to project portfolio objectives, PPM objectives, strategic objectives (Ghasemi et al., 2018; Sanchez et al., 2008; Teller, 2013), and the financial performance of projects from an organizational perspective (Panadero et al.,

2020; Yan and Ji, 2017). However, risk management based only on financial risk ignores intangible aspects such as the effect on success factors or strategic objectives (Drake and Byrd, 2006; Sharifighazvini et al., 2018).

Hence methodologies have been proposed to consider threats and opportunities' impact on strategic aspects, through which the project portfolio performance could be monitored from a strategic perspective (Sanchez and Robert, 2010b; Sanchez et al., 2008; Teller and Kock, 2013). Also, the literature shows that risk management positively influences project portfolio success (Teller, 2013; Teller and Kock, 2013), so the effect of risk factors on possible success factors that condition project portfolio success, also called negative phenomena, have been evaluated (Hofman et al., 2017). As a consequence, a link between risk factors, success factors, strategic objectives, portfolio performance, and portfolio success could be stablished (Ghasemi et al., 2018; Hofman et al., 2017; Sanchez and Robert, 2010b).

Therefore, an expanded view of risk evaluation could consider the impact of risk factors beyond the performance and outcome of projects that make up the portfolio. Thus, risk assessment from a portfolio perspective should consider these impacts and characteristics at higher level (Ghasemi et al., 2018; Sanchez and Robert, 2010b; Sanchez et al., 2008). In this regard, it is necessary to define the level on which project portfolio results are represented. For this reason, the impact of changes in risk factors on the defined project portfolio level frames the design of any PPRA.

vii) Relation of risk among portfolio levels:

PPM has been defined as the bridge between strategy and projects for which the coordination between project, program, and portfolio levels is a PPM fundamental element. In this regard, previous studies showed that, for instance, project management efficiency influences PPM (Teller et al., 2014). Accordingly, Teller et al. (2014) evidenced that project risk management is positively linked to project portfolio success so that joint risk management at both management levels increases the positive influence on project portfolio success. Thus, the literature claims that PPM processes should integrate both project and portfolio risk levels from a risk management perspective (Olsson, 2008; Sanchez et al., 2008; Teller et al., 2014).

Since PPRM would not be independent of project and program risk management, it must allow integrated risk management among decision levels of the project portfolio. It must also help monitor if projects and programs are performing adequately and are in line with portfolio expectations (Arena et al., 2014; Sanchez and Robert, 2010a). Moreover, the literature suggests PPRM must be integrated into

enterprise risk management, supporting the integration and coordination of decisions between each organizational level (Arena et al., 2014; da Silva et al., 2017). For instance, Paquin et al. (2016) proposed the evaluation of portfolio risk based on the risk that the portfolio delivers to the organization's operation.

Then, PPRA as an element of PPRM could also adopt an integrated perspective between portfolio-related levels, focused on the integration of some of these levels, or be exclusively oriented towards the project portfolio level. As examples, Hofman et al. (2018) conducted a risk assessment based exclusively on risk factors at the portfolio level, Ghasemi et al. (2018) integrated risk at the project and portfolio levels, and Q. Wang et al. (2017) conducted a risk assessment based on risk factors derived from the projects. Thus, the framing of PPRA at different portfolio-related levels modifies its structure, requirements, and expected results.

4.1.3 Organizational Components

Two components for PPRA constitute the organizational components category: (viii) environment characteristics and (ix) project portfolio and organizational processes.

viii) Environment characteristics:

Competitive dynamics and the organization's environment are determining elements in PPRM processes because they affect both risk perception and risk conditions (Floricel and Ibanescu, 2008; Sanchez et al., 2008). Besides, risk sources are dynamically and constantly modified, making necessary the development of risk management capabilities that are appropriate to each organization's environment (Floricel and Ibanescu, 2008). Thus, the risk profile of a project portfolio must be characterized by its dynamic and changing nature during the PPM (Hofman et al., 2017).

Environment characteristics can be associated, without being exclusive, with the project portfolio composition (Heinrich et al., 2014; Q. Wang et al., 2017)and the portfolio role in the parent organization (Arena et al., 2014; Olsson, 2008). Regarding portfolio composition, Q. Wang et al. (2017), for instance, showed that, if the group of projects is highly homogeneous, the risk is easily spread amongst projects when the risk occurs randomly. However, other aspects, such as the relevance of risk information into portfolio management, seem to be similar among projects portfolios. Specifically, Teller et al. (2014) showed it by contrasting R&D- and non-R&D-dominated portfolios. Although some aspects could remain homogenous between different types of project portfolios, other aspects related to the portfolio composition could lead to considering different conditions into PPRA as an element of the PPRM.

Regarding the role of the portfolio in the parent organization, the literature recognizes that project portfolios in project-based and non-project-based companies represent a difference in the structure and meaning of both project portfolios expected results and PPR. In the first case, project portfolio represents the core operation of the organization (Olsson, 2008). In this regard, the scope of the project portfolio could cover both execution of projects and their business phase such as portfolios of energy exploration projects (Tang et al., 2017; Yan and Ji, 2017). But, in other cases, the project portfolio only covers the execution of projects such as project portfolios of software development companies (Costa et al., 2007; Q. Wang et al., 2017).

For non-project-based companies, project portfolios are usually oriented to internal developments through which operation and strategic deployment are supported. For instance, D. Guan et al. (2017) showed a technology information project portfolio executed in a bank, and Sanchez et al. (2008) focused on project portfolios oriented to directly impact strategic objectives. Thus, portfolio outputs represent inputs for the parent organization, or, in other words, portfolio expected results are associated to the value provided to the parent organization.

Then, given the differences in the project portfolio composition and the portfolio role in the parent organization, PPRA orientation is not necessarily the same in each case because it must respond to the particular needs of organizations (Arena et al., 2014; Olsson, 2008).

ix) Project portfolio and organizational processes:

Management capabilities framed in PPRM are emphasized in this component since several strategies that lead to project portfolio success can be established through risk management capabilities, causing a positive impact on organizational objectives (Arena et al., 2014; Floricel and Ibanescu, 2008). In addition, Teller et al. (2014) posited a link among the style of project management, risk management, and project portfolio success. Similarly, a relationship between risk management process and project portfolio success can be posed, where, among other factors, risk management processes formalization or risk management culture could influence risk management quality (Teller and Kock, 2013).

Management quality is related to information quality associated with information transparency, resource allocation quality, cooperation between management roles quality, and termination quality related to decisions of abort projects (Rank et al., 2015). In this regard, risk information may lead to the postponement or cancellation of projects (Teller et al., 2014). Thus, project portfolio and organizational processes are related to how the PPR is managed but also to identifying elements that influence the expected results of the project portfolio. To complement this, PPR visualization has been also emphasized

in the literature as critical to facilitating the planning, monitoring, and controlling risk throughout the entire project portfolio life cycle (da Silva et al., 2017; Q. Wang et al., 2017).

4.2 Project Portfolio Risk Categorization

Olsson (2008) and Sanchez et al. (2008) proposed methodological frameworks for risk identification in the project portfolio context. Opportunities identification is done through analysis of experiences from previous projects, analysis of portfolio execution, and considering the risk and project interactions (Olsson, 2008; Sanchez et al., 2008). In addition, Hofman et al. (2017) suggested that the efficiency of risk management can be increased if the identification of risks is carried out constantly, both for projects that will be initiated as well as for projects in execution and already completed. Floricel and Ibanescu (2008) defined that risk of R&D project portfolios can be affected by four dimensions of a dynamic environment, such as velocity, turbulence, growth, and instability.

Thus, some authors have identified different 'PPR categories' such as cultural and climate risks and risks related to contracts, being this associated to each project within the portfolio. Other authors have identified risk factors derived from the relationship between projects, and other publications have been focused on risk factors at the project portfolio level. Table 4.1 presents a summary of explicit risk sources categories identified in studies in which risk management has been incorporated in project portfolio decisions. In addition, Table 4.1 shows the specific context in which each risk categorization was proposed or analyzed.

These categories are associated with risk sources, i.e., risk factors. For instance, risk factors are identified and assessed in some publications according to their impact on each project, i.e., by considering the impact on projects (see Chatterjee et al., 2018; or Sharifighazvini et al., 2018). While in other publications, risk factors are identified and assessed by considering the impact on portfolio goals or portfolio level (see Ghasemi et al., 2018; and Hofman and Grela, 2018). Also, some publications focus on risk factors associated with the business phase (Razi et al., 2015), while others consider risk factors related to the portfolio execution (Drake and Byrd, 2006). The above shows that different types of considerations about how risk factors impact the project portfolio can be considered into PPRA.

Table 4.1. PPR factors

Reference	Context	PPR categories
Sanchez et al. (2008)	General project portfolios.	(1) External risks associated with sources of risk deriving from the project portfolio interaction with the context, and (2) sources of risk related to the project portfolio interaction with internal processes.
Hofman and Grela (2015), Hofman et al. (2017)	General project portfolios.	(1) Structural risks associated with the composition of a group of projects and the potential interdependencies among components. (2) Component risks are project risks that the project manager needs to adjust to the portfolio level for obtaining information or taking action. (3) The overall risk considers the interdependencies between projects.
Chatterjee et al. (2018)	General project portfolios.	(1) Fund arrival rate, (2) technical risk, (3) ratio of completion time and average, (4) financial risk, (5) quality risk, (6) transportation availability, (7) legal exposure, and (8) political impact.
Hofman and Grela (2015)	General project portfolios. Based on most important areas forming the source of PPR.	(1) Unpredictable phenomena appearing in the portfolio environment and changes in the basic parameters of projects and programs implemented, (2) problems with the availability of resources, irregularities in processing, (3) aggregating and distributing information as well as improper knowledge transfer , (4) conflicts between the portfolio manager and middle and top management as well as the lack of involvement of top management, (5) improper portfolio structure resulting from mistakes in prioritization that fail to guarantee the achievement of strategic goals, (6) improper management of the life cycle of projects and programs and the problems with the flow of products, and (7) problems with financing stability and the financial liquidity of the portfolio.
Sharifighazvini et al. (2018)	General project portfolios. Case study: Company producing steel sheets.	(1) Changes in inflation rate, (2) change currency, (3) subsidy, (4) changes in government policies, (5) international restrictions, (6) complexity of design, (7) lack of skilled manpower, (8) risks related to contract, (9) changes in the scope and running time, and (10) weather conditions.
Guan et al. (2017)	General project portfolios. Application for IT portfolio.	Internal interactions of a project portfolio composed by (1) benefit interaction, (2) resource interaction, and (3) technology interaction.
Ghasemi et al. (2018)	General project portfolios. Application in construction portfolio.	(1) Portfolio-level risk, (2) risk of each independent project, and (3) project interdependency risk composes by (3.1) value interdependency, (3.2) resource interdependency, (3.3) accomplishment dependency, (3.4) outcome dependency.
Drake and Byrd (2006)	Information technology (IT) project portfolios.	(1) Strategic alignment risks, (2) organization and management risks, (3) cultural and climate risks, (4) project relationship risks, and (5) financial risks.
Petit and Hobbs (2010)	Based on software development portfolio case study.	(1) New product (scope), (2) project performance, (3) changes in processes, (4) need for customization, (5) new customers and new market (scope change), (6) changes in agreements with third-party suppliers (scope change), (7) structural reorganizations, (8) technology, and (9) change in business strategy.
	Based on financial services portfolio case study.	(1) New interpretations of the norms (scope change), (2) changes in the norms (scope change), (3) project performance, (3) portfolio budget reduction, (4) technology, (5) organizational change, and (6) changes in strategy.
Relich and Pawlewski (2017)	New product development (NDP) portfolios.	(1) Lack of sufficient resources to achieve the objectives of NPD project, (2) suppliers that are not able to deliver the required materials, and (3) competitors who develop the similar product first.
Razi et al. (2015)	Oil project portfolios.	(1) Political risk, (2) environmental risk, (3) technical risk, (4) trade risk composed by finance risk and tariff risk, and (5) economic risk composed by price risk, exchange risk, and inflation risk.

As such, identified risk categories can be considered as an input for the risk identification element, which, in turn, represents the primary input for PPRA. However, according to the above described, from a PPRA perspective it is not just focusing on which risk factors will be considered but also on how to represent the different impact extending from those risk factors to the project portfolio. In this regard, Hofman and Grela (2018), for instance, identified specific risk factors for a project portfolio and classified them in three risk categories: Component, structural, and overall risk. However, the authors assessed the impact of all risk factors based on the impact on project portfolio goals as an aggregated value. Only Ghasemi et al. (2018) assessed and categorized risk factors according to the extended level impact on the portfolio or portfolio components. The levels are defined as (i) portfolio level risk and (ii) project total risk. The last one is composed by interdependent projects risk and dependent projects risk. The portfolio level risk is associated with risk factors derived from project portfolio success factors and PPM objectives.

A similar categorization of risk factors was established by Drake and Byrd (2006). They mentioned that there are three risk areas to consider in the project portfolio context: (i) risk of the projects themselves, (ii) risk from the relationship of projects, and (iii) risk of the whole portfolio. However, Drake and Byrd (2006) did not move towards representing the impact derived from each of these three levels. This categorization was drawn on the concepts of systematic and unsystematic risk derived from MPT (Drake and Byrd, 2006). In project portfolio context, unsystematic risk, also called non-systematic risk or specific risk, is associated with risk from individual projects and the relationship between projects' risk (Costa et al., 2007; Drake and Byrd, 2006; Paquin et al., 2016). Systematic risk refers to risk that affects the entire portfolio, which cannot be diversified because it relates to external conditions (Drake and Byrd, 2006; Paquin et al., 2016).

Q. Wang et al. (2017) mentioned that some researches use the MPT applied to project portfolio to incorporate the systematic risk. The above can be observed in publications associated with the optimization of project portfolio selection with risk consideration, which are framed in risk planning based on a general management approach. As was mentioned previously (see Section 2.4.1), these works are mainly focused on risk consideration during the business phase of projects within the portfolio and establishing risk measures as aggregate measures based on monetary values. In those works, the probability distributions of project's net cash flows represent the total risk, whereas the systematic risk is captured by the discount rate, which is the same for all projects within the portfolio(Paquin et al., 2016; Paquin, Tessier, and Gauthier, 2015).

However, this approach has some limitations in practical applications (Q. Wang et al., 2017). For instance, in addition to risk from individual projects and the relationship between projects' risk, project portfolios present interdependencies between projects that also influence the success or failure of other projects (Drake and Byrd, 2006). In addition, while in security portfolio diversification, the systematic risk is non-diversifiable and unalterable, in the project portfolio context, it can be reduced through risk management and efficiency management policies associated with the operational non-diversifiable risk (Paquin et al., 2016).

The categorization of PPR as systematic and non-systematic risk could provide a representation of the impact extent of risk factors on the project portfolio. At the same time, it helps to support risk management (Drake and Byrd, 2006; Paquin et al., 2016). In this regard, Costa et al. (2007, p. 17) mentioned that while systematic risks "are useful for analyzing how external issues may affect an organization, specific risks look for internal factors that can affect its performance". However, this conceptualization of risk categories has been mainly adopted for risk incorporation in the optimization of project portfolio selection, which is centered on an aggregated measure based on monetary terms. Also, moving from security portfolios toward considering all life cycle in project portfolios requires considering the differences presented by Drake and Byrd (2006), Costa et al. (2007), Paquin et al. (2015), and Paquin et al. (2016).

Thus, the literature shows a broad spectrum of risk categories through which risk factors are grouped according to risk sources (as illustrated in Table 4.1). However, the literature is still scarce in terms of the extent to which risk factors impact the portfolio and how these different categories are represented in a risk assessment that recognizes the entire project portfolio life cycle. Therefore, a broader understanding about this topic is still required to ensure that PPR categorization processes are based on valid and context information and feasible in practice (Costa et al., 2007; Ghasemi et al., 2018; Hofman et al., 2017).

Resulting from the literature analysis regarding risk categorization, four portfolio risk categories could be identified followed by specific sub-groups of portfolio risks sources. Table 4.2 describes the main characteristics of each category. These categories represent a first level for PPR categorization associated with risk sources as, from a PPRA perspective, different types of risk factors must be considered to adequately represent the PPR.

Table 4.2. PPR categories (source risk categories)

Category	Description
Project portfolio management level	It covers aspects related to aggregating and distributing information in an inadequate way among decision levels, improper sharing of knowledge between stakeholders, lack of transparency or quality of information. In general, it is associated to aspects that lead to the making of wrong decisions by the portfolio manager as well as by other decisions-makers related to the management of project portfolio (Ghasemi et al., 2018; Hofman and Grela, 2015). Another group of aspects that is part of this category is related to inadequate management of culture and organizational climate, such as conflicts between decision-makers, conflicts between stakeholders, loss of knowledge and skills due to lack of stability of staff, recurrent operational approach changes, low cooperation level among project teams, and low cross-trained staff to support changes during portfolio execution, among other aspects (Drake and Byrd, 2006; Hofman and Grela, 2015). Lack of PPM capacities is the third component of this category, generating an inadequate prioritization between portfolio components, low decision-making capabilities to face risk management process, to incorporate efficiently organizational changes in portfolio management and to balance portfolio components, resources and capabilities available in each planning and execution period (Drake and Byrd, 2006; Ghasemi et al., 2018; Hofman and Grela, 2015).
Project interactions	Resource interdependency is an important risk source in the project portfolio context. Resource interdependency can generate errors in resource allocation, lack of sufficient resources required for attaining the objectives, technology interdependences and conflict between project managers. Thus, delays in one project may affect the start of some activities of another project because resources required are not available (Ghasemi et al., 2018; Hofman and Grela, 2015; Relich and Pawlewski, 2017). Some projects are undertaken because, if they are conducted in combination with other projects, they generate some benefits (programs) like cost reduction, economies of scale, or knowledge generation. However, it should be considered that failure, delays, or cancellation of one of these projects generates negative effects on other projects, and, therefore, the success of one component has impact on the success of other projects. In the same way, relationships between projects, in which developing one depends on one or more outputs from another project, must also be considered (Drake and Byrd, 2006; D. Guan et al., 2017).
External conditions	It includes aspects associated to supplier and contracts. Supplier and contracts capacity for delivering the required products and services, changes in agreements with suppliers and contracts, and changes in the competitive environment and business strategy of suppliers and contracts, are part of this category (Petit and Hobbs, 2010; Sharifighazvini et al., 2018). The effect on project portfolio performance of new norms or changes in current norms (internal and external), changes in the competitive environmental, or changes in weather conditions correspond to a second group of aspects that should be considered (Chatterjee et al., 2018; Petit and Hobbs, 2010; Razi and Shariat, 2017; Sharifighazvini et al., 2018). The third aspect that composes this category is associated with changes in external conditions that can impact both portfolio and organization, such as changes in sectoral, national or international policies, or changes in economic conditions like currency change or changes in prices of supplies of high impact on project portfolio (Chatterjee et al., 2018; Razi et al., 2015; Sharifighazvini et al., 2018).
Organizational conditions	Organizational conditions can generate risk on the project portfolio. Some risk factors could be associated with improper portfolio structure from portfolio selection, which generates lacking or low strategic alignment. Other considerations are associated with impacts of structural reorganizations of the company or portfolio, changes in internal policies, and changes in the business strategy (Drake and Byrd, 2006; Hofman and Grela, 2017; Petit and Hobbs, 2010). Fund arrival rate, financial stability, and the financial liquidity of portfolios are also part of this PPR category (Chatterjee et al., 2018; Hofman and Grela, 2015; Razi et al., 2015). Changes in the basic parameters of projects and programs, like changes in the scope and schedule can be considered part of this category. These changes could be associated with the complexity of design or need for

Category	Description
	customization of some products or processes for specific projects or programs (Hofman and Grela, 2015; Petit and Hobbs, 2010; Sharifighazvini et al., 2018). Another aspect that must be considered is associated with project and program management life cycle processes, which might incorporate problems related to flow and quality of products, project performance, changes in processes, irregularities in processing, irregularities in raw materials, lack of manpower skills, changes in technical conditions, among others (Chatterjee et al., 2018; Hofman and Grela, 2015; Sharifighazvini et al., 2018).

Figure 4.2 shows a representation of the four categories described in Table 4.2. As previously mentioned, these categories represent sources of risk factors. However, although the literature recognizes different extensions and moments of impact on the portfolio, no structure to categorize the types of impact was identified. Then, the impact representation is illustrated in Figure 4.2 in a consolidated manner.

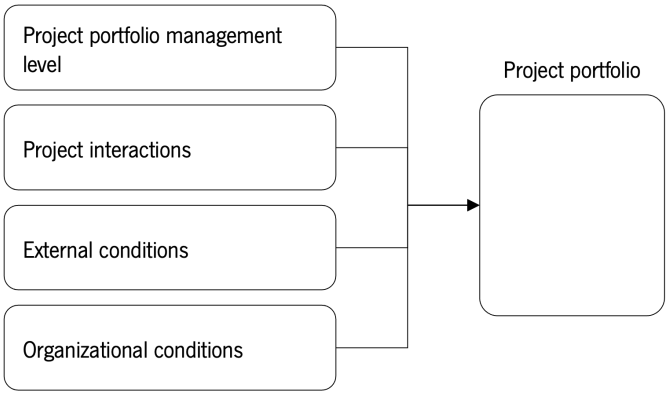


Figure 4.2. Representation of PPR categories

4.3 Project Portfolio Success Dimensions

A successful project portfolio has a positive impact on the organization's strategy success or business success (Meskendahl, 2010; Petro and Gardiner, 2015). A work that has been fundamental for the definition of 'project portfolio success dimensions' is the publication of Cooper, Edgett, and Kleinschmidt (2002) as the four goals proposed by them for product development project portfolios have been widely accepted in the general project portfolio context (Meskendahl, 2010; Petro and Gardiner, 2015). The four goals of PPM defined by Cooper et al. (2002) are: (i) maximize the value of the portfolio, (ii) balance portfolio or right mix of projects, (iii) achieve a strategically aligned portfolio, and (iv) achieve the right number of projects for the limited resources available. These authors also posed that these goals are in conflict so that "the right portfolio approach depends on which goal your leadership team has explicitly or implicitly highlighted" (Cooper et al., 2002, p. 5).

In this regard, some authors, such as Voss (2012) and Meskendahl (2010), have carried out their research focusing on PPM success, while other authors have focused on analyzing the project portfolio success (Petro and Gardiner, 2015; Teller and Kock, 2013). However, studies associated with PPM success and project portfolio success have been based on a similar set of success dimensions, which are mainly derived from the PPM objectives defined by Cooper et al. (2002).

Four 'project portfolio success dimensions' are conceptually described by Voss (2012): (i) average project success, (ii) strategic fit, (iii) portfolio balance, and (iv) future preparedness, being the success dimensions (i), (ii), and (iii) based on PPM goals defined by Cooper et al. (2002). Also from a PPM success perspective, Meskendahl (2010) considered average project success, strategic fit, and portfolio balance as success dimensions, together with one additional dimension, namely synergies between projects within the portfolio. Also, the author considered that the four 'project portfolio success dimensions' are positively related to business success dimensions. In this regard, Meskendahl (2010) stated that future preparedness and economic success represent business success dimensions more than 'project portfolio success dimensions'. In contrast, from a project portfolio success perspective, Teller and Kock (2013) incorporated those two dimensions (economic success and preparing for the future) as part of 'project portfolio success dimensions'.

Thus, project portfolio success and its relationship with the PPM objectives are a well-established construct widely used in the literature. However, although there is no complete agreement on all of them, seven 'project portfolio success dimensions' have been employed in the literature (see Table 4.3)

Average single project success of the portfolio, portfolio's overall fit with the firm's business strategy, and portfolio's balance represent success dimensions with wide acceptance and agreement in the literature, and these dimensions have been tackled and incorporated by several authors in different publications. Notwithstanding , the use of portfolio synergies as a success dimension, although not being part of all works, has been found in a large number of them (Meskendahl, 2010; Petro and Gardiner, 2015; Teller and Kock, 2013; Unger et al., 2012). The success dimensions related to economic success or preparation for the future have been incorporated by some works as a project portfolio success dimensions (Teller and Kock, 2013; Voss, 2012). Other publications stated these dimensions as business success dimensions, and therefore, as a positive consequence of the project portfolio success (Meskendahl, 2010). However, future preparedness has been more considered than not since it reflects a direct influence from the project portfolio.

Table 4.3. Project portfolio success dimension mentioned in the literature

	Average project success	Strategic fit	Portfolio balance	Future preparedness	Synergies exploitation	Economic success	Average product success
Voss (2012)	X	X	X	X			
Meskendahl (2010)	X	X	X		X		
Teller and Kock (2013)	X	X	X	X	X	X	
Petro and Gardiner (2015)	X	X			X		
Oostuizen, Grobbelaar, and Bam (2018)	X	X	X		X		
Kopmann et al. (2017)	X	X	X	X	X		
Kopmann, Kock, Killen, and Gemünden (2015)	X	X	X	X	X		X
Kock, Heising, and Gemünden (2015)	X	X	X	X		X	
Unger, Rank, and Gemünden (2014)		X	X				
Jonas et al. (2013)	X	X	X		X		
Voss and Kock (2013)	X	X	X	X	X	X	
Beringer et al. (2013)	X	X					
Heising (2012)		X	X	X		X	
Teller, Unger, Kock, and Gemünden (2012)	X	X	X		X		
Jonas (2010)	X	X	X		X		
Teller and Kock (2013)	X	X	X	X		X	X
Teller et al. (2014)	X	X	X	X		X	X
Rank et al. (2015)				X	X		
Kock, Heising, and Gemünden (2016)	X	X	X	X		X	
Teller (2013)	X	X	X	X	X	X	X

Then, average project success, strategic fit, portfolio balance, synergies exploitation, and future preparedness represent the more common 'project portfolio success dimensions' employed in the literature. Table 4.4 provides a description of these 'project portfolio success dimensions'. An important consideration that must be taken into account is the difference between project portfolio success and project portfolio efficiency, because efficiency is concerned with the adequate use of resources, tools, and techniques, while success is concerned with the benefits realization and overall achieved goals. In a project level context, the literature establishes a positive association between efficiency and success (Petro and Gardiner, 2015).

Table 4.4. Description of 'project portfolio success dimensions'

Success dimension	Description
Strategic fit	This dimension represents the degree to which the project portfolio reflects the company's strategy, considering aspects as structure, technology, or environment (Meskendahl, 2010; Voss, 2012). On this dimension, Meskendahl (2010, p. 809) noted that "there is not much literature on a theoretical construct strategic fit for project portfolios".
Synergies exploitation	The literature states that it refers to the cross-project coordination including synergies related to technologies, market, knowledge and resources (Meskendahl, 2010; Petro and Gardiner, 2015). However, practices focused on this dimension "are often not put into practice due to complexity of the numerous interdependencies within the portfolio" (Meskendahl, 2010, p. 809).
Portfolio balance	Portfolio balance states that the project portfolio incorporates a balance of different dimensions to achieve its objectives at the same time that is exposed to a risk level reasonable, but the literature does not present an agreement on the aspects that are covered by this dimension (Meskendahl, 2010). Thus, portfolio balance includes criteria as short-term and long-term benefits, well-adjusted risk level, project types and sizes, use of new and existing technologies, and resource adequacy (Ghasemi et al., 2018; Voss, 2012).
Future Preparedness	This dimension considers long-term benefits and opportunities offered by the project portfolio. It is based on the creation of new markets, new or improved technologies or processes, positive impact on brand value or employer reputation, and the capability to adapt and react to technology or market changes (Voss, 2012).
Average project success	Average project success reflects two main aspects; the first one is associated with project performance measures, which is measured through criteria such as budget, schedule, quality and customer satisfaction; the second one is associated with market and commercial performance of each project, being these aspects measured with financial performance criteria (Teller and Kock, 2013; Voss, 2012).

4.4 Methods Applied to PPRA

Optimization approaches for project portfolio selection are used to establish efficient frontiers based on the risk-return relationship (Panadero et al., 2020; Sharifighazvini et al., 2018; Tofighian et al., 2018; Yan and Ji, 2017; Yousefi et al., 2018). In this regard, the estimation of PPR has been based mainly on MPT (Brester et al., 2017; Heydari et al., 2016; Kettunen and Salo, 2017; Tang et al., 2017; Yousefi et al., 2018). Although this type of approach is adopted for both mono- and multi-period optimization (Heydari et al., 2016; Tofighian et al., 2018), PPR estimation follows the same approach based on MPT in most of the studies.

MPT is one of the classical theories of combinatory optimization (Tang et al., 2017). This theory was complemented with goal programming to develop a proposal in which project interaction effects related to shared resources in each period of time could be incorporated (Heydari et al., 2016). Mazelis and Solodukhin (2015) incorporated resources constraints in a model based on MPT. They proposed a multiperiod optimization model where the utility is determined as the qualitative evaluation of the

expected impact of each project on strategic objectives. They noted that, in this type of models, the risk level limitation "may lead to the fact that the portfolio does not include projects whose budgets allow this (given the limitations on the overall cost)" (Mazelis and Solodukhin, 2015, p. 795).

In risk assessment based on MPT, portfolio risk is defined based on measures related to the variance of monetary expected returns. Portfolio risk is composed by the individual risk and the inter-project risk (Tang et al., 2017; Yousefi et al., 2018). Therefore, estimations of the variance of expected results are required for each project. Thus, given the nature of this type of risk assessment, the risk approach in which risk is a consequence of uncertainty is usually the one adopted. In this regard, a relevant element of risk estimation is associated with how uncertainty is represented.

Simulation-optimization models have been considered to incorporate uncertainty into risk analysis, being Monte Carlo simulation a technique widely used to model uncertainty. Thus, based on MPT, Kettunen and Salo (2017) proposed a procedure based on historical data and Monte Carlo simulation to adjust the bias in the PPR estimation. It includes the maximum risk level expected as a constraint and incorporates risk aversion through an exponential utility function that allows compensating the bias effect. Lopes and de Almeida (2015) integrated a utility function into the objective function of a multiperiod optimization model that includes three decision criteria, being one of them the risk where uncertainty is incorporated through Monte Carlo simulation. Sefair et al. (2017) suggested Mixed-Integer Quadratic Programming complemented with Monte Carlo simulation for uncertainty representation. Other authors that considered simulation-optimization approaches are Tang et al. (2017), Panadero et al. (2020), and Shafi et al. (2017).

Another approach used for the uncertainty representation in risk assessments is fuzzy logic, being proposed as a complementary approach to mathematical modeling and to qualitative analysis (Mohagheghi et al., 2017; Sharifighazvini et al., 2018). Fuzzy logic has been integrated with Data Envelopment Analysis and Analytic Network Process (Sharifighazvini et al., 2018). It also has been integrated with MPT, establishing that impact on strategic objectives represent the expected utility of each project within the portfolio (Mazelis et al., 2016). Fuzzy logic also allows modeling the uncertainty that is present in the net cash flow and in the investment capital (Mohagheghi et al., 2015). In a complementary way, fuzzy logic has been used to qualify the risk of each project as one decision criteria (Mohagheghi et al., 2016).

Fuzzy sets and genetic algorithms can also be used to generate the Pareto risk front. For that, Grey Relational Analysis is used because it allows to calculate the correlative degrees between two

sequences and clustering the projects with similar specifications (Razi et al., 2015). Fuzzy logic is also integrated with Kohonen neural networks by allocating clusters based on profitability and risk measures (Broilo and Nazarova, 2016). Additionally, it is compared to two other ranking techniques to establish which method generates a better project grouping. The conclusion was that Grey Relational Analysis has the best performance (Razi and Shariat, 2017).

Thus, risk assessment has been incorporated as part of optimization methods for project portfolio selection with risk considerations. It is an integrated part of the project portfolio selection based on MPT, Data Envelopment Analysis, and Grey Relational Analysis. Specifically, risk assessment is framed in the risk approach in which risk is a consequence of uncertainty. For that, Monte Carlo simulation and Fuzzy logic have been introduced to represent uncertainty. In addition, these approaches are focused on the risk associated with expected financial results, without establishing a relation with the 'project portfolio success dimensions' in most cases and generally defining risk as an aggregated measure.

From another perspective, but also considering Monte Carlo simulation, Costa et al. (2007) assessed PPR based on credit risk theory. The authors suggested that not all risk factors have the same weight in the PPR quantification. For this reason, they used expert judgment through pairwise comparison to estimate the impact of each risk factor on the portfolio. On the other hand, the risk dependencies quantification used by Cooley et al. (2012), although allowing a systemic analysis of the impact that risks could generate on the portfolio, is characterized by the high amount of historical data necessary to obtain reliable information, being this the main weakness of this approach in a project portfolio context (Cooley et al., 2012). Although, the quantification of risks is proposed in monetary terms, other effects should be evaluated as well, such as the risk impact on portfolio objectives and strategic objectives.

Based on structural funds of the European Union Member States environment, an indicator for monetary loss risk was proposed by Bolos et al. (2016). The indicator was structured according to statistical measures, like mean, standard deviation, and covariance, and it is the result of integrating the monetary loss probability that stems from delays in the execution of each project.

From another perspective, Bayesian Networks have been used to model the interactions between projects and between risks (Ghasemi et al., 2018; D. Guan et al., 2017), which allows to evaluate their impact on the PPR when a project is added or eliminated (Ghasemi et al., 2018). Combining the set theory with Bayesian Networks to evaluate the impact of the interaction between projects on PPR has also been investigated by D. Guan et al. (2017). Neumeier et al. (2018) highlighted that Bayesian Networks is a widely used approach to assess cascading effects in other research fields. The authors

suggested that technical and resources dependencies could be assessed through a transitive dependencies model, like Bayesian Networks. According to the above, Neumeier et al. (2018) proposed a Bayesian Network approach to identify the critical projects of a portfolio by considering the cascading effect that each project can generate on the success or failure of other projects.

For Namazian and Yakhchali (2018), the influence on the occurrence or non-occurrence of one risk factor due to occurrence of other risk factor can be also quantified using Bayesian networks and Monte Carlo simulation. Thus, the authors proposed an approach based on Bayesian Networks to represent and quantify the interaction between risk factors associated with schedule delays and cost overruns in gas field development projects.

For IT project portfolios, Peters and Verhoef (2008) proposed a method to evaluate the risk effects in the project portfolio execution phase and defined a methodology to evaluate this impact on the NPV of each project and the NPV of the whole project portfolio. Also in the IT project portfolios context, Q. Wang et al. (2017) highlighted the importance of considering the human factor influence on the project portfolio as it brings more complexity and uncertainty to projects. Q. Wang et al. (2017) identified that the traditional PPM approach, seen as a management approach based on processes, has been complemented by a project portfolio approach such as knowledge networks. Q. Wang et al. (2017) argued that, for the analysis of interactions and complexity, the traditional approach of PPM needs to be updated to integrate a systemic analysis of portfolio risk. For this reason, they proposed an approach to PPR analysis as a biological network, where the risk is evaluated as the success or failure probability.

4.5 Framework for PPRA Design

Once the four constructs were characterized, a literature-based framework for PPRA design is proposed based on how these four constructs are linked. Figure 4.3 shows the integration of the nine 'components for PPRA', the four 'PPR categories' associated to risk sources, and the five 'project portfolio success dimensions' identified from the conventional CA. The representation of how risk factors and success dimensions are linked to each other was not established in the framework. The reason for the absence of such representation is associated with how each 'risk assessment method' allows modeling risk factors' impacts as a pre-established method was not defined. Thus, even though different risk assessment methods applied to PPRA were identified in the literature, the representation of the construct 'risk assessment method' was not pre-established. However, the characterization of that construct (Section 4.4) provides a basis for Phase III, i.e., for definition and structuration of the PPRA model.

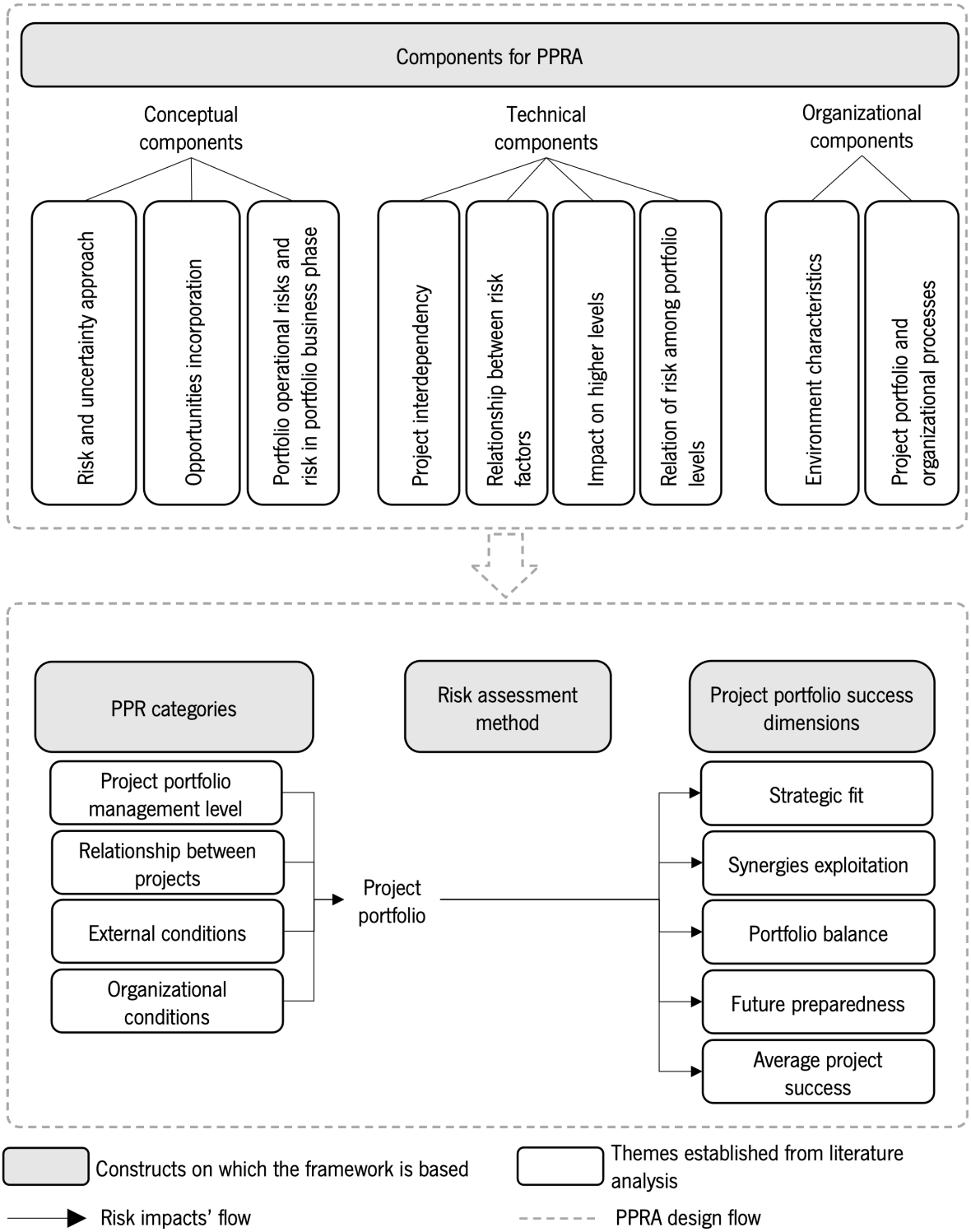


Figure 4.3. Literature-based framework for PPRA design

The framework was developed under two considerations: (i) PPRA is an element of the PPRM so that, although belonging to the group of elements for managing portfolio risk, it is related or conditioned by decisions derived from the element defined as portfolio risk management plan; and (ii) PPR indicates the amount or measure of impact on project portfolio expected results due to changes in risk factors, where expected results can be represented by project portfolio success.

The ‘components for PPRA’ correspond to inputs required from the PPRM plan to the PPRA design. In this regard, they are transversal to the PPRM group of elements defined as managing portfolio risk also covering the design of risk identification and response. The constructs ‘PPR categories’, ‘Risk assessment Method’, and ‘project portfolio success dimensions’ corresponds to the PPRA structure itself, which is informed from the risk identification element and must support the risk response. These three constructs reflect the conceptualization of risk as a measure of impact on expected results due to changes in risk.

4.6 Summary

A literature-based framework for PPRA design was established in this chapter. The framework is the result of an exploratory analysis of literature in PPRM field, which was conducted following a conventional CA. The framework for PPRA design is composed by four constructs: ‘components for PPRA’, ‘PPR categories’, ‘project portfolio success dimensions’, and the ‘PPRA assessment method’.

The construct ‘components for PPRA’, even though required for the design of the PPRA, is transversal to other PPRM elements. The constructs ‘PPR categories’ and ‘project portfolio success dimensions’ reflect the PPR definition adopted in this research, where PPR is understood as the amount or measure of impact on project portfolio results due to changes in risk factors. In this case, project portfolio results are represented by the project portfolio success dimensions.

Nine ‘components for PPRA’ were identified, characterized, and classified into three groups: conceptual, technical, and organizational components. Conceptual PPRA components concern aspects related to theoretical or conceptual approaches’ definitions or decisions within the risk assessment’s conceptual scope, for instance, the definition of the risk approach in which PPRA could be framed. Conceptual category comprises three components: (i) risk and uncertainty approach, (ii) opportunities incorporation, and (iii) portfolio operational risk and risk in portfolio business phase. Technical PPRA components are related to decisions as to the PPR representation into the PPRA. Thus, technical PPRA components define the attributes to be represented into the PPRA, as well as the scope and depth to which they are considered. This category comprises four additional components: (iv) project interdependency, (v) risk factor interdependency, (vi) impact on higher levels, and (vii) relation of risk among portfolio levels. Organizational PPRA components are concerned with aspects of the organizational environment (both internal and external) related to the project portfolio and the processes that should be considered as part of the definition or design of the PPRA. This category comprises two

additional components: (viii) environment characteristics and (ix) project portfolio and organizational processes.

Regarding 'PPR categories' the literature evidenced that most works categorized risk factors based on their sources, while only several works advance in a classification based on the type of impact. Based on risk factor sources, the information regarding the construct 'PPR categories' was categorized in four groups: (i) project portfolio management level, (ii) project interactions, (iii) external conditions, and (iv) organizational conditions. Although it was not incorporated into the framework, categorization of PPR as systematic and non-systematic risk derived from Modern Portfolio Theory (MPT) provides a representation of the impact extent of risk factors on the project portfolio, however it is centered on an aggregated measure based on monetary terms.

The third construct 'project portfolio success dimensions' comprises the five most common dimensions in literature: (i) strategic fit, (ii) synergies exploitation, (iii) portfolio balance, (iv) future preparedness, and (v) average project success.

A fourth construct identified in the literature corresponds to 'risk assessment method'. This construct represents how it is modeled the relationship between risk factors, or uncertainty, impact on the expected results. Specifically, to represent how 'PPR categories' and 'project portfolio success dimensions' are linked to each other. However, the representation of this construct was not incorporated into the literature-based framework because the different methods attend to considerations and characteristics that are not generalizable. This construct was characterized in Section 4.4 to provide a basis for Phase III, i.e., for definition and structuration of the PPRA model. On one hand, risk assessment has been incorporated as part of optimization methods for project portfolio selection with risk considerations. It makes part of the project portfolio selection based on MPT, Data Envelopment Analysis, and Grey Relational Analysis. On the other hand, Credit Risk Theory, Bayesian Networks, and Complex Networks are the most relevant methods identified when the risk is assessed under a project management approach considering interdependencies between projects or interdependencies between risk factors.

5. A COMPREHENSIVE PPRA CONCEPTUALIZATION [2]

Phase II of this research project was oriented to conceptualize an approach to support the operationalization of PPRA in a practical context. In studies that incorporate exploratory searches, semi-structured interviews can offer a rich overview and understanding of organizational realities and provide or build explanations of a specific, clear topic so that issues previously defined can be addressed (Saunders et al., 2019). In this regard, the framework for PPRA design presented in the previous chapter was used for designing a protocol of semi-structured interviews to be conducted with practitioners. In other words, the three constructs comprising the framework for PPRA design were used to explore how PPRA is perceived by practitioners. Specifically, the empirical study was focused on portfolios of organizational development projects. Thus, twenty-eight semi-structured interviews were conducted.

This chapter shows the figurative core of PPRA derived from practitioners' perspective, i.e., it describes how PPRA is objectified by adopting SRT as the theoretical lens in this empirical phase. Six interdependent themes were identified as representation of the figurative core. Section 5.1 describes the themes and presents a graphical representation of how the themes are interrelated. The findings are discussed in Section 5.2, framing the six themes into the constructs comprising the literature-based framework for PPRA design. Discussion led to defined four propositions for PPRA, which are the basis of the proposal of conceptualization of a comprehensive PPRA for portfolios of organizational development projects. Specifically, conceptualization of a comprehensive PPRA is presented in Section 5.2.5. The proposed conceptualization of a comprehensive PPRA corresponds to the first practical output defined for this research project (see Figure 3.1 in Section 3.1).

5.1 PPRA: Disclosing the Practitioners' Perspective

The representation of the figurative core based on the analysis of the interviewees' perceptions is presented in this Section. As mentioned in Section 3.3.6, the figurative core is represented in six themes which were obtained by conducting reflexive TA. The established themes are described in the following sections. To that end, once each theme is described, a graphical representation is presented at the end of the respective Section. Thus, each theme is represented as a rectangle with the name of the theme inside it, and its main attributes are illustrated in the box below it. As the description of the themes

[2] This Section was partially the object of the papers: Micán, C., Fernandes, G., & Araújo, M. (2022). Disclosing the Tacit Links between Risk and Success of Organizational Development Project Portfolios. *Sustainability*, 14(9), 5235. https://doi.org/10.3390/su14095235
Micán, C., Fernandes, G., & Araújo, M. A Comprehensive Approach to Project Portfolio Risk Assessment – An Organizational Perspective, submitted to *Project Management Journal* (Under evaluation).

progresses the representation of the themes includes how each new theme relates with the previous themes.

5.1.1 Organizational Capabilities as Portfolio Results in which PPR can Be Assessed

The PPR representation as a PPRA result was anchored by the interviewees to the impact on the expected project portfolio outcomes at the organizational level. For example, interviewee 26 mentioned "*I would imagine it as the risk of fulfilling and implementing the entire portfolio, if we are really achieving the expected results*". In this matter, it was specifically mentioned that "*as result, a portfolio produces organizational capabilities to be used in the operation, but that is very difficult to measure*" [I9]. Then, impact on the organizational capabilities generated by the project portfolio could be denoted as a construct for the primary representation of the PPRA outcome.

Regarding the impact on the expected results of the portfolio, represented by the PPRA in the impact on the expected organizational capabilities, it is stated that *"it translates into the non-achievement of the expected impact on the organization's strategy, but the business measures are mediated by other factors that are no longer purely of the portfolio" [I9].* Thus, the expected organizational capabilities to be generated by the portfolio are the path through achieving the expected strategic impacts derived from the project portfolio. PPRA oriented to capabilities also reflected the fact that *"<<to the extent that>> the capabilities are not delivered, we understand that it is the <<project or portfolio>> manager's responsibility, but if the capabilities are delivered but not properly exploited, we have a shared responsibility"* [I16]. This suggests that a capability-based PPRA would recognize the project portfolio limits in terms of its organizational contribution.

In this regard, a PPRA based on the expected organizational capabilities also involves the organizational use of the capabilities provided by the portfolio. Specifically, interviewee 28 exemplifies this with one of their project portfolios through which "*we are going out with digital channels and in all these issues as so disruptive and innovative, there are some really delicate cyber-security risks*", mentioning in this regard that "*those risks sometimes one does not see them, because they are end-user risks*", i.e., that type of impact is hidden from the project portfolio execution view.

In the case exemplified by interviewee 28, it is shown that a PPRA oriented to organizational capabilities would allow not only to assess risk factors associated with the projects that seek to generate digital channels, but also to incorporate the risk factors associated with cybersecurity, which is related to the use of the capability generated as a result of the project portfolio. Thus, a risk assessment approach

oriented to establish the impact on the organizational capabilities derived from the project portfolio could allow capturing into the PPRA the way in which the portfolio delivers value to its parent organization.

Therefore, PPR representation as a PPRA result was anchored by the interviewees to the impact on the expected project portfolio outcomes at the organizational level, being organizational capabilities produced by the project portfolio highlighted as an adequate representation of the portfolio outcomes. Thus, the theme 'organizational capabilities as portfolio results in which PPR can be assessed' is framed as such: The PPR associated to capabilities generation, i.e., the risks that affect capabilities generation; and PPR associated with the use of capabilities, i.e., the risks that might endanger adequate use of capabilities by the organization; and the organizational capabilities generated by the project portfolio leading to strategic impacts on the organization. Figure 5.1 shows the representation of this theme.

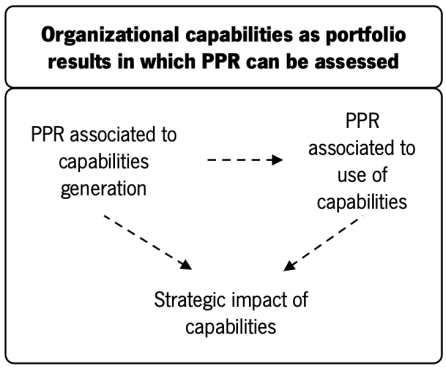


Figure 5.1. Representation of 'organizational capabilities as portfolio results in which PPR can be assessed'

5.1.2 Project Portfolio Levels as Risk Sources in PPRA

Concerning the risk factors representation, the practitioners expressed that risk factors derived directly from the projects within the portfolio and from the interdependence between projects is the first level of factors to be considered in PPRA. However, other portfolio-related levels could be incorporated into the PPRA, since, as stated by interviewee 9 "*not necessarily the operational risk of the projects is what I would do the portfolio analysis with, suddenly there are other elements that determine that [...] some very important of them are those that I can control into my portfolio and others that are business or external which I do not control; some that are due to portfolio external factors but not necessarily external to the company; others related to industrial sector; and others at macro-economic level*". This suggests the PPRA could recognize risk factors derived at the project portfolio level and derived at the organizational level (internal and external).

Then, according to the above, risk factors could be derived from: Each project, where the projects represent the constituent components of the portfolio; risk sources associated at the project portfolio level in which the project portfolio is in itself a unit of management; and risk derived from the interaction

of the portfolio with the organization or even risk derived at the organizational level, recognizing the interaction of the project portfolio with other organizational units.

Risk sources associated with problems with portfolio-financing capital and problems derived from portfolio structure, which are part of the category organizational conditions, were the risks most often acknowledged by the interviewees concerning risk sources derived from the organizational level. For example, interviewee 9 mentioned that "*a stakeholder with high organizational influence can affect or modify the portfolio structure in the wrong way [...] generating risk for the portfolio's success*". Likewise, risks such as changes in the competitive environment and changes in external conditions related to norms and reference models, which are part of the category external conditions, were frequently highlighted by the interviewees.

Concerning risk related to the category PPM level, PPR associated with an inadequate distribution of information, imbalanced management of stakeholder expectations, or lack of capability at both PPM and project management level were all repeatedly mentioned. Interviewee 1 commented on lack of capability "*I had cases where a good project manager was promoted to be portfolio manager, but the abilities required were different. He needed to take a strategic perspective [...] he had to have a more comprehensive perspective than just try and solve operational issues*".

PPR derived from projects within the portfolio was mainly related to problems with suppliers or contracts and to project interdependency. On the subject of project interdependency, for example, interviewee 4 highlighted that "*not being able to see interdependencies, neither seeing the system as a whole has been another risk we have had to deal with*", while interviewee 16 observed "*We literally saw it in this way: This <<project>> was delayed, [...] it began to have problems with deliverables that were interdependent with other projects, [...] then this <<project>> was negatively impacted and started to generate negative impacts on the other <<projects>> as well*". However, some interviewees mentioned that this type of risk corresponds to the project or program management level, as in the observation made by interviewee 15: "*It could be that, due to its characteristics, this is more related to the project and program management levels*".

Also, it was emphasized the inter-relationship between risk factors levels – project, portfolio, and organization. Regarding the representation of risk factors derived from the different levels, it was mentioned that "*it is clearer in terms of delivering the capabilities; because I go from portfolio to project, and from project to portfolio, it is necessary that one does not lose sight of that integration*" [I16]. And that "*at the project portfolio risk level, the first thing is the financial aspects, the financing of the portfolio.*

Inadequate cash flow management has an impact on the entire portfolio. In this concern, the right execution of the financial milestones of the projects is required according to the portfolio cycle" [I17], interrelating with this, project portfolio and project level risk factors.

The PPRA could be oriented to establish the importance of risk factors from each project portfolio level considering the extent in which these factors impact the project portfolio through their impact either on the projects or directly on the portfolio. Then, 'Project portfolio levels as risk sources in PPRA' is defined as another theme which is defined as: Project portfolios are affected by a set of specific risk factors arising at the project portfolio level, as well as risk factors that emerge from the projects and programs as the operational units of the portfolio, and risk factors derived from the organizational influence. Figure 5.2 shows the representation of this theme.

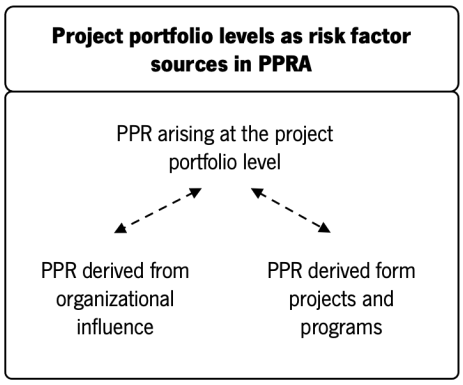


Figure 5.2. Representation of 'Project portfolio levels as risk sources in PPRA'

5.1.3 Extent of Impact of Risk Factors on the Project Portfolio

An important objectification manner of risk factors established by the interviewees was about how risk factors impact the project portfolio. In this regard, it was identified that the risk factors derived from the organizational, portfolio, and project levels impact the project portfolio in different impact ways and extent. Interviewee 17 exemplifies the interconnection between source level and extent of impact, by mentioning that "*there are those that are common factors between projects and that can rise to the portfolio level, or risks that by their nature are very complex or large*". This raises the first form of impact, which is associated with the impact on the portfolio through common risk factors of a specific subset of projects. In this regard, the project management capabilities of a specific project manager who has a subset of projects within their remit is an example of this type of impact, since that, the risk factor impacts initially on a specific set of projects, and then, the impact on these projects gives rise to PPR.

Other risk factors could impact the portfolio's capability to produce the expected results in a generalized manner, i.e., they have a generalized impact on the whole portfolio outputs. For example,

"*the issue of capacity in terms of staff, in terms of equipment, and in terms of organizational infrastructure is one that should be considered at the project portfolio level to know whether everything that is being planned for the project portfolio can be, or cannot be, actually implemented*" [I27]. Organizational capabilities provided by the organization for supporting the flow and aggregation of information, as well as changes in portfolio structure, exemplify other 'risk factors' that have a general or global impact on expected portfolio outputs.

In line with the above, interviewee 6 stated that *"capabilities that the organization provides to support communication and aggregation of information have an important influence on all the projects"*. The above pose a second way or impact extent derived from the risk factors. In this case the risk factors give rise to general or global impacts on all expected outputs from the projects within the portfolio.

An additional way or extent of risk factors impact was established based on the impact on project portfolio outcomes. In this concern, for instance, interviewee 15 exemplified "*the company is no longer going in this <<strategic>> direction, now it is going in another <<strategic>> direction, that is a very critical risk for the portfolio success and for each project, because you have to find a way to steer everything in that new <<strategic>> orientation <<defined by the company>>*". This means that to achieve the expected positive impact on the organization, the portfolio outcomes must be re-aligned according to the new organizational orientation.

Also referring to risk factors impact on portfolio outcomes, considering the cyber-security risk derived from the results of the implementation of digital channels within the parent organization, interviewee 28 mentioned that "*it is not about waiting to close the portfolio and say to executives: There you have the projects' results, now invest quickly in some cybersecurity to be able to use them*". In this case, the impact is also associated with the portfolio outcomes, specifically, it is associated with how well the organization is prepared to use the results. Thus, a third impact extent is associated with the impact on the portfolio outcomes, either because it modifies the expected outcome itself or because it affects the organization's ability to use the respective outcome. In this regard, by considering that portfolios of organizational development projects are structured to have an impact on the process and business model of the organization, PPR could give rise to impacts on how the project portfolio outcomes leads to achieving the organizational results for which the portfolio was designed.

Thus, risk factors impact on the project portfolio was objectified in three different impact extent: (i) impact on a project or subset of projects, which, in turn, affect the PPR (ii); general or global impact on the whole portfolio; and (iii) impact on the expected outcomes. Therefore, the theme 'Extent of impact

of risk factors on the project portfolio' is framed as such: PPRA should integrate the diverse ways in which risk factors jointly impact the project portfolio expected results, which can be derived from the impact on a group of projects, on the portfolio as a whole, or portfolio outcomes. Figure 5.3 shows the representation of this theme.

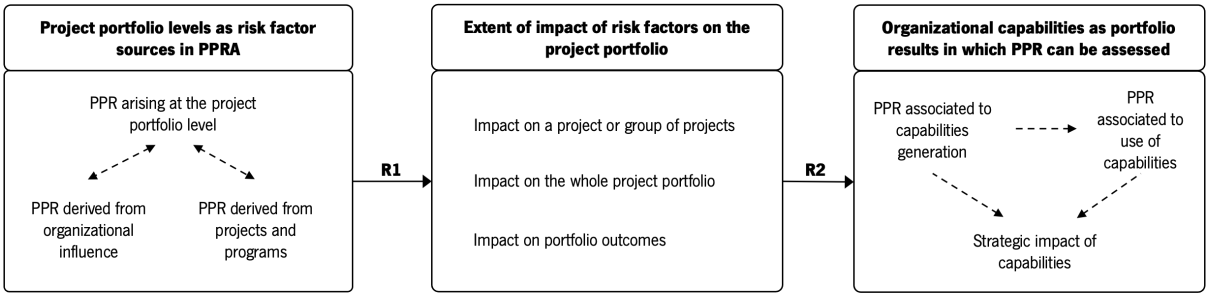


Figure 5.3. Representation of 'Extent of impact of risk factors on the project portfolio' and its relationship with the previous themes

In addition, considering that the integration between the risk sources from different levels would be represented in the extent in which it impact the project portfolio, as well as that "*projects are grouped for a reason, so the risk assessment should be performed on that reason*" [I1] and that the first theme states that 'organizational capabilities as portfolio results in which PPR can be assessed'; the way in which risk factors sources generate different impacts on the project portfolio (see relationship R1 in Figure 5.3) could be represented through impact on the expected capabilities and on the way in which the parent organization will used them (see relationship R2 in Figure 5.3).

5.1.4 Project Portfolio as the Organizational Unit for PPRA

In line with what has been identified in the literature regarding conceptualization of risk and uncertainty approaches perspectives (see Section 4.1.1), the interviewees put forward the risk conceptualization from different perspectives. However, they converge and emphasize that the risk approach to be adopted for PPRA should be aligned with the risk approach adopted at the organizational level. For instance, referring to the risk approach to adopt for PPRA, interviewee 16 mentioned "*it is important to make visible how the <<PPR>> approach has to be aligned with the organizational level in terms of the corporate approach that the organization takes. I believe that this link is necessary because it already recognizes the particularities of the organization [...] if one becomes detached from the other, I think there is a problem there*".

The above suggests that a first element that would allow recognizing the relationship between the project portfolio and the parent organization is the integration or transversality of the risk approach adopted. Specifically, to formalize this interconnection beyond just the risk approach to be adopted, it is

proposed that the PPRA could incorporate organizational risk factors that, although not exclusively inherent to the portfolio, influence the PPR. For instance, interviewee 16 referred "*what we try to do, a little bit from experience, is to recognize from the beginning not only the risk derived from the projects but also the corporate risks that one would be accepting*". While, referring to this type of risk factors, interviewee 19 stated that "*I know that it is said that there are some portfolio inherent risks, and I wonder, what are these risks? What are the risks that are only for the portfolio, and which are aside from the whole environment in which it is being framed?*".

Thus, these organizational risk factors would make it possible to incorporate characteristics of the parent organization and its environment into the assessment, recognizing in turn, through the PPRA, that these factors associated with the organizational level influence the PPR. One of these organizational risk factors was exemplified by interviewee 7, who mentioned that "*one that is always there and that we never included, but that, because lessons learned, we are now incorporating, is staff turnover at the organizational level, [...] it is a latent risk and for our company, it is one of the most significant risks*"; to which the interviewee 7 subsequently supplemented "*that always has an impact of slowing down the knowledge transfer when we close the projects [...] the turnover can slow down the knowledge transfer and stabilization for up to six months, so there are impacts that we already know about*".

This suggests that organizational risks not solely influence how the project portfolio is executed, but also influence how it delivers or transfers results to its parent organization. That is, recognizing 'Project portfolio as the organizational unit for PPRA' would, in turn, lead to recognizing into PPRA the interaction between the project portfolio and its parent organization arising from the delivery or transfer of results, i.e., arising from the delivery organizational capabilities. In this regard, 'organizational capabilities as portfolio results in which PPR can be assessed' would acknowledge and operationalize this kind of interaction into the PPRA (see relationship R3 in Figure 5.4).

Another aspect that would allow recognizing the interaction between the project portfolio and its parent organization is evidenced "*When I have internal resources, especially staff, I have a problem in terms of the fact that the staff will continue in their regular duties and, they will participate in the portfolio, in one or more of the projects they are involved in. And there I have a risk in terms of the portfolio versus operation. They are going to have two bosses, and also each one is going to pull in their own direction, and if another portfolio appears in which they also have to participate, then the risk level that I have in my portfolio will become more and more entangled*" [I1].

In this regard, interviewee 20 stated that "*there are companies where the culture is that this does not concern me, I have a totally limited scope and anything that goes beyond that simply does not concern me*". While interviewee 14 mentioned, "*if we are talking about a small company, with authoritarian leaders, for example, where there is no leadership model that allows these issues to flow more generally within the organization and that they are being worked on permanently, then the <<project portfolio>> risk increases*". That is, project portfolio interaction with other organizational units can generate some risk factors for the project portfolio, so that, the specific way in which this type of risk factors affect the project portfolio could be explored into PPRA. In this regard, organizational factors related to organizational culture, the current digital context, and strategic management were emphasized by the interviewees, and therefore, could be explored into PPRA.

Based on what has been described above, the 'project portfolio as the organizational unit for PPRA' is defined explicitly as a theme to be integrated into the design and analysis of the PPRA. This theme is defined as: The risk assessment of project portfolios should recognize the organizational risk approach and its implications for PPRA, as well as acknowledge the interaction between project portfolio and the organization's processes, and the influence of the organizational risk factors in the PPR. Figure 5.4 shows the representation of this theme.

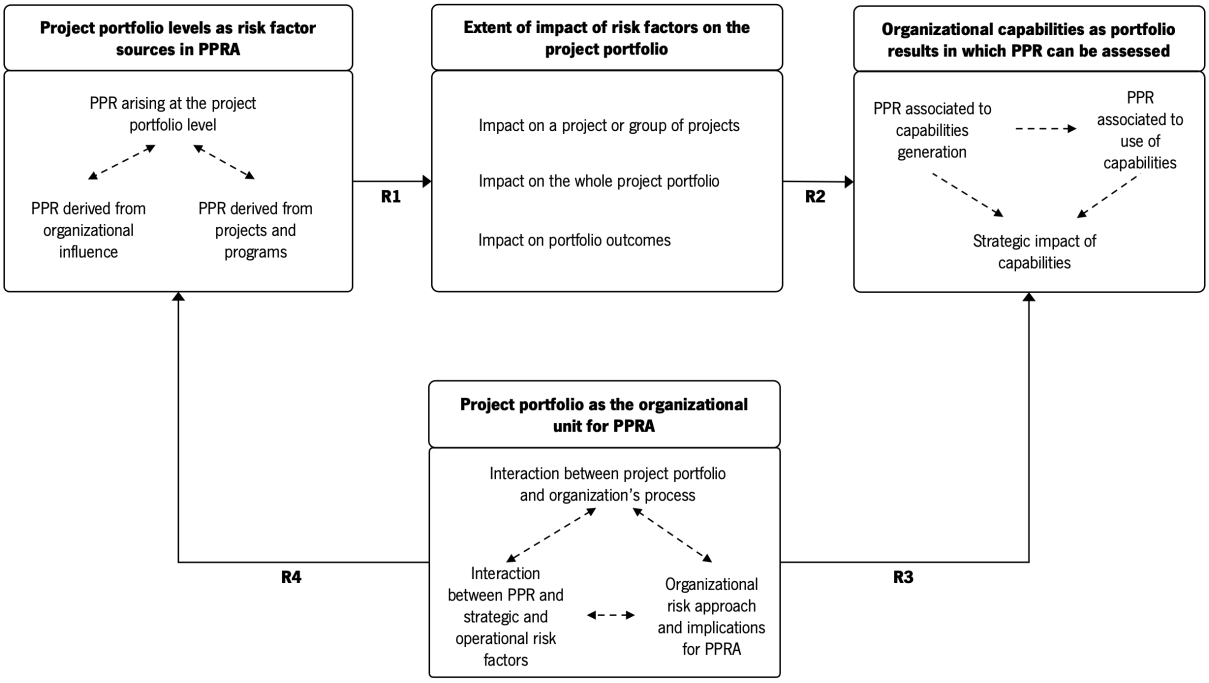


Figure 5.4. Representation of 'Project portfolio as the organizational unit for PPRA' and its relationship with the previous themes

In addition, considering 'project portfolio as the organizational unit for PPRA' implies recognizing that risk factors derived from the organizational level can impact the project portfolio results, which

implies their incorporation into PPRA to provide a comprehensive assessment. This is reflected in the inclusion of such factors as one of the 'project portfolio levels as risk sources for PPRA'. Considering the above, a relationship between the themes 'project portfolio as the organizational unit for the PPRA' and 'project portfolio levels as risk sources for PPRA' is suggested (see relationship R4 in Figure 5.4).

5.1.5 Balance Between Project Portfolio Attributes and Complexity

Attributes that have been previously recognized in the literature related to PPRA were also recognized by the interviewees. These attributes are associated to interdependencies between projects, the positive impact (opportunities) and negative impact (threats) of risk factors, and interdependencies between risks. Likewise, the fact that in PPRA, project interdependencies can be represented as part of the risk factors, was also highlighted by the interviewees.

However, interviewees highlighted as a critical issue the complexity of incorporating these attributes into PPRA and that, for instance, the risk interdependencies "*should only be worked on if you have a high maturity level both in the organization and in the portfolio management.*" [I17]. Likewise, it was also mentioned that its incorporation into the PPRA may take into account that *"The project world is dynamic, so, for me the point is in the balance in which it <<the risk assessment>> provides me with information in an agile and dynamic way and considers or not the inter-relationships between risks"* [I17]. That is, although the incorporation of these attributes in the PPRA could allow a more detailed representation of the impact of risk factors, the incorporation of these attributes into the PPRA require to be analyzed considering the characteristics of each project portfolio and its parent organization, the complexity generated by their incorporation and the value they can add to the decision-making process.

In this regard, the considerations adopted in relation to the attributes to be incorporated in a PPRA would be reflected in the representation of the way in which the risk factors impact the expected outcomes of the project portfolio, i.e., in the way in which PPRA represents the risk factors impact derived from the project portfolio levels on the expected organizational capabilities to be generated by the project portfolio (see relationship R5 in Figure 5.5). In addition, from the perspective of the PPRA as a support for decision making, interviewee 9 stated that "*I do not know if it is by areas, by processes or by types of projects, but there has to be a risk classification and it has to be linked to the organization*". Therefore, the PPRA requires to be supported on a strategy for the representation or visualization of risk factors and their importance, which is in line with the decision-making processes at both the portfolio and organizational levels.

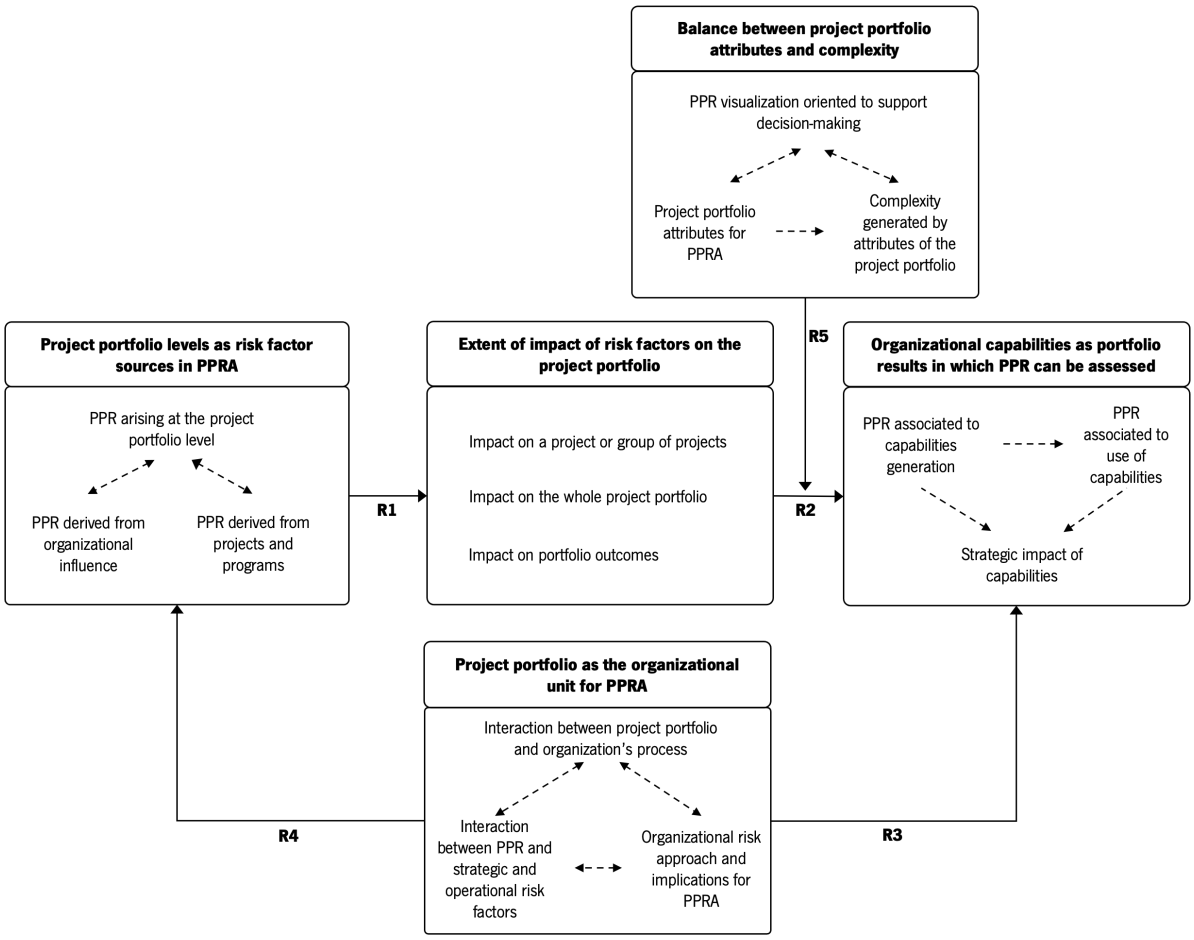


Figure 5.5. Representation of 'balance between project portfolio attributes and complexity' and its relationship with the previous themes

Hence, the 'balance between project portfolio attributes and complexity' is established as a theme for PPRA. This theme frame project portfolio attributes such as project interdependencies, opportunities incorporation, and risk interdependencies, which have been considered as part of the PPRA in the literature. However, the complexity generated by attributes of the project portfolio may also be considered. Particular attention should be paid to the visualization of the PPRA results, since PPR visualization oriented to support decision-making adds relevance and value to project portfolio decisions when considered in the organizational perspective. Thus, it is necessary to balance the relevance, complexity, and value added of PPRA. So, the fifth theme is framed as such: The extent of incorporation of project interdependencies, opportunities, and risk interdependencies is relative to the balance between relevance for the project portfolio, organizational conditions, and added value for the decision-making process at the organizational level. Figure 5.5 shows the representation of this theme.

5.1.6 Portfolio Success Representation Based on a Subset of the Portfolio Success Dimensions

For the construct of 'project portfolio success' the figurative core was associated to the dimensions linked to the expected portfolio impacts or outcomes. Strategic fit was not only the dimension most

spontaneously triggered by interviewees, but it was also the dimension with the highest agreement level. This might be a result of the strategic relationship between portfolio structure and organizational strategy. For example, according to interviewee 7 "*It is considered successful if it meets the promised KPIs [...] The organization has a strategic map. This strategic map <<allows us to>> generate strategic objectives, specific objectives, and action plans. The initiatives are linked to the action plans*", while interviewee 21 observed "*When I am aware that the projects we are doing are really impacting the strategy, and I am really orienting <<the project portfolio>> to the strategy, then I am going to feel satisfied*".

Future preparedness was the second dimension with the highest percentage of positive mentions. Project portfolio helps to develop organizational capabilities for the organization to become competitive in the future, interviewee 9 mentioned that "*if capabilities are being enabled to have competitive advantages in the different areas in which the company is competing, it can be said that transformation based on the portfolios is achieved*".

Economic success (financial or social) and stakeholder satisfaction were also mentioned spontaneously by the interviewees as possible 'project portfolio success dimensions'. Interviewees were clearly firm in highlighting stakeholder satisfaction; for example, interviewee 22 affirmed "*we have to give them something [...] they must receive benefits*" while interviewee 9 stated that "*in portfolios, there are some variables that are very pragmatic, senior management's satisfaction level or well-being <<regarding project portfolio performance or partial results>> is one of these <<pragmatic>> variables*". On the subject of economic success, interviewee 16 stated "*We evaluate that the portfolio produces minimum expected profitability at the economic level for the organization, [...] and that our sub-portfolio that has social implications maximizes the use of the resources at the same time as maximizing the social benefit*".

Then, the figurative core of 'project portfolio success' from the interviewees' perspective is represented by strategic fit, future preparedness, stakeholder satisfaction and economic success. Regarding other success dimensions such as average of the project success, synergies exploitation and portfolio balance, the interviewees recognized their importance but not from a perspective of 'project portfolio success' but from a PPM process perspective.

Average project success received a low percentage of positive mentions, although this does not mean that interviewees considered project success to be irrelevant. Indeed, some interviewees argued for its importance but stipulated that it corresponds to being a performance indicator. On this point, interviewee 5 affirmed that *"obviously it is a measure that gives you a view of how favorably the portfolio*

management is being carried out but it doesn't necessarily concern project portfolio success". In the view of other interviewees, applying an average measure as a success dimension could generate inadequate or imprecise information. For example, interviewee 27 observed that *"it may be that when a project is implemented you have some easier or simpler projects, and this helps to increase <<the average>>, but the portfolio may have a problem with projects of greater complexity".*

As for the synergy exploitation and portfolio balance dimensions, the most part of the interviewees mentioned that they do not consider these to be 'project portfolio success' dimensions but rather, dimensions associated with key portfolio management practices, similar to portfolio management practices such as appropriate change management processes, or to the definition of strategies or methods for project and program monitoring. In light of this, interviewee 9 stated that "*these are optimizing factors that enable me to have good practices but not measures of success*", interviewee 23 affirmed "*I think it <<synergy exploitation>> is more linked to being an element of management that may or may not have an impact on the result*", and interviewee 21 observed "*it is more about how all this management helps me to obtain certain results [...] initial balancing maybe helps me to carry out analyses to finally show those results*".

Thus, it is important to highlight that the interviewees implied that synergy exploitation and portfolio balance could be considered as PPM success dimensions, since adequate management of these dimensions helps to improve project portfolio performance. This leads to the need to identify the dimensions which can be associated with 'project portfolio success' and those which can be associated with PPM success, and the differences between them. Thus, 'portfolio success representation based on a subset of the portfolio success dimensions' represents the sixth theme which is posited as: Project portfolio success could be represented based on the dimensions strategic fit, future preparedness, and stakeholder satisfaction, which jointly with average of the project success, synergies exploitation, and portfolio balance represent the PPM success.

Considering that (i) the first theme defines that the organizational capabilities generated by the project portfolio lead to strategic impacts on the organization, and (ii) these success dimensions represent strategic aspects associated with the project portfolios; then it could be stablished this sixth theme as an extended representation of the strategic impacts established in the first theme (see relationship R6 in Figure 5.6). Figure 5.6 illustrates the six themes established by conducting reflexive TA. Also, it illustrates the relationship between them. The above mean that Figure 5.6 shows the figurative core for PPRA from the practitioners' perspective.

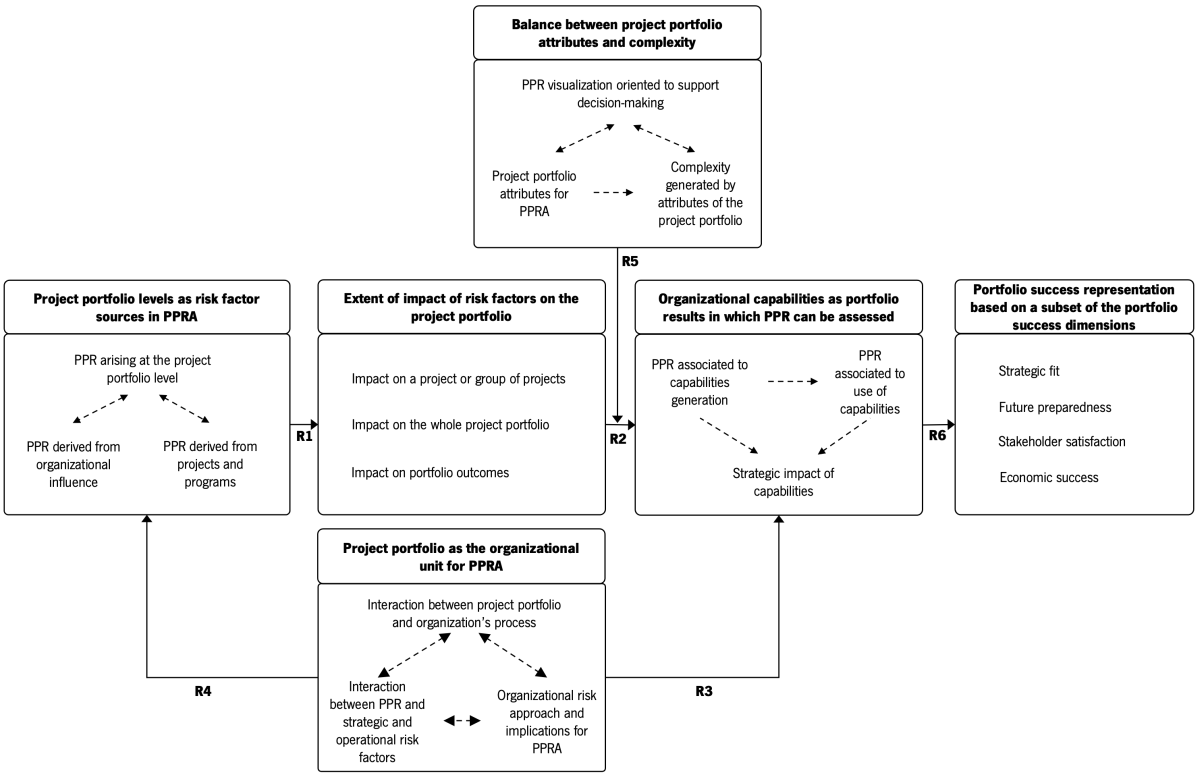


Figure 5.6. Representation of figurative core for PPRA from the practitioners' perspective

5.2 Discussion

Figure 5.6 illustrated the objectification of PPRA from portfolio practitioners. This objectification was developed based on the constructs derived from the literature analysis. Even though the six interdependent themes for PPRA are not generalizable, they suggest an expanded view of PPRA which may serve as starting point to pose an alternative PPRA conceptualization for organizational development project portfolios.

5.2.1 Practitioners-Based Framework for PPRA Operationalization

Thus, framed in the framework for PPRA design developed from SLR, the theme 'project portfolio levels as risk sources for PPRA' represents an organizational perspective of PPR sources, which could be considered an alternative perspective of the four risk sources categorization presented in the literature-based framework for PPRA design. Therefore, this theme is included in the construct 'PPR categories'. In this regard, it makes explicit that PPRA should assess more than just risk factors derived from the projects within the portfolio. The theme 'extent of impact of risk factors on the project portfolio' represents how risk factors impact the project portfolio, i.e., the paths through which risk factors affect the project portfolio. Then, this theme represents the link between risk factors and the project portfolio. Considering

that definition of construct 'PPR categories' incorporate both type of sources and impacts, theme 'extent of impact of risk factors on the project portfolio' is also contained in this construct.

The themes 'organizational capabilities as portfolio results in which PPR can be assessed' and 'portfolio success representation based on a subset of the portfolio success dimensions' describe the expected results of the portfolio, which are subsequently influenced by the impact of risk factors on the project portfolio. The theme 'organizational capabilities as portfolio results in which PPR can be assessed' describes the primary portfolio result level impact by the risk factors, while the theme 'portfolio success representation based on a subset of the portfolio success dimensions' evidences that a subset of success dimensions could be used as representation of the second level of portfolio results that are impacted by risk factors as a consequence of the organizational capabilities generated. In this regard, in term of the project portfolio expected results organizational capabilities generated emerge as an additional construct to 'project portfolio success' to represent the project portfolio expected results to be affected by the risk factors.

The theme 'balance between project portfolio attributes and complexity' relates to the attributes that could be incorporated to appraise the risk factor impact on the project portfolio expected results. For instance, positive or negative impact, interdependency between risk factors, and interdependency between projects. Thus, although explicit exploration of the construct 'risk assessment method' was not the focus of this research phase, TA of 'components for PPRA' led to identify a theme that falls within the construct 'risk assessment method'. Thus, this theme represents a first element to consider for defining a 'risk assessment method' for modeling the risk impact on portfolio success dimensions.

Finally, the theme 'project portfolio as the organizational unit of PPRA' represents that project portfolio is part of a parent organization that influences and is influenced by the project portfolio. In this regard, this theme shows the strategic nature of PPRA and frames it as an element of something larger. In contrast, the other themes represent the operationalization of PPRA.

Figure 5.7 illustrates a primary representation of the integration of the six themes into the literature-based framework for PPRA design. Even though the six interdependent themes for PPRA are not generalizable, they suggest an expanded view of PPRA which may serve as starting point to pose an alternative PPRA conceptualization through which it can be operationalized in practice. In this frame, the discussion below leads to develop a proposed conceptualization of a comprehensive PPRA based on a sequential logical path of four propositions to be considered for PPRA operationalization in practice. However, to become more generalizable they require further research.

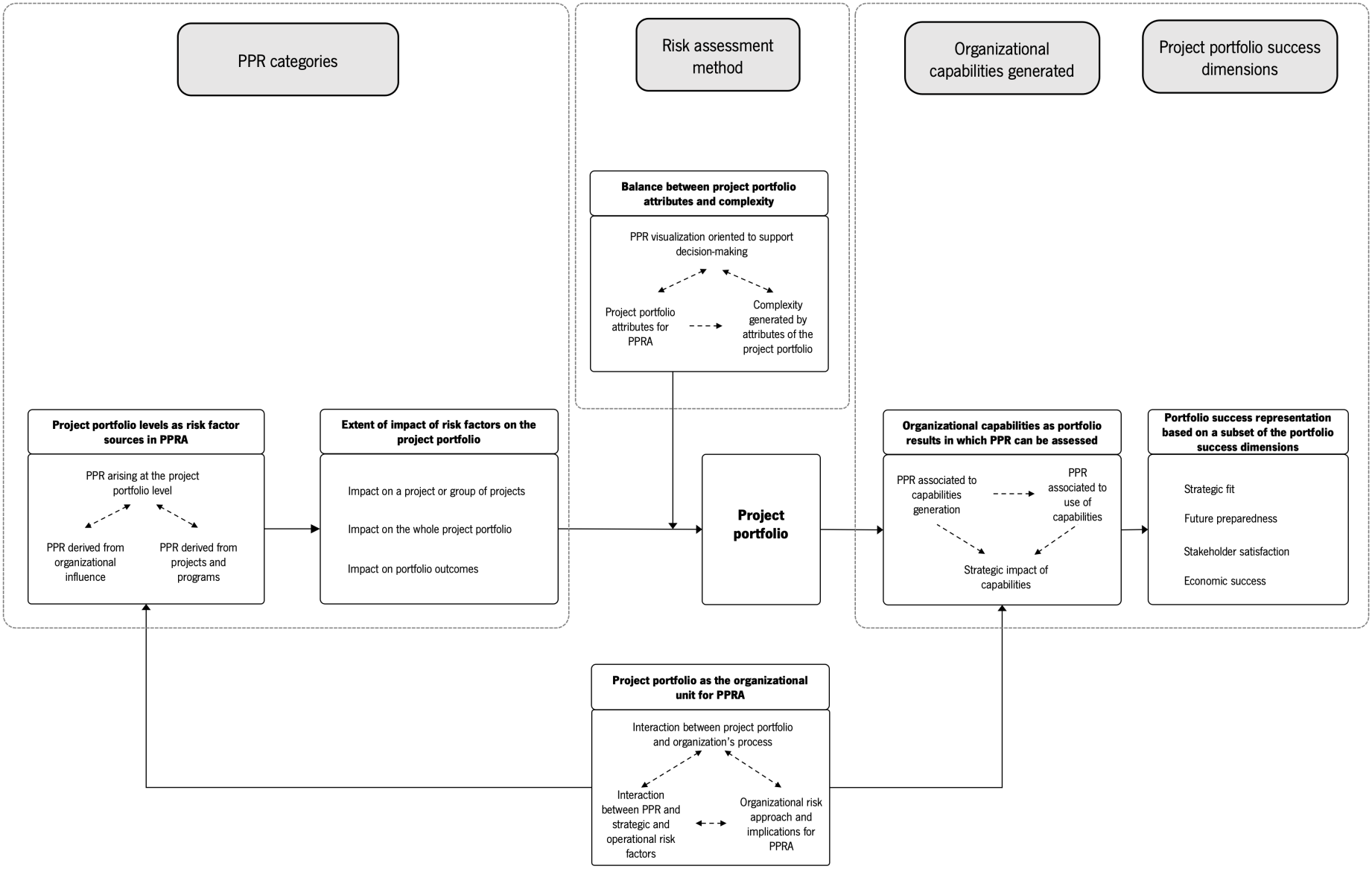


Figure 5.7. Practitioners-based framework for PPRA in organizational development project portfolios

5.2.2 Portfolio Success as the Representation of Project Portfolio Expected Results

An organizational view of projects portfolios helps to understand and examine its strategic role focusing on portfolio effectiveness over portfolio efficiency (Martinsuo and Geraldi, 2020, p. 1), i.e., it helps to focus on achieving the project portfolio expected results. In this regard, the literature shows 'project portfolio success' dimensions cover both the project portfolio effectiveness and efficiency. For Kock et al. (2020) the success dimensions strategic fit, future preparedness, and portfolio balance are associated to portfolio effectiveness, and 'average of project success' and synergy exploitation are associated to portfolio efficiency.

The findings show that PPR is associated with success dimensions linked directly with project portfolio results, or in other words, with project portfolio impacts on the parent organization. The above is in line with the success dimensions associated to portfolio effectiveness. Thus, the figurative core identified for the construct 'project portfolio success dimensions' included two of the success dimensions associated in the literature to portfolio effectiveness, strategic fit and future preparedness. Strategic fit incorporates aspects that reflect the alignment with the intended strategy and future preparedness reflects the long-term perspective on portfolio success (Kopmann et al., 2017). Also, the literature recognizes project portfolios are structured and oriented to both support the deployment of a set of organizational strategic goals and contribute to the parent organization being prepared for the future (Lehnert, Linhart, and Roeglinger, 2017; Teller et al., 2014; L. Wang et al., 2020).

Therefore, considering that strategic fit and future preparedness have been identified by both the literature and the interviewees as linked to the portfolio effectiveness, they are proposed to be part of the representation of the project portfolio results that are impacted by the PPR factors.

In addition, the figurative core derived from the practitioners' perspective incorporated stakeholder satisfaction as a dimension associated with the portfolio expected results. 'Stakeholders satisfaction' has been proposed at the project level by several authors who incorporate customer satisfaction as a major project success criterion (Jonas et al., 2013; Lechler and Dvir, 2010). However, at the project portfolio level stakeholder satisfaction has not explicitly been the subject of profound studies and debate as a project portfolio success dimension. So that, this success dimension requires further empirical and analytical studies to be confirmed or generalized in the frame of PPR analysis. Consequently, it is proposed that stakeholder satisfaction can be incorporated as a third success dimension associated to portfolio expected results, i.e., associated to portfolio effectiveness.

However, another success dimension associated to portfolio effectiveness in the literature, portfolio balance, was not recognized as such into the practitioners' figurative core identified. While Kock et al. (2020) mention portfolio balance as a dimension associated with portfolio effectiveness, the findings suggest that this dimension could be associated with portfolio efficiency. Interviewees associated portfolio balance with a key portfolio management practice, but one related to PPM optimization. In this concern, interviewees mentioned it as a very important part of PPM and considered it to be an integral part of the PPM process more than a portfolio results representation. Thus, the responses of the interviewees suggest that portfolio balance is a dimension related to the efficiency of the project portfolio.

This result contrasts with the literature, where portfolio balance has been associated with portfolio effectiveness (Kock et al., 2020). The above can be associated with the fact that interviewees mentioned that, in organizational development project portfolios, the balance between long- and short-term opportunities, in terms of innovativeness levels, are derived from a strategic plan of the organization and from specific goals defined in the organization's action plans. Therefore, the subject related to the portfolio is associated with how organizational resources and capabilities are used to achieve their goals.

This dimension was associated with aspects related to an adequate use of organizational resources, and therefore, in the frame of PPRA of organizational development project portfolios, portfolio balance is proposed as a dimension associated with portfolio efficiency more than a representation of project portfolio expected results.

Synergy exploitation and average project success are the success dimensions associated to portfolio efficiency in the literature. Synergy exploitation was mainly considered to be part of the PPM process or practices oriented to improving or maximizing the impact of PPM. As such, the interviewees associated synergy exploitation with the efficient management of resources rather than seeing it as a dimension oriented to defining whether the results of a project portfolio are successful or not. In this regard, aspects related to how synergies between projects are used have been associated with the efficiency of the project portfolio (Kock et al., 2020). Thus, the interviewees' considerations regarding this success dimension were consistent with the definition of synergy exploitation associated with the efficiency of the project portfolio.

Average project success was mentioned by interviewees as an aggregated measure, and it should not be considered as adequate because it can hide specific problems or difficulties within the projects. In addition to this, although they recognize that portfolio success is associated with project success, they stated that project success analysis should not be carried out as an aggregate measure but as an

individual project analysis, and therefore could correspond to project level success and to PM level. For example, interviewee 15 stated "*we monitor that <<project success>>, of course, but it is not the measure of <<portfolio>> success for us [...] <<project success>> could be considered as an <<portfolio>> operational measure*".

According to Kock et al. (2020, p. 232) "doing projects right, by looking at the success of all the containing projects" is part of the set of considerations covered by aspects related to the efficiency of the portfolio. At the portfolio level, aspects related to this dimension represent a monitoring process to enable projects to be executed well. Hence, similar to synergy exploitation, the findings regarding average project success are consistent with the concept of portfolio efficiency.

Thus, it is posed that success dimensions portfolio balance, synergy exploitation, and average project success are associated to portfolio efficiency. In this concern, as mentioned by some of the interviewees, the success dimensions associated with project portfolio efficiency could be seen as drivers towards the achievement of portfolio results rather than the representation of the portfolio results. For instance, interviewee 21 regarding 'synergies exploitation' mentioned: "*it is more about how its management helps me to obtain certain results"*. Therefore, approaches such as those carried out by Ghasemi et al. (2018) or Hofman et al. (2017) show the relevance of considering the success dimensions for planning and design the risk identification, which is the previous element to PPRA.

Economic success was a dimension mentioned spontaneously by few interviewees. However, according with Meskendahl (2010), economic success is considered to be a business success dimension which is influenced by project portfolio success rather than a project portfolio success dimension itself. Nevertheless, it was considered that an organization willing to incorporate this dimension into its PPRA could add it in as one of the indicators associated with the portfolio sponsor as a stakeholder, i.e., as part of the stakeholder satisfaction success dimension.

Thus, strategic fit, future preparedness, and stakeholder satisfaction are success dimensions that could be associated to portfolio effectiveness, while portfolio balance, synergy exploitation, and average project success to portfolio efficiency. And economic success is considered a business success dimension. The above is in line with the project portfolio results which could be associated, on one hand, with the fact that through the project portfolios the parent organization is looking for achieving strategic benefits (L. Wang et al., 2020); and, on the other hand, with the expectation that "project portfolio success depends on what kind of impact stakeholders want to achieve" (Martinsuo and Geraldi, 2020, p. 1). Then, the expected results derived from projects portfolios are related to achieving the expectation

of stakeholders, helping the parent organization to be prepared for the future, and achieving a set of strategic goals. Therefore, this insight led to the first proposition:

> **Proposition 1:** For PPRA design, the project portfolio expected results can be associated with success dimensions linked to portfolio effectiveness, specifically, with stakeholder satisfaction, future preparedness, and strategic fit.

5.2.3 Capabilities Generated as the Link Between Projects and Portfolio Success

As a consequence of considering 'project portfolio as the organizational unit for the PPRA', it was identified that the PPRA could represent the interaction between the portfolio and the parent organization, based on the impact of risk factors on the delivery or transfer of project portfolio results to the parent organization. Although this portfolio-organization relationship has been recognized in the general project portfolio literature, it has not yet been explicitly integrated into PPRA proposals. In this regard, considering 'organizational capabilities as portfolio results in which PPR can be assessed' would acknowledge and operationalize this interaction into the PPRA.

Usually, PPRA proposals consider that portfolio risks are mainly associated, on one hand, to project-level attributes such as the duration or total cost of projects (Ahmadi-Javid et al., 2020; Neumeier et al., 2018), or on the other hand, to business-level attributes such as the impact on the expected profitability derived from the portfolio (D. Guan et al., 2017). This research findings, contrast with these PPRA proposals, by identifying that PPRA could represent the impact of risk factors in terms of the way in which these factors impact the achievement of the expected organizational capabilities to be generated by the project portfolio. This raises the recognition of a construct for impact representation into risk assessment which is explicitly associated with the project portfolio level more than a general level or project level.

A PPRA oriented to assess the impact on the organizational capabilities to be generated by the project portfolio is in line with the PPRA orientation in which the impact on the organization's strategic goals is assessed. In this concern, a PPRA conceptualization based on expected capabilities does not ignore the relationship between projects within the portfolio and organizational strategy recognized in the literature (Relich and Pawlewski, 2017; Serra and Kunc, 2015), but it would recognize that strategic impacts from the project portfolio are derived from the organizational capabilities generated.

A project portfolio is structured to fill a value gap defined by the parent organization in its strategic plan (Lehnert et al., 2017; Serra and Kunc, 2015). Then, project portfolios give value to the parent

organization and its strategy, as well as to the project portfolio stakeholders (internal and external), by new or improved capabilities that are delivered from projects within the project portfolio to the parent organization (Lehnert et al., 2017). In this regard, Capability-Based Planning (CBP) has been identified as a paradigm that allows relating projects to the strategic capabilities they impact (Aldea, Iacob, Daneva, and Masyhur, 2019; Shafi et al., 2017). The notion of CBP first emerged in the context of defense planning (Aldea et al., 2019; Shafi et al., 2017). In that context, a capability refers to the capacity or ability to achieve an operational effect, and, from an extended perspective, a capability is defined as the power or ability to do something (Shafi et al., 2017).

Thereby, from a capability-based view, a project portfolio is oriented to achieve operational effects in the parent organization or, in other words, to provide the ability to do something new or in a better way, enabling positive and clearly defined strategic benefits. In this regard, in the frame of business process improvement, project portfolios help to develop both organizational capabilities by improving a set of specific processes and the organization's business process management capabilities (Lehnert et al., 2017). Process improvement positively influences organizational performance and contributes to achieving organizational goals, while business process management capabilities help to enable business improving processes more easily in the future (Lehnert et al., 2017; Niehaves, Plattfaut, and Sarker, 2011).

Hence, the projects within the portfolio should be managed according to the value generated by each project in supporting the value to be provided by the project portfolio level to the parent organization (L. Wang et al., 2020) or, in other words, to offer new and improved capabilities to currently compete and succeed in the future context (Lehnert et al., 2017; Santhanam and Hartono, 2003).

The above means that risk factors impact could be assessed based on the direct impact on the expected organizational capabilities to be generated by the project portfolio which represent the driver to give delivering value to the parent organization. Hence, the impact on capabilities to be generated by the portfolio is, in turn, transferred to the parent organization and its strategy, as well as to the organizational stakeholders at the project portfolio level. This perspective allows to assess the portfolio risk based on the portfolio expected results from an organizational view, i.e., directly on how the project portfolio delivers value to the parent organization – the expected organizational capabilities. Thus, this insight extends that concept as a construct for the primary representation of risk factor impacts.

In addition, according to Serra and Kunc (2015) strategic impacts derived from projects within the portfolio are mediated by other factors which cannot exclusively be associated with the project portfolio,

rather with organizational, operational, or strategic factors. Hence, PPRA based on expected organizational capabilities would recognize that, although there is a relationship between portfolio and strategy, assessing risk directly on the expected strategic impacts would involve more than just the assessment of risk of the project portfolio. Thus, this insight led to the second proposition:

> **Proposition 2:** The capabilities to be generated by the project portfolio can be used as the portfolio primary results on which PPRA can assess the risk of the project portfolio, establishing the impact of PPR on the project portfolio value delivering to the parent organization.

5.2.4 Extent of Risk Factors Impact

PPRA proposals have mainly focused on an inward risk assessment considering in most cases only the risk derived from projects and their interdependencies (D. Guan et al., 2017; Neumeier et al., 2018; Q. Wang et al., 2017). In this concern, for instance, the literature has identified that the interdependence between risk factors influences the extent to which projects are impacted (Q. Wang et al., 2017; Zou et al., 2021). Likewise, current PPRA proposals suggest that project interdependencies represent project-derived risk factors which, in turn, impact both the projects and project portfolio expected results (D. Guan et al., 2017; Neumeier et al., 2018). These types of considerations, typically addressed into PPRA, according to the interviews analysis were represented in the theme 'balance between portfolio attributes and complexity'.

However, although the literature recognizes that project portfolios are not an isolated element of its parent organization (Bai et al., 2020; Martinsuo and Geraldi, 2020), and that the study of risk factors at project portfolio level has recently been called upon (Ghasemi et al., 2018; Hofman and Grela, 2015), PPRA that comprehensively incorporates the impact of risk factors of an organizational nature, as well as those derived at the project portfolio level, as highlighted by interviewees (see theme 'project portfolio levels as risk sources for PPRA'), has been scarcely explored. In this regard, the impact of risk factors on the project portfolio was represented in the figurative core in accordance with the 'extent of impact of risk factors on the project portfolio'.

In the theme 'extent of impact of risk factors on the project portfolio' emerged that risk factors can impact the project portfolio by impacting a project or a specific group of projects, the whole projects within the portfolio, or the portfolio outcomes. The first two types of extent of risk factor impact are related to impacts on portfolio outputs, while the last one to portfolio outcomes. In this concern, the deviation between expected capabilities and realized capabilities provided by the project portfolio could be associated with both risk factors related to the capabilities development process and risk factors related

to the preparation of the parent organization to use them. In this regard, the way in which capabilities are developed leads to generating the expected outputs, while the use of them to produce strategic benefits embodies the portfolio outcomes. The above is in line with the fact that project portfolios aim to achieve desired mid- or long-term outcomes (Richard et al., 2021).

Thus, analogous to the project-level analysis made by Serra and Kunc (2015), but considering the project portfolio level, it is posed that deviations derived from both project portfolio outputs and outcomes may lead to not achieving the expected impacts on the parent organization. Therefore, both risk factors associated with the project portfolio outputs and outcomes could impact on project portfolio expected results, so that, both kinds of risk factors should be incorporated into risk assessment.

For the conceptualization of a comprehensive PPRA, risk factors associated with the outputs were named output-related risk factors, and risk factors associated with the outcomes were defined as outcome-related risk factors. The output-related risk factors are related to the execution of projects within the project portfolio through which capabilities are developed, i.e., risk factors that produce a direct impact on projects within the portfolio. The outcome-related risk factors are directly related to the preparation of the organization to use capabilities to produce the expected strategic benefits. The above led to defining the third proposition.

Proposition 3: The risk factors that impact the project portfolio expected results can be represented into PPRA as output-related risk factors and outcome-related risk factors.

Regarding risk factors with a direct impact on projects within the portfolio, the literature recognizes that some of them generate impacts on only one of the projects, but other risk factors generate an impact on two or more projects within the portfolio, being identified as shared risk factors (Ahmadi-Javid et al., 2020; Ghasemi et al., 2018). In this regard, Ahmadi-Javid et al. (2020) defined as 'local risks' those risk factors that impact only one project, while those that are shared between projects and consequently impact two or more projects as 'global risks'.

The shared risk factors and their impact have been incorporated in PPRA mainly based on project interdependencies considering, in most cases, resource and output interdependencies (Ghasemi et al., 2018; D. Guan et al., 2017). Similarly, in approaches focused on project portfolio selection this type of impact derived from shared risk sources is usually incorporated into PPRA using measures that represent the risk relationship between projects, such as co-variance between expected monetary results of each pair of projects. Then, the risk factor impact on one or a subset of projects within the portfolio has been previously identified and incorporated in PPRA proposals identified in the literature. So that, this type of

risk factor impact posed by interviewees is in line with previous studies in the field. Incorporation of a second type of extent of risk factor impact associated to impact on the whole projects within the portfolio has been scarcely incorporated in approaches for portfolio risk assessment, except for those based on MPT. Specifically, only in the studies conducted by Hofman and Grela (2018) and Ghasemi et al. (2018), where the risk assessment approaches are not based on MPT, have that type of general impact been assessed. However, in an integrated manner with risk factors that impact a project or a subset of projects only in Ghasemi et al. (2018) proposal can this incorporation be found. Concerning that, Ghasemi et al. (2018) have designated these risk factors as portfolio-level risk factors. Nevertheless, for Hofman and Grela (2018) in that category are also being included risk factors that are associated with project interdependency but they do not necessarily impact all projects within the portfolio. In other words, there is no evidence that the approaches being followed present an agreement on how to categorize the risk factors that impact the project portfolio directly (defined as output-related risk factors in proposition 3).

In contrast, from MPT applied to project portfolios the concepts of unsystematic and systematic risk are widely accepted to denote the two types of risk generated on the portfolio. The concept of unsystematic risk comprises the portfolio risk contributions derived from both individual project risk contributions and contributions derived from risk correlation between each pair of projects within the portfolio (Tang et al., 2017). Systematic risk comprises the portfolio risk contribution derived from exogenous events that affect the whole project portfolio, i.e., widespread across the system. In this regard, the two type of output-related risk factors derived from the practitioners' figurative core present a significant similitude with the concepts of systematic and unsystematic risk factors.

The impact produced by risk factors only on a project or a group of them could be represented as unsystematic risk factors, while the influence on portfolio risk derived from risk factors that impact on the whole portfolio could be represented as systematic risk factors. However, that association requires a careful analysis given the differences of risk representation between an approach based on MPT and an approach based on the figurative core illustrated in Figure 5.7. In approaches based on MPT risk assessment is focused on the risk of the expected monetary profitability as representation of the project portfolio expected results. Regarding that approach, the literature mentions that assessing risk only in monetary terms does not recognize the strategic orientation and neglects to acknowledge how the project portfolios deliver value to the parent organization (Bai et al., 2021; Sanchez and Robert, 2010b; Sanchez et al., 2008; L. Wang et al., 2020). In contrast, the figurative core of PPRA derived from practitioners' perspective shows the capabilities to be generated by the portfolio as representation of how portfolio

delivers value to the parent organization, i.e., as a primary representation of expected portfolio results affected by the PPR. The above means that the unit of impact is not represented by monetary units.

Another difference to consider is that in MPT systematic risk is non diversifiable in nature. However, as mentioned in Section 4.2, in project portfolios systematic risk can be reduced through risk management and efficiency management policies associated with the operational non-diversifiable risk (Paquin et al., 2016). Then, systematic risk comprises the portfolio risk contribution derived from events that affect the whole project portfolio, however it could be reduced through risk management and efficiency management policies. Regarding non-systematic risk, the individual project risk contribution is derived from risk factors impacts on each project, while the influence from project dependency and shared risk factors between projects is the analogy of what in MPT is represented as impact on portfolio risk derived from the correlation between risk of each pair of projects. Thus, based on the concepts of systematic and non-systematic risk, the fourth proposition was posed.

Proposition 4: The extent of the impact on projects within the portfolio from output-related risk factors can be represented as systematic or non-systematic into PPRA.

5.2.5 Risk Transferring Path: From Risk Factors to Portfolio Success

Based on the four propositions Figure 5.8 shows the empirical conceptualization of how the risk is transferred from risk factors to project portfolio success in portfolios of organizational development projects. Thus, it is posed that the impact of risk factors on the project portfolio expected results could be based on the risk transferred from output-related risk factors and outcome-related risk factors to projects within the portfolio, capabilities, and in turn, portfolio success.

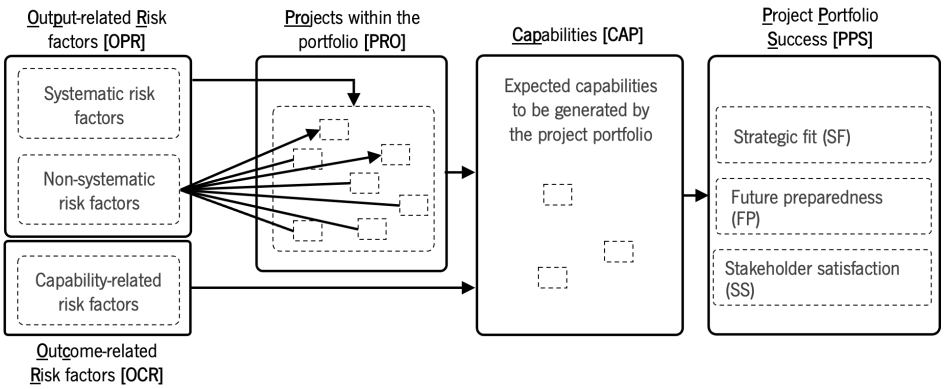


Figure 5.8. Conceptualization of how risk is transferred from risk factors to portfolio success

Thus, Figure 5.8 depicts a conceptual integration of risk factors as input with portfolio expected results as the output of PPRA. Figure 5.8 is the representation of what a PPRA model should incorporate to assess the portfolio risk in portfolios of organizational development projects. By integrating the

figurative core of the practitioners' perspective with the four propositions derived from the results discussion, Figure 5.9 illustrates the proposal for a comprehensive PPRA based on organizational development projects.

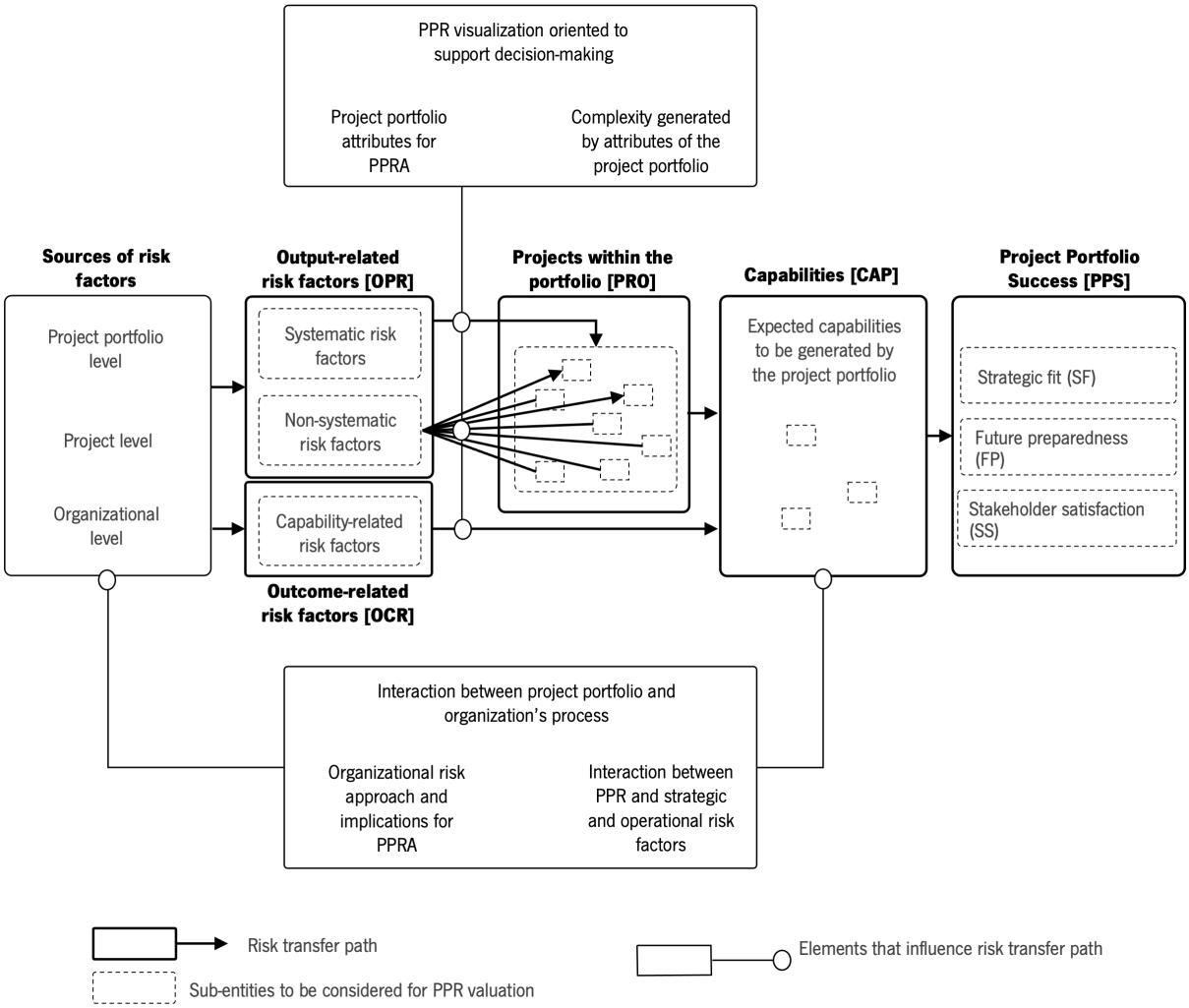


Figure 5.9. Conceptualization of a comprehensive PPRA in organizational development project portfolios

According to the research paradigm adopted, it represents an approach suited to design organizational processes, while helping to understand how PPRA can incorporate the characteristics of the project portfolio and how it interacts with the parent organization from a risk perspective. In this regard, the approach recognizes the project portfolio as an organization hosting temporary organizations (projects), and therefore, recognizes that interactions that occur within each project and between projects could represent risks to the portfolio. It also recognizes that the project portfolio interacts with its context, specifically with its parent organization.

The proposed approach posits that PPRA could be designed by considering the primary impact on organizational capabilities to be generated by the project portfolio as representation of how the value is delivered by the project portfolio to the parent organization. Additionally, it also posits that as a

consequence of the incorporation of organizational capabilities into the parent organization, the risk is transferred to the 'project portfolio success dimensions' that reflect the portfolio effectiveness. Thus, for PPRA planning and design, both capabilities and success dimensions represent attributes that are affected by the risk, reflecting the risk impact on how project portfolios deliver value to the parent organization and its strategy.

5.3 Summary

This chapter reports the qualitative analysis of the twenty-eight interviews, in order to incorporate the practitioners' view into the literature-based framework for PPRA design, and then derive a comprehensive PPRA conceptualization. The interview data analysis led to identification of six interdependent themes through which practitioners' perspective can be schematized. The themes were defined as follow:

Organizational capabilities as portfolio results in which PPR can be assessed: the PPR associated to capabilities generation, i.e., the risks that affect capabilities generation; and PPR associated with the use of capabilities, i.e., the risks that might endanger adequate use of capabilities by the organization; and the organizational capabilities generated by the project portfolio leading to strategic impacts on the organization.

Project portfolio levels as risk sources for PPRA: project portfolios are affected by a set of specific risk factors arising at the project portfolio level, as well as risk factors that emerge from the projects and programs as the operational units of the portfolio, and risk factors derived from the organizational influence.

Extent of impact of risk factors on the project portfolio: PPRA should integrate the diverse ways in which risk factors jointly impact the project portfolio expected results, which can be derived from the impact on a group of projects, on the portfolio as a whole, or portfolio outcomes.

Project portfolio as the organizational unit for PPRA: the risk assessment of project portfolios should recognize the organizational risk approach and its implications for PPRA, as well as acknowledge the interaction between project portfolio and the organization's processes, and the influence of the organizational risk factors in the PPR.

Balance between project portfolio attributes and complexity: The extent of incorporation of project interdependencies, opportunities, and risk interdependencies is relative to the balance between relevance for the project portfolio, organizational conditions, and added value for the decision-making process at the organizational level.

Portfolio success representation based on a subset of the portfolio success dimensions: framed in PPRA, project portfolio success could be represented based on the dimensions strategic fit, future preparedness, and stakeholder satisfaction which are linked to portfolio effectiveness.

These themes were framed into the literature-based framework for PPRA design and then discussed. Discussion led, additionally, to the definition of four main propositions:

Proposition 1: For PPRA design, the project portfolio expected results can be associated with success dimensions linked to portfolio effectiveness, specifically, with stakeholder satisfaction, future preparedness, and strategic fit.

Proposition 2: The capabilities to be generated by the project portfolio can be used as the portfolio primary results on which PPRA can assess the risk of the project portfolio, establishing the impact of PPR on the project portfolio value delivering to the parent organization.

Proposition 3: The risk factors that impact the project portfolio expected results can be represented into PPRA as output-related risk factors and outcome-related risk factors.

Proposition 4: The extent of the impact on projects within the portfolio from output-related risk factors can be represented as systematic or non-systematic into PPRA.

Based on the empirical findings and their discussion, a comprehensive PPRA conceptualization was proposed in this chapter (see Figure 5.9) to support organizations on their PPRA design process. The central structure of the proposed conceptualization of a comprehensive PPRA is composed by sources of risk factors, output- and outcome-related risk factors, projects within the portfolio, capabilities to be generated by the portfolio, and portfolio success dimensions associated with portfolio effectiveness. That central structure represents the path through which risk factors impact project portfolio success. In addition, that central structure is guided by two themes: 'Balance between project portfolio attributes and complexity', and 'Project portfolio as the organizational unit for PPRA'. The conceptualization of a comprehensive PPRA corresponds to the first output defined for this research project.

PART III. RESEARCH DEVELOPMENT: A PPRA MODEL

6. PPRA MODEL STRUCTURE [3]

Phase III of this research project was focused on enabling the practical use of the conceptualization of a comprehensive PPRA that was proposed in the previous chapter. For that, an analytical model was formulated and later applied in an organizational development project portfolio belonging to a Colombian organization. Therefore, this chapter describes the proposed analytical model – the application in the case study is reported in the following Chapter 7. First, a general structure that would allow to model the proposed PPRA was required. Thus, the model structure is based on Meta-Network Analysis (MNA) and is described in Section 6.1. That structure helps modeling relationships between the elements comprising the system to be modeled, in this case, risk factors, projects, organizational capabilities, and success dimensions. Also, it allows modeling interdependencies within each element according to its specific characteristics.

Derived from the proposed model structure three stages were defined for its practical use. Stage 1 is associated with analysis of risk factors interdependencies. The description of this Stage is reported in Section 6.2. Dependencies between risk factors were modeled based on Interpretive Structural Modeling (ISM) and Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC – acronym in French that stands for Matrice d'Impacts Croisés Multiplication Appliquée à un Classement). In Stage 2 is modeled how the risk is transferred from risk factors to success dimensions based on the model structure previously defined in Section 6.1. Description of Stage 2 is provided in Section 6.3. Finally, Section 6.4 shows the third Stage of the proposed PPRA model. This third Stage is focused on the results representation in line with the fact that PPRA must provide information on the risk composition at the portfolio level, helping the decision-makers manage portfolio risk and supporting risk response decisions.

6.1 PPRA Model Overview

Following the conceptualization described in Section 5.2.5, five types of entities should be recognized for assessing the PPR: 1) **O**ut**p**ut-related **R**isk factors [OPR], 2) **O**ut**c**ome-related **R**isk factors [OCR], 3)

[3] This chapter was partially the object of the papers: Micán, C., Fernandes, G., & Araújo, M. (2021). Incorporating the Influence of Risk Factor Interdependencies and Shared Risk Factors into Project Portfolio Risk Assessment. In 2021 *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 994-998. https://doi.org/10.1109/IEEM50564.2021.9673024
Micán, C., Fernandes, G., & Araújo, M. (2022). A method for project portfolio risk assessment considering risk interdependencies – A network perspective. *Procedia Computer Science*, 196, 948-955. https://doi.org/10.1016/j.procs.2021.12.096
Micán, C., Fernandes, G., & Araújo, M. A Method for Assessing the Impact of Project Portfolio Risk on the Portfolio Success considering Risk Factors Interdependency. It is expected to be submitted to: *Computers and industrial engineering*.

Projects within the portfolio [PRO], 4) **Cap**abilities [CAP], and 5) **P**roject **P**ortfolio **S**uccess [PPS]. Regarding each entity, the literature recognized the existence of internal interdependencies. For example, regarding considerations about risk factors interdependency, the literature highlights that the evaluation of interdependencies and the correlation between risk factors allow for the identification of risk factors with a greater impact over the portfolio's objectives not only due to their direct impact but also because of the indirect effect they may generate through other risk factors (Cooley et al., 2012; Q. Wang et al., 2017).

Similarly, it has been identified that interdependencies between projects generate both positive and negative effects on projects and the project portfolio (Ghasemi et al., 2018; Neumeier et al., 2018; Olsson, 2008). For instance, the interaction between stakeholders or between strategic objectives has been analyzed by recognizing the relevance of these kinds of interactions for the decision-making process, from both risk analysis and organizational perspectives (Bai et al., 2021; Chen, Chuang, Sangaiah, Lin, and Huang, 2019). Regarding how projects within the portfolio deliver value to the parent organization, L. Wang et al. (2020), for instance, studied how the interaction between the value realization from the projects within the portfolio influences the value added to the parent organization.

Thus, each of the entities comprising the PPRA system could be considered as an independent subsystem in which its internal entities are interdependent. Hence, each entity could represent a network itself, which is interconnected with other entities following the connections between them, as described in Figure 5.9. Therefore, this structure could be modeled as a meta-network. A meta-network can be conceptualized as a multi-node and multi-link network composed of different node entities and connections among them (Y. Li et al., 2015; T. Wang et al., 2021). According to T. Wang et al. (2018), MNA has been conducted in diverse fields such as supply chains, e-commerce, knowledge networks, and public health systems.

MNA allows that changes in an entity can be expressed as changes in other entities or in the relationships between them. Additionally, MNA can effectively handle the complexity associated with multi-objective management and cater for risk intervention based on the assessment results (T. Wang et al., 2021). In light with the above, the proposed PPRA model was based on MNA. Hence, five entities were defined in the project portfolio conceptualization as the units of analysis for PPRA (see Figure 5.9) and established as connected entity nodes. However, due to the focus of the present research project, the proposed model presented herein concentrates on the incorporation of risk interdependency and the establishment of a strategy for transferring the risk from risk factors to the portfolio success.

The proposed model was structured in three stages. The first one is oriented to the risk interdependency analysis, i.e., to modeling internal links between output-related risk factors and between outcome-related risk factors as well as the links between those two entities. The second Stage aims at determining the impact of a set of risk factors on portfolio success, i.e., to determine the impact on strategic fit, future preparedness, and stakeholder satisfaction. In the last Stage, the results obtained in the previous two Stages are processed to report the PPR and provide information to support future risk response planning. Thus, Stage 1 and Stage 2 are associated with modeling the meta-network for PPRA, while Stage 3 concerns PPRA results reporting. Figure 6.1 illustrates the representation of the Meta-Network and the PPRA Stages.

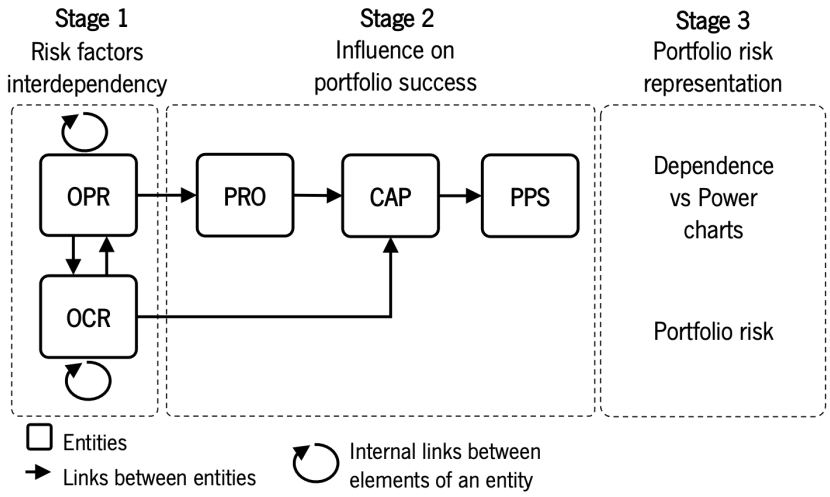


Figure 6.1. Stages of the PPRA model proposed based on meta-network representation

Regarding risk factors, the literature has identified some aspects to be considered for their adequate representation. Specifically, considerations relate to 1) risk factor attributes, and 2) the incorporation of threats (negative risk factors) and opportunities (positive risk factors) (D. Guan et al., 2017; PMI, 2017a). Concerning the first one, attributes such as occurrence, severity, and detection have been identified in the literature as candidates to properly represent risk factors (Ahmadi-Javid et al., 2020; PMI, 2017a). As in Ahmadi et al. (2020), occurrence and severity were adopted as the attributes for risk factor representation in the PPRA model proposed herein.

Regarding threats and opportunities incorporation, both of them as well as their compensatory effects have been highlighted in the literature (Ahmadi-Javid et al., 2020; PMI, 2017a). Therefore, they were both considered for the design of the proposed PPRA model. Thus, based on the five entities and the relationship between them that was previously described, Figure 6.2 shows a representation of the system to be modeled.

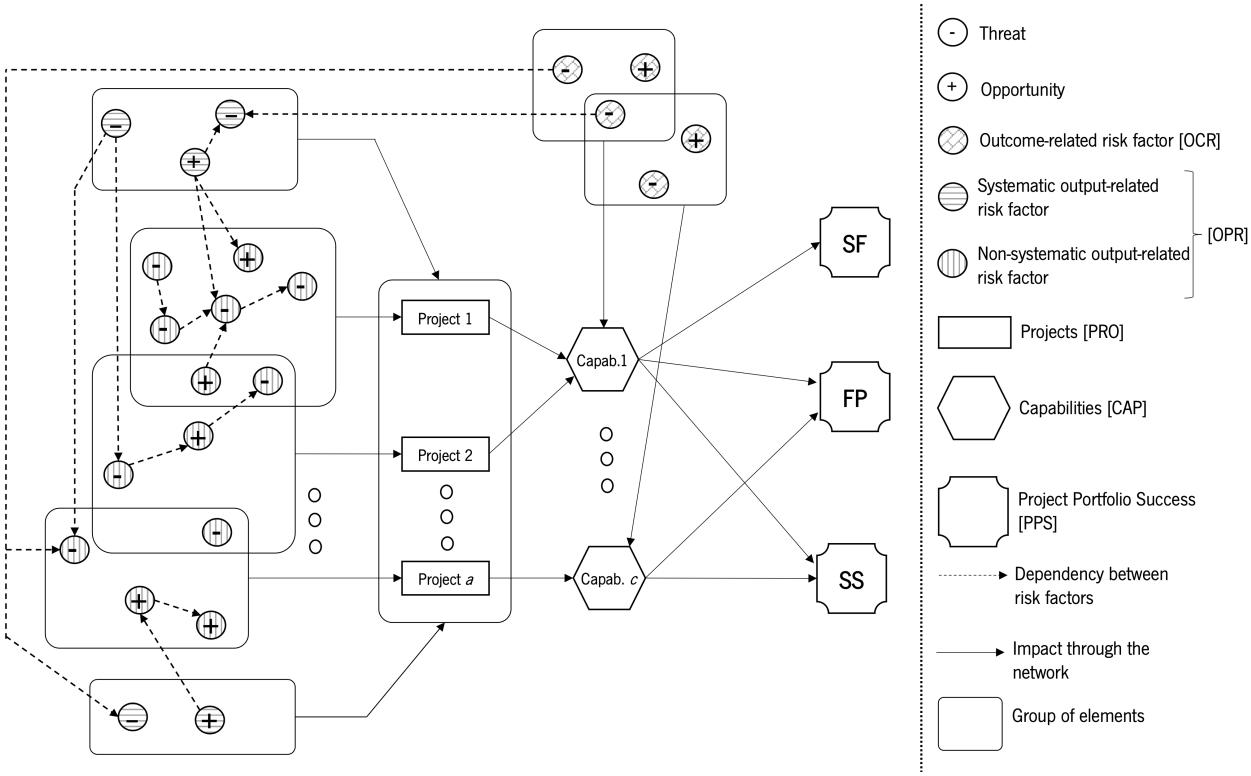


Figure 6.2. Representation of the system to be modeled (Illustration)

6.2 Incorporation of Project Portfolio Risk Interactions

In this Stage, the internal networks of the entities output-related risk factors and outcome-related risk factors are modeled, as well as the relation between them. For that, a method based on ISM and MICMAC is proposed. The ISM method aims to identify the interrelation between complex factors within a system. Specifically, concerning risk analysis, the ISM method is characterized as an effective tool for identifying risk factor interdependencies, since it helps to identify all possible pairwise relations of system elements based on the identification of the risk transmission between elements through network paths (L. Guan et al., 2020).

The ISM and MICMAC methods can be combined since both methods are based on a structural analysis matrix (Dandage et al., 2019; L. Guan et al., 2020). In this regard, the MICMAC has been conducted to establish the strength to which a risk factor influences the other factors, i.e., to establish the drive power, and to determine the strength to which a risk factor is affected by the others, i.e., the dependence power. Then, MICMAC helps analyze the drive and dependence power of the elements involved, which could be identified based on an ISM model (Dandage et al., 2019; L. Guan et al., 2020).

Thus, for Stage 1 of the proposed model, a network structure with risk factor paths is established following the ISM method, which is based on the direct risk factor interdependencies. MICMAC method

is conducted to evaluate the drive/dependence power of risk factors as a function of the potential risk variation derived from each risk factor, and to determine the adjusted value of the risk factors' parameters by considering the influence from risk factor interdependency. Figure 6.3 shows the four steps proposed to implement Stage 1. These three steps are described in the following subsections and illustrated by numerical examples after the mathematical formulation is presented.

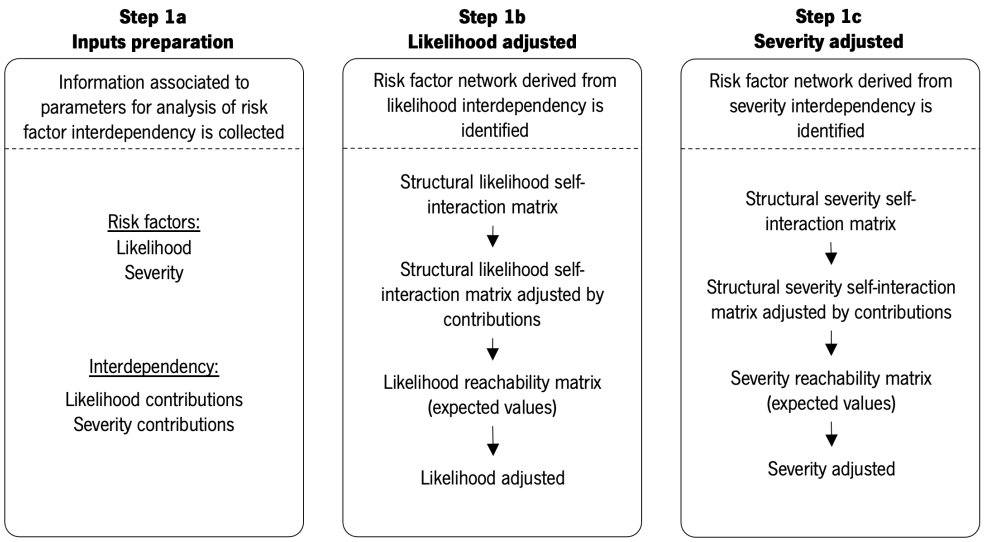


Figure 6.3. Steps to implement Stage 1 of the PPRA proposed model

6.2.1 Step 1.a – Inputs Preparation for Stage 1

The following parameters represent the inputs for the risk factor interdependency incorporation, i.e., the inputs required for the next steps.

$\boldsymbol{li_i}$: Likelihood of the risk factor $\boldsymbol{i}$

$\boldsymbol{sep_{ia}}$: Severity of risk factor $\boldsymbol{i}$ on the project $\boldsymbol{a}$

$\boldsymbol{sec_{ic}}$: Severity of risk factor $\boldsymbol{i}$ on capability $\boldsymbol{c}$

$\boldsymbol{lc_{ij}}$: Likelihood contribution from risk factor $\boldsymbol{i}$ to risk factor $\boldsymbol{j}$

$\boldsymbol{sc_{ij}}$: Severity contribution from risk factor $\boldsymbol{i}$ to risk factor $\boldsymbol{j}$

A Likert scale from 0 to 5 was adopted for risk factors likelihood (li_i). The value 1 corresponds to very low likelihood, while 5 corresponds to very high likelihood. The value 0 is required for risk factor interdependency considerations, since, for example, the occurrence of a specific risk factor could lead to the non-occurrence of another risk factor as a consequence of them being two mutually exclusive factors.

For parameters associated with severity, sep_{ia} and sec_{ic}, it was also adopted a Likert scale from -5 to 5. The severity level is associated with the impact on the expected outputs or with the impact on the expected outcomes from output-related risk factors (sep_{ia}) or from outcome-related risk factors (sec_{ic}), respectively. Thus, severity derived from both output-related and outcome-related risk factors

defined as threats are qualified from 0 to -5; and severity derived from both output-related and outcome-related risk factors defined as opportunities are qualified from 0 to 5.

The values 1 or -1 correspond, respectively, to a very low positive or negative severity level, while 5 or -5 correspond, respectively, to a very high positive or negative severity level. The value 0 is required since risk factors do not have impact on all entities (outputs or outcomes). For example, a specific non-systematic risk factor could impact one or more projects within the portfolio, however, it does not impact all the projects, which implies that the severity of that risk factor associated with non-impacted projects will be equal to 0.

The influence or contribution from one risk factor to another could take values from –5 to 5. The lc_{ij} value of –5 and the sc_{ij} value of – 5 means that, if risk factor 'i' materializes, the likelihood or the severity level of risk factor 'j' can decrease by up to five levels, respectively. On the contrary, a lc_{ij} = 5, or sc_{ij} = 5, means that, if risk factor 'i' materializes, the likelihood level of risk factor 'j', for lc_{ij}, or the severity of the risk factor 'j', for sc_{ij}, can increase by up to five levels.

Table 6.1 shows an example of the inputs for a hypothetical project portfolio. In this case, four output-related (risk factors 1 to 4) and two outcome-related risk factors (risk factors 5 and 6) are exemplified. Table 6.1 allows identifying that the numerical example is composed of three projects and two capabilities. Also, Table 6.1 illustrates that risk factors 1, 3, 5, and 6 are threats, whereas risk factors 2 and 4 are opportunities. According to Table 6.1, risk factor 1 impacts projects 1 and 2 while risk factor 2 only impacts project 1, for instance.

Table 6.1. Illustrative example of parameters li_i, sep_{ia}, and sec_{ic}

Risk factor	$\boldsymbol{li_i}$	$\boldsymbol{sep_{ia}}$			$\boldsymbol{sec_{ic}}$	
		$\boldsymbol{a = 1}$	$\boldsymbol{a = 2}$	$\boldsymbol{a = 3}$	$\boldsymbol{c = 1}$	$\boldsymbol{c = 2}$
$\boldsymbol{i = 1}$	3	–2	–3	0	-	-
$\boldsymbol{i = 2}$	4	3	0	0	-	-
$\boldsymbol{i = 3}$	2	0	–2	–2	-	-
$\boldsymbol{i = 4}$	2	0	0	4	-	-
$\boldsymbol{i = 5}$	3	-	-	-	–2	0
$\boldsymbol{i = 6}$	2	-	-	-	–2	–3

Table 6.2 shows an example of parameters of likelihood and severity influence between risk factors. In this example, risk factor 2 has a positive likelihood influence on risk factor 3 equivalent to 2 levels. The above means that the likelihood level of the risk factor 3 could increase by up to two levels, i.e., the likelihood of the risk factor 3, initially defined as level 2 (Table 6.1), could increase up to level 4. Moreover, Table 6.2 shows that risk factor 4 has no likelihood or severity influence on any other risk factor.

Table 6.2. Illustrative example of parameters lc_{ij} and sc_{ij}

$\boldsymbol{lc_{ij}}$	$\boldsymbol{sc_{ij}}$
$lc_{12} = 3$	$sc_{23} = 2$
$lc_{23} = 2$	$sc_{34} = -2$
$lc_{34} = 2$	$sc_{63} = 2$
$lc_{63} = -2$	$sc_{56} = -3$

Regarding severity influence between risk factors, Table 6.2 shows, for instance, that risk factor 6 has a positive severity influence on risk factor 3 equivalent to 2 levels. This means that the severity level of the risk factor 3 could increase by up to two levels, i.e., the severity of the risk factor 3, initially defined as level –2 for projects 1 and 2, could increase to level –4 due to the influence from risk factor 6. Another case illustrated in Table 6.2 corresponds to risk factor 3, which has a negative severity influence on risk factor 4 equivalent to –2 levels. This is to say that the severity level of risk factor 4 could decrease by up to two levels, i.e., the severity of risk factor 4, initially defined as level 4 for project 3, could decrease until level 1 due to the influence from risk factor 3.

The information described in Table 6.1 and Table 6.2 would be collected from both project portfolio information and qualitative perceptions of the people related to the projects, portfolio, and risk management process in each organization.

6.2.2 Step 1.b – Likelihood Adjusted due to Risk Factor Interdependency

<u>Structural likelihood self-interaction matrix:</u>

As for the inputs of the structural likelihood self-interaction matrix, the likelihood contributions between each pair of risk factors (lc_{ij}) correspond to the elements that constitute the interdependency network to be represented. Thus, the set of lc_{ij} constitutes the elements of the initial structural likelihood self-interaction matrix '$SC(lc_{ij})$' as shown in Equation (1). In this regard, the system to be analyzed is composed of 'n' output-related risk factors and 'm' outcome-related risk factors. Therefore, the self-interaction matrix is composed of $n + m$ rows and $n + m$ columns, i.e., the dimension of the matrix is $(n + m)x(n + m)$.

$$SI(lc_{ij}) = [lc_{ij}]_{(n+m)(n+m)} \quad \textbf{(1)}$$

Since lc_{ij} could lead to li_j to be greater than its maximum possible value or to be less than the minimum possible value (li_j can increase in the case of lc_{ij} >0 or decrease for lc_{ij} <0), a structural likelihood self-interaction adjusted matrix is required to ensure that the adjusted likelihood of any risk factor derived from the influence of another risk factor remains within the established limits for li_j. This

matrix is defined by Equation (2), where alc_{ij} represents the maximum possible contribution (positive or negative) from risk factor 'i' on risk factor 'i' given the initial value of the parameter li_j. The alc_{ij} values are calculated following Equation (3).

$$SI(alc_{ij}) = [alc_{ij}]_{(n+m)(n+m)} \quad \textbf{(2)}$$

$$alc_{ij} = \begin{cases} Min\,(lc_{ij}; 5 - li_j), & lc_{ij} > 0 \\ -Min(li_j; -lc_{ij}), & lc_{ij} < 0 \\ 0, & lc_{ij} = 0 \end{cases} \quad \textbf{(3)}$$

Continuing with the example in use in the previous step, thus, based on the information of lc_{ij} from Table 6.2, Table 6.3 introduces an example of the matrix $SI(lc_{ij})$. Table 6.4 shows the respective matrix $SI(alc_{ij})$ according to Equation (2) and (3). Considering that the influence level from risk factor 1 on risk factor 2 is equal to 3, alc_{ij} for i=1 and j=2 corresponds to the minimum between lc_{ij} and $5 - li_j$, i.e., the minimum value between 3 and *5–4*, as demonstrated in Equation (3). Thus, the value of alc_{12} is equivalent to 1 as shown in Table 6.4.

Table 6.3. Illustrative example of matrix $SI(lc_{ij})$

i / j	**1**	**2**	**3**	**4**	**5**	**6**
1	-	3				
2		-	2			
3			-	2		
4				-		
5					-	
6			–2			-

Table 6.4. Illustrative example of matrix $SI(alc_{ij})$

i / j	**1**	**2**	**3**	**4**	**5**	**6**
1	-	1				
2		-	2			
3			-	2		
4				-		
5					-	
6			–2			-

<u>Reachability likelihood matrix:</u>

To capture indirect contributions between each pair of risk factors, which are given through the intermediate risk factors, a reachability matrix must be calculated. Then, the reachability matrix aims to

capture the transitivity between each pair of risk factors. Therefore, the grades between risk factors must be identified.

The grades between each pair of risk factors correspond to the maximum number of intermediate-risk factors through which two risk factors are connected, including the final risk factor. Therefore, the grades between two risk factors represent the maximum intermediate contributions that a risk factor can generate on another, i.e., the maximum iterations necessary to obtain the value of the receptor risk factor in the reachability matrix. In this regard, 'g' denotes the number of intermediate connections between two risk factors, including the final risk factor for a specific path. Therefore, the iterations required to calculate the reachability matrix correspond to the maximum grade between any pair of risk factors. The reachability matrix is defined as in Equation (4).

$$RA(tlc_{ij}) = [tlc_{ij}]_{(n+m)(n+m)} \quad \textbf{(4)}$$

where tlc_{ij} corresponds to the total contribution from risk factor 'i' to risk factor 'j', given direct and indirect connections between them, i.e., given the contribution derived from g = 1 and the indirect contributions derived from each path in which $g>1$ exists between 'i' and 'j'. Therefore, tlc_{ij} for each path with 'g' intermediate-risk factors between 'i' and 'j' is calculated following Equation (5).

$$tlc_{ij}^{g} = \begin{cases} (alc_{ij})(li_i/5) \;\; \forall i \neq j, & if\ g = 1 \\ (E_{ij}^{g}) \sum_{k} \left[\frac{tlc_{ik}}{5}\right] alc_{kj} \;\; \forall i \neq k, \forall k \neq j, & if\ g > 1 \end{cases} \quad \textbf{(5)}$$

Where $(alc_{ij})(li_i/5)$ represents the expected value associated with the direct contribution from 'i' on 'j', i.e., tlc_{ij}^{1}; $[tlc_{ij}^{1}/5]alc_{kj}$ denotes the expected value derived from indirect contribution from risk factor 'i' on 'j' through a path in which risk 'k' is the immediate predecessor of risk factor 'j'; and E_{ij}^{g} is a binary variable that represents whether or not there is at least one path with 'g' intermediate risk factors, including the final risk factor between risk factors 'i' and 'j', in which risk factor 'k' is the immediate predecessor of risk factor 'j'. E_{ij}^{g} is calculated as presented in Equation (6) and (7).

$$E_{ij}^{1} = \begin{cases} 1, & if\ \ alc_{ij} \neq 0 \\ 0, & if\ \ alc_{ij} = 0 \end{cases} \quad \textbf{(6)}$$

$$E_{ij}^{g} = \begin{cases} 1, & if \left[\sum_{k} (E_{ik}^{g-1} E_{kj}^{1})\right] \left[1 - \sum_{k} E_{ij}^{g-1}\right] \geq 1, \;\; \forall g > 1, \;\; \forall i \neq j \neq k \\ 0, & if \left[\sum_{k} (E_{ik}^{g-1} E_{kj}^{1})\right] \left[1 - \sum_{k} E_{ij}^{g-1}\right] < 1, \;\; \forall g > 1, \;\; \forall i \neq j \neq k \end{cases} \quad \textbf{(7)}$$

Finally, tlc_{ij} is calculated as shown in Equation (8), where 'G' corresponds to the maximum grades between any pair of risk factors.

$$tlc_{ij} = \sum_{g} tlc_{ij}^{g}, \ \ \forall i \neq j \tag{8}$$

According to the above and based on the illustrative example, alc_{12}, alc_{23}, alc_{34}, alc_{63} values are non-zero (see Table 6.4), and, following Equation (6), E_{12}^{1}, E_{23}^{1}, E_{34}^{1}, and E_{63}^{1} are equal to 1. In addition, since risk factor 2 has an influence on risk factor 3 (alc_{23}=2, see Table 6.4) and risk factor 2 is influenced by risk factor 1 (alc_{12}=1, see Table 6.4), risk factor 1 has an indirect influence on risk factor 3 by using risk factor 2 as an intermediate risk factor. The above means 'g' value for the relationship between risk factor 1 and risk factor 3 is equal to 2. In this case, this value represents that risk factor 1 produces an impact on two different risk factors. Figure 6.4 shows the relationship between risk factor 1 and risk factor 3.

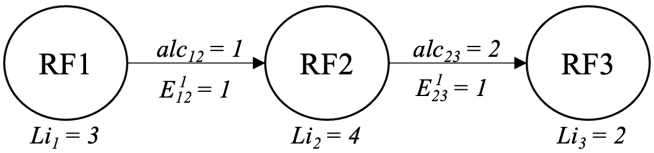


Figure 6.4. Representation of the indirect relationship between risk factor 1 and risk factor 3

Considering the above, Equation (7) can be used to estimate the E_{13}^{2} because the value of 'g' between risk factors 1 and 3 is equal to two, being risk factor 2 the intermediate-risk factor (index 'k' in Equation (7)). A similar situation applies to relations between risk factors 2 and 4 and between risk factors 6 and 4. Table 6.5 shows, according to Equation (7), the estimation of the variables E_{13}^{2}, E_{24}^{2}, and E_{64}^{2}, and exemplifies the estimation of E_{14}^{2} which have no grade two relations. For instance, Table 6.5 shows that the unique possible path by which risk factor 1 affects risk factor 3 is through risk factor 2.

Table 6.5. Illustrative example of estimation of the variables E_{ij}^{2}

Variable	**Estimation**
E_{13}^{2} = 1	$[(E_{12}^{1})(E_{23}^{1})+(E_{14}^{1})(E_{43}^{1})+(E_{15}^{1})(E_{53}^{1})+(E_{16}^{1})(E_{63}^{1})](1-E_{13}^{1})$ = [(1)(1)+(0)(0)+(0)(0)+(0)(0)](1–0) = 1; 1≥0
E_{24}^{2} = 1	$[(E_{21}^{1})(E_{14}^{1})+(E_{23}^{1})(E_{34}^{1})+(E_{25}^{1})(E_{54}^{1})+(E_{26}^{1})(E_{64}^{1})](1-E_{24}^{1})$ = [(0)(0)+(1)(1)+(0)(0)+(0)(0)](1–0) = 1; 1≥0
E_{64}^{2} = 1	$[(E_{61}^{1})(E_{14}^{1})+(E_{62}^{1})(E_{24}^{1})+(E_{63}^{1})(E_{34}^{1})+(E_{65}^{1})(E_{54}^{1})](1-E_{64}^{1})$ = [(0)(0)+(0)(0)+(1)(1)+(0)(0)](1–0) = 1; 1≥0
E_{14}^{2} = 0	$[(E_{12}^{1})(E_{24}^{1})+(E_{13}^{1})(E_{34}^{1})+(E_{15}^{1})(E_{54}^{1})+(E_{16}^{1})(E_{64}^{1})](1-E_{14}^{1})$ = [(0)(0)+(0)(0)+(0)(0)+(0)(0)](1–0) = 0; 0<1

The same process is carried out to identify whether there are grade three ($g = 3$) relationships between risk factors. For that, based on Equation (7), an estimation of the variables E_{ij}^{3} is conducted.

Table 6.6 exemplifies the estimation of some E_{ij}^{3} variables, one of which is E_{14}^{3}, which represents the unique grade 3 relationship between two risk factors in the case example. Figure 6.5 provides a representation of the indirect relationship between risk factor 1 and risk factor 4, where for E_{14}^{3}, the intermediate node is risk factor 3 (*index* $k = 3$) as it is the immediate predecessor of risk factor 4 in the referred path.

Table 6.6. Illustrative example of estimation of the variables E_{ij}^{3}

Variable	Estimation
E_{14}^{3} = 1	$[(E_{12}^{2})(E_{24}^{1})+(E_{13}^{2})(E_{34}^{1})+(E_{15}^{2})(E_{54}^{1})+(E_{16}^{2})(E_{64}^{1})](1-E_{14}^{1}-E_{14}^{2})$ = [(1)(0)+(1)(1)+(0)(0)+(0)(0)](1–0–0) = 1; 1≥0
E_{64}^{3} = 0	$[(E_{61}^{2})(E_{14}^{1})+(E_{62}^{2})(E_{24}^{1})+(E_{63}^{2})(E_{34}^{1})+(E_{65}^{2})(E_{54}^{1})](1-E_{64}^{1}-E_{64}^{2})$ = [(0)(0)+(0)(0)+(0)(0)+(0)(0)](1–0–1) = 0; 0<1
E_{41}^{3} = 0	$[(E_{42}^{2})(E_{21}^{1})+(E_{43}^{2})(E_{31}^{1})+(E_{45}^{2})(E_{51}^{1})+(E_{46}^{2})(E_{61}^{1})](1-E_{41}^{1}-E_{41}^{2})$ = [(0)(0)+(0)(0)+(0)(0)+(0)(0)](1–0–0) = 0; 0<1

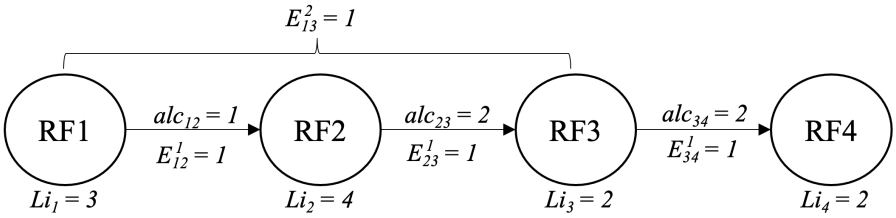


Figure 6.5. Representation of the indirect relationship between risk factor 1 and risk factor 4

Once the grade 3 interdependencies have been established, the same process is carried out to identify whether there are grade four ($g = 4$) relationships between risk factors. For that, based on Equation (7), an estimation of the variables E_{ij}^{4} is conducted. Given that the case example has no grade four ($g = 4$) relationships between risk factors, all E_{ij}^{4} variables are equal to zero. This means that the maximum grades between any pair of risk factors are equal to three, i.e., $G = 3$. Table 6.7 shows some examples of the estimation of E_{ij}^{4}.

Table 6.7. Illustrative example of estimation of the variables E_{ij}^{4}

Variable	Estimation
E_{16}^{4} = 0	$[(E_{12}^{3})(E_{26}^{1})+(E_{13}^{3})(E_{36}^{1})+(E_{14}^{3})(E_{46}^{1})+(E_{15}^{3})(E_{56}^{1})](1-E_{16}^{1}-E_{16}^{2}-E_{16}^{3})$ = [(0)(0)+(0)(0)+(1)(0)+(0)(0)](1–0–0–0) = 0; 0<1
E_{32}^{4} = 0	$[(E_{31}^{3})(E_{12}^{1})+(E_{34}^{3})(E_{42}^{1})+(E_{35}^{3})(E_{52}^{1})+(E_{36}^{3})(E_{62}^{1})](1-E_{32}^{1}-E_{32}^{2}-E_{32}^{3})$ = [(0)(1)+(0)(0)+(1)(0)+(0)(0)](1–0–0–0) = 0; 0<1
E_{63}^{4} = 0	$[(E_{61}^{3})(E_{13}^{1})+(E_{62}^{3})(E_{23}^{1})+(E_{64}^{3})(E_{43}^{1})+(E_{65}^{3})(E_{53}^{1})](1-E_{63}^{1}-E_{63}^{2}-E_{63}^{3})$ = [(0)(1)+(0)(0)+(1)(0)+(0)(0)](1–1–0–0) = 0; 0<1

Thus, all E_{ij}^{g} values were estimated, and the G value was established. Based on the above, the values of tlc_{ij}^{g} can be estimated following Equation (5). Table 6.8 exemplifies the estimation of some tlc_{ij}^{1} variables. According to Equation (5), as well as Table 6.8 shows (see for example tlc_{21}^{1} or tlc_{26}^{1}), risk factors without direct relation obtain tlc_{ij}^{1} equal to zero because there are no contributions between them. Table 6.9 shows the values of tlc_{ij}^{1}.

Table 6.8. Illustrative example of estimation of the variables tlc_{ij}^{1}

Variable	**Estimation**
$tlc_{12}^{1} = 0.6$	$(alc_{12})(li_1/5) = (1)(3/5) = 0.6$
$tlc_{21}^{1} = 0$	$(alc_{21})(li_2/5) = (0)(4/5) = 0$
$tlc_{23}^{1} = 1.6$	$(alc_{23})(li_2/5) = (2)(4/5) = 1.6$
$tlc_{26}^{1} = 0$	$(alc_{26})(li_2/5) = (0)(4/5) = 0$
$tlc_{34}^{1} = 0$	$(alc_{34})(li_3/5) = (2)(2/5) = 0.8$
$tlc_{63}^{1} = -0.8$	$(alc_{63})(li_6/5) = (-2)(2/5) = -0.8$

Table 6.9. Illustrative example of Values of tlc_{ij}^{1} for the case example

i* / *j	**1**	**2**	**3**	**4**	**5**	**6**
1	-	0.6				
2		-	1.6			
3			-	0.8		
4				-		
5					-	
6			-0.8			-

Estimation of values for tlc_{ij}^{2} and tlc_{ij}^{3} are also carried out following Equation (5). Table 6.10 depicts the estimation for tlc_{12}^{2}, tlc_{24}^{2}, tlc_{64}^{2} and tlc_{14}^{3}, which correspond to risk factors with interdependence grade. Also, Table 6.10 illustrates the estimation for tlc_{14}^{3}, which corresponds to the only grade 3 interdependence in the case example. The remaining values of the variables tlc_{ij}^{2} and tlc_{ij}^{3} that are not shown in the table are equal to zero because, in all cases, their corresponding parameter E_{ij}^{g} is zero.

Then, Equation (8) allows calculating the value of tlc_{ij} for each pair of risk factors, i.e., the direct and indirect contribution from risk factor 'i' to risk factor 'j'. Table 6.11 exemplifies the estimation of tlc_{12}, tlc_{64}, and tlc_{14}. Finally, by following Equation (4), Table 6.12 contains the matrix $RA(tlc_{ij})$.

Table 6.10. Illustrative example of the variables tlc_{ij}^2 and tlc_{ij}^3

Variable	Estimation
$tlc_{13}^2 = 0.24$	$(E_{13}^2)\{[(tlc_{12}^1)/5](alc_{23}) + [(tlc_{14}^1)/5](alc_{43}) + [(tlc_{15}^1)/5](alc_{53}) + [(tlc_{16}^1)/5](alc_{63})\}$ = (1){[(0.6)/5)](2)+[(0)/5)](0)+[(0)/5)](0)+[(0)/5)](-2)} = 0.24
$tlc_{24}^2 = 0.64$	$(E_{24}^2)\{[(tlc_{21}^1)/5](alc_{14}) + [(tlc_{23}^1)/5](alc_{34}) + [(tlc_{25}^1)/5](alc_{54}) + [(tlc_{26}^1)/5](alc_{64})]\}$ = (1){[(0)/5)](0)+[(1.6)/5)](2)+[(0)/5)](0)+[(0)/5)](0)} = 0.64
$tlc_{64}^2 = -0.32$	$(E_{64}^2)\{[(tlc_{61}^1)/5](alc_{14}) + [(tlc_{62}^1)/5](alc_{24}) + [(tlc_{63}^1)/5](alc_{34}) + [(tlc_{65}^1)/5](alc_{54})\}$ = (1){[(0)/5)](0)+[(0)/5)](0)+[(-0.8)/5)](2)+[(0)/5)](0)} = -0.32
$tlc_{14}^3 = 0.096$	$(E_{14}^3)\{[(tlc_{12}^2)/5](alc_{24}) + [(tlc_{13}^2)/5](alc_{34}) + [(tlc_{15}^2)/5](alc_{54}) + [(tlc_{16}^2)/5](alc_{64})\}$ = (1){[(0)/5)](0)+[(0.24)/5)](2)+[(0)/5)](0)+[(0)/5)](0)} = 0.096

Table 6.11. Illustrative example of estimation of the variables tlc_{ij}

Variable	Estimation
$tlc_{12} = 0.6$	$tlc_{12}^1 + tlc_{12}^2 + tlc_{12}^3 = 0.6 + 0 + 0 = 0.6$
$tlc_{64} = -0.32$	$tlc_{64}^1 + tlc_{64}^2 + tlc_{64}^3 = 0 - 0.32 + 0 = -0.32$
$tlc_{14} = 0.096$	$tlc_{14}^1 + tlc_{14}^2 + tlc_{14}^3 = 0 + 0 + 0.096 = 0.096$

Table 6.12. Illustrative example of values of tlc_{ij} for the case example

i* / *j	**1**	**2**	**3**	**4**	**5**	**6**
1	-	0.60	0.24	0.096		
2		-	1.60	0.64		
3			-	0.80		
4				-		
5					-	
6			-0.80	-0.32		-

<u>Likelihood adjusted:</u>

Based on $RA(tlc_{ij})$, which corresponds to the matrix of possible likelihood contributions between each pair of risk factors, the likelihood adjusted due to risk factor interdependency is estimated based on Equation (9), where 'la_j' denotes the likelihood adjusted of the risk factor 'j' due to risk factor interdependency.

$$la_j = \begin{cases} 0, & if \;\; li_j + \sum_i (tlc_{ij}) < 0, \;\; \forall j \\ li_j + \sum_i tlc_{ij}, & if \;\; 0 \le li_j + \sum_i (tlc_{ij}) \le 5, \;\; \forall j \\ 5, & if \;\; li_j + \sum_i (tlc_{ij}) > 5, \;\; \forall j \end{cases} \quad \textbf{(9)}$$

Based on the data from the case example, Table 6.13 exemplifies the estimation of la_i variables. The single case in which the result was outside the established thresholds (0-5) was la_4 as the obtained value was higher than the maximum threshold. Therefore, following Equation (9), la_4 took the value of the maximum threshold, i.e., 5.

Table 6.13. Illustrative example of estimation of the variables la_i

Variable	Estimation
$la_1 = 3.0$	$li_1 + (tlc_{21} + tlc_{31} + tlc_{41} + tlc_{51} + tlc_{61}) = 3 + (0 + 0 + 0 + 0 + 0) = 3.0$
$la_2 = 4.6$	$li_2 + (tlc_{12} + tlc_{32} + tlc_{42} + tlc_{52} + tlc_{62}) = 4 + (0.6 + 0 + 0 + 0 + 0) = 4.6$
$la_3 = 3.04$	$li_3 + (tlc_{13} + tlc_{23} + tlc_{43} + tlc_{53} + tlc_{63}) = 2 + (0.24 + 1.6 + 0 + 0 - 0.8) = 3.04$
$la_4 = 3.22$	$li_4 + (tlc_{14} + tlc_{24} + tlc_{34} + tlc_{54} + tlc_{64}) = 2 + (0.1 + 0.64 + 0.8 + 0 - 0.32) = 3.22$
$la_5 = 3.0$	$li_5 + (tlc_{15} + tlc_{25} + tlc_{35} + tlc_{45} + tlc_{65}) = 3 + (0 + 0 + 0 + 0 + 0) = 3$
$la_6 = 2.0$	$li_6 + (tlc_{16} + tlc_{26} + tlc_{36} + tlc_{46} + tlc_{56}) = 2 + (0 + 0 + 0 + 0 + 0) = 2$

6.2.3 Step 1.c – Severity Adjusted due to Risk Factor Interdependency

Structural severity self-interaction matrix:

As inputs of the structural severity self-interaction matrix, the severity contributions between each pair of risk factors, sc_{ij}, correspond to the elements that constitute the interdependency network to be represented. Thus, the set of sc_{ij} constitutes the elements of the initial structural severity self-interaction matrix '$SI(sc_{ij})$' as shown in Equation (10). Analogous to $SI(sc_{ij})$, the system to be analyzed is also composed of 'n' output-related risk factors and 'm' outcome-related risk factors.

$$SI(sc_{ij}) = [sc_{ij}]_{(n+m)(n+m)} \quad \textbf{(10)}$$

For both sep_{ia} and sec_{ic}, the severity adjusted due to contributions from risk factors interdependency cannot be greater than their limits, i.e., severity adjusted values must remain between 0 and 5 for opportunities and between –5 and 0 for threats. Consequently, to ensure that the adjusted severity of any risk factor remains inside of sep_{ia} and sec_{ic} limits, adjusted values of sc_{ij} are established according to the initial severity level on each project or capability. Then, it was established that scp_{ija} represents the maximum possible contribution (positive or negative) from risk factor 'i' to the expected severity of the risk factor 'j' on the project 'a' given the initial value of the parameter sc_{ij}. Analogously, scc_{ijc} represents the maximum possible contribution (positive or negative) from risk factor 'i' to the expected severity of the risk factor 'j' on the capability 'c' given the initial value of the parameter sc_{ij}.

Equations (11) and (12) show, respectively, the scp_{ija} and scc_{ijc} estimation for output-related risk factors and outcome-related risk factors.

$$scp_{ija} = \begin{cases} Min(sc_{ij}; 5H_{ja} - |sep_{ja}|), & if\ sc_{ij} > 0 \\ Max(sc_{ij}; -|sep_{ja}|), & if\ sc_{ij} \leq 0 \end{cases} \quad \textbf{(11)}$$

$$scc_{ijc} = \begin{cases} Min(sc_{ij}; 5F_{jc} - |sec_{jc}|), & if\ sc_{ij} > 0 \\ Max(sc_{ij}; -|sec_{jc}|), & if\ sc_{ij} \leq 0 \end{cases} \quad \textbf{(12)}$$

Where, *'OPR'* denotes the set of output-related risk factors, and *'OCR'* denotes the set of outcome-related risk factors; H_{ja} is a binary variable representing whether or not there is an impact from the risk factor 'j' on the project 'a'; and, F_{jc} is a binary variable representing whether or not there is an impact from the risk factor 'j' on the capability 'c'. Correspondingly, H_{ja} and F_{jc} are represented as in Equations (13) and (14).

$$H_{ja} = \begin{cases} 1, & if\ \ sep_{ia} \neq 0 \\ 0, & if\ \ sep_{ia} = 0 \end{cases} \quad \textbf{(13)}$$

$$F_{jc} = \begin{cases} 1, & if\ \ sec_{ia} \neq 0 \\ 0, & if\ \ sec_{ia} = 0 \end{cases} \quad \textbf{(14)}$$

Consequently, for the severity interdependency, $n + m$ adjusted self-interaction matrices are generated, where each one denotes the maximum influence from severity interdependency to each project or capability. For the influence on output-related factors, the adjusted self-interaction matrix is defined as in Equation (15), and as in Equation (16) for the influence on outcome-related risk factors.

$$SI(scp_{ija}) = [scp_{ija}]_{(n+m)(n)} \quad \forall j \in OPR \quad \textbf{(15)}$$

$$SI(scc_{ijc}) = [scc_{ijc}]_{(n+m)(m)} \quad \forall j \in OCR \quad \textbf{(16)}$$

Based on the information of sc_{ij} from Table 6.2, an example of the matrix $SI(sc_{ij})$ is presented in Table 6.14.

Table 6.14. Illustrative example of matrix $SI(sc_{ij})$

i / j	**1**	**2**	**3**	**4**	**5**	**6**
1	-					
2		-	2			
3			-	–2		
4				-		
5					-	–3
6			4			-

By following Equations (13) and (14), Table 6.15 exemplifies the estimation of H_{ia} and F_{ic}. Then, using Equations (11) and (12), Table 6.16 shows several examples for the estimation of variables scp_{ija} and scc_{ijc}.

Table 6.15. Illustrative example of estimation of variables H_{ja} and F_{jc}

Variable	Estimation	Variable	Estimation
$H_{12} = 1$	$sep_{12} = -3\,; -3 \neq 0$	$F_{51} = 1$	$sec_{51} = -2\,; -2 \neq 0$
$H_{33} = 1$	$sep_{33} = -2\,; -2 \neq 0$	$F_{52} = 0$	$sec_{52} = 0\,; 0 = 0$
$H_{31} = 0$	$sep_{31} = 0\,; 0 = 0$	$F_{62} = 1$	$sec_{62} = -3\,; -3 \neq 0$

Table 6.16. Illustrative example of estimation of variables scp_{ija} and scc_{ijc}

Variable	Estimation
$scp_{231} = 0.0$	$sc_{23} > 0;\ Min(sc_{23}; 5H_{31} - \lvert sep_{31}\rvert) = Min(2; (5)(0) - 0) = 0$
$scp_{232} = 2.0$	$sc_{23} > 0;\ Min(sc_{23}; 5H_{32} - \lvert sep_{32}\rvert) = Min(2; (5)(1) - 2) = 2$
$scp_{233} = 2.0$	$sc_{23} > 0;\ Min(sc_{23}; 5H_{33} - \lvert sep_{33}\rvert) = Min(2; (5)(1) - 2) = 2$
$scp_{341} = 0.0$	$sc_{34} \leq 0;\ Max(sc_{34}; -\lvert sep_{41}\rvert) = Max(-2; -0) = 0$
$scp_{342} = 0.0$	$sc_{34} \leq 0;\ Max(sc_{34}; -\lvert sep_{42}\rvert) = Max(-2; -0) = 0$
$scp_{343} = -2.0$	$sc_{34} \leq 0;\ Max(sc_{34}; -\lvert sep_{43}\rvert) = Max(-2; -4) = -2$
$scp_{631} = 0.0$	$sc_{63} > 0;\ Min(sc_{63}; 5H_{31} - \lvert sep_{31}\rvert) = Min(2; (5)(0) - 0) = 0$
$scp_{632} = 3.0$	$sc_{63} > 0;\ Min(sc_{63}; 5H_{32} - \lvert sep_{32}\rvert) = Min(2; (5)(1) - 2) = 3$
$scp_{633} = 3.0$	$sc_{63} > 0;\ Min(sc_{63}; 5H_{32} - \lvert sep_{32}\rvert) = Min(2; (5)(1) - 2) = 3$
$scc_{361} = 0.0$	$sc_{36} \leq 0;\ Max(sc_{36}; -\lvert sec_{61}\rvert) = Max(0; -2) = 0$
$scc_{561} = -2.0$	$sc_{56} \leq 0;\ Max(sc_{56}; -\lvert sec_{61}\rvert) = Max(-3; -2) = -2$
$scc_{562} = -3.0$	$sc_{56} \leq 0;\ Max(sc_{56}; -\lvert sec_{62}\rvert) = Max(-3; -3) = -3$

Based on values of scp_{ija}, Table 6.17 outlines the adjusted self-interaction matrix for the output-related factor $j = 3$, i.e., the maximum severity influence from each risk factor on risk factor 3 (see Equation (15)).

Table 6.17. Illustrative example of adjusted self-interaction matrix for scp_{i3a}

	$\boldsymbol{a = 1}$	$\boldsymbol{a = 2}$	$\boldsymbol{a = 3}$
$\boldsymbol{i = 1}$			
$\boldsymbol{i = 2}$		2	2
$\boldsymbol{i = 3}$			
$\boldsymbol{i = 4}$			
$\boldsymbol{i = 5}$			
$\boldsymbol{i = 6}$		3	3

Similarly, based on values of scc_{ijc}, Table 6.18 depicts the adjusted self-interaction matrix for the outcome-related risk factor $j = 6$, i.e., the maximum severity influence of each risk factor on risk factor 6 (see Equation (16)).

Table 6.18. Illustrative example of the adjusted self-interaction matrix for scc_{i6c}

	$\boldsymbol{c = 1}$	$\boldsymbol{c = 2}$
$\boldsymbol{i = 1}$		
$\boldsymbol{i = 2}$		
$\boldsymbol{i = 3}$		
$\boldsymbol{i = 4}$		
$\boldsymbol{i = 5}$	–2	–3
$\boldsymbol{i = 6}$		

Reachability severity matrix:

Variations in the severity level of a risk factor occur when the precedent risk factor materializes. Then, the variation of the severity level is conditioned by the likelihood level of the precedent risk factor. Therefore, just the severity level of the dependent risk factor is being affected, not its likelihood level. Then, its influence on the severity of other risk factors is not affected since its likelihood level is not being modified. The above means that changes in the severity level of a risk factor do not lead to modifying the influence it has on the severity level of other risk factors, i.e., this kind of dependence does not produce an indirect influence between risk factors.

In this regard, the reachability matrix is composed of the expected value of the direct severity contributions between each pair of risk factors. Thus, the reachability matrix for severity dependencies is defined as in Equations (17) and (18). tsp_{ija} represents the expected value of the severity contribution on project 'a' from risk factor 'i' to risk factor 'j' being calculated as shown in Equation (19). Also, tsc_{ijc} represents the expected value of the severity contribution to capability 'c' from risk factor 'i' to risk factor 'j' being calculated as shown in Equation (20).

$$RA(tsp_{ija}) = [tsp_{ija}]_{(n+m)(n)} \quad \forall j \in OPR \tag{17}$$

$$RA(tsc_{ijc}) = [tsc_{ijc}]_{(n+m)(m)} \quad \forall j \in OCR \tag{18}$$

$$tsp_{ija} = (scp_{ija})(la_i/5) \quad \forall j \in OPR \tag{19}$$

$$tsc_{ijc} = (scc_{ijc})(la_i/5) \quad \forall j \in OCR \tag{20}$$

Based on the case example, Table 6.19 shows several examples of tsp_{ija} and tsc_{ijc} estimation (Equations (19) and (20)).

Table 6.19. Illustrative example of estimation of variables tsp_{ija} and tsc_{ijc}

Variable	**Estimation**
$tsp_{231} = 0.0$	$(scp_{231})(la_2/5) = (0)(4.6/5) = 0$
$tsp_{232} = 1.84$	$(scp_{232})(la_2/5) = (2)(4.6/5) = 1.84$
$tsp_{632} = 1.2$	$(scp_{632})(la_6/5) = (3)(2/5) = 1.2$
$tsc_{561} = -1.2$	$(scc_{561})(la_5/5) = (-2)(3/5) = -1.2$
$tsc_{562} = -1.8$	$(scc_{562})(la_5/5) = (-3)(3/5) = -1.8$
$tsc_{361} = 0.0$	$(scc_{361})(la_3/5) = (0)(3.04/5) = 0$

Based on values of tsp_{ija}, Table 6.20 depicts the reachability matrix for the output-related factor $j = 3$, i.e., the expected value of the severity influence derived from each risk factor on risk factor 3 (see Equation (17)). Similarly, based on values of tsc_{ijc}, Table 6.21 depicts the reachability matrix for the outcome-related risk factor $j = 6$ (see Equation (18)).

Table 6.20. Illustrative example of reachability matrix for the output-related factor j=3 (tsp_{i3a})

	$\boldsymbol{a = 1}$	$\boldsymbol{a = 2}$	$\boldsymbol{a = 3}$
$\boldsymbol{i = 1}$			
$\boldsymbol{i = 2}$		1.84	1.84
$\boldsymbol{i = 3}$			
$\boldsymbol{i = 4}$			
$\boldsymbol{i = 5}$			
$\boldsymbol{i = 6}$		1.2	1.2

Table 6.21. Illustrative example of reachability matrix for the outcome-related factor j=6 (tsc_{i6c})

	$\boldsymbol{c = 1}$	$\boldsymbol{c = 2}$
$\boldsymbol{i = 1}$		
$\boldsymbol{i = 2}$		
$\boldsymbol{i = 3}$		
$\boldsymbol{i = 4}$		
$\boldsymbol{i = 5}$	–1.2	–1.8
$\boldsymbol{i = 6}$		

<u>Severity adjusted:</u>

Based on $RA(tsp_{ija})$ and $RA(tsc_{ijc})$, the severity adjusted due to risk factor interdependency is estimated based on Equations (21), (22), (23), and (24), where sap_{ja} denotes the adjusted severity from

risk factor 'j' to project 'a' due to risk factor interdependency, and sac_{jc} denotes the adjusted severity from risk factor 'j' to capability 'c' due to risk factor interdependency.

$if\ sep_{ja} \geq 0$:

$$sap_{ja} = \begin{cases} 0, & if\ sep_{ja} + \sum_i tsp_{ija} < 0 \\ sep_{ja} + \sum_i tsp_{ija}, & if\ 0 \leq sep_{ja} + \sum_i tsp_{ija} \leq 5 \\ 5, & if\ sep_{ja} + \sum_i tsp_{ija} > 5 \end{cases} \quad \textbf{(21)}$$

$if\ sep_{ja} < 0$:

$$sap_{ja} = \begin{cases} -5, & if\ sep_{ja} - \sum_i tsp_{ija} < -5 \\ sep_{ja} - \sum_i (tsp_{ija}), & if\ -5 \leq sep_{ja} + \sum_i tsp_{ija} \leq 0 \\ 0, & if\ sep_{ja} + \sum_i tsp_{ija} > 0 \end{cases} \quad \textbf{(22)}$$

$if\ sec_{jc} \geq 0$:

$$sac_{jc} = \begin{cases} 0, & if\ sec_{jc} + \sum_i tsc_{ijc} < 0 \\ sec_{jc} + \sum_i tsc_{ijc}, & if\ 0 \leq sec_{jc} + \sum_i tsc_{ijc} \leq 5 \\ 5, & if\ sec_{jc} + \sum_i tsc_{ijc} > 5 \end{cases} \quad \textbf{(23)}$$

$if\ sec_{jc} < 0$:

$$sac_{jc} = \begin{cases} -5, & if\ sec_{jc} - \sum_i tsc_{ijc} < -5 \\ sec_{jc} - \sum_i tsc_{ijc}, & if\ -5 \leq sec_{jc} + \sum_i tsc_{ijc} \leq 0 \\ 0, & if\ sec_{jc} + \sum_i tsc_{ijc} > 0 \end{cases} \quad \textbf{(24)}$$

By following Equations (21) to (24), Table 6.22 exemplifies the estimation of several sap_{ja} and sac_{jc}. All values of sap_{ja} and sac_{jc} are within the established thresholds, so it was not necessary to adjust any of them to the maximum or minimum threshold as demonstrated in Equations (21), (22), (23), and (24) for cases in which such adjustment is necessary.

Table 6.22. Illustrative example of estimation of the variables sap_{ja} and sap_{jc}

Variable	Estimation
$sap_{21} = 3.0$	$sep_{21} + (tsp_{121} + tsp_{221} + tsp_{321} + tsp_{421} + tsp_{521} + tsp_{621})$ $= 3 + (0 + 0 + 0 + 0 + 0 + 0) = 3.0$
$sap_{33} = -5.0$	$sep_{33} - (tsp_{133} + tsp_{233} + tsp_{333} + tsp_{433} + tsp_{533} + tsp_{633})$ $= -2 - (0 + 1.84 + 0 + 0 + 0 + 1.2) = -5.04$
$sap_{43} = 2.784$	$sep_{43} + (tsp_{143} + tsp_{243} + tsp_{343} + tsp_{443} + tsp_{543} + tsp_{643})$ $= 4 + (0 + 0 - 1.216 + 0 + 0 + 0) = 2.784$
$sac_{62} = -1.2$	$sec_{62} - (tsc_{162} + tsc_{262} + tsc_{362} + tsc_{462} + tsc_{562} + tsc_{662})$ $= -3 - (0 + 0 + 0 + 0 - 1.8 + 0) = -1.2$
$sac_{61} = -0.8$	$sec_{61} - (tsc_{161} + tsc_{261} + tsc_{361} + tsc_{461} + tsc_{561} + tsc_{661})$ $= -2 - (0 + 0 + 0 + 0 - 1.2 + 0) = -0.8$
$sac_{52} = 0.0$	$sec_{52} + (tsc_{152} + tsc_{252} + tsc_{352} + tsc_{452} + tsc_{552} + tsc_{652})$ $= 0 + (0 + 0 + 0 + 0 + 0 + 0) = 0.0$

Finally, considering the values of sap_{ja} and sac_{jc}, Table 6.23 shows the severity adjusted by impact interdependency for each risk factor. In Table 6.23, it can be identified that severity adjusted of risk factors 1, 2, and 5 was not modified (see initial values in Table 6.1). The above is due to the fact those risk factors are not influenced by other risk factors (see sc_{ij} values in the illustrative example of matrix $SI(sc_{ij})$ displayed in Table 6.14).

Table 6.23. Illustrative example of severity adjusted

Risk factor	sap_{ja}			sac_{jc}	
	$a = 1$	$a = 2$	$a = 3$	$c = 1$	$c = 2$
$i = 1$	–2	–3	0	-	-
$i = 2$	3	0	0	-	-
$i = 3$	0	–5	–5	-	-
$i = 4$	0	0	2.784	-	-
$i = 5$	-	-	-	–2	0
$i = 6$	-	-	-	–0.8	–1.2

6.3 Incorporation of Risk Factors Impact on Project Portfolio Success

In this Stage, nodes associated with the entities output-related risk factors and outcome-related risk factors are connected with the other nodes following the links established in Section 6.1 (see Figure 6.1). Based on the associations among different kinds of nodes, four types of connections were defined: OPR-PRO (from output-related risk factors to projects), OCR-CAP (from outcome-related risk factors to capabilities), PRO-CAP (from projects to capabilities), and CAP-PSS (from capabilities to portfolio success). Since the connections OPR-OCR (from output-related risk factors to outcome-related risk factors) and OCR-OPR (from outcome-related risk factors to output-related risk factors) were considered

and quantified in Stage 1. These connections are established as an input. In this regard, likelihood adjusted, and severity adjusted, derived from Stage 1, are used as inputs for Stage 2.

The network conveys the risk through the established connections. Thus, this Stage leads to determining the PPR, which is estimated based on the impact on project portfolio success due to changes in expected capabilities, resulting from the materialization of risk factors. The algorithms proposed by T. Wang et al. (2018) and T. Wang et al. (2021) were adopted. They proposed an algorithm to estimate, based on MNA, the indirect impact of risk factors on projects objectives for construction projects. The adaptation of the algorithm for MNA sought to estimate the indirect impact of risk factors on the success of portfolios of organizational development projects.

Thus, the impact of risk factors on different projects and capabilities is calculated based on the links between risk factor networks and projects, capabilities, and portfolio success networks. Based on T. Wang et al. (2018) and T. Wang et al. (2021) proposals, a set of steps is proposed to estimate the indirect impact of risk factors on project portfolio success. Figure 6.6 shows the two proposed steps, i.e., step (a) and step (b).

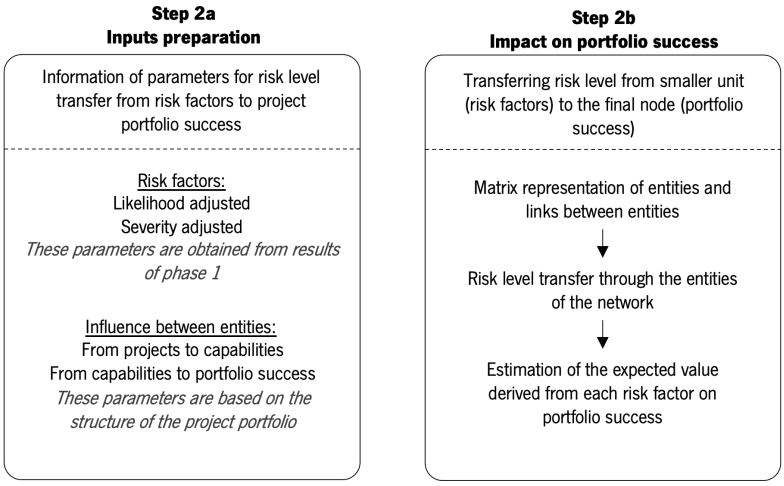


Figure 6.6. Steps to implement Stage 2 of the PPRA proposed model

6.3.1 Step 2.a – Inputs Preparation for Stage 2

The following parameters represent the inputs for the calculation of risk transfer through the network.

$\boldsymbol{la_i}$: Likelihood adjusted of the risk factor $\boldsymbol{i}$

$\boldsymbol{sap_{ia}}$: Severity adjusted of risk factor $\boldsymbol{i}$ on project $\boldsymbol{a}$

$\boldsymbol{sac_{ic}}$: Severity adjusted of risk factor $\boldsymbol{i}$ on capability $\boldsymbol{c}$

$\boldsymbol{ipc_{ac}}$: Influence of project $\boldsymbol{a}$ on capability $\boldsymbol{c}$

$\boldsymbol{ics_{cl}}$: Influence of capability $\boldsymbol{c}$ on attribute $\boldsymbol{l}$ of the portfolio success

The parameters la_i, sap_{ia}, and sac_{ic} are obtained from the results of Stage 1. According to T. Wang et al. (2018), the connections between nodes for the level of risk transfer efficiency may be different. In this regard, the relationship between projects to capabilities, and between capabilities and portfolio success need to be judged, so the parameters ipc_{ac} and ics_{cl} respectively denote these relationships. The values assigned to these relationships represent the strength of the associations between different entities.

Similar to the parameters established in Stage 1 and following the scale proposed by T. Wang et al. (2018) and T. Wang et al. (2021), a Likert scale from 0 to 5 was adopted for both ipc_{ac} and ics_{cl}. Thus, when ipc_{ac} value is 5, the project 'a' has a high impact concerning the expected capability 'c', whereas value 0 means there is no impact from project 'a' to capability 'c'. Similarly, when ics_{cl} value is 5, the capability 'c' has a high impact regarding the attribute 'l' of the portfolio success, while value 0 means there is no impact. For that, it was established that each success dimension has a set of attributes that in total represent w number of attributes. Thus, for instance, the set of strategic objectives related to the project portfolio corresponds to the set of strategic fit attributes; the set of future preparedness goals corresponds to the set of future preparedness attributes; and, the set of stakeholders identified for the project portfolio corresponds to the set of stakeholder satisfaction attributes.

Information to exemplify parameters la_i, sap_{ia}, and sac_{ic} is presented in Table 6.13 and Table 6.23 (see Section 6.2). Table 6.24 and Table 6.25 exemplify ipc_{ac} and ics_{cl} values. Table 6.24 shows the relationship between three projects and to two capabilities. Thus, for instance, project 1 ($a = 1$) generates a level four impact on the achievement of capability 1 ($c = 1$) and generates no impact on capability 2 ($c = 2$).

Table 6.24. Illustrative example of ipc_{ac}

Projects	**Capabilities**	
	$\boldsymbol{c = 1}$	$\boldsymbol{c = 2}$
$\boldsymbol{a = 1}$	4	
$\boldsymbol{a = 2}$	1	3
$\boldsymbol{a = 3}$		3

Table 6.25. Illustrative example of isc_{cl}

Capabilities	**Success dimensions**					
	Strategic fit		**Future preparedness**		**Stakeholder satisfaction**	
	$\boldsymbol{l = 1}$	$\boldsymbol{l = 2}$	$\boldsymbol{l = 3}$	$\boldsymbol{l = 4}$	$\boldsymbol{l = 5}$	$\boldsymbol{l = 6}$
$\boldsymbol{c = 1}$	2	4		2	3	2
$\boldsymbol{c = 2}$		2	5		3	

As illustrated in Table 6.25, for example being used, each success dimension comprises two attributes, i.e., two strategic fit attributes ($l = 1$ and $l = 2$), two future preparedness attributes ($l = 3$ and $l = 4$), and two stakeholders ($l = 5$ and $l = 6$). Table 6.25 also shows, for instance, that capability 1 ($c = 1$) impact both strategic fit attributes, just one of the future preparedness attributes, and both stakeholders. In this regard, specifically, capability 1 generates an impact level 2 and impact level 4 on each strategic fit attribute, respectively.

The data required for Table 6.24 and Table 6.25 would be collected from project portfolio information derived from the project portfolio structuration. Also, this information could be collected from qualitative perceptions of professionals and decision makers concerning both the portfolio structuration and the portfolio strategic orientation.

6.3.2 Step 2.b – Impact on Project Portfolio Success

From the MNA perspective, the nodes and links among nodes can be regarded as matrices. Thus, these matrices represent the transfer of risk levels from smaller units to the final node (T. Wang et al., 2021). The smaller unit for PPRA here proposed corresponds to risk factors, both output-related and outcome-related risk factors, since they contain the primary source of risk for the project portfolio. The final node corresponds to project portfolio success as illustrated in Figure 6.1.

The nodes are represented by vectors and the links among nodes are represented by matrices. Then, risk factors, projects, capabilities, and attributes of portfolio success dimensions are represented as vectors. The vector of risk factors is composed by values of la_i as shown in Equation (25), where there are n output-related risk factors and m outcome-related risk factors. Vectors for projects, capabilities, and attributes of portfolio success dimensions are represented as respectively shown in Equations (26), (27), and (28).

$$RF(la_i) = (la_1, la_2, la_3, \dots, la_n, la_{n+1}, \dots, la_{n+m}) \quad \textbf{(25)}$$

$$PRO(po_a) = (po_1, po_2, po_3, \dots, po_u) \quad \textbf{(26)}$$

$$CAP(ca_c) = (ca_1, ca_2, ca_3, \dots, ca_v) \quad \textbf{(27)}$$

$$PPS(ps_l) = (ps_1, ps_2, ps_3, \dots, ps_w) \quad \textbf{(28)}$$

The matrices associated with the links between nodes correspond to OPR-PRO (from output-related risk factors to projects), OCR-CAP (from outcome-related risk factors to capabilities), PRO-CAP (from projects to capabilities), and CAP-PPS (from capabilities to success dimensions). Matrix OPR-PRO is composed of sap_{ia} (Equation (29)), while matrix OCR-CAP is composed of sac_{ic} values (Equation (30)).

$$OPR - PRO(sap_{ia}) = [sap_{ia}]_{(nxu)}, \ \forall i \in OPR \quad \textbf{(29)}$$

$$OCR - CAP(sac_{ic}) = [sac_{ic}]_{(mxv)}, \ \forall i \in OCR \quad \textbf{(30)}$$

For the proposed PPRA model, values of ipc_{ac} and isc_{cw}, which obtained in Step 1.c (Table 6.23 for the illustrative example), corresponds to Equation (31) and (32) respectively. In other words, PRO-CAP (Equation (31)) is equivalent to ipc_{ac} values, and CAP-PPS (Equation (32)) is equivalent to isc_{cw} values, both obtained from Stage 1 of the proposed PPRA model. This shows how Stage 1 is an input for Stage 2 of the proposed PPRA model.

$$PRO - CAP(ipc_{ac}) = [ipc_{ac}]_{(uxv)} \quad \textbf{(31)}$$

$$CAP - PPS(isc_{cl}) = [isc_{cl}]_{(vxw)} \quad \textbf{(32)}$$

Based on vectors and matrices that were previously defined, the impact of output-related risk factors on capabilities and on portfolio success are calculated using Equations (33) and (34), correspondingly. The impact of outcome-related risk factors on portfolio success is calculated following Equation (35).

$$OPR - CAP(sac_{ic}) = [PR - PO(sap_{ia})] \text{ X } [PO - CA(ipc_{ac})], \ \forall i \in OPR \quad \textbf{(33)}$$

$$OPR - PPS(sas_{il}) = [PR - CA(sac_{ic})] \text{ X } [CA - SD(isc_{cl})], \ \forall i \in OPR \quad \textbf{(34)}$$

$$OCR - PPS(scs_{il}) = [CR - CA(sac_{ic})] \text{ X } [CA - SD(isc_{cl})], \ \forall i \in OCR \quad \textbf{(35)}$$

OPR-PPS(sas_{il}) and OCR-PS(scs_{il}) represent the indirect impact from output-related and outcome-related risk factors on project success, respectively. The severity from both types of risk factors is not mixed or consolidated in either the risk transfer process or the final impact on each attribute of the project portfolio success. The risk representation is based on bi-dimensional variables since it was considered that the severity measure on projects has a different nature or meaning than the severity on capabilities so that they cannot be mixed. The above implies that the dimension of the final values derived from both types of risk factors are not comparable.

Then, the risk of each attribute of project portfolio success was defined as a bi-dimensional variable. These variables represent both risk impact derived from projects and capabilities. Based on the above, the matrix of expected values of the risk level for Portfolio Success Attributes (PSA) is given by Equation (36), where y_{il} denotes the expected bi-dimensional value of the risk level derived from risk factor 'i' to the attribute 'l' of project portfolio success (Equation (37)).

$$PSA(y_{il}) = [y_{il}]_{(n+m)\ x\ w} \quad \textbf{(36)}$$

$$y_{il} = \begin{cases} (la_i)(sas_{il}), & \forall l, \forall i \in OCR \\ (la_i)(scs_{il}), & \forall l, \forall i \in OPR \end{cases} \quad \textbf{(37)}$$

According to Equations (29) and (30), and the parameters established in Section 6.3.1, the matrices $OPR - PRO(sap_{ia})$ and $OCR - CAP(sac_{ic})$ are estimated for the illustrative example and the values are presented on Table 6.26 and on Table 6.27, respectively.

Table 6.26. Illustrative example of matrix $OPR - PRO(sap_{ia})$

Output-related risk factors	**Projects**		
	$\boldsymbol{a = 1}$	$\boldsymbol{a = 2}$	$\boldsymbol{a = 3}$
$\boldsymbol{i = 1}$	–2.0	–3.0	
$\boldsymbol{i = 2}$	3.0		
$\boldsymbol{i = 3}$		–5.0	–5.0
$\boldsymbol{i = 4}$			2.78

Table 6.27. Illustrative example of matrix $OCR - CAP(sac_{ic})$

Outcome-related risk factors	**Capabilities**	
	$\boldsymbol{c = 1}$	$\boldsymbol{c = 2}$
$\boldsymbol{i = 5}$	–2	0
$\boldsymbol{i = 6}$	–0.8	–1.2

For the numerical example, Table 6.24 and Table 6.25 (see Section 6.3.1) represent the matrices $PRO - CAP(ipc_{ac})$ and $CAP - PPS(isc_{cl})$, respectively, which are defined in Equations (31) and (32). Once the initial matrices are defined, Equations (33), (34) and (35) are applied so that the corresponding matrices $OPR - CAP(sac_{ic})$, $OPR - PPS(sas_{il})$, and $OCR - PPS(scs_{il})$ are estimated. These matrices are displayed respectively in Table 6.28, Table 6.29 and Table 6.30.

Table 6.28. Illustrative example of matrix $OPR - CAP(sac_{ic})$

	$\boldsymbol{c = 1}$	$\boldsymbol{c = 1}$
$\boldsymbol{i = 1}$	–11.0	–9.0
$\boldsymbol{i = 2}$	12.0	0.0
$\boldsymbol{i = 3}$	–5.0	–30.0
$\boldsymbol{i = 4}$	0.0	8.34

Table 6.29. Illustrative example of matrix $OPR - PPS(sas_{il})$

	$l = 1$	$l = 2$	$l = 3$	$l = 4$	$l = 5$	$l = 6$
$i = 1$	–22	–62	–45	–22	–60	–22
$i = 2$	24	48	0	24	36	24
$i = 3$	–10	–80	–150	–10	–105	–10
$i = 4$	0	16.68	41.7	0	25.02	0

Table 6.30. Illustrative example of matrix $OCR - PPS(scs_{il})$

	$l = 1$	$l = 2$	$l = 3$	$l = 4$	$l = 5$	$l = 6$
$i = 5$	–4	–8	0	–4	–6	–4
$i = 6$	–1.6	–5.6	–6	–1.6	–6	–1.6

Thus, assuming that all dimensions are equally important, Table 6.29 shows that among output-related risk factors, risk factor 3 ($i = 3$) is the one that generates the highest negative impact on the project portfolio. Similarly, Table 6.30 shows that among outcome-related risk factors, risk factor 5 ($i = 5$) is the one that generates the highest negative impact on the project portfolio. However, these results do not incorporate the likelihood of each risk factor, so, by applying Equations (36) and (37), the result can be presented as shown in Table 6.31.

Table 6.31. Illustrative example of matrix $PSA(y_{il})$

	$l = 1$	$l = 2$	$l = 3$	$l = 4$	$l = 5$	$l = 6$
$i = 1$	–66	–186	–135	–66	–180	–66
$i = 2$	110.4	220.8	0	110.4	165.6	110.4
$i = 3$	–30.4	–243.2	–456.0	–30.4	–319.2	–30.4
$i = 4$	0	83.4	20.5	0	125.1	0
$i = 5$	–12	–24	0	–12	–18	–12
$i = 6$	–3.2	–11.2	–12	–3.2	–12	–3.2

Values in Table 6.31 represents the expected value of the risk generated from each risk factor on each attribute of the success dimensions, i.e., they represent how severity established for the risk factors was transferred to attributes of the success dimensions through the network comprises by risk factors, projects, capabilities, and success dimensions. These values, jointly with la_i, sap_{ja}, sac_{jc}, tlc_{ij}, tsp_{ija}, and tsc_{ijc} values obtained in step 1, are the inputs for Stage 3 of the proposed PPRA model.

6.4 Representation of Project Portfolio Risk

The results obtained after performing Stage 1 and Stage 2 represent the combination required for PPR as proposed on the research here reported. The PPR representation consolidates each risk factor's expected risk contribution, which is represented as the product of probability and severity. For this, three considerations were taken into account: 1) there are two types of risk factors, output- and outcome-related risk factors; 2) some risk factors impact multiple projects or capabilities; and 3) risk assessment is oriented to providing information on the importance of risk factors.

Regarding the first consideration, according to what was previously described in Section 6.3.2, the severity from output-related and outcome-related risk factors cannot be mixed or directly compared, because 'severity on projects' has a different nature or meaning than 'severity on capabilities'. Then, each portfolio success attribute 'l 'has two risk contributions, risk contribution derived from output-related risk factors and risk contribution derived from outcome-related risk factors. Therefore, the PPR representation should be represented in the same manner, i.e., PPR comprises indirect risk from projects and direct risk from capabilities.

The second consideration implies that the risk contribution from a specific risk factor should assess the cumulative severity derived from the severity of the set of multiple projects or multiple capabilities impacted. Finally, the third consideration indicates that PPR representation is not just about the consolidation of risk factors' impact on expected results, but it should also allow identifying the importance of each risk factor regarding the entire PPR. Thus, bearing in mind the three general considerations described, four steps are proposed for PPR representation (see Figure 6.7).

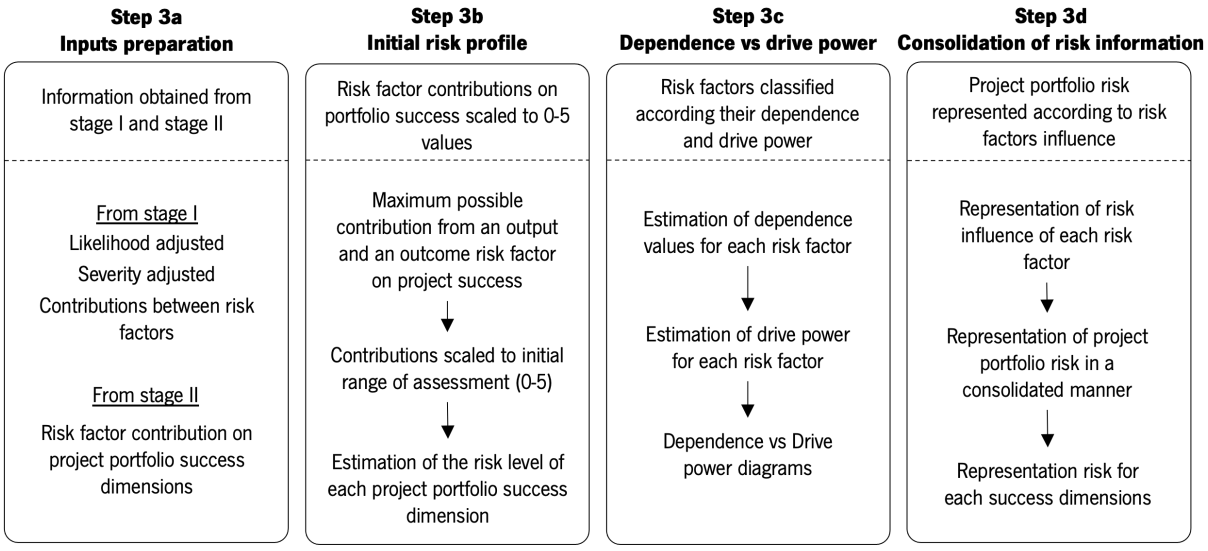


Figure 6.7. Steps to implement Stage 3 of the PPRA proposed model

6.4.1 Step 3a – Inputs Preparation

As illustrated in Figure 6.7, the parameters required for this Stage are from both Stage 1 and Stage 2. The following parameters represent the inputs for the PPR representation.

$\boldsymbol{la_i}$: Likelihood adjusted of the risk factor $\boldsymbol{i}$

$\boldsymbol{sap_{ja}}$: Severity adjusted from risk factor $\boldsymbol{j}$ to project $\boldsymbol{a}$

$\boldsymbol{sac_{jc}}$: Severity adjusted from risk factor $\boldsymbol{j}$ to capability $\boldsymbol{c}$

$\boldsymbol{tlc_{ij}}$: Total likelihood contribution from risk factor $\boldsymbol{i}$ to risk factor $\boldsymbol{j}$

$\boldsymbol{tsp_{ija}}$: Total contribution from risk factor $\boldsymbol{i}$ to the severity of risk factor $\boldsymbol{j}$ on project $\boldsymbol{a}$

$\boldsymbol{tsc_{ijc}}$: Total contribution from risk factor $\boldsymbol{i}$ to the severity of risk factor $\boldsymbol{j}$ on capability $\boldsymbol{c}$

For the illustrative case, parameters la_i, sap_{ja}, sac_{jc}, and tlc_{ij} correspond to information presented in Table 6.13, Table 6.23, and Table 6.12. Information related to tsp_{ija} and tsc_{ijc} was displayed in Table 6.20 and Table 6.21.

6.4.2 Step 3b – Project Portfolio Risk Profile

This step seeks to comprehensively represent the risk factors and their contribution to the portfolio risk. For this, risk factor contributions are scaled to the same initial parameter values, i.e., from 0 to 5 and -5 to 0 for opportunities and threats, respectively. First, considering only one output-related risk factor and only one outcome-related risk factor, the process described in step 2b (see Section 6.3.2) is conducted to establish the maximum possible value that could be obtained in both cases. The likelihood level is 5 for both risk factors, the output-related severity level is 5 for all projects, and the outcome-related severity is 5 for all capabilities. Analogously, the maximum impact produced from threats is equivalent to the negative value of the maximum positive impact. Positive and negative values were defined as A and B, respectively.

The maximum contribution from an output-related risk factor to the attribute 'l' of the success dimensions was defined as MP_l, while the maximum contribution from an outcome-related risk factor to the attribute 'l' of the success dimensions was defined as MC_l. Then, based on these maximum values, the risk contribution from each risk factor is scaled as a value from 0 to 5 for opportunities or -5 to 0 for threats (see Equation (38)).

$$x_{il} = \begin{cases} (5)(y_{il}/MP_l), & \forall l, \forall i \in OCR \\ (5)(y_{il}/MC_l), & \forall l, \forall i \in OPR \end{cases} \quad \textbf{(38)}$$

Assuming that the attributes within each success dimension are also equally important, Equations (39), (40), and (41) allow calculating the risk contribution from each risk factor to strategic fit, future preparedness, and stakeholder satisfaction, respectively. DSF, DFP, and DSS represent the subset of attributes 'l' comprising strategic fit, future preparedness, and stakeholder satisfaction, respectively. And nsf, nfp, and nss mean the number of attributes 'l' containing strategic fit, future preparedness, and stakeholder satisfaction, respectively. In addition, assuming that all success dimensions are equally important, the risk contribution from each risk factor to portfolio success can be estimated as shown in Equation (42).

$$SF_i = \left(\sum_l x_{il}\right)\left(\frac{1}{nsf}\right), \quad \forall l \in DSF \tag{39}$$

$$FP_i = \left(\sum_l x_{il}\right)\left(\frac{1}{nfp}\right), \quad \forall l \in DFP \tag{40}$$

$$SS_i = \left(\sum_l x_{il}\right)\left(\frac{1}{nss}\right), \quad \forall l \in DSS \tag{41}$$

$$PS_i = \frac{SF_i + FP_i + SS_i}{3} \tag{42}$$

Thus, the output-related risk factors and outcome-related risk factors with the highest potential risk contribution, positive or negative, can be identified as the ones with the highest PS values. A similar analysis could be conducted regarding each success dimension considering the SF_i, FP_i, or SS_i values in each case. Table 6.32 illustrates the parameters for MP_l and MC_l estimations according to the characteristics of the case example. These values are equivalent to the maximum likelihood and severity that any risk factor can get. According to the defined range for likelihood and severity in the proposed model, the maximum value in both cases equals 5.

Table 6.32. Illustrative example of parameters for MP_l and MC_l estimation

Risk factor	la_i	sap_{ja}			sac_{jc}	
		$a = 1$	$a = 2$	$a = 3$	$c = 1$	$c = 2$
1	5	5	5	5	-	-
2	5	-	-	-	5	5

Table 6.33 shows the respective values of MP_l and MC_l, and Table 6.34 shows the x_{il}. Values presented in Table 6.31 are the result of carry out the process established in Stage 2 (Section 6.3) only using the information presented in Table 6.32. In other words, values in Table 6.33 represent the

maximum possible risk contribution that any risk factor could generated on each attribute of the success dimensions. Values presented in Table 6.34 were obtained following Equation (38). For x_{il} estimation, y_{il} values were taken from Table 6.31.

Table 6.33. Illustrative example of MP_l and MC_l estimation

	$l = 1$	$l = 2$	$l = 3$	$l = 4$	$l = 5$	$l = 6$
MP_l	250	800	750	250	825	250
MC_l	50	150	125	50	150	50

Table 6.34. Illustrative example of x_{il} values

	$l = 1$	$l = 2$	$l = 3$	$l = 4$	$l = 5$	$l = 6$
$i = 1$	–1.32	–1.16	–0.90	–1.32	–1.09	–1.32
$i = 2$	2.21	1.38	0.00	2.21	1.00	2.21
$i = 3$	–0.61	–1.52	–3.04	–0.61	–1.93	–0.61
$i = 4$	0.00	0.34	0.90	0.00	0.49	0.00
$i = 5$	–1.20	–0.80	0.00	–1.20	–0.60	–1.20
$i = 6$	–0.32	–0.37	–0.48	–0.32	–0.40	–0.32

Based on Equations (39) to (42), Table 6.35 shows the risk contribution from each risk factor to each success dimension as well as the risk contribution from each risk factor to the portfolio success.

Table 6.35. Illustrative example of risk contribution from each risk factor

	SF	**FP**	**SS**	**PS**
$i = 1$	–1.24	–1.11	–1.21	–1.19
$i = 2$	1.79	1.10	1.61	1.50
$i = 3$	–1.06	–1.82	–1.27	–1.39
$i = 4$	0.17	0.45	0.24	0.29
$i = 5$	–1.00	–0.60	–0.90	–0.83
$i = 6$	–0.35	–0.40	–0.36	–0.37

6.4.3 Step 3c – Dependence and Drive Power Representation

Consolidated reachability matrix

This step is directly linked with the results from Stage 2, so it can be understood as part of the integration of the MICMAC method into the PPRA. In this regard, according to MICMAC, the drive power of each factor must be calculated to establish the strength to which a risk factor influences other factors. And, the power of dependence is calculated to determine the strength to which a risk factor is affected by

others. Both dependence and drive power values are calculated based on the reachability matrix obtained from the ISM method (Dandage et al., 2019; L. Guan et al., 2020).

In this case, the results from Stage 2 led to obtaining multiple reachability matrices, one for likelihood influences (see Equation (4) – Section 6.2.2), and derived from the influence on severity, as many reachability matrices as there are projects and capabilities (see Equation (17) and (18) – Section 6.2.3). Then, to estimate the drive and dependence power of each risk factor, the results from all those reachability matrices require to be consolidated.

Considering that each risk factor's expected risk contribution is represented as the product of likelihood and severity, dependence and drive power were associated with the variation of each risk factor's expected risk contribution. For that, a consolidated reachability matrix is proposed as shown in Equations (43) and (44). rlc_{ij} represents the risk contribution derived from the influence of the risk factor 'i' on the likelihood of risk factor 'j'. rsc_{ij} represents the risk contribution derived from the influence of the risk factor 'i' to the severity's risk factor 'j'.

$$RA(rc_{ij}) = [rc_{ij}]_{(n+m)(n+m)} \quad \textbf{(43)}$$

$$rc_{ij} = rlc_{ij} + rsc_{ij} \quad \textbf{(44)}$$

The influence on the risk contribution from each risk factor is represented by the variation of the expected contribution when risk factor interdependencies are considered. Thus, for each risk factor, changes in expected risk contribution derived from likelihood level variation can be expressed as the product between the variation in the likelihood level and the severity already established (see Equation (45)). Similarly, changes in expected risk contribution derived from the variation in the severity level can be expressed as the product between the variation in the cumulative severity level and the likelihood already established (see Equation (46)). Hence, following Equations (45) and (46), rlc_{ij} and rsc_{ij} can be respectively estimated.

$$rlc_{ij} = \begin{cases} (tlc_{ij}) \sum_{a} sap_{ja}, & \forall j \in OPR \\ (tlc_{ij}) \sum_{c} sac_{jc}, & \forall j \in OCR \end{cases} \quad \textbf{(45)}$$

$$rlc_{ij} = \begin{cases} (la_i) \sum_{a} tsp_{ija}, & \forall j \in OPR \\ (la_i) \sum_{c} tsc_{ijc}, & \forall j \in OCR \end{cases} \quad \textbf{(46)}$$

Table 6.36 shows the estimation of several rlc_{ij} and rsc_{ij} for the illustrative case example. For the estimation of rlc_{ij}, the tlc_{ij} values were taken from Table 6.12, while the sap_{ja} and sac_{jc} values were taken from Table 6.23. For the estimation of rsc_{ij}, Table 6.13 provided the la_i values, and Table 6.20 and Table 6.21 exemplify the tsp_{ija} and tsc_{ijc} values. Finally, following Equations (43) and (44), the consolidated reachability matrix is illustrated in Table 6.37.

Table 6.36. Illustrative example of the variables rlc_{ja} and rsc_{jc}

Variable	**Estimation**
$rlc_{12} = 1.8$	$(tlc_{12})(sap_{21} + sap_{22} + sap_{23}) = (0.6)(3 + 0 + 0) = 1.8$
$rlc_{23} = -16.0$	$(tlc_{23})(sap_{31} + sap_{32} + sap_{33}) = (1.6)(0 - 5 - 5) = -16.0$
$rlc_{43} = 0.0$	$(tlc_{43})(sap_{31} + sap_{32} + sap_{33}) = (0.0)(0 - 5 - 5) = 0.0$
$rlc_{45} = 0.0$	$(tlc_{45})(sac_{51} + sac_{52}) = (0.0)(-2 + 0) = 0.0$
$rlc_{56} = 0.0$	$(tlc_{56})(sac_{61} + sap_{62}) = (0.0)(-0.8 - 1.2) = 0.0$
$rsc_{12} = 0.0$	$(la_1)(tsp_{121} + tsp_{122} + tsp_{123}) = (3.0)(0 + 0 + 0) = 0.0$
$rsc_{23} = 16.93$	$(la_2)(tsp_{231} + tsp_{232} + tsp_{233}) = (4.6)(0 + 1.84 + 1.84) = 16.93$
$rsc_{43} = 0.0$	$(la_4)(tsp_{431} + tsp_{432} + tsp_{433}) = (3.2)(0 + 0 + 0) = 0.0$
$rsc_{45} = 0.0$	$(la_4)(tsc_{451} + tsc_{452}) = (3.2)(0 + 0) = 0.0$
$rsc_{56} = -9.0$	$(la_5)(tsc_{561} + tsc_{562}) = (3.0)(-1.2 - 1.8) = -9.0$

Table 6.37. Illustrative example of consolidated reachability matrix - $RA(rc_{ij})$

	1	**2**	**3**	**4**	**5**	**6**
1	0.0	**1.8**	**–2.40**	**0.28**	0.0	0.0
2	0.0	0.0	**0.93**	**1.78**	0.0	0.0
3	0.0	0.0	0.0	**–1.47**	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	**–9.0**
6	0.0	0.0	**12.80**	**–0.89**	0.0	0.0

Estimation of dependence and drive power

The dependence power of the risk factor 'j' is obtained by applying Equation (47). Thus, DE_j represents the strength to which the risk contribution of risk factor 'j' is affected by other risk factors.

$$DE_j = \sum_i |rc_{ij}| \quad \textbf{(47)}$$

Regarding drive power, it must be considered that each risk factor could contribute to both output-related and outcome-related risk factors. Given the different nature of the impact of each type of risk factor, the drive power from each risk factor to output-related risk factors and outcome-related risk factors

is estimated separately. Thus, the drive power from each risk factor to output-related risk factors is estimated as shown in Equation (48), while the drive power from each risk factor to outcome-related risk factors is estimated as shown in Equation (49).

$$DRA_i = \sum_j |rc_{ij}|, \quad \forall j \in OPR \tag{48}$$

$$DRC_i = \sum_j |rc_{ij}|, \quad \forall j \in OCR \tag{49}$$

Table 6.38, Table 6.39, and Table 6.40 show the estimations, for the case example, of variables DE_j, DRA_i, and DRC_i estimation for the case example.

Table 6.38. Illustrative example of the variable DE_j

Variable	Estimation
$DE_1 = 0.0$	$rc_{11} + rc_{21} + rc_{31} + rc_{41} + rc_{51} + rc_{61} = 0.0$
$DE_2 = 1.80$	$rc_{12} + rc_{22} + rc_{32} + rc_{42} + rc_{52} + rc_{62} = 1.8$
$DE_3 = 16.13$	$rc_{13} + rc_{23} + rc_{33} + rc_{43} + rc_{53} + rc_{63} = 16.13$
$DE_4 = 4.41$	$rc_{14} + rc_{24} + rc_{34} + rc_{44} + rc_{54} + rc_{64} = 4.41$
$DE_5 = 0.0$	$rc_{15} + rc_{25} + rc_{35} + rc_{45} + rc_{55} + rc_{65} = 0.0$
$DE_6 = 9.0$	$rc_{16} + rc_{26} + rc_{36} + rc_{46} + rc_{56} + rc_{66} = 9.0$

Table 6.39. Illustrative example of the variable DRA_i

Variable	Estimation
$DRA_1 = 4.47$	$rc_{11} + rc_{12} + rc_{13} + rc_{14} = 4.47$
$DRA_2 = 2.71$	$rc_{21} + rc_{22} + rc_{23} + rc_{24} = 2.71$
$DRA_3 = 1.47$	$rc_{31} + rc_{32} + rc_{33} + rc_{34} = 1.47$
$DRA_4 = 0.0$	$rc_{41} + rc_{42} + rc_{43} + rc_{44} = 0.0$
$DRA_5 = 0.0$	$rc_{51} + rc_{52} + rc_{53} + rc_{54} = 0.0$
$DRA_6 = 13.69$	$rc_{61} + rc_{62} + rc_{63} + rc_{64} = 13.69$

Table 6.40. Illustrative example of the variable DRC_i

Variable	Estimation
$DRC_1 = 0.0$	$rc_{15} + rc_{16} = 0.0$
$DRC_2 = 0.0$	$rc_{25} + rc_{26} = 0.0$
$DRC_3 = 0.0$	$rc_{35} + rc_{36} = 0.0$
$DRC_4 = 0.0$	$rc_{45} + rc_{56} = 0.0$
$DRC_5 = 9.0$	$rc_{55} + rc_{56} = 9.0$
$DRC_6 = 0.0$	$rc_{65} + rc_{66} = 0.0$

Risk factors categorization

Based on drive and dependence power, the elements can be classified into four clusters through a drive-dependence diagram (Dandage et al., 2019; L. Guan et al., 2020):

(I) autonomous factors – those with weak drive and dependence powers, signifying that they have a lower influence on the overall dynamic changes of a system in comparison to other variables;

(II) dependent factors – they have a weak drive power but a strong dependence power, which are highly sensitive to changes in those variables with a high drive power;

(III) linkage factors – they correspond to elements with strong drive and dependence powers, on which any actions exerted will have a subsequent effect on other variables;

(IV) independent factors – they have a strong drive power but a weak dependence power and should be addressed early.

These four clusters were adopted to classify the risk factors assessed. However, considering that drive power was categorized in two different groups of influence according to the nature of the risk factors influenced, two drive-dependence diagrams are proposed: 1) DE_j vs DRA_i, and 2) DE_j vs DRC_i. Figure 6.8 and Figure 6.9 depict the DE_j vs DRA_i and the DE_j vs DRC_i diagrams, respectively.

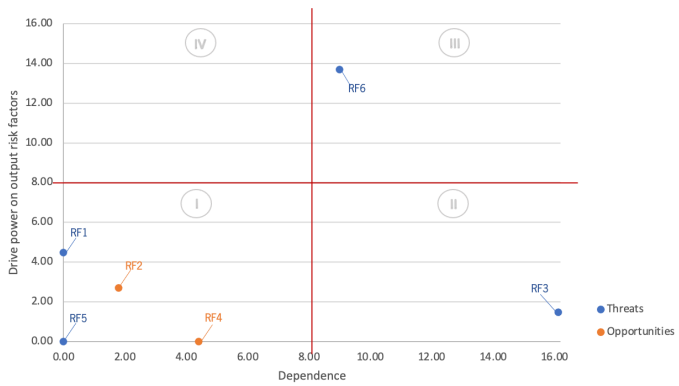


Figure 6.8. DE_j vs DRA_i diagram

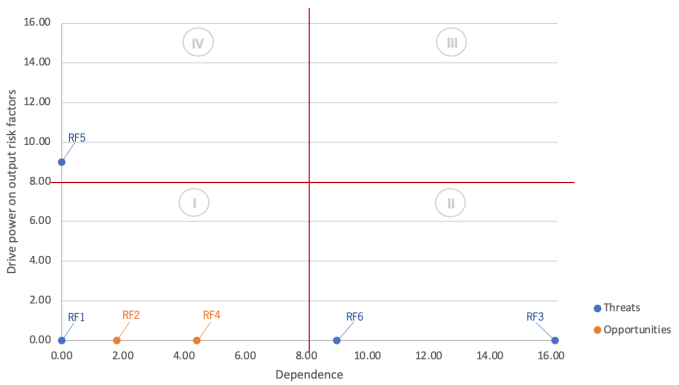


Figure 6.9. DE_j vs DRC_i diagram

6.4.4 Step 3d – Consolidation of Risk Information

Based on the results obtained in Step 3b and Step 3c, drive/dependence diagrams and impact on portfolio success required to be consolidated based on the visualization strategy. This strategy should be aligned with the visualization of project risk and organizational risk to support organizational decisions regarding planning risk responses in an integrative way.

6.5 Summary

A PPRA model is proposed in this chapter. The proposal corresponds to an analytical model of the proposed PPRA conceptualization to enable its practical use. The PPRA model is based on Meta-Network Analysis (MNA). Output-related risk factors, outcome-related risk factors, projects within the portfolio, organizational capabilities, and portfolio success dimensions were defined as network entities. MNA allows that, changes in an entity can be expressed as changes in other entities or in the relationships between them (T. Wang et al., 2021).

The proposed model requires as inputs: (i) risk factors, projects, capabilities, and attributes of the success dimensions, (ii) severity of each risk factor regarding projects and capabilities, (iii) likelihood of each risk factor, (iv) likelihood contribution between risk factors, (v) severity contribution between risk factors, (vi) influence level between projects and capabilities, and (vii) influence level between capabilities and attributes of the success dimension. These inputs should be provided by the parent organization to which the project portfolio belongs.

Based on these inputs, three stages were defined to operationalize the PPRA. The first Stage is focused on modeling interdependencies between risk factors. This Stage was based on the ISM-MICMAC method. In this Stage, it can be considered interdependencies between both threats and opportunities. Also, both positive and negative influence can be analyzed.

The second Stage is associated with how the risk is transferred from risk factors to success dimensions, i.e., it aims to determine the impact of output- and outcome-related risk factors on strategic fit, future preparedness, and stakeholder satisfaction, as success dimensions associated with the portfolio effectiveness. To estimate the impact, the MNA algorithms proposed by T. Wang et al. (2018) and T. Wang et al. (2021) were adopted. The network conveys the risk through the established connections between risk factors, projects, organizational capabilities, and success dimensions.

The third Stage aims to establish how the results could be represented according with the methods incorporated. Table 6.41 summarizes the inputs required from the parent organization, steps, range of equations, and results for each Stage of the proposed PPRA model.

Table 6.41. Description of inputs, steps, equations, and results of the proposed PPRA model

Stage	Inputs from the parent organization	Steps	Equations	Results
Stage 1	(i) Identifying risk factors, projects, capabilities, and attributes of the success dimensions. (ii) Likelihood of each risk factor. (iii) Severity of each risk factor regarding projects and capabilities. (iv) Likelihood contribution between risk factors. (v) Severity contribution between risk factors.	(1a) inputs preparation.	-	-
		(1b) likelihood adjusted due to risk factor interdependency.	Equations (1) to (9)	(i) adjusted likelihood adjusted for each risk factor considering risk factor interdependency. (ii) total severity contribution from each risk factor to other risk factors.
		(1c) severity adjusted due to risk factor interdependency.	Equations (10) to (24)	(iii) severity adjusted for each risk factor considering risk factor interdependency. (iv) total likelihood contribution from each risk factor to other risk factors.
Stage 2	(vi) Influence level between projects and capabilities. (vii) Influence level between capabilities and attributes of the success dimension.	(2a) inputs preparation.	-	-
		(2b) impact on success dimensions.	Equations (25) to (37)	(i) severity transferred from each risk factor to each attribute of the project portfolio success. (ii) risk contribution of each risk factor to each attribute of the project portfolio success.
Stage 3	-	(3a) inputs preparation.	-	-
		(3b) initial risk profile.	Equations (38) to (42)	(i) risk contribution of each risk factor on each success dimension. (ii) risk contribution of each risk factor on the portfolio success.
		(3c) dependence vs drive power.	Equations (43) to (49)	(iii) dependence and drive power of each risk factor regarding the other risk factors.
		(3d) consolidation of risk information	-	-

7. PPRA MODEL APPLICATION: CASE STUDY [4]

A case study was conducted to seek evidence that the proposed model can be used in practice. According to the research paradigm adopted for this research, it can be understood as the legitimation of that knowledge generated is enabled to be used for organizational design processes. In this regard, the application of the proposed model in a case study corresponds to the final activity of this research project, ending the Phase III of the project and defining the proposed PPRA model as the second main output of the project by legitimating it can be used in practice.

This chapter describes the application of the proposed PPRA model to a case study based on a portfolio of organizational development projects of a Colombian organization. To this end, the general characteristics of the case study are given in Section 7.1. The portfolio case study is composed by 18 projects, 31 risk factors, 4 organizational capabilities, and 11 attributes related to success dimensions. Then, a detailed description of the three stages needed to apply the PPRA proposal model is presented in Section 7.2, which also includes the final report of the results. In Section 7.3 the results are analyzed. Each type of risk factor was analyzed separately, i.e., results associated with non-systematic, systematic, and outcome-related risk factors are described independently. Then, risk analysis based on the 'project portfolio success dimensions' is presented at the chapter end.

7.1 Case Study Characterization

The project portfolio case study is from a company dedicated to the design, manufacture and marketing of women's and men's clothing and accessories. The company's headquarters is in Cali, Colombia. The company has approximately 4,000 employees, 3,000 in Colombia and 1,000 in other countries. In addition, it is estimated the generation of around 3,000 indirect jobs. The company has direct commercial operations, i.e., physical sales points, in four countries in South America and two in Central America. However, considering franchisees and distributors, the company covers a large part of the South, Central, and North American markets. Online sales channels have also allowed it to strengthen its commercial position throughout the Americas' market.

The company has a PMO working at the tactical-strategic level[5]. The PMO supports the project portfolio structuring process and its continuous monitoring. Likewise, the PMO leads the execution of the

[4] This chapter is partially the object of the paper: Micán, C., Fernandes, G., & Araújo, M. A Method for Assessing the Impact of Project Portfolio Risk on the Portfolio Success considering Risk Factors Interdependency. It is expected to be submitted to: *Computers and industrial engineering*.

[5] The PMO corresponds to a directive PMO (PMI, 2017a). The PMO takes control of the projects by directly managing them. The PMO plays a role in supporting strategic alignment and delivering organizational value.

projects within the portfolio. The project portfolio structuring is a process performed annually as it is linked to the organization's strategic planning cycle. Although project portfolio structuring is conducted once a year, the portfolio may be restructured in the six-monthly strategic review committee or through an extraordinary strategic committee within shorter periods.

Because the project portfolio is linked to strategic planning, it may cover projects with a planning window of more than one year. Therefore, although a portfolio structuring cycle is conducted annually, the projects within the portfolio may exceed the one-year execution window. That could happen either because some projects themselves overextend a one-year execution or because a sequence of interdependent projects leads to some of them being executed in subsequent years. As it is inherent to structuring project portfolios cycles, some projects could be already pre-defined from a previous cycle. These projects, however, could be refocused, suspended, or even eliminated given new strategic guidelines or expectations. In this concern, the detailed execution plan for each project is carried out only when required.

The parent organization defined the project portfolio as a portfolio that supports the digital transformation strategy, i.e., a project portfolio to transform corporate and operational processes. Specifically, the project portfolio supports the transformation towards an omnichannel commercial strategy. Omnichannel denotes a type of retail to selling products that is the same and equally good for the customer whether are buying from the different methods of shopping available. In this vein, the parent organization stated that the project portfolio is primarily anchored on projects that impact commercial transformation. However, projects that support an improvement in the value chain, resource profiles, and technologies are also required to achieve this. Thus, the organization defined a portfolio of projects focused on four axes: (i) commercial-omnichannel, (ii) value chain, (iii) control mechanisms, and (iv) financial support.

The PMO supports risk management activities. However, for this purpose, the PMO works in tandem with the parent organization's strategic and operational risk office. This coordination takes place both for risk identification for the project portfolio and for identification of risks that the project portfolio may generate to the company's strategy and operations. The PMO has a risk matrix for the project portfolio. The risk matrix is based on a linguistic scale for rating the probability and impact of each risk factor. The linguistic scale is composed by three categories: Low, medium, and high. Risk management is focused only on threats, i.e., risk factors with negative impacts.

Table 7.1 briefly describes the four axes on which the project portfolio is focused. These four axes are framed within what the organization defines as its strategic 'MEGAs' (MEGA refers to the definition given to the highest-level of organizational goals established by the organization): (i) increase sales, (ii) decrease costs, and (iii) increase margin. Framed in the four axes, the portfolio is composed by 18 projects and has a 36-month scope. Table 7.2 shows the projects within the portfolio and their expected duration in months. Regarding the definition of capabilities to be generated by the project portfolio, it was established that the four axes represented these capabilities. Thus, four organizational capabilities were defined as: (i) ensuring an omnichannel purchasing experience, (ii) internal production cycle adapted to omnichannel requirements, (iii) support for operational and strategic risk management based on control mechanisms, and (iv) agile financial model that responds to new requirements.

Table 7.1. Axes on which the project portfolio is focused – Case study

Axes	**Description**
commercial-omnichannel	An omnichannel commercial experience is required through which the customer is ensured to have the same shopping experience given any permutation in their shopping behavior. Shopping behavior includes product selection, product payment, product pick-up, product returns, and refunds.
Value chain	It refers to the organization's administrative and operational processes that support the value chain to produce and distribute the products that are marketed. These processes must ensure that information and products required to support the omnichannel commercial strategy are available.
Control mechanisms	Strategic transformation implies controls to new variables and permutations that will arise in operation due to omnichannel transactions. It is required to close lacks in access to information, price lists, omnichannel sales commissions lists, inventory, percentage of product lost (theft). Greater accuracy and transparency are required to ensure product and process control.
Financial support	A financial model must allow for agility to contrast the accounting notes, support the treasury to make payments to suppliers, better control income obtained from the different channels, etc.

The PMO develops a portfolio risk matrix as part of the project portfolio planning and monitoring. Similarly, as part of project planning, a risk matrix is established for each project within the portfolio. For applying the proposed PPRA model, the portfolio risk matrix was used as a baseline. The portfolio risk matrix was initially composed of 14 risk factors. Risk factors are classified by the PMO into eight local (L) and six global (G) risk factors. For the organization case study, a local risk factor is one that impacts projects in a particular manner, i.e., the impact on one project does not necessarily imply an impact on other projects in the portfolio. A global risk factor is one that impacts all the projects within the portfolio. Table 7.3 shows the 14 risk factors reported in the risk matrix.

Table 7.2. Projects within the portfolio – Case study

Axes	Projects		Duration
Commercial-omnichannel	P1	Normative project 'MinCiencias'	36
	P2	Tracking of products' shooting	6
	P3	Update billing software in physical sales points	12
	P4	Growth of ecommerce in the LATAM market	12
	P5	Expansion in e-marketplaces	12
	P6	Technology platforms to improve customer experience	12
Value chain	P7	Software for improve internal cycle of production	8
	P8	Technology platforms to improve material explosion (MRP) and production scheduling	18
Control mechanisms	P9	Information system to support quality management organizational system	4
	P10	Management of corporate access matrices by profiles	12
	P11	Information system to manage commissions of sales teams	8
	P12	Implementation of existing module to improve the supplier database update process	6
	P13	Kaizen: Inventory outflows	6
Financial support	P14	Information system for accounting authentications	8
	P15	Information system for facility leasing management	8
	P16	Information system to manage costing system	12
	P17	Kaizen: Revenue management	6
	P18	Kaizen: Cost overruns	6

Table 7.3. Initial list of risk factors – Case study

Risk factor	L	G
Brain drains or termination of contracts of personnel participating in the projects		X
No visible leader in the project	X	
Project requirements without proper formalization	X	
Negative QA test results requiring adjustments to developments	X	
Financial illiquidity for post-pandemic projects continuity		X
Law requirements impossible to be anticipated which suspends the work plan	X	
Non-compliance of expected deliverables from suppliers	X	
Lack of executive support for the execution of the projects within the portfolio		X
Project objective become out of alignment with organizational strategic goals	X	
New projects without analysis of the capabilities and capacities required for its implementation		X
Loss or leakage of information from each project	X	
Poor adherence to new processes being delivered by each project		X
Health-related work absenteeism of personnel participating in the projects		X
Non-compliance of payment obligations stipulated to suppliers	X	

It was determined that the factors referred to as 'local' corresponded to non-systematic risk factors, while 'global' ones corresponded to systematic risk factors. Only the risk factor 'Poor adherence to new processes being delivered by each project ' did not follow this association. In this case, the risk factor shifted from being 'global' to being typified as an outcome-related risk factor.

Moreover, following the structure of the proposed PPRA model, it was decided to revise the corporate, operational, and project risk matrices to complement the initial risk factors list. Thus, 17 additional risk factors were identified which, added to the 14 initial factors, resulted in 31 risk factors. Seventeen of these risk factors are non-systematic and eleven are systematic, i.e., 28 are output-related risk factors. However, 5 of the output-related factors also impact the capabilities, i.e., outcome-related risk factors. In addition, three risk factors that exclusive impact on capabilities were identifies. Thus, a total of 8 outcome-related risk factors were identified. Table 7.4 shows the 31 risk factors and their classification.

7.2 PPRA for the Case Study

As illustrated in Chapter 6, the PPRA proposal is composed of three stages. The way in which each of these stages was conducted is detailed in the following Sections. Thus, Section 7.2.1 describes the risk interdependence analysis, Section 7.2.2 describes the estimation of risk on project portfolio success, and Section 7.2.3 describes and consolidates the PPRA results.

7.2.1 Stage 1 – Risk factor interdependence

As described in Section 6.2, this Stage is composed of three steps. The first step is associated with the preparation of inputs, while the second and third steps seek to establish the adjusted occurrence and impact given the interdependencies between risk factors.

Step 1a. Inputs preparation

As mentioned in 7.1, in the portfolio case study, risk is assessed based on negative impacts, i.e., threats. Therefore, the same approach was adopted to apply the PPRA proposal and only threats were considered, as in the parent organization. As such, the application of the PPRA proposal does not include opportunities assessment. For each risk factor, the parent organization evaluates the occurrence and severity. As previously mentioned, the measurement scale is a qualitative scale with three levels: Low, medium, and high. This scale is applied throughout the organization. Therefore, it applies both to portfolio risk assessment and other risk assessment processes such as strategic risk or operational risk assessment.

Table 7.4. Final list of risk factors – Case study

Cod.	Risk factor description	NS	S	CR
F1	No visible leader in the project	X		
F2	Project requirements without proper formalization	X		
F3	Negative QA test results requiring adjustments to developments	X		
F4	Law requirements impossible to be anticipated which suspends the work plan	X		
F5	Non-compliance of expected deliverables from suppliers	X		
F6	Project objective become out of alignment with organizational strategic goals	X		
F7	Loss or leakage of information from each project	X		
F8	Non-compliance of payment obligations stipulated to suppliers	X		
F9	Conflicts between project managers	X		
F10	Poor commitment and lack of a teamwork culture	X		
F11	Lack of knowledge among team members	X		
F12	Experience and training gaps in key team members	X		
F13	Key team member being unfamiliar with the technology	X		
F14	Software failure leading to loss of key data	X		
F15	Poorly defined client role	X		
F16	Requirements are misinterpreted by the project team	X		X
F17	Lack of key technology	X		
F18	Lack of executive and operational support for the execution of the projects within the portfolio		X	
F19	Brain drains or termination of contracts of personnel participating in the projects		X	X
F20	Financial illiquidity for post-pandemic projects continuity		X	
F21	New projects without analysis of the capabilities and capacities required for its implementation		X	
F22	Health-related work absenteeism of personnel participating in the projects		X	
F23	Conflicts between portfolio managers and organizational decision makers		X	X
F24	Lack of information transparency within the portfolio		X	
F25	Lack of project portfolio familiarity from organizational processes		X	
F26	Lack of coordination of key resources within the portfolio		X	
F27	Lack of coordination of key resources between the portfolio and organizational processes		X	X
F28	Poor management of end-user expectations		X	X
F29	Poor adherence to new processes being delivered by each project			X
F30	Brain drains of personnel involved in organizational processes (high staff turnover)			X
F31	Users are unfamiliar with the technology and require additional training			X

Hence, no adjustments in the parameters to be evaluated were required since they coincide with those established in the PPRA proposal – likelihood and severity. However, to harmonize the scale used by the parent organization with the scale established in the PPRA proposal, it was decided that the three qualitative levels established by the parent organization represented ranges of the quantitative scale of the PPRA proposal. Table 7.5 shows the quantitative ranges defined with the parent organization to

harmonize its qualitative scale with the quantitative scale required in the proposed PPRA model. It also shows the color coding defined by the parent organization to represent each level.

Table 7.5. Numerical ranges for likelihood and severity – Case study

Level	Minimum	Maximum	Color
Low	(0.0	1.0]	Green
Medium	(1.0	3.0]	Yellow
High	(3.0	5.0]	Red

Specifically, an a priori valuation at the low level is considered a rating equivalent to 1 (minimum possible value in the numerical scale). An a priori valuation at the medium level is considered equivalent to 2 (mean of the medium level range). A qualitative valuation at the high level is considered equivalent to the numerical value equal to 4 (mean of the high-level range). The numerical ranges of each level are used to represent the level of influence of one risk factor over another.

It was considered impractical to contrast each of the 18 non-systematic risk factors against each of the 18 projects to assign severity values. Instead, it was decided to assign risk factors to groups of projects with common characteristics, adding two project categorizations to the two categories already defined in the organization. It should be noted that these project categories are not mutually exclusive but complementary so that a project could belong to one or more categories. The four categories are: (i) technology-intensive [T] vs non-technology-intensive [M], (ii) high external involvement [E] vs low external involvement [I], (iii) vertical to the organization's processes [V] vs focused on a specific process or subset of processes [F], and (iv) requires new knowledge [N] vs based on already acquired knowledge [C]. Table 7.6 shows the projects' categorization.

Once the categorization was established, it was identified which types of projects were affected by each risk factor. For instance, risk factor 2 mainly impacts projects categorized as vertical [V] or new knowledge [N]. Thus, according to the information registered in Table 7.7, it affects projects 1, 2, 3, 4, 7, 9, 11, and 18. Additionally, it was defined that the structure used by the organization would be preserved, so the severity value assigned to each risk factor is applied to all projects impacted by it. Therefore, this single impact value would be applied to the projects and capabilities that this factor impacts. Thus, for risk factor 2, the organization defined a medium level of severity, which, according to the established scale, corresponds to a value of 2. Since this risk factor impacts projects 1, 2, 3, 4, 7, 9, 11, and 18, a numerical valuation of 2 was assigned to those projects. Table 7.7 shows the parameters likelihood (li_i), severity on projects (sep_{ia}), and severity on capabilities (sec_{ic}) for each risk factor.

Table 7.6. Project categorization – Case study

Project	Categories			
	i	ii	iii	iv
1	M	I	V	C
2	T	I	V	N
3	T	E	F	N
4	T	I	V	C
5	T	E	F	C
6	T	E	F	C
7	T	E	F	N
8	T	E	F	C
9	T	E	V	C
10	G	E	F	C
11	T	I	F	N
12	T	I	F	C
13	G	I	F	C
14	T	E	F	C
15	T	E	F	C
16	T	E	F	C
17	G	I	F	C
18	G	I	V	C

By their nature, systematic risk factors homogeneously impact the entire portfolio, so an assignment process was not required. The severity value was assigned homogeneously to all projects within the portfolio. Finally, for the valuation of the impact on the capabilities, it was established which capacities were impacted by each of the eight capability-related risk factors, assigning the respective severity value to each capability impacted (see Table 7.7).

Once the likelihood and severity of risk factors on projects and capabilities were established, the influence between risk factors was also defined. Given that the scale of occurrence and impact does not take values of 1, 2, and 4, it was established with the organizations' representative that the influence between risk factors would take values multiples of 2 (positive or negative according to the type of influence) to simplify the quantification of interdependencies. According to the scale defined in the PPRA proposal, this would be equivalent to influence values corresponding to 2 and 4. It allows assuming that the influence from one factor on another leads to an increase in its likelihood or severity level by one level when the influence is equal to 2. In Table 7.7, values are negative because they represent threats.

Table 7.7. Parameters li_i, sep_{ia}, and sec_{ic} – Case study

RF	li_i	sep_{ia} Projects																		sec_{ic} Capabilities			
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**1**	**2**	**3**	**4**
1	1	-4	-4		-4														-4				
2	1	-2	-2	-2	-2			-2				-2							-2				
3	2		-4	-4	-4	-4	-4	-4	-4	-4		-4	-4		-4	-4	-4						
4	2		-2	-2				-2				-2											
5	2		-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4		-4	-4	-4						
6	1	-1	-1	-1	-1			-1				-1							-1				
7	1			-2		-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2					
8	2		-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4		-4	-4	-4						
9	1	-2	-2		-2														-2				
10	4	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2				-2	-2	-2		-2				
11	2		-2	-2				-2				-2											
12	2		-4	-4				-4				-4											
13	1		-1	-1	-1	-1	-1	-1	-1	-1		-1	-1		-1	-1	-1						
14	2		-2	-2	-2	-2	-2	-2	-2	-2		-2	-2		-2	-2	-2						
15	1	-4	-4	-4	-4			-4				-4							-4				
16	1	-4	-4		-4														-4	-4	-4	-4	-4
17	1		-4	-4	-4	-4	-4	-4	-4	-4		-4	-4		-4	-4	-4						
18	1	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4				
19	2	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4		-4	-4	
20	1	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4				
21	2	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4				
22	4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4				
23	1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2		-2	-2	
24	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				
25	1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2				
26	1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2				
27	1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2		-2	
28	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
29	1																			-4	-4	-4	-4
30	1																			-4	-4	-4	-4
31	2																			-2	-2	-2	-2

Table 7.8 shows the values for the influence in terms of likelihood for each pair of risk factors with interdependency between them. The interdependence between risk factors that is not reported in Table 7.8. is because its likelihood influence level equals 0. For instance, $lc_{(12)(15)}$ is reported in Table 7.8 with a value equals 2, i.e., risk factor 12 could increase the likelihood of the risk factor 15 from 1 to 3 (1 is the initial likelihood level assigned to risk factor 15 – see Table 7.7). $lc_{(1)(2)}$ is not reported in Table 7.8, that means that risk factor 1 has not influence on risk factor 2. As shown in Table 7.8, all the values were level 2 and positive, i.e., the influenced risk factor would increase from low to medium likelihood level or from medium to high likelihood level. The PPRA proposal labeled these likelihood influences between risk factors with the parameter lc_{ij}. Influences between risk factors at the impact level were not identified in the case study, i.e., the parameter sc_{ij} is equal to zero in all cases.

Table 7.8. Likelihood influence between risk factors – Case study

$lc_{(1)(8)} = 2$	$lc_{(10)(15)} = 2$	$lc_{(18)(25)} = 2$	$lc_{(22)(13)} = 2$	$lc_{(27)(13)} = 2$
$lc_{(1)(18)} = 2$	$lc_{(11)(2)} = 2$	$lc_{(19)(7)} = 2$	$lc_{(22)(25)} = 2$	$lc_{(27)(16)} = 2$
$lc_{(2)(9)} = 2$	$lc_{(12)(7)} = 2$	$lc_{(19)(12)} = 2$	$lc_{(22)(29)} = 2$	$lc_{(27)(23)} = 2$
$lc_{(5)(9)} = 2$	$lc_{(12)(15)} = 2$	$lc_{(19)(23)} = 2$	$lc_{(22)(31)} = 2$	$lc_{(28)(29)} = 2$
$lc_{(5)(17)} = 2$	$lc_{(12)(16)} = 2$	$lc_{(19)(25)} = 2$	$lc_{(23)(21)} = 2$	$lc_{(28)(31)} = 2$
$lc_{(8)(5)} = 2$	$lc_{(16)(6)} = 2$	$lc_{(19)(29)} = 2$	$lc_{(24)(25)} = 2$	$lc_{(30)(29)} = 2$
$lc_{(9)(7)} = 2$	$lc_{(16)(29)} = 2$	$lc_{(19)(31)} = 2$	$lc_{(24)(28)} = 2$	$lc_{(30)(31)} = 2$
$lc_{(10)(7)} = 2$	$lc_{(18)(6)} = 2$	$lc_{(21)(23)} = 2$	$lc_{(25)(21)} = 2$	

Step 1b. Estimation of adjusted likelihood

Table 7.9 shows the self-interaction matrix denoted as $SI(lc_{ij})$ in the PPRA proposal (see Equation (1)). Applying Equation (3), the adjusted self-interaction matrix represented as $SI(alc_{ij})$ in Equation (2) is calculated. $SI(lc_{ij})$ and $SI(alc_{ij})$ are coincident in this case study. Therefore, risk factors do not require adjustment in the maximum influence level received from another risk factor. Considering that $SI(lc_{ij})$ and $SI(alc_{ij})$ are equivalent, $SI(alc_{ij})$ is equal to the matrix presented in Table 7.9.

The final interaction matrix was calculated based on the adjusted self-interaction matrix (Equation (4)). The estimation of this matrix requires to estimate tlc_{ij} (Equation (8)), for which the calculation of the values of tlc_{ij}^{g} is previously required (Equation (5)). Likewise, variables E_{ij}^{g} are also required (Equations (6) and (7)). Table 7.10, Table 7.11, Table 7.12, and Table 7.13 depict a segment of E_{ij}^{1}, E_{ij}^{2}, E_{ij}^{3}, and E_{ij}^{4} matrices respectively. The G value was equal to 4, i.e., the maximum distance between two risk factors is four nodes. Table 7.14, Table 7.15, Table 7.16, and Table 7.17 illustrate a segment of the tlc_{ij}^{1}, tlc_{ij}^{2}, tlc_{ij}^{3}, and tlc_{ij}^{4} matrices, respectively.

Table 7.9. Likelihood self-interaction matrix $SI(lc_{ij})$ – Case study

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
1	-	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	-	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	-	0	0	0	**2**	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	**2**	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	**2**	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	**2**	0	0	-	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	-	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	**2**	0	0	0	0	-	0	0	**2**	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	**2**	0	0	0	0	0	0
19	0	0	0	0	0	0	**2**	0	0	0	0	**2**	0	0	0	0	0	0	-	0	0	0	**2**	0	**2**	0	0	0	**2**	0	**2**
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	**2**	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	-	0	0	**2**	0	0	0	**2**	0	**2**
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	-	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	**2**	0	0	**2**	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0	-	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	**2**	0	0	0	0	0	0	**2**	0	0	0	-	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	**2**	0	**2**
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	-	**2**
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-

Table 7.10. Illustration of E_{ij}^{1} values – Case Study

Risk factor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	0	0	0	0	0	0	0	**1**	0
2	0	0	0	0	0	0	0	0	**1**
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	**1**
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	**1**	0	0	0	0
9	0	0	0	0	0	0	**1**	0	0

Table 7.11. Illustration of E_{ij}^{2} values – Case Study

Risk factor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	0	0	0	0	**1**	**1**	0	0	0
2	0	0	0	0	0	0	**1**	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	**1**	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	**1**
9	0	0	0	0	0	0	0	0	0

Table 7.12. Illustration of E_{ij}^{3} values – Case Study

Risk factor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	0	0	0	0	0	0	0	0	**1**
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	**1**	0	0
9	0	0	0	0	0	0	0	0	0

Table 7.13. Illustration of E_{ij}^{4} values – Case study

Risk factor	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	**1**	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0

Table 7.14. Illustration of tlc_{ij}^{1} values – Case study

Risk factor	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	0	**0.4**	0
2	0	0	0	0	0	0	0	0	**0.4**
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	**0.8**
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	**0.8**	0	0	0	0
9	0	0	0	0	0	0	**0.4**	0	0

Table 7.15. Illustration of tlc_{ij}^{2} values – Case study

Risk factor	1	2	3	4	5	6	7	8	9
1	0	0	0	0	**0.16**	**0.16**	0	0	0
2	0	0	0	0	0	0	**0.16**	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	**0.32**	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	**0.32**
9	0	0	0	0	0	0	0	0	0

Table 7.16. Illustration of tlc_{ij}^{3} values – Case study

Risk factor	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	0	0	**0.064**
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	**0.128**	0	0
9	0	0	0	0	0	0	0	0	0

Table 7.17. Illustration of tlc_{ij}^{4} values – Case study

Risk factor	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	**0.026**	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0

Table 7.18 shows the tlc_{ij} values obtained by applying Equation (8), i.e., the reachability matrix. Based on the reachability matrix, the adjusted likelihood is calculated following Equation (9). Table 7.19 shows the values of the adjusted likelihood for each risk factor.

Table 7.18. Reachability matrix $RA(tlc_{ij})$ – Case study

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	0	0	0	0	**0.16**	**0.16**	**0.03**	**0.40**	**0.06**	0	0	0	0	0	0	0	**0.06**
2	0	0	0	0	0	0	**0.16**	0	**0.40**	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	**0.32**	0	**0.80**	0	0	0	0	0	0	0	**0.80**
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	**0.80**	0	**0.13**	0	**0.32**	0	0	0	0	0	0	0	**0.32**
9	0	0	0	0	0	0	**0.40**	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	**1.60**	0	0	0	0	0	0	0	**1.60**	0	0
11	0	0	0	0	0	**0.13**	**0.32**	0	0	0	0	**0.80**	0	0	**0.32**	**0.32**	0
12	0	0	0	0	0	**0.32**	**0.80**	0	0	0	0	0	0	0	**0.80**	**0.80**	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	**0.40**	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	**0.40**	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	**0.13**	**0.80**	0	0	0	0	**0.80**	0	0	**0.32**	**0.32**	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	**1.60**	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	**0.16**	0	0	0	0	0	0	**0.40**	0	0	**0.40**	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7.18 (continuation). Reachability matrix $RA(tlc_{ij})$ – Case study

	18	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**18**	**19**	**20**
1	**0.40**	0	0	**0.06**	0	**0.03**	0	**0.16**	0	0	0	0	0	0	**0.40**	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	**0.13**	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	**0.32**	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	**0.40**	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	**0.16**	0	**0.06**	0	**0.40**	0	0	0	0	0	0	0	0	0
19	0	0	0	**0.64**	0	**0.80**	0	**0.80**	0	0	0	**0.80**	0	**0.80**	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	**0.80**	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	**0.64**	0	**0.26**	0	**1.60**	0	0	0	**1.60**	0	**1.60**	0	0	0
23	0	0	0	**0.40**	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	**0.32**	0	**0.13**	0	**0.80**	0	0	**0.80**	**0.32**	0	**0.32**	0	0	0
25	0	0	0	**0.40**	0	**0.16**	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	**0.16**	0	**0.40**	0	0	0	0	0	**0.16**	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	**0.80**	0	**0.80**	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	**0.40**	0	**0.40**	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7.19. Likelihood adjusted la_i – Case study

Risk factor	*la*	Risk factor	*la*	Risk factor	*la*	Risk factor	*la*	Risk factor	*la*
1	1.0	8	2.4	14	2.0	20	1.0	26	1.0
2	1.0	9	2.6	15	4.0	21	4.8	27	1.0
3	2.0	10	4.0	16	2.8	22	4.0	28	2.8
4	2.0	11	2.0	17	2.2	23	3.6	29	5.0
5	3.0	12	3.6	18	1.4	24	2.0	30	1.0
6	2.7	13	3.0	19	2.0	25	4.8	31	5.0
7	5.0								

Step 1.c. Estimation of adjusted severity

The calculation of the adjusted severity values is based on the sc_{ij} parameters, which, as mentioned in step 1a, are equal to zero because no severity relationships between the risk factors were identified. Thus, the process described from Equation (10) to (21), which was established to calculate the adjusted severity, was not required. Consequently, the adjusted severity values are equivalent to the severity values initially established for each risk factor. In this regard, the values of sap_{ia} and sac_{ic} correspond to the values of sep_{ia} and sec_{ic} shown in Table 7.7.

7.2.2 Stage 2 – Impact on Project Portfolio Success

As described in Section 6.3, this Stage is composed of two steps. The first step is associated with input preparation, while the second step seeks to establish risk factors' impact on the project portfolio success.

Step 2a. Input preparation

As stated in Section 6.3.1, three of the inputs required for this Stage are obtained from Stage 1, namely, la_i, sap_{ia}, and sac_{ic}. The two additional parameters are ipc_{ac} and ics_{cl}. Parameter ipc_{ac} represents the impact of project 'a' on capability 'c'. And ics_{cl} represents the impact of capability 'c' on attribute 'l' of the project portfolio success. Although the organization has established how projects are related to the capabilities (see axes in Table 7.2), it has not established a range associated with the degree of impact on the capabilities. Then, it was decided to adopt the scale proposed in the PPRA model by common agreement. Similarly, the impact of capabilities on attributes of the success dimensions needed to be designed. For that, the range proposed in the PPRA model was also used. Thus, in both cases, the scale defined in the PPRA proposal was used, i.e., a Likert scale from 0 to 5. Table 7.20 illustrates the values established for the parameter ipc_{ac}.

Table 7.20. values established for parameter ipc_{ac} – Case study

Projects	Capabilities			
	$c = 1$	$c = 2$	$c = 3$	$c = 4$
$a = 1$	1			
$a = 2$	3			
$a = 3$	5			
$a = 4$	3			
$a = 5$	3			
$a = 6$	3			
$a = 7$		3		
$a = 8$		4		
$a = 9$			2	
$a = 10$			4	
$a = 11$			3	
$a = 12$			2	
$a = 13$			3	
$a = 14$				3
$a = 15$				3
$a = 16$				3
$a = 17$				2
$a = 18$				2

Concerning the parameter ics_{cl}, the attributes to be considered for each of the three success dimensions had to be established. It was determined that the three strategic 'MEGAs' would represent the attributes of the strategic alignment dimension of success, i.e., increase in sales, decrease in expenses, increase in margin. Regarding future preparedness attributes, the following attributes were defined: (i) labor capability readiness, (ii) product capacity (product curves), (iii) relationships with suppliers, and (iv) preparation for commercial timetables.

The attributes for stakeholder satisfaction were initially defined based on the five stakeholder groups currently identified in the PMO: sponsors, project managers, teams of the projects, clients, and users. However, when assessing the relationship between capabilities and attributes, it was identified that these attributes were associated with the stakeholders of each project and did not respond to a portfolio and capabilities perspective. Therefore, the attributes associated with stakeholder satisfaction were reconfigured as: (i) internal cycle of production, (ii) back-office processes, (iii) physical sale channels (own or franchised), and (iv) large distributors (physical and online). Table 7.21 shows the values assigned to the parameter ics_{cl} considering the four capabilities and the eleven portfolio success

attributes, three associated with strategic fit ($l = 1,\ l = 2,\ and\ l = 3$), four with future preparedness ($l = 4,\ l = 5,\ l = 6,\ and\ l = 7$), and four with stakeholder satisfaction ($l = 8,\ l = 9,\ l = 10,\ and\ l = 11$).

Table 7.21. Values established for the parameter isc_{cl} – Case study

Capabilities	Success dimensions										
	Strategic fit			Future preparedness				Stakeholder satisfaction			
	$l = 1$	$l = 2$	$l = 3$	$l = 4$	$l = 5$	$l = 6$	$l = 7$	$l = 8$	$l = 9$	$l = 10$	$l = 11$
$c = 1$	5.0	0.0	0.0	0.0	3.0	0.0	5.0	0.0	3.0	5.0	5.0
$c = 2$	0.0	2.0	5.0	5.0	0.0	3.0	0.0	4.0	1.0	0.0	0.0
$c = 3$	0.0	2.0	0.0	2.0	0.0	2.0	0.0	1.0	3.0	1.0	0.0
$c = 4$	0.0	2.0	0.0	0.0	0.0	2.0	0.0	1.0	3.0	1.0	0.0

Step 2b. Estimation of impact on project portfolio success

Equations (25), (26), (27), and (28) represent the vectors composed of thirty-one risk factors, eighteen projects, four capabilities, and eleven attributes associated with the success dimensions. The risk factors are listed in Table 7.4, and projects are listed in Table 7.2. The four axes grouping the projects, illustrated in Table 7.2, represent the four organizational capabilities to be generated by the portfolio. The eleven attributes of the success dimensions were described in step 1b of this Section.

Equation (29) denotes the relationship between output-related risk factors and projects, defined as $OPR - PRO(sap_{ia})$. As previously mentioned, in this case, sap_{ia} values are equivalent to sep_{ia} values presented in Table 7.7. Equation (30) denotes the relationship between outcome-related risk factors and capabilities, denoted as $OCR - CAP(sac_{ic})$. Like sap_{ia}, in this case study, sac_{ic} values are equivalent to sec_{ic} values reported in Table 7.7. Table 7.20 corresponds to Equation (31), i.e., it represents the relationship between projects and capabilities. Table 7.21 corresponds to Equation (32), i.e., it represents the relationship between capabilities and attributes of the success dimensions.

Table 7.22 shows the relationship between output-related risk factors and capabilities obtained by applying Equation (33). This matrix represents how output-related risk factors indirectly impact capabilities through their direct impact on projects and the relationship between projects and capabilities. Table 7.23 depicts the relationship between output-related risk factors and success attributes (Equation (34)), and Table 7.24 shows the relationship between outcome-related risk factors and success attributes (Equation (35)).

Table 7.22. Severity contribution from output-related risk factors to capabilities – Case study

	$c=1$	$c=2$	$c=3$	$c=4$		$c=1$	$c=2$	$c=3$	$c=4$
$i=1$	-28	0	-8	-8	$i=17$	-68	-28	-28	-36
$i=2$	-24	-6	-10	-4	$i=18$	-72	-28	-56	-52
$i=3$	-68	-28	-28	-36	$i=19$	-72	-28	-56	-52
$i=4$	-16	-6	-6	0	$i=20$	-72	-28	-56	-52
$i=5$	-68	-28	-44	-36	$i=21$	-72	-28	-56	-52
$i=6$	-12	-3	-5	-2	$i=22$	-72	-28	-56	-52
$i=7$	-22	-14	-28	-22	$i=23$	-36	-14	-28	-26
$i=8$	-68	-28	-44	-36	$i=24$	-18	-7	-14	-13
$i=9$	-14	0	-4	-4	$i=25$	-36	-14	-28	-26
$i=10$	-36	-14	-12	-22	$i=26$	-36	-14	-28	-26
$i=11$	-16	-6	-6	0	$i=27$	-36	-14	-28	-26
$i=12$	-32	-12	-12	0	$i=28$	-36	-14	-28	-26
$i=13$	-17	-7	-7	-9	$i=29$	0	0	0	0
$i=14$	-34	-14	-14	-18	$i=30$	0	0	0	0
$i=15$	-48	-12	-20	-8	$i=31$	0	0	0	0
$i=16$	-28	0	-8	-8					

Table 7.23 shows that risk factors 29, 30 and 31 do not impact success attributes using the risk factors-projects-capabilities-success attributes path. That is consistent with the fact that these three risk factors are the only factors that do not directly impact the projects, i.e., they are not output-related risk factors. Table 7.23 also shows that systematic risk factors have a greater contribution to portfolio risk than non-systematic risk factors. That was expected since systematic risk factors impact all projects in the portfolio while non-systematic risk factors impact only some of the projects. However, it also shows that some non-systematic risk factors can have a level of impact similar to some systematic risk factors. For example, considering success attribute 1, risk factor 10 delivers the same severity contribution than risk factor 23.

Table 7.24 shows that only risk factors 16, 19, 23, 27, 28, 29, 30, and 31 contribute to portfolio risk through the risk factors-capabilities-success attribute path. That is consistent with the fact that these eight factors are the only risk factors that directly impact the capabilities.

Equation (36) and (37) aim to establish each risk factor's contribution to portfolio risk by integrating the occurrence and impact of each risk factor into a single measure. However, this estimation was not performed in the case study because the parent organization, and consequently its PMO, has defined a risk management process based on the visualization of both metrics and not on an aggregated metric. Therefore, occurrence and severity were not aggregated into a single measure. Thus, to obtain the values

of the $PSA(y_{il})$ matrix derived from Equation (36) and (37), a likelihood level equal to 1 was assumed for all risk factors aiming at not modifying the values obtained for the severity contribution on the success attributes. Thus, Table 7.23 and Table 7.24 represent the severity contribution of each risk factor to the success attributes. The value for each risk factor regarding each success attribute in Table 7.23 and Table 7.24 represent the bi-dimensional nature of the y_{il} variable (see Section 6.3.2).

Table 7.23. Contribution of output risk factors to attributes of success dimensions – Case study

	Attributes of success dimensions (l)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
$\boldsymbol{i=1}$	-140	-32	0	-16	-84	-32	-140	-16	-132	-156	-140
$\boldsymbol{i=2}$	-120	-40	-30	-50	-72	-46	-120	-38	-120	-134	-120
$\boldsymbol{i=3}$	-340	-184	-140	-196	-204	-212	-340	-176	-424	-404	-340
$\boldsymbol{i=4}$	-80	-24	-30	-42	-48	-30	-80	-30	-72	-86	-80
$\boldsymbol{i=5}$	-340	-216	-140	-228	-204	-244	-340	-192	-472	-420	-340
$\boldsymbol{i=6}$	-60	-20	-15	-25	-36	-23	-60	-19	-60	-67	-60
$\boldsymbol{i=7}$	-110	-128	-70	-126	-66	-142	-110	-106	-230	-160	-110
$\boldsymbol{i=8}$	-340	-216	-140	-228	-204	-244	-340	-192	-472	-420	-340
$\boldsymbol{i=9}$	-70	-16	0	-8	-42	-16	-70	-8	-66	-78	-70
$\boldsymbol{i=10}$	-180	-96	-70	-94	-108	-110	-180	-90	-224	-214	-180
$\boldsymbol{i=11}$	-80	-24	-30	-42	-48	-30	-80	-30	-72	-86	-80
$\boldsymbol{i=12}$	-160	-48	-60	-84	-96	-60	-160	-60	-144	-172	-160
$\boldsymbol{i=13}$	-85	-46	-35	-49	-51	-53	-85	-44	-106	-101	-85
$\boldsymbol{i=14}$	-170	-92	-70	-98	-102	-106	-170	-88	-212	-202	-170
$\boldsymbol{i=15}$	-240	-80	-60	-100	-144	-92	-240	-76	-240	-268	-240
$\boldsymbol{i=16}$	-140	-32	0	-16	-84	-32	-140	-16	-132	-156	-140
$\boldsymbol{i=17}$	-340	-184	-140	-196	-204	-212	-340	-176	-424	-404	-340
$\boldsymbol{i=18}$	-360	-272	-140	-252	-216	-300	-360	-220	-568	-468	-360
$\boldsymbol{i=19}$	-360	-272	-140	-252	-216	-300	-360	-220	-568	-468	-360
$\boldsymbol{i=20}$	-360	-272	-140	-252	-216	-300	-360	-220	-568	-468	-360
$\boldsymbol{i=21}$	-360	-272	-140	-252	-216	-300	-360	-220	-568	-468	-360
$\boldsymbol{i=22}$	-360	-272	-140	-252	-216	-300	-360	-220	-568	-468	-360
$\boldsymbol{i=23}$	-180	-136	-70	-126	-108	-150	-180	-110	-284	-234	-180
$\boldsymbol{i=24}$	-90	-68	-35	-63	-54	-75	-90	-55	-142	-117	-90
$\boldsymbol{i=25}$	-180	-136	-70	-126	-108	-150	-180	-110	-284	-234	-180
$\boldsymbol{i=26}$	-180	-136	-70	-126	-108	-150	-180	-110	-284	-234	-180
$\boldsymbol{i=27}$	-180	-136	-70	-126	-108	-150	-180	-110	-284	-234	-180
$\boldsymbol{i=28}$	-180	-136	-70	-126	-108	-150	-180	-110	-284	-234	-180
$\boldsymbol{i=29}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=30}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=31}$	0	0	0	0	0	0	0	0	0	0	0

Table 7.24. Contribution of outcome risk factors to attributes of success dimensions – Case study

	Attributes of success dimensions (l)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
$\boldsymbol{i=1}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=2}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=3}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=4}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=5}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=6}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=7}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=8}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=9}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=10}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=11}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=12}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=13}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=14}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=15}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=16}$	-20	-24	-20	-28	-12	-28	-20	-24	-40	-28	-20
$\boldsymbol{i=17}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=18}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=19}$	0	-16	-20	-28	0	-20	0	-20	-16	-4	0
$\boldsymbol{i=20}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=21}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=22}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=23}$	0	-8	-10	-14	0	-10	0	-10	-8	-2	0
$\boldsymbol{i=24}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=25}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=26}$	0	0	0	0	0	0	0	0	0	0	0
$\boldsymbol{i=27}$	-10	-4	0	-4	-6	-4	-10	-2	-12	-12	-10
$\boldsymbol{i=28}$	-10	-12	-10	-14	-6	-14	-10	-12	-20	-14	-10
$\boldsymbol{i=29}$	-20	-24	-20	-28	-12	-28	-20	-24	-40	-28	-20
$\boldsymbol{i=30}$	-20	-24	-20	-28	-12	-28	-20	-24	-40	-28	-20
$\boldsymbol{i=31}$	-10	-12	-10	-14	-6	-14	-10	-12	-20	-14	-10

7.2.3 Stage 3 – Project Portfolio Risk Representation

As described in Section 6.4, this Stage is composed of four steps. The first step is associated with input preparation. The second step is the representation of the initial risk profile. The third step concerns the estimation of the dependence and drive power of risk factors. And the last one shows the consolidation of the information obtained from PPRA performed.

Step 3a. Input preparation

All inputs required for this Stage were obtained in the two previous stages. Specifically, adjusted occurrence values (la_i), adjusted severity (sap_{ja} and sac_{jc}), and contributions between risk factors (tlc_{ij}) were obtained in Stage 1. In this case, because no interdependencies between factors at the impact level were identified in Stage 1, severity contributions between factors are equal to zero (tsp_{ija} and tsc_{ijc}). The $OPR - PPS(sas_{il})$ and $OCR - PPS(scs_{il})$ matrices obtained in Stage 2 were also required (Table 7.23 and Table 7.24) as they represent the two dimensions of the y_{il} variable. The adjusted likelihood was also required because likelihood and severity were not consolidated into an aggregated risk measure (see Step 2.b in Section 7.2.2).

Step 3b. Initial risk profile

Following the description established in Section 6.4.2, the maximum possible contribution of each type of risk factor, defined as MP_l for output-related risk factors and MC_l for outcome-related risk factors, should be calculated. Table 7.25 shows the values obtained for MP_l and MC_l.

Table 7.25. Maximum contribution from risk factor to the attributes of success – Case study

	Attributes of success dimensions (l)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
MP	450	340	175	315	270	375	450	275	710	585	450
MC	25	30	25	35	15	35	25	30	50	35	25

Applying Equation (38), the contribution of risk factors severity to the attributes of success was scaled to values between 0 and 5, which corresponds to the scale defined in the PPRA proposal. Table 7.26 and Table 7.27 show the respective results.

Applying Equations (39), (40), and (41), the average contribution of each risk factor on each success dimension – strategic fit (SF), future preparedness (FP), and stakeholder satisfaction (SS), was calculated. Table 7.28 shows the consolidated results. Additionally, following Equation (42), Table 7.28 also shows the contribution from risk factors to portfolio success (PS).

Table 7.26. Contribution from output risk factors scaled to 0-5 values – Case study

	Attributes of success dimensions (l)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
$\boldsymbol{i = 1}$	-1.6	-0.5	0.0	-0.3	-1.6	-0.4	-1.6	-0.3	-0.9	-1.3	-1.6
$\boldsymbol{i = 2}$	-1.3	-0.6	-0.9	-0.8	-1.3	-0.6	-1.3	-0.7	-0.8	-1.1	-1.3
$\boldsymbol{i = 3}$	-3.8	-2.7	-4.0	-3.1	-3.8	-2.8	-3.8	-3.2	-3.0	-3.5	-3.8
$\boldsymbol{i = 4}$	-0.9	-0.4	-0.9	-0.7	-0.9	-0.4	-0.9	-0.5	-0.5	-0.7	-0.9
$\boldsymbol{i = 5}$	-3.8	-3.2	-4.0	-3.6	-3.8	-3.3	-3.8	-3.5	-3.3	-3.6	-3.8
$\boldsymbol{i = 6}$	-0.7	-0.3	-0.4	-0.4	-0.7	-0.3	-0.7	-0.3	-0.4	-0.6	-0.7
$\boldsymbol{i = 7}$	-1.2	-1.9	-2.0	-2.0	-1.2	-1.9	-1.2	-1.9	-1.6	-1.4	-1.2
$\boldsymbol{i = 8}$	-3.8	-3.2	-4.0	-3.6	-3.8	-3.3	-3.8	-3.5	-3.3	-3.6	-3.8
$\boldsymbol{i = 9}$	-0.8	-0.2	0.0	-0.1	-0.8	-0.2	-0.8	-0.1	-0.5	-0.7	-0.8
$\boldsymbol{i = 10}$	-2.0	-1.4	-2.0	-1.5	-2.0	-1.5	-2.0	-1.6	-1.6	-1.8	-2.0
$\boldsymbol{i = 11}$	-0.9	-0.4	-0.9	-0.7	-0.9	-0.4	-0.9	-0.5	-0.5	-0.7	-0.9
$\boldsymbol{i = 12}$	-1.8	-0.7	-1.7	-1.3	-1.8	-0.8	-1.8	-1.1	-1.0	-1.5	-1.8
$\boldsymbol{i = 13}$	-0.9	-0.7	-1.0	-0.8	-0.9	-0.7	-0.9	-0.8	-0.7	-0.9	-0.9
$\boldsymbol{i = 14}$	-1.9	-1.4	-2.0	-1.6	-1.9	-1.4	-1.9	-1.6	-1.5	-1.7	-1.9
$\boldsymbol{i = 15}$	-2.7	-1.2	-1.7	-1.6	-2.7	-1.2	-2.7	-1.4	-1.7	-2.3	-2.7
$\boldsymbol{i = 16}$	-1.6	-0.5	0.0	-0.3	-1.6	-0.4	-1.6	-0.3	-0.9	-1.3	-1.6
$\boldsymbol{i = 17}$	-3.8	-2.7	-4.0	-3.1	-3.8	-2.8	-3.8	-3.2	-3.0	-3.5	-3.8
$\boldsymbol{i = 18}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i = 19}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i = 20}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i = 21}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i = 22}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i = 23}$	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
$\boldsymbol{i = 24}$	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
$\boldsymbol{i = 25}$	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
$\boldsymbol{i = 26}$	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
$\boldsymbol{i = 27}$	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
$\boldsymbol{i = 28}$	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
$\boldsymbol{i = 29}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i = 30}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i = 31}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7.27. Contribution from outcome risk factors scaled to 0-5 values – Case study

	Attributes of success dimensions (l)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
$\boldsymbol{i=1}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=2}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=3}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=4}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=5}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=6}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=7}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=8}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=9}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=10}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=11}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=12}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=13}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=14}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=15}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=16}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i=17}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=18}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=19}$	0.0	-2.7	-4.0	-4.0	0.0	-2.9	0.0	-3.3	-1.6	-0.6	0.0
$\boldsymbol{i=20}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=21}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=22}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=23}$	0.0	-1.3	-2.0	-2.0	0.0	-1.4	0.0	-1.7	-0.8	-0.3	0.0
$\boldsymbol{i=24}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=25}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=26}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\boldsymbol{i=27}$	-2.0	-0.7	0.0	-0.6	-2.0	-0.6	-2.0	-0.3	-1.2	-1.7	-2.0
$\boldsymbol{i=28}$	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
$\boldsymbol{i=29}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i=30}$	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i=31}$	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0

Table 7.28. Contribution from risk factors to portfolio success – Case study

	From output-related risk factors					From outcome-related risk factors			
	SF	**FP**	**SS**	**PS**		**SF**	**FP**	**SS**	**PS**
$\boldsymbol{i=1}$	-1.0	-0.9	-1.0	-1.0	$\boldsymbol{i=1}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=2}$	-0.9	-1.0	-1.0	-1.0	$\boldsymbol{i=2}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=3}$	-3.5	-3.4	-3.4	-3.4	$\boldsymbol{i=3}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=4}$	-0.7	-0.7	-0.7	-0.7	$\boldsymbol{i=4}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=5}$	-3.7	-3.6	-3.5	-3.6	$\boldsymbol{i=5}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=6}$	-0.5	-0.5	-0.5	-0.5	$\boldsymbol{i=6}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=7}$	-1.7	-1.6	-1.5	-1.6	$\boldsymbol{i=7}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=8}$	-3.7	-3.6	-3.5	-3.6	$\boldsymbol{i=8}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=9}$	-0.5	-0.5	-0.5	-0.5	$\boldsymbol{i=9}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=10}$	-1.8	-1.7	-1.8	-1.8	$\boldsymbol{i=10}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=11}$	-0.7	-0.7	-0.7	-0.7	$\boldsymbol{i=11}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=12}$	-1.4	-1.4	-1.3	-1.4	$\boldsymbol{i=12}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=13}$	-0.9	-0.8	-0.8	-0.9	$\boldsymbol{i=13}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=14}$	-1.7	-1.7	-1.7	-1.7	$\boldsymbol{i=14}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=15}$	-1.9	-2.0	-2.0	-2.0	$\boldsymbol{i=15}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=16}$	-1.0	-0.9	-1.0	-1.0	$\boldsymbol{i=16}$	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i=17}$	-3.5	-3.4	-3.4	-3.4	$\boldsymbol{i=17}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=18}$	-4.0	-4.0	-4.0	-4.0	$\boldsymbol{i=18}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=19}$	-4.0	-4.0	-4.0	-4.0	$\boldsymbol{i=19}$	-3.3	-3.4	-1.8	-2.9
$\boldsymbol{i=20}$	-4.0	-4.0	-4.0	-4.0	$\boldsymbol{i=20}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=21}$	-4.0	-4.0	-4.0	-4.0	$\boldsymbol{i=21}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=22}$	-4.0	-4.0	-4.0	-4.0	$\boldsymbol{i=22}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=23}$	-2.0	-2.0	-2.0	-2.0	$\boldsymbol{i=23}$	-1.7	-1.7	-0.9	-1.4
$\boldsymbol{i=24}$	-1.0	-1.0	-1.0	-1.0	$\boldsymbol{i=24}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=25}$	-2.0	-2.0	-2.0	-2.0	$\boldsymbol{i=25}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=26}$	-2.0	-2.0	-2.0	-2.0	$\boldsymbol{i=26}$	0.0	0.0	0.0	0.0
$\boldsymbol{i=27}$	-2.0	-2.0	-2.0	-2.0	$\boldsymbol{i=27}$	-1.3	-1.3	-1.3	-1.3
$\boldsymbol{i=28}$	-2.0	-2.0	-2.0	-2.0	$\boldsymbol{i=28}$	-2.0	-2.0	-2.0	-2.0
$\boldsymbol{i=29}$	0.0	0.0	0.0	0.0	$\boldsymbol{i=29}$	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i=30}$	0.0	0.0	0.0	0.0	$\boldsymbol{i=30}$	-4.0	-4.0	-4.0	-4.0
$\boldsymbol{i=31}$	0.0	0.0	0.0	0.0	$\boldsymbol{i=31}$	-2.0	-2.0	-2.0	-2.0

Step 3.c. Dependence and drive power estimation

Following Equation (45), rlc_{ij} variables were calculated. These variables represent the influence generated on the risk factors given the likelihood interdependence. Table 7.29 shows a section of the resulting matrix. The rsc_{ij} values (Equation (46)) are equivalent to zero because there are no relationships between risk factors in terms of severity.

Table 7.29. Section of the resulting rlc_{ij} matrix – Case study

i / j	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	**-8.96**	**-1.28**	**-0.72**	**-22.4**	**-0.64**	0	0	0
2	0	0	0	0	0	0	**-4.48**	0	**-4.00**	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	**-8.96**	0	**-8.00**	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	**-44.8**	0	**-3.58**	0	**-3.20**	0	0	0
9	0	0	0	0	0	0	**-11.2**	0	0	0	0	0
10	0	0	0	0	0	0	**-44.8**	0	0	0	0	0
11	0	0	0	0	0	**-1.02**	**-8.96**	0	0	0	0	**-12.8**
12	0	0	0	0	0	**-2.56**	**-22.4**	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0

Equation (44) stated that the rlc_{ij} values correspond to the sum of rlc_{ij} and rsc_{ij}. Given that the rsc_{ij} values are zero in the case study, rc_{ij} values are equal to rlc_{ij} values. Thus, these values would be the ones that constitute the consolidated reachability matrix. For the estimation of dependence, Equation (47) was followed. And for the estimation of drive power, Equations (48) and (49) were applied. The risk factors dependence was separated from the dependence associated with the impact on projects and capabilities. This was made because some factors are simultaneously output- and outcome-related risk factors and, therefore, directly impact both projects and capabilities.

Table 7.30 shows the values for the dependence and drive power. Column 'DEA' shows the dependence of each factor in terms of severity contribution from output-related risk factors, and column 'DEC' shows the dependence of each factor in terms of severity contribution from outcome-related risk factors. Similarly, column 'DRA' shows the drive power on output-related risk factors, and column 'DRC' shows the drive power on outcome-related risk factors. Table 7.30 also shows the quadrant (Q) in terms of dependence vs. drive power to which each risk factor belongs. Figure 7.1 shows the DRA vs DEA chart, and Figure 7.2 shows the DRC vs DEC chart. These figures are the graphical representation of the information presented in Table 7.30.

Table 7.30. Dependence and drive power – Case study

	DEA	DRA	Q		DEC	DRC	Q
i=1	0.0	77.4	I(L–L)	**i=1**	0.0	0.1	I(L–L)
i=2	0.0	8.5	I(L–L)	**i=2**	0.0	0.0	-
i=3	0.0	0.0	I(L–L)	**i=3**	0.0	0.0	-
i=4	0.0	0.0	I(L–L)	**i=4**	0.0	0.0	-
i=5	53.8	58.6	I(L–L)	**i=5**	0.0	0.0	-
i=6	13.6	0.0	I(L–L)	**i=6**	0.0	0.0	-
i=7	127.5	0.0	II(H–L)	**i=7**	0.0	0.0	-
i=8	22.4	68.2	I(L–L)	**i=8**	0.0	0.0	-
i=9	15.8	11.2	I(L–L)	**i=9**	0.0	0.0	-
i=10	0.0	96.0	I(L–L)	**i=10**	0.0	0.0	-
i=11	0.0	39.4	I(L–L)	**i=11**	0.0	7.2	I(L–L)
i=12	25.6	66.6	I(L–L)	**i=12**	0.0	17.9	I(L–L)
i=13	26.0	0.0	I(L–L)	**i=13**	0.0	0.0	-
i=14	0.0	0.0	I(L–L)	**i=14**	0.0	0.0	-
i=15	97.3	0.0	I(L–L)	**i=15**	0.0	0.0	-
i=16	36.8	3.2	I(L–L)	**i=16**	29.4	6.4	I(L–L)
i=17	61.6	0.0	I(L–L)	**i=17**	0.0	0.0	-
i=18	28.8	31.4	I(L–L)	**i=18**	0.0	0.3	I(L–L)
i=19	0.0	156.5	IV(L–H)	**i=19**	0.0	27.5	I(L–L)
i=20	0.0	0.0	I(L–L)	**i=20**	0.0	0.0	-
i=21	200.4	28.8	II(H–L)	**i=21**	0.0	3.2	I(L–L)
i=22	0.0	133.7	IV(L–H)	**i=22**	0.0	39.4	IV(L–H)
i=23	94.8	28.8	I(L–L)	**i=23**	10.5	0.0	I(L–L)
i=24	0.0	85.2	I(L–L)	**i=24**	0.0	14.6	I(L–L)
i=25	135.4	34.6	II(H–L)	**i=25**	0.0	0.6	I(L–L)
i=26	0.0	0.0	I(L–L)	**i=26**	0.0	0.0	-
i=27	0.0	40.4	I(L–L)	**i=27**	0.0	10.6	I(L–L)
i=28	28.8	0.0	I(L–L)	**i=28**	6.4	19.2	I(L–L)
i=29	0.0	0.0	-	**i=29**	78.8	0.0	II(H–L)
i=30	0.0	0.0	-	**i=30**	0.0	9.6	I(L–L)
i=31	0.0	0.0	-	**i=31**	31.4	0.0	I(L–L)

For both types of direct impact from risk factors, i.e., impact on projects or capabilities, no risk factors with high drive power and high dependence were identified (Quadrant III in Figure 7.1 and Figure 7.2). In the first case, influence on output-related risk factors, it was identified that factors 19 and 22 have high drive power and low dependence (Quadrant IV - see Table 7.30). In the second case, influence on outcome-related risk factors, one risk factor was identified as having high drive power, namely, factor 22 (Quadrant IV - see Table 7.30).

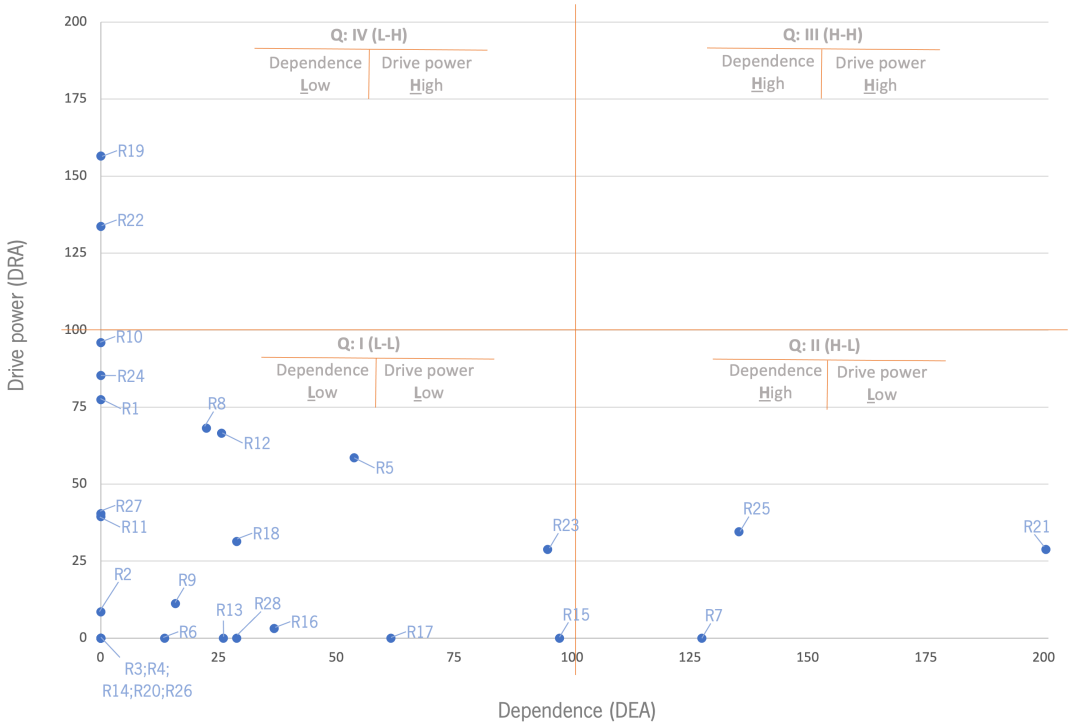


Figure 7.1. Drive vs Dependence chart (DRA vs DEA) – Case study

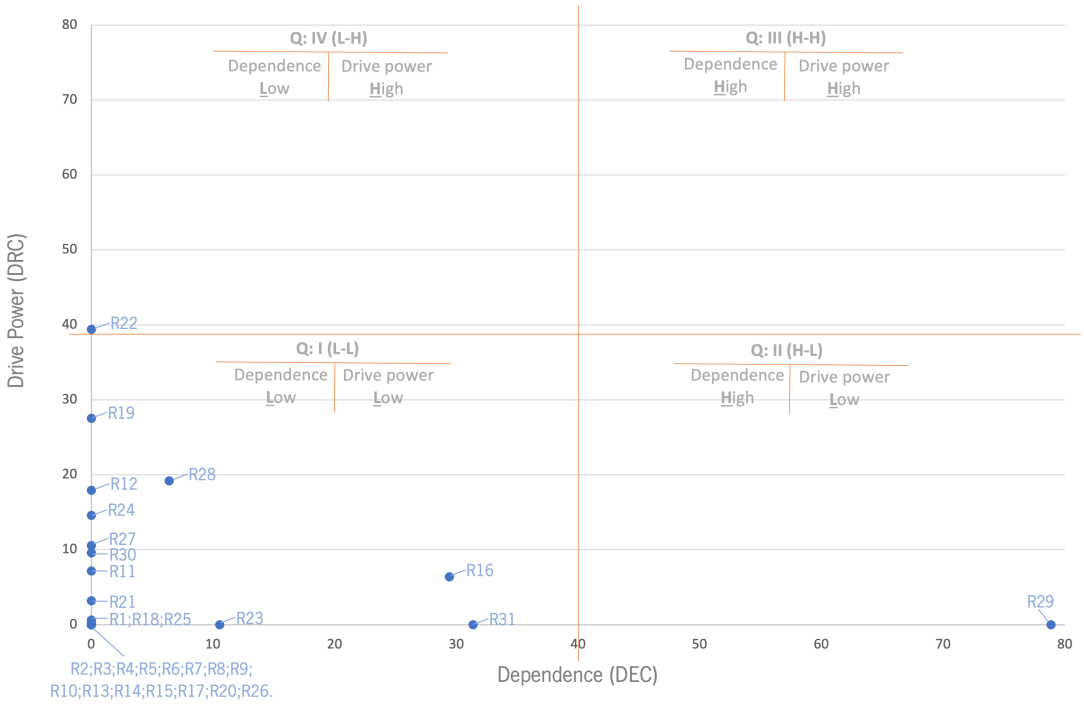


Figure 7.2. Drive vs Dependence chart (DRC vs DEC) – Case study

<u>Step 3d. Consolidation of the information</u>

For portfolio risk representation, the same scale adopted for scoring the parameters of each risk factor was used (see Section 7.2.1, step 1a), i.e., both likelihood adjusted and severity on portfolio success were represented based on three levels: Low, medium, and high.

The adjusted likelihood (see Table 7.19) and severity contribution on the project portfolio success (see column PS in Table 7.28) were represented based on the ranges illustrated in Table 7.5. For instance, risk factor 1 has an adjusted likelihood equal to 1.0, so it is in the 'low' level of likelihood. Also, this risk factor has a severity contribution from output-related risk factors on the portfolio success equal to 1.0, which means a 'low' severity level. In addition, in terms of drive power over other output-related risk factors, risk factor 1 is in Quadrant I (see Table 7.30), i.e., it has a low drive power and low dependence. A relevant aspect is that, although risk factor 1 has no direct impact on the portfolio's outcomes, it does have, albeit low, an influence on outcome-related risk factors. That is evidenced by the drive power of the risk factor 1 on outcome-related risk factors (see Table 7.30). Figure 7.3 shows a consolidated representation of risk factor 1.

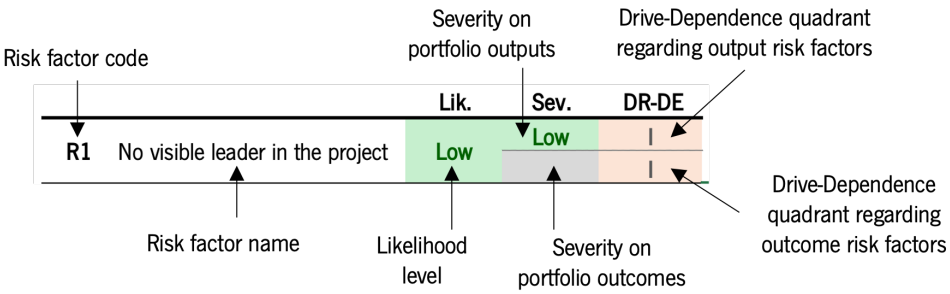


Figure 7.3. Representation of risk factor 1

Thus, risk factor 1 has a low likelihood level, a low severity contribution on portfolio outputs, and a null direct severity contribution on outcomes. Also, this risk factor does not have a high influence on other risk factors, and its management could be carried out independently of other risk factors as it has low levels of dependence.

Figure 7.4 contains another example of the obtained results showing, specifically, the results for risk factor 19. This risk factor has a medium level of likelihood, a high severity contribution on portfolio outputs, and a medium level of severity contribution on portfolio outcomes. Given that it has a high drive power on output-related risk factors (Quadrant IV), this risk factor, in addition to its high direct impact, also has a high indirect impact on the portfolio's outputs. In other words, managing this risk factor will positively impact other risk factors. Finally, given that it presents a low level of dependence from both output- and outcome-related risk factors (Quadrants IV and I, respectively), its management does not depend significantly on managing it coordinately with other risk factors.

R19	Brain drain or termination of contracts of personnel participating in the projects	Medium	High	IV (low-high)
			Medium	I (low-low)

Figure 7.4. Representation of risk factor 19

Figure 7.3 and Figure 7.4 exemplify the detailed information obtained for two risk factors, whereas Figure 7.5 illustrates the results obtained for the 31 risk factors.

	Lik.	Sev.	DE-DR
R1	Low	Low	I (low-low)
			I (low-low)
R2	Low	Low	I (low-low)
R3	Medium	High	I (low-low)
R4	Medium	Low	I (low-low)
R5	Medium	High	I (low-low)
R6	Medium	Low	I (low-low)
R7	High	Medium	II (high-low)
R8	Medium	High	I (low-low)
R9	Medium	Low	I (low-low)
R10	High	Medium	I (low-low)
R11	Medium	Low	I (low-low)
			I (low-low)

	Lik.	Sev.	DE-DR
R12	High	Medium	I (low-low)
			I (low-low)
R13	Medium	Low	I (low-low)
R14	Medium	Medium	I (low-low)
R15	High	Medium	I (low-low)
R16	Medium	Low	I (low-low)
		High	I (low-low)
R17	Medium	High	I (low-low)
R18	Medium	High	I (low-low)
			I (low-low)
R19	Medium	High	IV (low-high)
		Medium	I (low-low)
R20	Low	High	I (low-low)
R21	High	High	II (high-low)
			I (low-low)

	Lik.	Sev.	DE-DR
R22	High	High	IV (low-high)
			IV (low-high)
R23	High	Medium	I (low-low)
		Medium	I (low-low)
R24	Medium	Low	I (low-low)
			I (low-low)
R25	High	Medium	II (high-low)
			I (low-low)
R26	Low	Medium	I (low-low)
R27	Low	Medium	I (low-low)
		Medium	I (low-low)
R28	Medium	Medium	I (low-low)
		Medium	I (low-low)
R29	High		
		High	II (high-low)
R30	Low		
		High	I (low-low)
R31	High		
		Medium	I (low-low)

Figure 7.5. Representation of risk factors impact on project portfolio success

This detailed information about each risk was consolidated to obtain a complete PPR representation for the case study. Figure 7.6 shows the consolidation of impact from outcome-related risk factors. As eight outcome-related risk factors were evaluated, four of them represent a high risk, three a medium risk, and one a low risk. Moreover, sixteen risk factors can influence these eight factors (see DR-DE in Figure 7.6). These 16 factors could be either output- or outcome–related risk factors as was exemplified with risk factor 1 and risk factor 19 in Figure 7.3 and Figure 7.4, respectively. However, 15 of these 16 factors have low drive power (Quadrants I and II). Only one risk factor has high drive power over outcome-related risk factors (Quadrant IV), which, according to Figure 7.5, corresponds to risk factor 22.

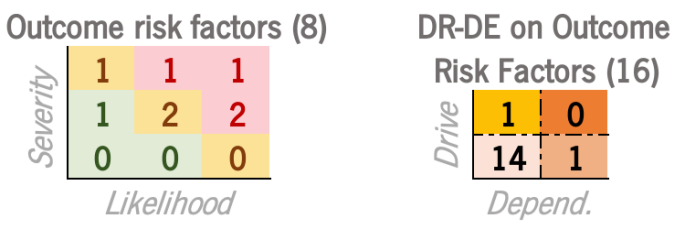


Figure 7.6. Consolidation of outcome risk for the case study

The average outcome-related PPR level was defined using the following rule: If most of the risk factors were in the high-risk zone or on the low-risk zone, then the average risk would be defined

respectively as high or low, otherwise, it would be established as medium risk level. Therefore, the outcome-related PPR was set at the medium level. The information related to output-related risk factors was consolidated in the same way. However, it was further disaggregated into non-systematic and systematic risk factors. Figure 7.7 shows the PPRA consolidated results considering the interaction between risk factors and their impact on portfolio success.

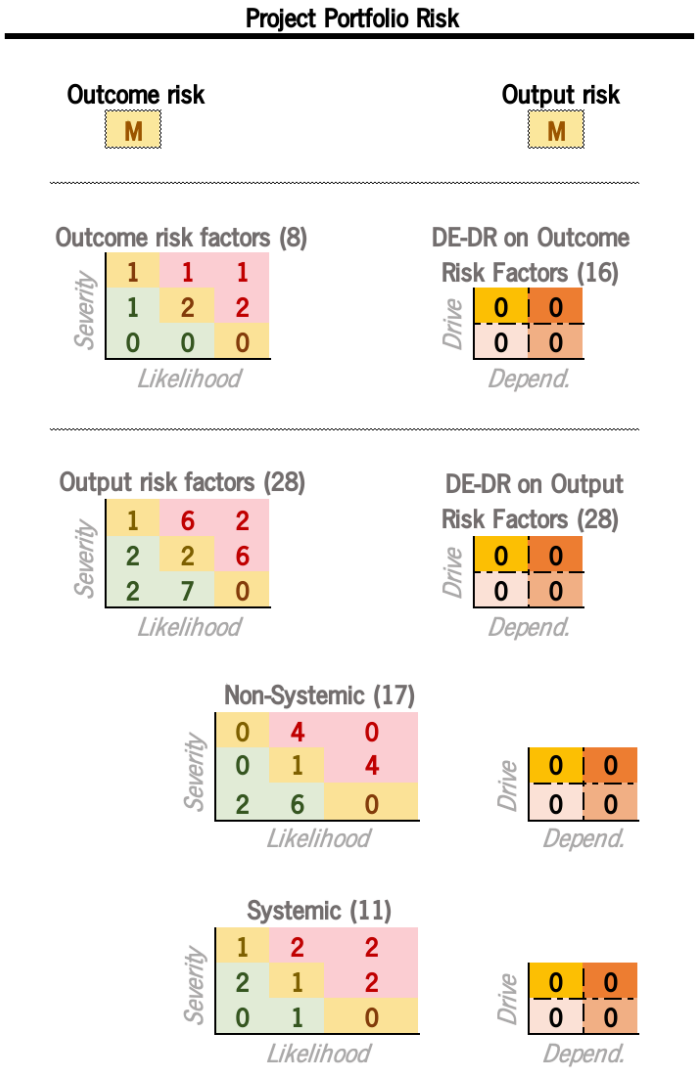


Figure 7.7. PPRA consolidated results at project portfolio success level – Case study

Based on the information consolidated in step 3b, PPRA results can be reported disaggregated by each success dimension, by the attributes of the success dimensions, or by capabilities, which leads to establishing an average risk level for each case. Figure 7.8 shows the average risk level for each success dimension, each attribute of the success dimensions, and each capability expected to be generated by the project portfolio.

Outcome risk			Output risk	
(8)	H	**Strategic fit**	M	(28)
(6)	M	Increase sales	M	(28)
(8)	M	Decrease costs	M	(28)
(7)	H	Increase margin	H	(25)
(8)	H	**Future Preparedness**	M	(28)
(8)	H	Labor capacity	M	(28)
(6)	M	Product capacity (product bends)	M	(28)
(8)	M	Relationship with suppliers	M	(28)
(6)	M	eparation of commercial schedu	M	(28)
(8)	M	**Stakeholders' satisfaction**	M	(28)
(8)	H	roduction process - Internal cycl	M	(28)
(8)	M	Back office processes	M	(28)
(8)	M	Sales channels points - Own	M	(28)
(6)	M	Sales channels points - External	M	(28)
(6)	M	Commercial-omnichannel	M	(28)
(8)	H	Value chain	M	(28)
(7)	H	Control mechanisms	H	(25)
(5)	H	Financial support	M	(25)

Figure 7.8. Risk level of success dimensions and capabilities – Case study

Next to the risk level of each item, it is reported the number of impacting risk factors. Thus, for example, the attribute 'increase margin' has a high outcome-risk level produced by the impact of seven risk factors, i.e., at least four of the seven risk factors are in the high-risk zone. Regarding the output-related risk, the attribute 'increase margin' also has a high-risk level produced by twenty-five risk factors, i.e., at least 13 of the 25 risk factors are in the high-risk zone. To exemplify the results of this attribute in more detail, Figure 7.9 shows the consolidated result for the attribute 'increase margin'. Appendix C shows the detailed results considering the three 'project portfolio success dimensions', the nine attributes of success, and the four expected capabilities to be generated by the project portfolio. Figure 7.10 shows the consolidated PPRA results for the case study.

Increase margin

Outcome risk	Output risk
H	H

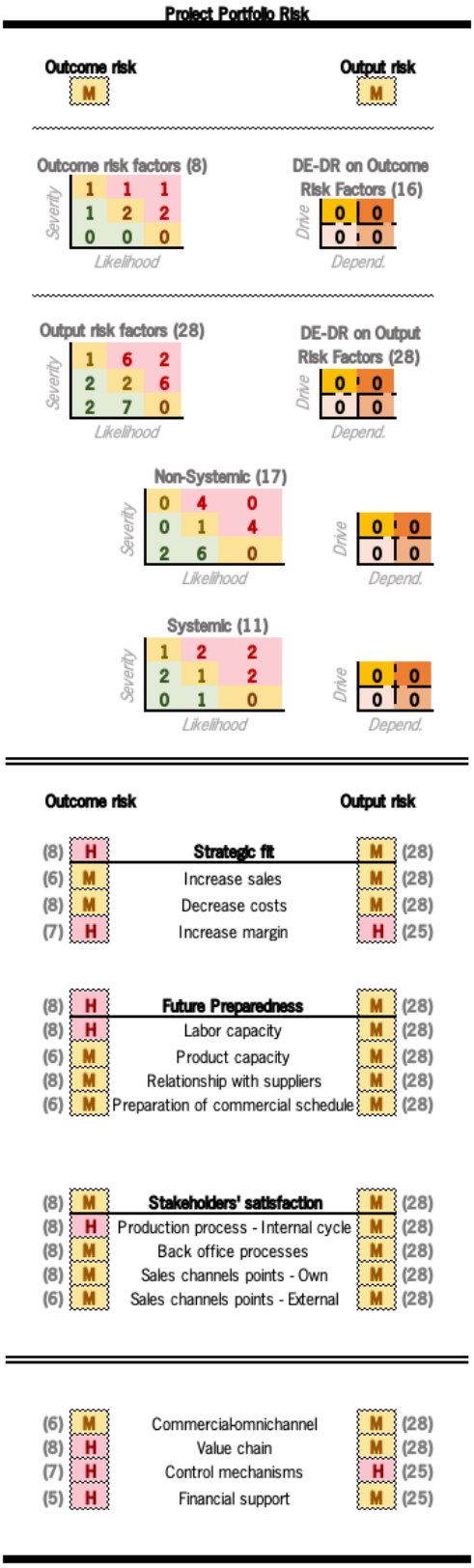
Outcome risk factors (7)

Severity \ Likelihood			
	1	2	1
	0	1	2
	0	0	0

Output risk factors (25)

Severity \ Likelihood			
	1	6	2
	2	2	6
	1	5	0

Figure 7.9. Risk level of the attribute of success 'increase margin' – Case study



		Portfolio success		
		Lik.	Sev.	DE-DR
R1	No visible leader in the project	Low	Low	I (low-low) I (low-low)
R2	Project requirements without proper formalization	Low	Low	I (low-low)
R3	Negative QA test results requiring adjustments to developments	Medium	High	I (low-low)
R4	Law requirements impossible to be anticipated which suspends the work plan	Medium	Low	I (low-low)
R5	Non-compliance of expected deliverables from suppliers	Medium	High	I (low-low)
R6	Project objective become out of alignment with organizational strategic goals	Medium	Low	I (low-low)
R7	Loss or leakage of information from each project	High	Medium	II (high-low)
R8	Non-compliance of payment obligations stipulated to suppliers	Medium	High	I (low-low)
R9	Conflicts between project managers	Medium	Low	I (low-low)
R10	Poor commitment and lack of a teamwork culture	High	Medium	I (low-low)
R11	Lack of knowledge among team members	Medium	Low	I (low-low) I (low-low)
R12	Experience and training gaps in key team members	High	Medium	I (low-low) I (low-low)
R13	Key team member being unfamiliar with the technology	Medium	Low	I (low-low)
R14	Software failure leading to loss of key data	Medium	Medium	I (low-low)
R15	Poorly defined client role	High	Medium	I (low-low)
R16	Requirements are misinterpreted by the project team	Medium	Low High	I (low-low) I (low-low)
R17	Lack of key technology	Medium	High	I (low-low)
R18	Lack of executive and operational support for the execution of the projects within the portfolio	Medium	High	I (low-low) I (low-low)
R19	Brain drain or termination of contracts of personnel participating in the projects	Medium	High Medium	IV (low-high) I (low-low)
R20	Financial illiquidity for post-pandemic projects continuity	Low	High	I (low-low)
R21	New projects without analysis of the capabilities and capacities required for its implementation	High	High	II (high-low) I (low-low)
R22	Health-related work absenteeism of personnel participating in the projects	High	High	IV (low-high) IV (low-high)
R23	Conflicts between portfolio managers and organizational decision makers	High	Medium Medium	I (low-low) I (low-low)
R24	Lack of information transparency within the portfolio	Medium	Low	I (low-low) I (low-low)
R25	Lack of project portfolio familiarity from organizational processes	High	Medium	II (high-low) I (low-low)
R26	Lack of coordination of key resources within the portfolio	Low	Medium	I (low-low)
R27	Lack of coordination of key resources between the portfolio and organizational processes	Low	Medium Medium	I (low-low) I (low-low)
R28	Poor management of end-user expectations	Medium	Medium Medium	I (low-low) I (low-low)
R29	Poor adherence to new processes being delivered by each project	High	High	II (high-low)
R30	Brain drains of personnel involved in organizational processes	Low	High	I (low-low)
R31	Users are unfamiliar with the technology and require additional training	High	Medium	I (low-low)

Figure 7.10. Consolidated PPRA results – Case study

Figure 7.11 and Figure 7.12 show the detailed representation of the impact on portfolio success derived from the two types of risk factors. According to the portfolio risk assessment, there are four high-

level outcome-related risk factors, corresponding to factors 16, 23, 29, and 31, where risk factor 29 is the one with the highest risk level because it presents a high-risk level for both likelihood and severity. This factor has a high dependence, so response planning should consider direct actions and actions on the risk factors that influence its likelihood level.

Regarding the output-related risk, there are 14 risk factors in the high-risk zone, where two of them present both high likelihood and severity: Risk factor 21 and risk factor 22. However, while risk factor 21 has high dependence, risk factor 22 has low dependence. Thus, factor 22 could be managed independently of other factors, while the management of risk factor 21 must consider the factors that influence it to obtain effective response plans. Another aspect to consider is that risk factor 23 is in the high-risk zone in both output- and outcome–related risks. Therefore, the management of this risk factor could positively impact the portfolio's overall risk.

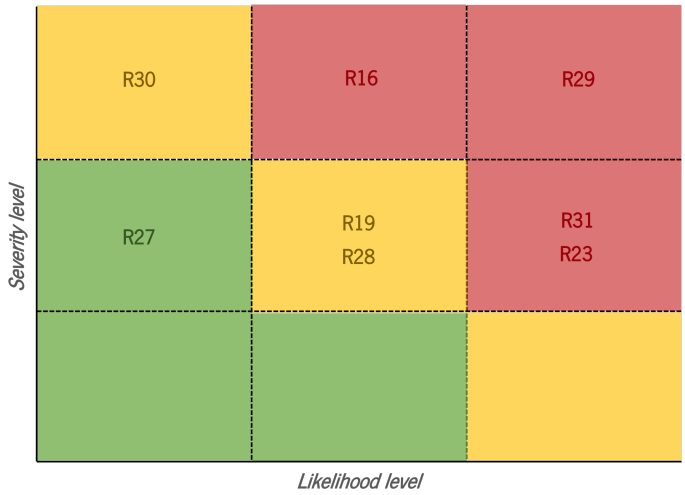


Figure 7.11. Configuration of outcome-related risk factors impact

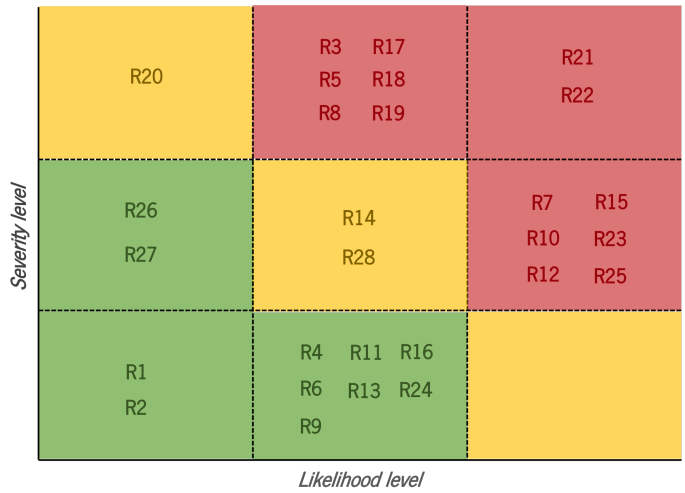


Figure 7.12. Configuration of output-related risk factors impact

7.3 Results Analysis

The results are analyzed in five sections. Section 7.3.1 presents the analysis of how the non-systematic risk factors behave. Section 7.3.2 and Section 7.3.3 describe the behavior of systematic risk factors and outcome-related risk factors. In all three cases, the analysis is performed based on a subset of risk factors to provide a detailed description of how the results regarding each type of risk factors is interpretated. Section 7.3.4 compares five scenarios, contrasting the current risk assessment approach implemented in the case study with several scenarios based on the PPRA conceptualization proposed in this research. Finally, Section 7.3.5 shows the results analysis of the PPRA applied to the case study focusing on success dimensions.

7.3.1 Results Analysis Based on Non-Systematic Risk Factors

For the analysis of non-systematic risk, risk factors R1, R3, R7, and R11 were taken examples for the analysis. The analysis is performed on a subgroup of risk factors seeking greater detail in the description, which can be extended to the other risk factors. Factors R1 and R3 have the same initial severity level, i.e., high severity. Factors R7 and R11 also share the same initial severity level, i.e., a medium severity level. Table 7.31 shows the initial data for the four risk factors selected to be analyzed. Regarding the results reported in Table 7.31, it is important to keep in mind that, in the proposed PPRA, the severity is evaluated in terms of impact on project portfolio success. In contrast, the initial assessment evaluates the severity in terms of impact on projects.

Table 7.31. Non-systematic risk factors analyzed – Case study

Risk factor	Initial qualification			Proposed PPRA model		
	Likelihood	Severity	Risk zone	Likelihood	Severity	Risk zone
FR1	Low	High	Medium	Low	Low	Low
FR3	Medium	High	High	Medium	High	High
FR7	Low	Medium	Low	High	Medium	High
FR11	Medium	Medium	Medium	Medium	Low	Low

Based on the information from these four risk factors, the PPR profile would be modified after applying the PPRA proposal. The initial assessment identifies one factor in the low-risk zone, two in the medium-risk zone, and one in the high-risk zone. In contrast, according to the proposed assessment model, the two factors that were initially in the medium-risk zone, i.e., risk factors R1 and R11, were shifted to the low-risk zone. The factor that was originally located in the low-risk zone, i.e., risk factor R7,

was shifted to the high-risk zone. And the factor that was initially in the high-risk zone, i.e., risk factor R3 remained in the same risk zone.

Regarding risk factor R7, the risk level increase is due to the variation in its occurrence caused by the influence it receives from other risk factors. Among the four risk factors analyzed, solely R7 was influenced by other factors, so it was the only one that had its occurrence level modified. However, R1 and R11 show variations in their risk level. This is because their severity level was altered once the proposed PPRA model was applied. In this regard, R1 decreased from high to low severity level, and R11 decreased from medium to low severity level. Thus, while two of the risk factors decreased their severity level, the other two factors remained at the same severity level as in the initial assessment.

The intermediate matrix of risk factors' impacts on capabilities was investigated to better understand the severity level of the four non-systematic risk factors under analysis. Table 7.32 shows the severity level of the four risk factors on each one of the four organizational capabilities to be generated by the project portfolio.

Table 7.32. Severity of R1, R3, R7, and R11 regarding organizational capabilities – Case study

	Capabilities			
	C1	**C2**	**C3**	**C4**
R1	Medium		Low	Low
R3	High	High	Medium	Medium
R7	Medium	Medium	Medium	Medium
R11	Low	Low	Low	

Regarding risk factor R1, it impacts three of the four expected capabilities to be generated by the project portfolio. Specifically, R1 has no impact on capability 2, i.e., R1 does not impact any of the projects related to that capability. Table 7.31 showed that R1 was initially assigned a high severity level (initial assessment in the PMO´s risk matrix); however, it has a low impact on capabilities 3 and 4 (see Table 7.32). It means that risk factor R1 impacts a low number of projects related to these organizational capabilities. Therefore, risk factor R1 is critical for several projects but has a low severity when analyzed at the portfolio level. The above is because R1 has no impact on one of the capabilities and has a low impact on two of three impacted capabilities.

In contrast, risk factor R3, which also has a high initial severity level, remains at a high severity level at the portfolio level (Table 7.31). From Table 7.32, it can be inferred that risk factor R3 impacts projects which, in turn, impact the four capabilities. Additionally, this risk factor remains at a high severity

level for capabilities 1 and 2, i.e., it impacts a significant number of projects related to these two capabilities. Regarding capabilities 3 and 4, risk factor R3 shows a medium severity level. This means that, although it does not impact a large number of projects related to these two capabilities, it does impact several of them. Thus, R3 is a critical risk factor because its high severity at the project level is transferred to the portfolio level, indicating a high severity level for two capabilities and a medium severity level for the remaining two capabilities.

Considering the analysis process exemplified with risk factors R1 and R3, it can be stated that severity at the portfolio level is caused by: The convergence of aspects, such as the initial impact at the level of each project; the impact on the capabilities through the impacted projects; and how these capabilities are related to the project portfolio success. This is in line with the conceptual representation of PPRA established in Figure 16 and consequently represented in the PPRA model proposed in Chapter 6.

An aspect to consider is that, in all cases, the severity at the portfolio level was equal to or lower than the rating assigned at the project level. This behavior is expected since a high severity level is attributed to a risk factor because of its impacts on a set of projects and not because of its impacts on all projects within the portfolio. In other words, the PPRA model proposed considers that the actual severity of a risk factor is equals to zero for projects that are not impacted by it.

Additionally, the proposed PPRA allows establishing two additional aspects for each risk factor: Dependence and driver power. Table 7.30 (see Section 7.2.3) showed that risk factors R1, R3, and R11 are in Quadrant I in terms of dependence and driver power, i.e., these risk factors have low influence on other risk factors and are slightly or not influenced by other risk factors. This information provides further characterization of risk factors, which aid in the design of risk responses. For instance, R7 is in Quadrant II, which implies that it is a risk factor highly influenced by other risk factors. Then, when designing response strategies, it should be considered the factors that influence R7 for its adequate management.

7.3.2 Results Analysis Based on Systematic Risk Factors

Four systematic risk factors were further analyzed. Table 7.33 shows the initial data for the four risk factors and the results once the PPRA proposed model was applied. Table 7.33 shows that the severity remained at the same initial level in all four cases. This result was expected given that: (i) severity-related relationships between risk factors were not identified in the case study, so the severity level of the factors would not be affected by other risk factors; and (ii) these risk factors have a systematic nature

as they affect the entire portfolio at the same severity level. In this regard, it can be inferred that the PPRA proposed model adequately represents the systematic impact of this type of risk factor.

Table 7.33. Systematic risk factors analyzed – Case study

Risk factors	Initial qualification			Proposed PPRA model		
	Likelihood	**Severity**	**Risk zone**	**Likelihood**	**Severity**	**Risk zone**
FR19	Medium	High	High	Medium	High	High
FR22	High	High	High	High	High	High
FR23	Low	Medium	Medium	High	Medium	High
FR24	Medium	Low	Low	Medium	Low	Low

The above can also be noted in the severity level of risk factors concerning each of the four capacities to be generated by the portfolio. Table 7.34 shows the severity of the four risk factors regarding the four capabilities. It can be observed that each risk factor presents the same level of severity across all the capabilities. It provides evidence of the systematic nature of each one of these risk factors.

Table 7.34. Severity of R19, R22, R23, and R24 regarding organizational capabilities – Case study

	Capabilities			
	C1	**C2**	**C3**	**C4**
RF19	High	High	High	High
RF22	High	High	High	High
RF23	Medium	Medium	Medium	Medium
RF24	Low	Low	Low	Low

In terms of occurrence, it can be appreciated that risk factor R23 increased from a low to a high occurrence level. This variation in the occurrence level is associated with the influence received by R23 from other risk factors, i.e., due to interdependencies between risk factors. Since only interdependencies of increased occurrence were considered in the case study, it is natural that the occurrence values remain at the same or higher level than the ones established without considering interdependencies between risk factors.

Although risk factor R23 shifted from a low to a high level of occurrence, this is not reflected in the classification of dependence vs. drive power since the risk factor is in Quadrant I (see Table 7.30), i.e., in one of the quadrants for risk factors with low dependence. When this risk factor is examined in detail, it can be established that its dependence value is equal to 94.8 (see Table 7.30 - Colum DEA),

which is close to the limit value for the risk factor dependence level (limit = 100, see Figure 7.1). This implies that defining the limits for the quadrants associated to dependence/drive power diagram is highly relevant to achieving a detailed and appropriate categorization of each risk factor.

7.3.3 Results Analysis Based on Outcome Risk Factors

The analysis was performed based on four risk factors as in the previous sections. As example, risk factors R16, R19, R23, and R30 were analyzed. Table 7.35 shows the initial data for the four risk factors and the results once the PPRA proposal was applied.

Table 7.35. Outcome risk factors analyzed – Case study

Risk factors	Initial qualification			Proposed PPRA model		
	Likelihood	Severity	Risk zone	Likelihood	Severity	Risk zone
FR16	Medium	High	High	Medium	High	High
FR19	Medium	High	High	Medium	Medium	Medium
FR23	Low	Medium	Low	High	Medium	High
FR30	Low	High	Medium	High	High	High

Table 7.35 shows that three of the four factors are in the high-risk zone in the proposed PPRA, while two of them were in the high-risk zone in the initial rating. Factor R16 remained in the high-risk zone, while factors R23 and R30 moved from low and medium risk to the high-risk zone. In contrast, risk factor R19 shifted from the high-risk zone to the medium-risk zone. In this case, the interdependence between risk factors modified the level of occurrence of factors R23 and R30. Thus, this increase in the occurrence level of factors R23 and R30 placed them in the high-risk zone at the portfolio level. Risk factor R23 is a particular case since it is both an output- and outcome-related risk factor. This shows the capability of the proposed PPRA to represent different types of impact of the same risk factor while keeping occurrence as a common attribute.

R16 and R30 are risk factors that directly impact the four capabilities. Then, the severity initially assigned to these risk factors is represented at the same level for the four expected capabilities and, consequently, at the project portfolio success level. In other words, the severity level assigned to these risk factors was carried over to the severity level on portfolio success since they impacted all capabilities. In contrast, both risk factors R23 and R19 impact two of the four expected capabilities (see Table 7.7); however, according to the proposed PPRA, this does not mean that the severity at the portfolio level necessarily decreases. Table 7.35 shows that, while severity at the project portfolio success level for risk

factor R19 decreased from high to medium level, it remained at the same initial level for risk factor R23, i.e., medium level.

The above also shows that, for the case study, the capabilities are transversal to the three success dimensions (see Table 7.21). Thus, even if a risk factor does not impact all the capabilities, it could impact all the success dimensions. For instance, risk factor R23 impacts only capabilities 2 and 3, but both of them relate to attributes of all three success dimensions. Therefore, risk factor R23 impacts all dimensions that represent the success of the project portfolio. This behavior could be understood as a way through which portfolio risk is distributed among the different expected results. For instance, if one of the success dimensions was impacted by only one or a subset of capabilities, portfolio success dependency would be generated from those capabilities. That could be an element to consider when structuring the project portfolio, seeking to avoid portfolio success dependency from one or a subset of capabilities.

One aspect that cannot be overlooked is that the variation in the severity level of risk factors also depends on the quantitative limits established for each risk level. Thus, the definition of limits could lead to a risk factor being classified as, e.g., high or medium, depending on risk levels' thresholds. The risk factor R19 is an example of the above since its severity level on the portfolio success equals 2.9 (see Table 7.28). So, if the numerical boundary between medium and high severity levels were equivalent to, e.g., 2.8, the risk factor R19 would remain at a high severity level. Therefore, the implications of risk ranges and thresholds for interpreting and representing results must be acknowledged.

7.3.4 Scenario Analysis

Five different scenarios were compared to analyze the results from the proposed PPRA model. With these scenarios, it was sought to determine how the proposed PPRA model responds to the two aspects that led to the general objective of the research project, namely: i) the incorporation of interactions between risk factors into risk assessment; ii) risk assessment based on project portfolio success rather than only projects. Table 7.36 summarizes the five scenarios analyzed.

Figure 7.13 shows the detailed results for the five scenarios analyzed. When interpreting Figure 7.13, it must be considered that the severity is assessed based on projects in S1, S2, and S3. In contrast, in S4 and S5, the severity is represented based on the project portfolio success. Compared with the first scenario, all four other scenarios present a broader perspective of the risk factors that could impact the project portfolio. That is primarily due to the number and type of risk factors incorporated into the assessment. For S2, S3, S4, and S5, 17 additional risk factors were incorporated into the case study.

These risk factors emerged from the portfolio-related levels, i.e., the project level, the project portfolio itself, and the parent organization. Although these additional factors were already identified in the parent organization, they were evaluated under risk approaches independent of the project portfolio perspective. In this regard, the perspective of the project portfolio as an organization, which was adopted when designing the proposed PPRA, led to the incorporation of these risk factors in risk assessment and gave a more comprehensive view of the PPR.

Table 7.36. Characterization of scenarios analyzed – Case study

Scenario	Code	Description
Scenario 1	S1	Risk assessment performed for the portfolio case study after applying the proposed PPRA. This scenario is based on the qualification of the 14 risk factors illustrated in Table 7.3.
Scenario 2	S2	Risk assessment based on the assessment structure used in the case study but considering the 31 risk factors derived from the three levels of risk sources associated with the construct 'PPR categories'.
Scenario 3	S3	Risk assessment considering interactions between the 31 risk factors, i.e., applying only Stage 1 of the PPRA proposed.
Scenario 4	S4	Risk assessment considering the impact on portfolio success, but without considering interactions between risk factors. That is, applying only Stage 2 of the PPRA proposed.
Scenario 5	S5	Risk assessment applying the proposed PPRA entirely. It corresponds to the results described in Section 7.2.2 and Section 7.2.3.

In S2 and S3, the severity of each risk factor was the same. This is because severity interdependencies between risk factors were not identified in the case study. However, S3 shows the relevance of considering interdependencies between the likelihood of risk factors. In this regard, S3 shows that once risk factor interdependency was incorporated, the likelihood of risk factors remained at the same or higher level. As previously mentioned, this is because influences that increased the likelihood were the only ones considered in the case study (initial parameters of the case study – Section 7.2).

In addition, S3 helps identify the three risk factors with the greatest dependence, namely, risk factors R15, R21, and R29 (located in Quadrant II). Likewise, S3 shows that factors R19 and R22 have the greatest influence on other risk factors. In other words, R19 and R22 are relevant because of their direct and indirect influence. Then, R19 and R22 require additional attention from decision-makers related to portfolio strategies.

Consequently, S3 shows that the consideration of interdependencies between risk factors, on one hand, modified the portfolio risk profile, and, on the other hand, provided information regarding risk factor behavior for an informed risk response planning. This also highlights the relevance of understanding risk assessment as one of the elements of risk management.

	Lik.	Sev.
R1	Low	High
R2	Low	Medium
R3	Medium	High
R4	Medium	Medium
R5	Medium	High
R6	Low	Low
R7	Low	Medium
R8	Medium	High
R18	Low	High
R19	Medium	High
R20	Low	High
R21	Medium	High
R22	High	High
R29	Low	High

Scenario 1

	Lik.	Sev.
R1	Low	High
R2	Low	Medium
R3	Medium	High
R4	Medium	Medium
R5	Medium	High
R6	Low	Low
R7	Low	Medium
R8	Medium	High
R9	Low	Medium
R10	High	Medium
R11	Medium	Medium
R12	Medium	High
R13	Low	Low
R14	Medium	Medium
R15	Low	High
R16	Low	High
R17	Low	High
R18	Low	High
R19	Medium	High
R20	Low	High
R21	Medium	High
R22	High	High
R23	Low	Medium
R24	Medium	Low
R25	Low	Medium
R26	Low	Medium
R27	Low	Medium
R28	Medium	Medium
R29	Low	High
R30	Low	High
R31	Medium	Medium

Scenario 2

	Lik.	Sev.	DR-DE
R1	Low	High	I
R2	Low	Medium	I
R3	Medium	High	I
R4	Medium	Medium	I
R5	Medium	High	I
R6	Medium	Low	I
R7	High	Medium	I
R8	Medium	High	I
R9	Medium	Medium	I
R10	High	Medium	I
R11	Medium	Medium	I
R12	High	High	I
R13	Medium	Low	I
R14	Medium	Medium	I
R15	High	High	II
R16	Medium	High	I
R17	Medium	High	I
R18	Medium	High	I
R19	Medium	High	IV
R20	Low	High	I
R21	High	High	II
R22	High	High	IV
R23	High	Medium	I
R24	Medium	Low	I
R25	High	Medium	I
R26	Low	Medium	I
R27	Low	Medium	I
R28	Medium	Medium	I
R29	High	High	II
R30	Low	High	I
R31	High	Medium	I

Scenario 3

	Lik.	Sev.
R1	Low	Low
		I
R2	Low	Low
R3	Medium	High
R4	Medium	Low
R5	Medium	High
R6	Low	Low
R7	Low	Medium
R8	Medium	High
R9	Low	Low
R10	High	Medium
R11	Medium	Low
R12	Medium	Medium
R13	Low	Low
R14	Medium	Medium
R15	Low	Medium
R16	Low	Low
		High
R17	Low	High
R18	Low	High
R19	Medium	High
		Medium
R20	Low	High
R21	Medium	High
R22	High	High
R23	Low	Medium
		Medium
R24	Medium	Low
R25	Low	Medium
R26	Low	Medium
R27	Low	Medium
		Medium
R28	Medium	Medium
		Medium
R29	Low	High
R30	Low	High
R31	Medium	Medium

Scenario 4

	Lik.	Sev.	DR-DE
R1	Low	Low	I
			I
R2	Low	Low	I
R3	Medium	High	I
R4	Medium	Low	I
R5	Medium	High	I
R6	Medium	Low	I
R7	High	Medium	II
R8	Medium	High	I
R9	Medium	Low	I
R10	High	Medium	I
R11	Medium	Low	I
			I
R12	High	Medium	I
			I
R13	Medium	Low	I
R14	Medium	Medium	I
R15	High	Medium	I
R16	Medium	Low	I
		High	I
R17	Medium	High	I
R18	Medium	High	I
			I
R19	Medium	High	IV
		Medium	I
R20	Low	High	I
R21	High	High	II
			I
R22	High	High	IV
			IV
R23	High	Medium	I
		Medium	I
R24	Medium	Low	I
			I
R25	High	Medium	II
			I
R26	Low	Medium	I
R27	Low	Medium	I
		Medium	I
R28	Medium	Medium	I
		Medium	I
R29	High	High	II
R30	Low	High	I
R31	High	Medium	I

Scenario 5

Figure 7.13. Detailed results for the five scenarios analyzed – Case study

S4 and S5 show the impact of risk factors on the project portfolio in greater detail, specifically show the result of consider how the severity is transferred from risk factors to success dimensions. The adoption of an approach based on organizational capabilities and oriented to portfolio success leads to a risk classification in which different types of impacts (generated by risk factors) are recognized. As mentioned in the previous Sections, this assessment allows evaluating both those risk factors that impact how the capabilities are built, i.e., impact the projects, and those risk factors associated with how the portfolio prepares the organization for using the new or improved capabilities generated. Additionally, risk

factors that simultaneously impact the building of capabilities and the organization's preparation to use them were identified and evaluated, e.g., R16, R19, R23, R27, and R28.

Categorizing risk factors according to their impact on the portfolio also provides additional information for the risk response planning element, as it would allow differentiation in the scope of the response plans to be designed. For instance, response plans are associated with the life cycle of projects within the portfolio for output-related risk factors. In contrast, organizational response plans may be required for outcome-related risk factors that go beyond the life cycle of projects. In addition, identifying factors that are simultaneously output- and outcome–related risk factors provides an additional criterion for the prioritization of risk factors.

Also, as it can be inferred from contrasting S3 and S5, PPRA oriented to portfolio success allows distinguishing between risk factors that have different severity levels at project and portfolio levels. For instance, risk factor R1 has a high severity level in the third scenario but a low severity level in the fifth scenario. As mentioned in Section 7.3.1, the proposed PPRA allows assessing how the initial severity on projects is transferred or distributed to the expected capacities and, in turn, to the project portfolio success.

The interdependencies between risk factors have a high contribution to the PPR. This relevance can be observed when comparing the results between S2 and S3 or between S4 and S5. In both cases, an increase in the likelihood levels can be noted. Also, the incorporation of interdependencies provided additional information in relation to the dependence and drive power of each risk factor. Figure 7.14 shows the risk profile of the five scenarios evaluated. These portfolio risk profiles represent a consolidated version of the results shown in Figure 7.13.

The risk profiles illustrated in Figure 7.14 show that S5, which corresponds to the full application of the proposed PPRA model, is the most complex risk profile to interpret because described information regarding two main types of risk impact (output and outcome) and for each one present information regarding risk factors' dependence and drive power. However, risk assessment as an element of portfolio risk management must be designed to provide information regarding the risk behavior and support an informed decision-making process, as done by the proposed PPRA and reflected in the portfolio risk profile obtained in S5.

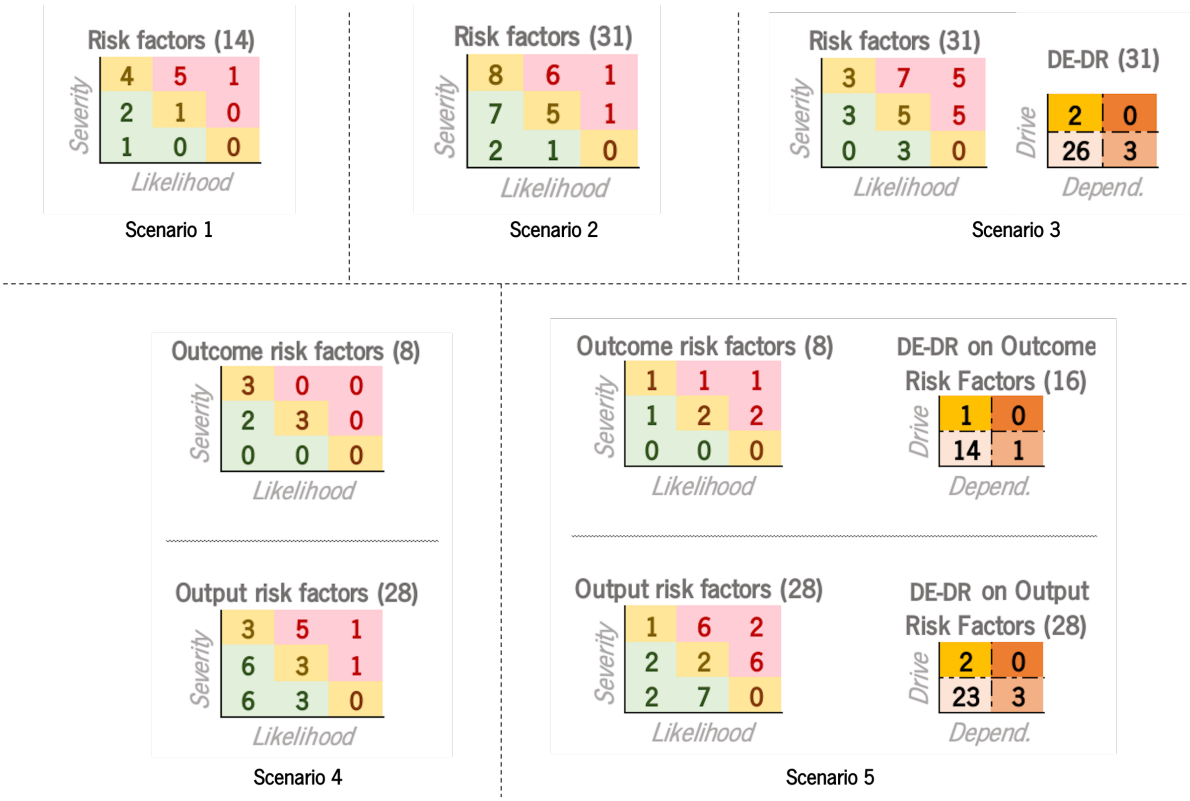


Figure 7.14. PPR profiles for the five scenarios analyzed – Case study

7.3.5 Risk Analysis Based on the Success Dimensions

Figure 7.15 shows the results of the risk assessment in terms of the success dimensions strategic fit, future preparedness, and stakeholder satisfaction. It can be noted that all risk factors impact each of the three success dimensions. Also, although risk profiles are not the same for the three success dimensions, they are significantly similar in terms of both output- and outcome-related risk factors impact. The most significant difference is the distribution of outcome-related risk factors influencing the stakeholder satisfaction, as only three of the eight factors are in the high-risk zone for this dimension. However, for strategic fit and future preparedness, most risk factors are in the high-risk zone (5 out of 8 risk factors in each case). That means stakeholder satisfaction was the success dimension the least impacted by outcome-related risk factors.

R16, R29, and R31 are the outcome-related risk factors that are in the high-risk zone in all three cases. These factors correspond to 'Requirements are misinterpreted by the project team', 'Poor adherence to new processes being delivered by each project', and 'Users are unfamiliar with the technology and require additional training', respectively. These three factors could be considered critical outcome-related risk factors at the portfolio level by considering their impact on the three dimensions of success. Additionally, risk factors R19 and R23, corresponding respectively to 'Brain drains or termination of contracts of personnel participating in the projects' and 'Health-related work absenteeism

of personnel participating in the projects', are critical outcome-related risk factors for two of the three success dimensions. Consequently, these two factors could also be considered critical for the project portfolio success.

Strategic fit

Outcome risk: H — Output risk: M

Outcome risk factors (8)

Severity \ Likelihood			
	1	2	1
	1	1	2
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	3	3	6
	1	6	0

Future preparedness

Outcome risk: H — Output risk: M

Outcome risk factors (8)

Severity \ Likelihood			
	1	2	1
	1	1	2
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	3	2	6
	1	7	0

Stakeholders' satisfaction

Outcome risk: M — Output risk: M

Outcome risk factors (8)

Severity \ Likelihood			
	1	1	1
	1	2	1
	0	0	1

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	4	3	6
	0	6	0

			Success dimensions		
		Lik.	ST	FP	SS
R1	No visible leader in the project	Low	Medium	Low	Medium
R2	Project requirements without proper formalization	Low	Low	Medium	Medium
R3	Negative QA test results requiring adjustments to developments	Medium	High	High	High
R4	Law requirements impossible to be anticipated which suspends the work plan	Medium	Low	Low	Low
R5	Non-compliance of expected deliverables from suppliers	Medium	High	High	High
R6	Project objective become out of alignment with organizational strategic goals	Medium	Low	Low	Low
R7	Loss or leakage of information from each project	High	Medium	Medium	Medium
R8	Non-compliance of payment obligations stipulated to suppliers	Medium	High	High	High
R9	Conflicts between project managers	Medium	Low	Low	Low
R10	Poor commitment and lack of a teamwork culture	High	Medium	Medium	Medium
R11	Lack of knowledge among team members	Medium	Low	Low	Low
R12	Experience and training gaps in key team members	High	Medium	Medium	Medium
R13	Key team member being unfamiliar with the technology	Medium	Low	Low	Low
R14	Software failure leading to loss of key data	Medium	Medium	Medium	Medium
R15	Poorly defined client role	High	Medium	Medium	Medium
R16	Requirements are misinterpreted by the project team	Medium	Medium High	Low High	Medium High
R17	Lack of key technology	Medium	High	High	High
R18	Lack of executive and operational support for the execution of the projects within the portfolio	Medium	High	High	High
R19	Brain drain or termination of contracts of personnel participating in the projects	Medium	High High	High High	High Medium
R20	Financial illiquidity for post-pandemic projects continuity	Low	High	High	High
R21	New projects without analysis of the capabilities and capacities required for its implementation	High	High	High	High
R22	Health-related work absenteeism of personnel participating in the projects	High	High	High	High
R23	Conflicts between portfolio managers and organizational decision makers	High	Medium Medium	Medium Medium	Medium Low
R24	Lack of information transparency within the portfolio	Medium	Low	Low	Low
R25	Lack of project portfolio familiarity from organizational processes	High	Medium	Medium	Medium
R26	Lack of coordination of key resources within the portfolio	Low	Medium	Medium	Medium
R27	Lack of coordination of key resources between the portfolio and organizational processes	Low	Medium Medium	Medium Medium	Medium Medium
R28	Poor management of end-user expectations	Medium	Medium Medium	Medium Medium	Medium Medium
R29	Poor adherence to new processes being delivered by each project	High	High	High	High
R30	Brain drains of personnel involved in organizational processes	Low	High	High	High
R31	Users are unfamiliar with the technology and require additional training	High	Medium	Medium	Medium

Figure 7.15. Detailed PPRA results based on success dimensions – Case study

The output-related risk factors show a high degree of homogeneity concerning factors located in the high-risk zone for the three success dimensions. There are 14 output-related risk factors in the high-risk zone in the three cases, two of them with high occurrence and severity. These two factors are R21 and R22, corresponding to 'New projects without analysis of the capabilities and capacities required for its implementation' and 'Health-related work absenteeism of personnel participating in the projects', respectively. These two output-related risk factors could have the greatest impact on the project portfolio success. The other twelve output-related risk factors in the high-risk zone are R3, R5, R7, R8, R10, R12, R15, R17, R18, R19, R23, and R25.

As previously mentioned, the results of the proposed PPRA model show that the new or improved organizational capabilities to be generated by the project portfolio are transversally related to all three dimensions of success. In other words, each success dimension is not highly dependent on one or a subset of capabilities. This suggests that portfolio risk associated with each success dimension is diversified across the four expected capabilities rather than concentrated in one capability.

Risk analysis that considers the impact of different risk factors on success dimensions can provide information to establish targeted response plans. In other words, if a risk factor or group of risk factors is expected to have a more significant impact on one of the success dimensions, risk responses could focus on aspects that are explicitly related to that dimension. Also, when it is identified that some risk factors have a cross-cutting impact on success dimensions, as occurred in the case study, risk response planning should consider overarching strategies. In this regard, the proposed PPRA model, besides providing information about each risk factor behavior, shows whether the portfolio risk is diversified among its different components or concentrated in some of them.

7.4 Summary

A case study based on a portfolio belonging to a Colombian organization was used to apply the proposed PPRA model. The portfolio case study was composed by 18 projects, 31 risk factors, 4 organizational capabilities, and 11 attributes related to success dimensions. It was evidenced that the proposed PPRA model is flexible to incorporate specific conditions associated to the case study. For instance, the model was robust enough to adopt the qualitative scale used by the parent organization for risk qualification.

The results show that information about the impact of each risk factor can be obtained and analyzed. Also, the results show information regarding how each risk factor influences other factors. According with the ranges defined by the organization case study, the project portfolio has a medium-

risk level regarding both output- and outcome-related risk. However, the success dimensions strategic fit and future preparedness present a high-risk level concerning outcome-related risk. The results also show that 'poor adherence to new processes being delivered by each project' is the most critical outcome-related risk factor, and that 'new projects without analysis of the capabilities and capacities required for its implementation' and 'health-related work absenteeism of personnel participating in the projects' are the most critical output-related risk factors, both being systematic. In addition, it was identified that 'conflicts between portfolio managers and organizational decision makers' is a risk factor that could have high impact on both outputs and outcomes, so that it was also identified as critical for the project portfolio success.

Based on the scenarios analyzed, it was identified that considering risk factor interdependency and impact on portfolio success have significant implications in the portfolio risk profile. Also, it was identified that the model provides rich and detailed information regarding the risk composition at the portfolio level, considering the influence of risk factors on other risk factors and the impact on the project portfolio success.

PART IV. RESEARCH CONTRIBUTIONS

8. CONCLUSIONS

This concluding chapter starts with a summary of the main findings, theoretical and practical contributions, limitations, and future research. In Section 8.1 the findings are discussed in the frame of current risk planning approaches to incorporate risk assessment in decisions associated with project portfolios. That led to identify the main contributions of this research to the body of knowledge in the field. Section 8.2 discusses the three main theoretical contributions derived from this research and Section 8.3 the practical contributions. Then, Section 8.4 presents the research limitations and Section 8.5 the future research. Finally, a synthesis of scientific publications as a result of this research project is presented in Section 8.6.

8.1 Summary of Main Findings

This research project contributes to the PPRA body of knowledge by addressing the gap identified in the literature related to: how to assess the project portfolio risk considering risk factor interactions and their impact on the project portfolio success dimensions. For that, two main outputs are derived from this research project: (i) A comprehensive PPRA conceptualization, and (ii) a proposed PPRA model.

A comprehensive PPRA conceptualization was developed based on: a SLR process, which resulted into four constructs that comprise a literature-based framework for PPRA design (see Figure 4.3); the conduction of an empirical study supported by twenty-eight semi-structured interviews that led to identify six interrelated themes for PPRA representation (see Figure 5.6); and, finally, the development, by contrasting the four constructs identified in the literature review with the empirical findings, resulting in four propositions. Based on the six themes and four propositions, a comprehensive PPRA conceptualization is proposed (see Figure 5.9).

A proposal to operationalize the PPRA conceptualization was developed, leading to an analytical PPRA model (see Figure 6.2). The proposed model considers shared risk factors between projects and interdependencies between risk factors, and the impact of risk factors on expected organizational capabilities to be generated by the portfolio. Based on the impact on organizational capabilities, the proposed model allows assessing the impact of risk factors on the project portfolio success dimensions. Then, based in a case study, it is demonstrated that the model is enabled to be applied in practice (see Chapter 7).

Considering the two outputs, this research responds to the call to studies oriented to PPRA that considers: (i) the impact of the variety of risk factors of different nature on project portfolios; these have not been addressed in an integrated manner from a wide-portfolio perspective, previously, which does not allow a comprehensive view of the PPR or an appropriate understanding of the relevance of these risk factors; (ii) the project portfolio success as the representation of the project portfolio expected results, where the PPR to be assessed would correspond to a multi-dimensional risk measure; and (iii) the impact from risk factors on the project portfolio can be generated not only through direct impact but also due to indirect impacts that risk factors generate on other risk factors.

Risk planning approaches of diverse nature have been adopted to incorporate risk assessment in decisions associated with project portfolios. Those approaches are mainly derived from both financial portfolios and project risk management considering interdependencies between projects (Ahmadi-Javid et al., 2020). Regarding the first one, the organizational importance has been recognized as it considers the risk of the monetary investment made by the parent organization (Tang et al., 2017). Regarding the second one, the relevance of incorporating how project interdependencies influence performance and expected results of each project has been evidenced (Neumeier et al., 2018; Zou et al., 2021). However, the literature highlights that risk planning approaches that recognize project portfolio characteristics and project portfolio level itself are required (Ahmadi-Javid et al., 2020; Ghasemi et al., 2018; L. Wang et al., 2020). Specifically, approaches through which PPRA incorporates the strategic relevance of project portfolios and how project portfolios deliver value to the parent organization (Abbasi et al., 2020; Kaiser et al., 2015; L. Wang et al., 2020; Wu et al., 2021). Also, portfolio risk and its management require a perspective beyond the risk of each project within the portfolio (Ghasemi et al., 2018; Teller et al., 2014).

The proposed conceptualization of a comprehensive PPRA fits the call to recognize project portfolio characteristics in portfolio risk management, particularly focusing on PPRA. In this regard, the proposed approach extends the conceptualization of PPR by considering it as the impact of risk factors on the organizational capabilities to be generated by the portfolio, which, in turn, is transferred to impacts on the project portfolio success. That is, by considering the risk factors impact on the project portfolio as an organizational unit rather than on measures associated with the projects within the portfolio or on monetary investment made by the parent organization.

The foregoing does not mean that the conceptualization of a comprehensive PPRA proposal ignores that the risk of a project portfolio is highly related to the projects that comprise it (Ahmadi-Javid et al., 2020; Ghasemi et al., 2018; Zou et al., 2021), nor that a project portfolio interacts with the parent

organization and its strategy (Abbasi et al., 2020; Martinsuo and Geraldi, 2020). On the contrary, the proposed PPRA conceptualization incorporates both aspects into the risk assessment. For instance, it recognizes that intrinsic characteristics of the projects within the portfolio generate risk to the project portfolio, which was defined as the non-systematic risk in the proposed PPRA conceptualization. However, it also recognizes that other contributions to the PPR are not associated only with the characteristics of the projects but also with the project portfolio as an organizational unit, and with how the project portfolio delivers value to the parent organization. These risk contributions were defined as systematic risk and outcome-related risk, respectively.

The proposed conceptualization of a comprehensive PPRA is based on the six themes derived from how portfolio practitioners represent PPRA integrated with the four propositions that emerged from the themes' discussion against current literature. Then, the conceptualization of a comprehensive PPRA integrates empirical and theoretical evidence. Nevertheless, the focus on organizational development project portfolios adopted for the empirical phase led to the proposed PPRA conceptualization not being generalizable. In fact, as mentioned in Section 3.1, "the constructivist view of organizational design science confronts researchers with the issues of generalizing local knowledge and justifying generalization" (Avenier, 2010, p. 1240).

In this concern, the generalization of singularities of local knowledge could take the form of consistent propositions or knowledge artifacts such as generic frameworks or models (Avenier, 2010). Although the proposed PPRA conceptualization represents local knowledge, the four propositions and the PPRA itself provide valuable insights and knowledge regarding how the risk can be represented and assessed. Also, it discloses a structure that could be explored in further research by adopting a perspective of both organizational development projects and other types of project portfolios. Particularly, the proposed PPRA conceptualization contributes to knowledge advancement in the field of PPRM, and specifically in risk assessment as an element of PPRM, by: i) extending the conceptualization of the type of impact derived from risk factors; ii) adopting organizational capabilities to be generated by the portfolio as a construct for PPRA; iii) posing a risk assessment orientation towards portfolio success dimensions associated with portfolio effectiveness; iv) introducing an analytical PPRA model. These contributions are detailed below.

i) <u>extending the conceptualization of the type of impact derived from risk factors</u>

As described in Section 4.2, risk factors are mostly categorized according to their risk source. Only in the works of Ghasemi et al. (2018) and Hofman and Grela (2018) risk factors are categorized in terms

of the type of impact that they generate on the project portfolio. Jointly, those two works lead to identifying that risk factors can impact project portfolios in two ways: on one hand, impacting a project or several projects; and on the other hand, generating a global impact on the whole project portfolio. The proposed PPRA conceptualization recognizes and incorporates both types of impacts. However, it extends the conceptualization of the type of impact on project portfolios derived from risk factors by identifying and incorporating a third type of impact, labeled as outcome-related. That type of impact is not associated directly with the projects within the portfolio, but with the portfolio's outcomes through which the project portfolio delivers value to the parent organization – new or improved organizational capabilities, in the case of organizational development project portfolios.

Then, the comprehensive PPRA conceptualization calls to incorporate those diverse types of impact on the project portfolio into PPRA in contrast with the approaches in which risk factors impact is represented exclusively as the impact on the projects within the portfolio, considering interdependencies between projects (see for instance Neumeier et al., 2018; Zou et al., 2021). In this regard, a clear differentiation seems necessary between risk assessment of the projects within a portfolio considering interdependencies between projects, or considering a multi-project environment, and PPRA. The last one implies incorporating and assessing the different types of impact generated by risk factors more than just considerations regarding the impact on the projects. According to the research findings, those types of impact can be categorized as output- and outcome-related risk factors. Output-related risk comprises non-systematic and systematic risk. Systematic risk comprises the portfolio risk contribution derived from events that affect the whole project portfolio, however, in project portfolios it could be reduced through risk management and efficiency management policies. Non-systematic risk corresponds to the individual project risk contribution derived from risk factors impact on each project, as well as derived from shared risk factors between projects.

ii) <u>adopting organizational capabilities to be generated by the portfolio as a construct for PPRA</u>

Introducing the construct organizational capabilities into PPRA is oriented to recognize how project portfolios deliver value to the parent organization. In this regard, for instance, Richard et al. (2021) describe how project portfolios associated with digital transformation are oriented to deliver new or improved organizational capabilities to the parent organization. Also, Shafi et al. (2017) pose a capability-based approach for selecting national defense project portfolios, where capabilities generated by the portfolio help face the national strategic risk. Even so, organizational capabilities had not been incorporated into PPRA.

In addition, considering the organizational capabilities to be generated by the project portfolio as the representation of the portfolio's outcomes on which the risk can be primary assessed, it is in line with the works of Sanchez et al. (2010b), Ghasemi et al. (2018), and Hofman and Grela (2018), who highlight that PPR should be assessed based on portfolio objectives. In this regard, a perspective of project portfolio as an organization that deliver value to its parent organization was adopted in this research. Organizational capabilities to be deliver by the portfolio represent the project portfolio objectives. Thus, incorporation of organizational capabilities into PPRA, framed in the idea of PPR is not represented solely on project measures or on financial measures more associated to risks of organizational investment.

iii) posing risk assessment orientation towards portfolio success dimensions associated with portfolio effectiveness

Posing that the primary representation of risk factors impact is on new or improved organizational capabilities emphasizes that the project portfolios have a strategic impact in its parent organization and that, therefore, the portfolio risk should reflect on that expected strategic impact. Although adopting a perspective based on uncertainty analysis, L. Wang et al. (2020) and Bai et al. (2021) show how uncertainty influences the expected strategic impact derived from a project portfolio. In fact, that premise is not new in the literature. For instance, Sanchez et al. (2008) highlighted the relevance of considering the risk factors impact on organizational strategic objectives representing strategic consequences derived from the project portfolio. The proposed PPRA conceptualization is consistent with Sanchez et al. (2008) by considering the strategic impact of the risk on strategic considerations.

However, the proposed PPRA conceptualization extends the representation strategic impact of PPR by considering the risk factors impact on success dimensions associated with portfolio effectiveness. The findings suggest that strategic fit, future preparedness and stakeholder satisfaction represent success dimensions associated with portfolio effectiveness. Thus, portfolio risk analysis oriented on strategic objectives highlighted by Sanchez et al. (2008) and Bai et al. (2021) is represented by the portfolio success dimension strategic fit in the proposed PPRA conceptualization. Nevertheless, the proposed approach extends that conceptualization of strategic impacts by complementing strategic fit with future preparedness and stakeholder satisfaction. Then, those three success dimensions are proposed to represent the impact of risk factors on the strategic aspects influenced by the project portfolio. Therefore, the proposal of a PPRA oriented to assess the risk impact on portfolio success is underpinned by the

construct of 'portfolio success dimensions', a well-established construct in the literature (Teller and Kock, 2013; Unger et al., 2012).

iv) introducing an analytical PPRA model

For project or portfolio risk assessment, approaches based on network theory have been adopted (see for instance Ghasemi et al., 2018; Neumeier et al., 2018; Zou et al., 2021). Approaches based on networks capture the complexity associated with interdependencies and how the risk (or uncertainty in line with the perspective adopted) is transferred across the elements comprising a project or project portfolio (Bai et al., 2021; Yang et al., 2022; Zou et al., 2021). In this regard, risk analysis considering networks of risk factors has been explored (see Ghasemi et al., 2018; Q. Wang et al., 2017). Likewise, networks of interdependent projects have been used to analyze risk propagation (see Neumeier et al., 2018). Also, networks through which the link between projects and strategic objectives is represented have been adopted in risk and uncertainty analysis frame (see Bai et al., 2021).

The research project findings suggest that the structure underlying the PPRA can be represented as a subset of linked networks. Particularly, the findings suggest that networks derived from risk factors, projects within the portfolio, expected organizational capabilities, and success dimensions are linked, representing how the risk impact is transferred from risk factors to success dimensions. The concept of Meta-Network represents the above. Structures based on Meta-Networks have been adopted in the project risk assessment frame (see T. Wang et al., 2018, 2021). However, that structure has not been explicitly adopted to support PPRA.

Even though it has not been explicitly adopted, some previous studies show an orientation towards risk analysis considering subsets of linked networks. For instance, from an uncertainty analysis perspective, Bai et al. (2021) adopted a representation of a network of projects linked to a network of strategic objectives. Also, the representation that the risk is transferred between elements comprising a project portfolio is not new in the PPR field. For instance, Sanchez et al. (2008) proposed a framework showing how shared resources and knowledge, projects, portfolio objectives, and strategic objectives are linked. Thus, considering empirical evidence and previous research results such as those conducted by Bai et al. (2021), Sanchez et al. (2008), and Ghasemi et al. (2018), the proposed PPRA model extends the PPRA representation to an analytical structure based on meta-networks.

Given the nature of this research, the analytical structure for PPRA is not generalizable. However, it did allow conducting a legitimization process based on its application in a case study – a project portfolio of a Colombian organization. For that, a quantitative model through which the PPRA can be

operationalized was proposed and legitimized. Enabling the practical use of knowledge is both a goal of knowledge generation in organizational design science and represents its legitimation (Avenier, 2010). Thus, the legitimization process evidenced that the proposed PPRA model is feasible to be used in practice. Also, it was evidenced that it is robust and flexible enough to recognize the particularities of a portfolio of organizational development projects and the influence derived from the parent organization.

8.2 Theoretical Contributions

There are three main theoretical contributions derived from this research project. First, the characterization of output-related risk was drawn based on risk composition derived from MPT. The literature shows that systematic risk in the investment phase is non-diversifiable, external to the organization, and non-manageable (Paquin et al., 2016). This research evidences that an analogy of risk composition between investment and execution phases can be made regarding the conceptualization of systematic and non-systematic risk. However, it also shows significant differences to be considered when systematic risk is conceptualized in the execution phase of the project portfolio.

In the execution phase, although the systematic risk is also external to the organization 'project portfolio', it can be managed or at least part of it. It means several risk factors associated with the systematic risk derived from the interaction between the project portfolio and the parent organization. Some examples of the above are the risk factors 'Conflicts between portfolio managers and organizational decision makers' and 'Lack of coordination of key resources between the portfolio and organizational processes' identified in the case study (see Section 7.1). Then, the findings of this research build knowledge in line with the theoretical approach raised by Paquin et al. (2016), which states that it is necessary to recognize the conceptual and practical dissimilarities of the systematic risk between investment and execution phases.

Second, this research shows and characterizes the risk planning approaches underlying risk assessment in a project portfolio context. In particular, the research identifies three major perspectives on which the body of knowledge in this field has been built. The first approach adopts a general management perspective associated with the risk generated by the project portfolio to the parent organization. In this case, the risk is mainly associated with the portfolio structuring processes considering a financial return for the parent organization (see for instance Tang et al., 2017; Xu et al., 2017). The second risk planning approach is derived from risk management applied at the project level. That approach considers the interdependencies between projects and how they contribute to the projects'

risk (see for instance Neumeier et al., 2018; Zou et al., 2021). The literature shows that these two approaches are relevant and necessary for the organization's financial management and project management.

However, a third risk planning approach was born as a response to recognizing the strategic nature of project portfolios and the risk that arises at the portfolio level itself (Bai et al., 2021; Ghasemi et al., 2018; Sanchez and Robert, 2010b). This research provides a conceptualization of a comprehensive PPRA framed in the third risk planning approach, evidencing, and characterizing the aspects that should be considered when assessing the portfolio risk. Thus, this research advances in conceptualizing the PPR by considering the project portfolio as the unit of analysis. That makes it possible to differentiate between portfolio risk, the financial risk of the organization derived from the investment in the portfolio, and the risk of the projects.

The third theoretical contribution is associated with the characterization of 'project portfolio success dimensions' according to the figurative core derived from the practitioners' perspective. In this regard, project portfolio stakeholder satisfaction was suggested as a 'project portfolio success dimension'. However, stakeholder satisfaction has not been previously raised as a project portfolio success dimension in the literature. Since this finding is based on twenty-eight interviews, this project portfolio success dimension proposed requires further empirical and analytical studies with larger samples to be confirmed or generalized. Integrating this dimension to success dimensions previously identified in the literature allows one to recognize the project portfolio interaction with its stakeholders beyond analyzing each group project's stakeholders.

8.3 Practical Contributions

There are two main practical contributions derived from this project research. First, the proposed PPRA conceptualization represents a comprehensive view of characteristics and aspects to be considered for conducting PPRA in practice. Then, considering PPRA as a PPRM element, the proposed approach can be used as an input for designing the PPRM plan and for risk identification. Identifying each of the attributes for each construct provides a comprehensive view of the project portfolio and how risk factors could affect the project portfolio expected results, giving a strategic perspective of the project portfolio and the implications associated with its risk. Thus, even if the proposed PPRA conceptualization is not operationalized, just the characterization of the attributes of each construct for a specific project portfolio

could deliver a complete view of the implications that risk factors can generate to the portfolio and its expected results.

For instance, as evidenced in the case study, in the project portfolio's characterization new elements emerged when availability information was contrasted with the requirements of the PPRA proposed model (see Section 7.1). New risk factors were identified for the project portfolio. They were not necessarily unfamiliar or unknown at the organizational levels since part of them derived from the corporative risk matrix. However, previously they had not been associated with the project portfolio.

The second practical contribution is the analytical model proposed for operationalizing the PPRA. In this regard, the case study application of the PPRA model evidenced that applying the proposed model is feasible in practice, providing rich information to support informed decision-making processes. The proposed model is flexible and adaptable to certain organizational and portfolio characteristics, for instance, adopting the qualitative scales used traditionally by the PMO and the parent organization as in the case study. In the same line, the proposed model allows conducting risk assessment without incorporating all the possible risk factors' attributes according to the available information. For instance, even though the model is designed to incorporate opportunities, in the case study opportunities were not considered relevant by the company, and the model was yet applied. Modifications in its structure were not required.

Based on that "the risk management process is worthless without considering risk responses" (Ahmadi-Javid et al., 2020, p. 2), adopting the proposed PPRA model can be used for designing, analyzing, and selecting risk responses. In this regard, the proposed model can be used to analyze scenarios associated with different risk response strategies and their impact on portfolio success. In addition, in practical terms, the proposed PPRA conceptualization and its operationalization based on the proposed model, do not substitute the project portfolio selection processes and the risk assessment for each project. The proposed PPRA complements them.

8.4 Research Limitations

A few limitations need to be noted regarding the present study. These limitations are described in the following paragraphs.

Although this research project started with a Systematic Literature review (SLR), Laursen and Svejvig (2016) and Xia et al. (2018) suggest that literature reviews can never be exhaustive and, therefore, in this process some articles or groups of articles may have been left out of the analysis.

Possible exclusions may be the result of several factors: the keywords used, the search equation structure, the search scope or methodological deficiencies that could potentially be identified by other researchers. Besides this, in the literature analysis process related to qualitative analysis, the cognitive bias cannot be fully eliminated (Xia et al., 2018).

In the research Phase II of this study mostly project portfolio managers were interviewed, which according to Teller (2013) and Korhonen, Laine, and Martinsuo (2014) can represent a single informant bias. Therefore, further studies could be oriented to acquire a more multi-perspective set of data from other stakeholders related with project portfolios. In that case, each theme and proposition established for the conceptualization of the comprehensive PPRA proposal could be analyzed. Similarly, the set of PPRA themes and their main aspects established herein could be explored in other types of project portfolios, expanding the scope and possible generalization of these PPRA themes, and identifying additional or specific aspects for PPRA in other types of portfolios.

A Social Representation Theory (SRT) lens helped to understand the objectification of the constructs, and consequently to identify a figurative core for these constructs. However, from a methodological standpoint, a complementary analysis focused on the anchoring process of these constructs would help to understand how practitioners anchor them within the organizational context, and how that anchoring process is related to and complemented by the objectification identified above.

As in the study carried out by van der Hoorn and Whitty (2019), theoretical and practical contributions are tempered with reference to the qualitative nature of the Phase II of this study and the characteristics of the sample. As the interviewees' profile was exclusively oriented towards Colombian portfolio practitioners with experience in portfolios of organizational development projects, the participant group can be considered homogeneous. In this regard, the sample's homogeneity limits the results' generalizability. So, the geographical focus represented in the fact that only Colombian professionals were interviewed, and the focus on a specific type of project portfolio, namely, organizational development project portfolios, limits the results' generalizability.

8.5 Future Research

The main results presented in this research study are exploratory. As is often the case with exploratory research, the results open some avenues for future research discussed in the following paragraphs.

Identification of capabilities framed into the PPRA opens pathways for further research. Although in Chapter 6 a PPRA model that incorporates the organizational capabilities to represent the primary

impact of risk factors, other modeling strategies could be explored and tested. Then, results could be compared leading to identify strengths and weaknesses regarding the modeling strategy and results' robustness, leading to build a pathway to improve PPRA in practice.

Both quantitative and qualitative studies are necessary to provide further exploration of each PPRA theme addressed in this study. In addition to this, research based on case studies could explore, in depth, each theme established. Then, case studies could be developed using the conceptualization of a comprehensive PPRA and PPRA model proposed herein. This would lead to an understanding of the relevance and importance of each construct and subtheme within the proposed PPRA conceptualization – for example of each risk category or each project portfolio success dimension in different types of portfolios.

Practical applications of the PPRA model could be complemented with incorporation of visualization strategies such as implementation of dashboards that help to present the results and support the decision-making process. Also, the proposed PPRA model can be used to explore scenarios concerning different risk response strategies. In this regard, Ahmadi-Javid et al. (2020) identify that risk response planning at the project level has been studied and explored, but it has not been addressed at the portfolio level.

Considering that this project research was focused on perspective of risk as independent element regarding uncertainty, complementary studies could help to identify how uncertainty is impacting both organizational capabilities to be generated by the project portfolio and project portfolio success. Moreover, existing literature regarding uncertainty analysis and management at portfolio level could be explored systematically to obtain a frame of aspects to consider when uncertainty is assessed at portfolio level. A quantitative perspective could be adopted to incorporate the uncertainty into the here proposed PPRA model. For instance, the literature shows that Monte Carlo simulation and fuzzy theory can be used to assess the uncertainty of the project portfolio expected results but also the uncertainty associated with the qualifications assigned to the parameters of the risk factors (Panadero et al., 2020; Wu et al., 2021).

8.6 Synthesis of Scientific Publications

Part of this research work was published:

Journal papers:

Micán, C., Fernandes, G., and Araújo, M. (2020). Project portfolio risk management: a structured literature review with future directions for research. *International Journal of information systems and project management*, *8*(3), 67-84. https://doi.org/10.12821/ijispm080304

Micán, C., Fernandes, G., and Araújo, M. Disclosing the Tacit Links between Risk and Success of Organizational Development Project Portfolios (2022). *Sustainability, 14(9), 5235*. https://doi.org/10.3390/su14095235

Conference papers:

Micán, C., Fernandes, G., Araújo, M., and Ares, E. (2019). Operational risk categorization in project-based organizations: A theoretical perspective from a project portfolio risk lens. *Procedia manufacturing*, *41*, 771-778. https://doi.org/10.1016/j.promfg.2019.09.069

Micán, C., Fernandes, G., Araújo, M., and Ares, E. (2021, October). Project portfolio risk assessment in digital transformation: challenges and opportunities. In *IOP Conference Series: Materials Science and Engineering*, 1193(1), 012111. IOP Publishing. https://doi:10.1088/1757-899X/1193/1/012111

Micán, C., Fernandes, G., and Araújo, M. (2021, December). Incorporating the Influence of Risk Factor Interdependencies and Shared Risk Factors into Project Portfolio Risk Assessment. In *2021 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 994-998. IEEE. https://doi:10.1109/IEEM50564.2021.9673024

Micán, C., Fernandes, G., and Araújo, M. (2022). A method for project portfolio risk assessment considering risk interdependencies–a network perspective. *Procedia Computer Science*, *196*, 948-955. https://doi.org/10.1016/j.procs.2021.12.096

The following paper was submitted and is currently under evaluation process:

Journal paper:

Micán, C., Fernandes, G., and Araújo, M. A Comprehensive Approach to Project Portfolio Risk Assessment – An Organizational Perspective. Submitted to: *Project Management Journal (April 21th, 2022).*

The following paper is currently in progress:

Journal paper:

Micán, C., Fernandes, G., and Araújo, M. A Method for Assessing the Impact of Project Portfolio Risk on Portfolio Success considering Risk Factors Interdependency. Expected to be submitted to: *Computers and Industrial Engineering.*

The following paper was presented in EURAM 2021 Annual conference:

Micán, C., Fernandes, G., and Araújo, M. Developing an integrated framework for project portfolio risk assessment. In EURAM 2021 Annual conference (16-18 June 2021). Online streaming.

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APPENDICES

Appendix A. Interview Documentation

A1. Briefing Document

Modeling the project portfolio risk considering interactions among risk factors and their impacts on project portfolio success dimensions – Second phase: Interviews

This study is being conducted by Camilo Micán a doctoral student in the Production and System Department at the University of Minho (Portugal) as part of his doctoral thesis. The supervising faculty member for this study are professors Madalena Araújo and Gabriela Fernandes. Camilo Micán is professor in the Industrial Engineering School at the University of Valle (Colombia). University of Valle and Colfuturo-Colciencias is funding this research project.

Key terms adopted in the study and their meaning

Project Portfolio management represents a coordinated management of a set of projects carried out by a specific organization, which allows a strategic management of the projects, through which scarce resources are balanced.

Project portfolio risk category corresponds to a set of risks with common characteristics that can be managed in an integrated way.

Project portfolio risk assessment components are common or transversal aspects that can be considered as part of a risk assessment applied to project portfolios.

Project portfolio success dimension is a set of criteria oriented to determine the project portfolio success level.

Research scope

The purpose of this research is to develop a ***project portfolio risk assessment model considering interactions among risk factors and their impacts on the project portfolio success dimensions***. In order to achieve this purpose, information regarding components that must be considered for the project portfolio risk assessment and about project portfolio risk categories is being collected as inputs for the design of a project portfolio risk assessment model.

Literature focused on project portfolio risk management and project portfolio success dimensions provides a general and theoretical perspective, for which, a rigorous literature review process corresponds to a first phase of this research project. In a complementary way, seeking to integrate a practical perspective to the theoretical perspective, the second phase is focused in conducting interviews to professionals with experience in managing project portfolios. Thus, a broader understanding of the

context studied will be defined. Finally, based on theoretical and practical contexts, a model for project portfolio risk assessment will be designed and tested.

Currently, the research project is in the second phase – exploratory interviews. I am collecting data from interviews to professionals with experience in managing project portfolios, which you have kindly agreed to help me with.

Interview scope

The interview seeks to identify, from a practical perspective based on interviewee experiences and perceptions, information that allows comparing, contrasting, and complementing the literature review findings about components for PPR assessment, and PPR categories. The interview process was designed to last one hour. The interview is based on the following questions, besides a short characterization of the interviewee:

Can you give me a short introduction of your professional background regarding project management and portfolio management?

Based on your professional experience:

- Could you identify the main aspects or components that should be considered for an adequate project portfolio risk assessment?
- Could you identify types of risks, groups of risks, or categories of risk that should be managed at project portfolio level?
- What criteria/dimension might represent project portfolio success?

Supplementary questions will be used to prompt more detailed responses to the above questions, if appropriate.

Do you consider that there are other aspects that should be measured or considered as part of project portfolio risk assessment?

*All participants will receive a summary of the main findings from the interviews.

Anonymity and confidentiality

All responses will remain confidential and will be reported only in anonymous, summary form in my final doctoral report or doctoral thesis and any sub-sequent research articles or presentations in conferences. You can withdraw from the interview at any time, and in this case any data collected will not be included in the study. There is no anticipated risk associated with your participation.

If you have any additional questions about this research before our interview, please feel free to contact me at camilo.mican@correounivalle.edu.co or +351 910631231.

A2. Interview Guide

Key terms adopted in the study and their meaning

Project Portfolio management represents a coordinated management of a set of projects carried out by a specific organization, which allows a strategic management of the projects, through which scarce resources are balanced.

Project portfolio risk category corresponds to a set of risks with common characteristics that can be managed in an integrated way.

Project portfolio risk assessment components are common or transversal aspects that can be considered as part of a risk assessment applied to project portfolios.

Project portfolio success dimension is a set of criteria oriented to determine the project portfolio success level.

Interview blocks

Block 1: Introduction and background of the interview.

Briefly introduce the interviewer and the research project, as well as the importance of the interview for the research project objectives. For this, the interviewer can use the briefing document which was previously sent to the interviewee.

Describe the scope, characteristics, and plan for the interview.

Assure the interviewee that data collected will be anonymized, treated as confidential and that it will be used only for academic purposes. Make it clear to the interviewee that he/she may withdraw from the interview at any time, and in this case, any data collected will not be included as part of the project research.

Explain the reasons for which the interviewer would want to record the interview.

State to the interviewee that hand notes will be taken.

Q1.1: Do you want to know more about the research project or about the interview?

Q1.2: Do you authorize the recording of this interview?

Q1.3: Can you give me a short introduction of your professional background regarding project management and portfolio management?

Block 2: Project portfolio success dimensions.

Q2.1: What criteria/dimension might represent project portfolio success?

*If some project portfolio success dimension identified in the literature is not mentioned by the interviewee, ask about that success dimension.

Project portfolio success dimensions identified in the literature: average project success; strategic fit; portfolio balance; future preparedness; synergies between projects; economic business success; average product success.

Q2.2: Do you perceive <<name of project portfolio success dimension identified in the literature>> as relevant for project portfolio risk assessment?

Block 3: Project portfolio risk categories.

Introduce the concept "project portfolio risk categories", explaining the relation of this concept with the research project scope.

Q3.1: Could you identify types of risks, groups of risks, or categories of risk that should be managed at project portfolio level?

*If some PPR category identified in the literature is not mentioned by the interviewee, ask about that category.

Project portfolio risk categories and sub-categories identified in the literature:

Project portfolio management level: Aggregating and distributing information; inadequate management of culture and organizational climate; lack in project portfolio management capacities.

Project interdependencies: Resource interdependency; relations among projects.

External conditions: Supplier and contracts; changes in the competitive environment or context conditions.

Organizational conditions: Organizational and portfolio conditions; changes in the basic parameters of projects and programs; projects and programs management life cycle process.

Q3.2: do you perceive <<name of PPR category identified in the literature >> as a relevant category for project portfolio risk assessment?

Block 4: Project portfolio risk assessment components.

Introduce the concept "project portfolio risk assessment component", explaining the relation of this concept with the research project scope.

Q4.1: Could you identify the main aspects or components that should be considered for an adequate project portfolio risk assessment?

*If some PPR assessment component identified in the literature is not mentioned by the interviewee, ask about that component.

Components identified in literature: risk and uncertainty approach; opportunities incorporation; portfolio operational risk and the risk in portfolio business phase; projects interdependencies; risk/opportunities interdependencies; environment characteristics; project portfolio and organizational processes; impact on higher levels; relation of risk among portfolio levels.

Q4.2: Do you perceive <<name of PPR component identified in the literature>> as a component of project portfolio risk assessment?

Block 5: Additional comments and interview feedback.

Q.5.1: Do you consider that there are other aspects that should be measured or considered as part of project portfolio risk assessment?

Q5.2: Do you want to add anything? Do you have any suggestions regarding the interview?

Advise that interviewees will receive, in one or two days, by e-mail a résumé of the interview for his/her validation and possible additional comments. Additionally, state that interviewees will receive a summary of the main findings from the interviews.

Register date and time, length, and place (with characteristics – quiet/noisy, small/large) of the interview.

A3. Confidentiality Agreement

Study title: Modeling the project portfolio risk considering interactions among risk factors and their impacts on project portfolio success dimensions.

Researcher name: Camilo Andrés Micán Rincón

	Yes	No
I have read and understood the briefing document and have had the opportunity to ask questions about the study.	☐	☐
I agree to take part in this research project and agree for my data to be used for the purpose of this study	☐	☐
I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected.	☐	☐
I agree with to tape record the interview	☐	☐

Data protection

I understand that information collected during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous.

Name of participant (print name): .....

Signature of participant: .....

Date: ..... / ..... / .....

Appendix B. Codes Description

Codes	Codes description	Sources	References
Risk and uncertainty approach			
PPR meaning	Means and definitions of PPR or risk and uncertainty in portfolio context.	14	21
Organizational risk	Relationship between PPR approach and organizational risk approach adopted.	5	8
Implications	Impacts of PPR approach on decision-making related to project portfolio.	7	9
Opportunities incorporation			
Relevance	Reason(s) why it is important to consider opportunities in a PPRA.	17	20
Complexity	Concerns and considerations regarding value added and difficulties when opportunities are incorporated.	10	11
Portfolio operational risk and risk in the portfolio business phase			
Organizational perspective	Scope of project portfolio in the organizational context and the perception of PPR in that context.	16	23
Risk factor sources	Project portfolio phases are in themselves sources of risk for project portfolio.	12	16
Risk assessment points	Expected results of each phase and the impact of PPR on them.	9	14
Other factors	Influence of factors external to project portfolio on organizational measures of portfolio impact.	5	7
Impact on higher levels			
Organizational strategy	Strategic expected results as a possibility of representation of PPR impact.	14	20
Capabilities generated	Capabilities generated by project portfolio as a direct result with which risk can be assessed.	7	10
Impact representation	PPR representation or visualization oriented to support decision-making process.	13	20
Project interdependency			
Interdependencies as a risk	Relevance of interdependencies between projects for PPRA and their representation as a source of PPR.	13	17
Source of complexity	Concerns about complexity generated by project interdependencies representation in PPRA.	7	10
Organizational issues	The influence of interdependencies between the projects and the organizational processes (areas) on PPR.	9	11
Risk factor interdependency			
Relevance and complexity	Relevance and complexity of incorporating risk interdependencies in a PPRA and the complexity generated.	13	17
Second level	Incorporation of risk interdependencies conditioned to the incorporation of other attributes, such as project interdependencies.	4	4
Relation of risk among portfolio levels			
Interaction between levels	Different levels identified from portfolio as an organization and relationships between these levels.	11	15
Projects and programs risk	Projects and programs as an operational level of project portfolio representing a primary source of PPR.	11	15
Portfolio risk	Risks at project portfolio level represent more than the sum of risks derived from projects and programs.	9	12
Risk derived from organization	Risk derived from organization as an external source of risk for project portfolio and its interrelation with PPR.	13	15
Environment characteristics			
Strategic management	Influence of strategic context on PPR and strategic management as a bridge between organizational context and project portfolio.	10	13
Technological context	Importance of issues related to current technological context of a PPR.	8	13
Organizational culture	Organizational culture and its relationship with aspects related to PPR.	9	10
Project portfolio and organizational processes			
Risk management process	Organizational risk management processes as a basis for PPRA.	10	14
Processes influence	Influence of characteristics of organizational processes on PPRA.	18	24

Appendix C. Detailed Representation of PPRA Results

Strategic fit

Outcome risk: H

Output risk: M

Outcome risk factors (8)

Severity \ Likelihood		
1	2	1
1	1	2
0	0	0

Output risk factors (28)

Severity \ Likelihood		
1	6	2
3	3	6
1	6	0

Future preparedness

Outcome risk: H

Output risk: M

Outcome risk factors (8)

Severity \ Likelihood		
1	2	1
1	1	2
0	0	0

Output risk factors (28)

Severity \ Likelihood		
1	6	2
3	2	6
1	7	0

Stakeholders' satisfaction

Outcome risk: M

Output risk: M

Outcome risk factors (8)

Severity \ Likelihood		
1	1	1
1	2	1
0	0	1

Output risk factors (28)

Severity \ Likelihood		
1	6	2
4	3	6
0	6	0

		Success dimensions			
		Lik.	ST	FP	SS
R1	No visible leader in the project	Low	Medium	Low	Medium
R2	Project requirements without proper formalization	Low	Low	Medium	Medium
R3	Negative QA test results requiring adjustments to developments	Medium	High	High	High
R4	Law requirements impossible to be anticipated which suspends the work plan	Medium	Low	Low	Low
R5	Non-compliance of expected deliverables from suppliers	Medium	High	High	High
R6	Project objective become out of alignment with organizational strategic goals	Medium	Low	Low	Low
R7	Loss or leakage of information from each project	High	Medium	Medium	Medium
R8	Non-compliance of payment obligations stipulated to suppliers	Medium	High	High	High
R9	Conflicts between project managers	Medium	Low	Low	Low
R10	Poor commitment and lack of a teamwork culture	High	Medium	Medium	Medium
R11	Lack of knowledge among team members	Medium	Low	Low	Low
R12	Experience and training gaps in key team members	High	Medium	Medium	Medium
R13	Key team member being unfamiliar with the technology	Medium	Low	Low	Low
R14	Software failure leading to loss of key data	Medium	Medium	Medium	Medium
R15	Poorly defined client role	High	Medium	Medium	Medium
R16	Requirements are misinterpreted by the project team	Medium	Medium High	Low High	Medium High
R17	Lack of key technology	Medium	High	High	High
R18	Lack of executive and operational support for the execution of the projects within the portfolio	Medium	High	High	High
R19	Brain drain or termination of contracts of personnel participating in the projects	Medium	High High	High High	High Medium
R20	Financial illiquidity for post-pandemic projects continuity	Low	High	High	High
R21	New projects without analysis of the capabilities and capacities required for its implementation	High	High	High	High
R22	Health-related work absenteeism of personnel participating in the projects	High	High	High	High
R23	Conflicts between portfolio managers and organizational decision makers	High	Medium Medium	Medium Medium	Medium Low
R24	Lack of information transparency within the portfolio	Medium	Low	Low	Low
R25	Lack of project portfolio familiarity from organizational processes	High	Medium	Medium	Medium
R26	Lack of coordination of key resources within the portfolio	Low	Medium	Medium	Medium
R27	Lack of coordination of key resources between the portfolio and organizational processes	Low	Medium Medium	Medium Medium	Medium Medium
R28	Poor management of end-user expectations	Medium	Medium Medium	Medium Medium	Medium Medium
R29	Poor adherence to new processes being delivered by each project	High	High	High	High
R30	Brain drains of personnel involved in organizational processes	Low	High	High	High
R31	Users are unfamiliar with the technology and require additional training	High	Medium	Medium	Medium

Strategic fit

Increase sales

Outcome risk	Output risk
M	M

Outcome risk factors (6)

Severity \ Likelihood			
	1	1	1
	1	1	1
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	4	3	6
	0	6	0

Decrease costs

Outcome risk	Output risk
M	M

Outcome risk factors (8)

Severity \ Likelihood			
	1	1	1
	0	2	2
	1	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	4	2
	2	4	5
	2	7	1

Increase margin

Outcome risk	Output risk
H	H

Outcome risk factors (7)

Severity \ Likelihood			
	1	2	1
	0	1	2
	0	0	0

Output risk factors (25)

Severity \ Likelihood			
	1	6	2
	2	2	6
	1	5	0

Future preparedness

Labor capacity

Outcome risk	Output risk
H	M

Outcome risk factors (8)

Severity \ Likelihood			
	1	2	1
	0	1	2
	1	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	2	2	6
	2	7	0

Product capacity

Outcome risk	Output risk
M	M

Outcome risk factors (6)

Severity \ Likelihood			
	1	1	1
	1	1	1
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	4	3	6
	0	6	0

Relationship with suppliers

Outcome risk	Output risk
M	M

Outcome risk factors (8)

Severity \ Likelihood			
	1	1	1
	0	2	2
	1	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	4	2
	2	4	5
	2	7	1

Preparation of commercial schedule

Outcome risk	Output risk
M	M

Outcome risk factors (6)

Severity \ Likelihood			
	1	1	1
	1	1	1
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	4	3	6
	0	6	0

Stakeholders' satisfaction

Production process - Internal cycle

Outcome risk	Output risk
H	M

Outcome risk factors (8)

Severity \ Likelihood			
	1	2	1
	0	1	2
	1	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	2	2	6
	2	7	0

Back office processes

Outcome risk	Output risk
M	M

Outcome risk factors (8)

Severity \ Likelihood			
	1	1	1
	1	2	1
	0	0	1

Output risk factors (28)

Severity \ Likelihood			
	1	4	2
	2	4	6
	2	7	0

Sales channels points - Own

Outcome risk	Output risk
M	M

Outcome risk factors (8)

Severity \ Likelihood			
	1	1	1
	1	1	1
	0	1	1

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	4	3	6
	0	6	0

Sales channels points - External

Outcome risk	Output risk
M	M

Outcome risk factors (6)

Severity \ Likelihood			
	1	1	1
	1	1	1
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	4	3	6
	0	6	0

		Lik.	SF1	SF2	SF3	FP1	FP2	FP3	FP4	SS1	SS2	SS3	SS4
R1	No visible leader in the project	Low	Medium	Low		Low	Medium	Low	Medium	Low	Low	Medium	Medium
R2	Project requirements without proper formalization	Low	Medium	Low	Low	Low	Medium	Low	Medium	Low	Low	Medium	Medium
R3	Negative QA test results requiring adjustments to developments	Medium	High	Medium	High	High	High	Medium	High	High	Medium	High	High
R4	Law requirements impossible to be anticipated which suspends the work plan	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
R5	Non-compliance of expected deliverables from suppliers	Medium	High	High	High	High	High	High	High	High	High	High	High
R6	Project objective become out of alignment with organizational strategic goals	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
R7	Loss or leakage of information from each project	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
R8	Non-compliance of payment obligations stipulated to suppliers	Medium	High	High	High	High	High	High	High	High	High	High	High
R9	Conflicts between project managers	Medium	Low	Low		Low	Low	Low	Low	Low	Low	Low	Low
R10	Poor commitment and lack of a teamwork culture	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
R11	Lack of knowledge among team members	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
R12	Experience and training gaps in key team members	High	Medium	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	Medium	Medium
R13	Key team member being unfamiliar with the technology	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
R14	Software failure leading to loss of key data	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
R15	Poorly defined client role	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
R16	Requirements are misinterpreted by the project team	Medium	Medium High	Low High	 High	Low High	Medium High	Low High	Medium High	Low High	Low High	Medium High	Medium High
R17	Lack of key technology	Medium	High	Medium	High	High	High	Medium	High	High	Medium	High	High
R18	Lack of executive and operational support for the execution of the projects within the portfolio	Medium	High	High	High	High	High	High	High	High	High	High	High
R19	Brain drain or termination of contracts of personnel participating in the projects	Medium	High	High Medium	High High	High High	High	High Medium	High	High High	High Medium	High Low	High
R20	Financial illiquidity for post-pandemic projects continuity	Low	High	High	High	High	High	High	High	High	High	High	High
R21	New projects without analysis of the capabilities and capacities required for its implementation	High	High	High	High	High	High	High	High	High	High	High	High
R22	Health-related work absenteeism of personnel participating in the projects	High	High	High	High	High	High	High	High	High	High	High	High
R23	Conflicts between portfolio managers and organizational decision makers	High	Medium	Medium Medium	Medium Medium	Medium Medium	Medium	Medium Medium	Medium	Medium Medium	Medium Low	Medium Low	Medium
R24	Lack of information transparency within the portfolio	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
R25	Lack of project portfolio familiarity from organizational processes	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
R26	Lack of coordination of key resources within the portfolio	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
R27	Lack of coordination of key resources between the portfolio and organizational processes	Low	Medium Medium	Medium Low	Medium	Medium Low	Medium Medium	Medium Low	Medium Medium	Medium Low	Medium Medium	Medium Medium	Medium Medium
R28	Poor management of end-user expectations	Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium
R29	Poor adherence to new processes being delivered by each project	High	High	High	High	High	High	High	High	High	High	High	High
R30	Brain drains of personnel involved in organizational processes	Low	High	High	High	High	High	High	High	High	High	High	High
R31	Users are unfamiliar with the technology and require additional training	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

Commercial-omnichannel

Outcome risk: M

Output risk: M

Outcome risk factors (6)

Severity \ Likelihood			
	1	1	1
	1	1	1
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	6	2
	4	3	6
	0	6	0

Control mechanisms

Outcome risk: H

Output risk: H

Outcome risk factors (7)

Severity \ Likelihood			
	1	2	1
	0	1	2
	0	0	0

Output risk factors (25)

Severity \ Likelihood			
	1	6	2
	2	2	6
	1	5	0

Value chain

Outcome risk: H

Output risk: M

Outcome risk factors (8)

Severity \ Likelihood			
	1	2	1
	1	1	2
	0	0	0

Output risk factors (28)

Severity \ Likelihood			
	1	4	2
	2	3	4
	2	8	2

Financial support

Outcome risk: H

Output risk: M

Outcome risk factors (5)

Severity \ Likelihood			
	1	1	1
	0	1	1
	0	0	0

Output risk factors (25)

Severity \ Likelihood			
	1	2	2
	2	6	4
	2	5	1

		Lik.	C1	C2	C3	C4
R1	No visible leader in the project	Low	Medium		Low	Low
R2	Project requirements without proper formalization	Low	Medium	Low	Low	Low
R3	Negative QA test results requiring adjustments to developments	Medium	High	High	Medium	Medium
R4	Law requirements impossible to be anticipated which suspends the work plan	Medium	Low	Low	Low	
R5	Non-compliance of expected deliverables from suppliers	Medium	High	High	High	Medium
R6	Project objective become out of alignment with organizational strategic goals	Medium	Low	Low	Low	Low
R7	Loss or leakage of information from each project	High	Medium	Medium	Medium	Medium
R8	Non-compliance of payment obligations stipulated to suppliers	Medium	High	High	High	Medium
R9	Conflicts between project managers	Medium	Low		Low	Low
R10	Poor commitment and lack of a teamwork culture	High	Medium	Medium	Low	Medium
R11	Lack of knowledge among team members	Medium	Low	Low	Low	
R12	Experience and training gaps in key team members	High	Medium	Medium	Low	
R13	Key team member being unfamiliar with the technology	Medium	Low	Low	Low	Low
R14	Software failure leading to loss of key data	Medium	Medium	Medium	Low	Medium
R15	Poorly defined client role	High	Medium	Medium	Medium	Low
R16	Requirements are misinterpreted by the project team	Medium	Medium High	 High	Low High	Low High
R17	Lack of key technology	Medium	High	High	Medium	Medium
R18	Lack of executive and operational support for the execution of the projects within the portfolio	Medium	High	High	High	High
R19	Brain drain or termination of contracts of personnel participating in the projects	Medium	High	High High	High High	High
R20	Financial illiquidity for post-pandemic projects continuity	Low	High	High	High	High
R21	New projects without analysis of the capabilities and capacities required for its implementation	High	High	High	High	High
R22	Health-related work absenteeism of personnel participating in the projects	High	High	High	High	High
R23	Conflicts between portfolio managers and organizational decision makers	High	Medium	Medium Medium	Medium Medium	Medium
R24	Lack of information transparency within the portfolio	Medium	Low	Low	Low	Low
R25	Lack of project portfolio familiarity from organizational processes	High	Medium	Medium	Medium	Medium
R26	Lack of coordination of key resources within the portfolio	Low	Medium	Medium	Medium	Medium
R27	Lack of coordination of key resources between the portfolio and organizational processes	Low	Medium Medium	Medium	Medium Medium	Medium
R28	Poor management of end-user expectations	Medium	Medium Medium	Medium Medium	Medium Medium	Medium Medium
R29	Poor adherence to new processes being delivered by each project	High	High	High	High	High
R30	Brain drains of personnel involved in organizational processes	Low	High	High	High	High
R31	Users are unfamiliar with the technology and require additional training	High	Medium	Medium	Medium	Medium