POLYTECHNIQUE MONTRÉAL

affiliée à l'Université de Montréal

Development of Indicators to Assess Project Resilience: The Case of Information Technology (IT) Projects

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Thèse présentée en vue de l'obtention du diplôme de *Philosophiæ Doctor*

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Development of Indicators to Assess Project Resilience: The Case of Information Technology (IT) Projects

présentée par **Khalil RAHI**

en vue de l'obtention du diplôme de *Philosophiæ Doctor*

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DEDICATION

To my lovely wife Helena, and my adorable three children Leana, Elicia and Kevin whose infinite love, support, and encouragement have empowered and inspired me to complete this research

To my backbone parents Haykal and Marcelle who offered unconditional love and support and have always been there for me

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RÉSUMÉ

En gestion de projet, la gestion des événements perturbateurs est un défi pour les praticiens et un sujet de recherche intéressant pour les académiciens. Ces événements entraînent de graves écarts par rapport aux objectifs du projet tout au long de son cycle de vie (ex., retards, dépassements de budget, qualité médiocre, portée incomplète, mécontentement de la clientèle, etc.).

Les approches pour gérer ces événements, dans la littérature en gestion de projet, consistent à gérer les risques, les vulnérabilités et à faire face aux besoins et requis du client et des parties prenantes dans l'environnement du projet (ex. Le concept de l'agilité). Cependant, malgré l'importance et l'applicabilité de ces approches, elles demeurent souvent inefficaces lorsque des événements imprévus, inconnus ou même considérés pratiquement impossibles, se réalisent. Par conséquent, l'introduction du concept de résilience en gestion de projet devient un sujet de recherche intéressant. Dans ce contexte, la résilience se manifeste par une attention vigilante envers de possibles événements perturbateurs et sur la capacité à s'adapter afin de pouvoir se remettre de tels événements.

Cette dissertation par articles vise à faire progresser les connaissances sur le concept émergent de résilience projet et à contribuer à une compréhension plus fine et plus intégrative de la résilience en gestion de projet.

En premier lieu, la littérature de gestion de projets est examinée selon quatre concepts; gestion des risques, gestion des vulnérabilités, l'agilité et la résilience des projets. L'objectif est de présenter les objectifs et les limites de chaque concept et d'initier le sujet de recherche principal de cette dissertation.

Dans le premier article publié, une définition et un cadre conceptuel de la résilience du projet sont présentés. Plus précisément, la résilience du projet est définie par la capacité du système projet à maintenir une attention vigilante ("awareness" en anglais) de son entourage, et à s'adapter afin de se remettre des événements perturbateurs. Les dimensions de la résilience projet sont: attention vigilante et capacité d'adaptation. En plus, cinq relations entre le concept de résilience projet, les risques connus et inconnus et les pratiques actuelles de gestion des risques sont également abordées.

Une fois que la résilience projet est conceptualisée, des indicateurs pour l'évaluer sont développés. La littérature empirique sur la résilience organisationnelle (un concept étroitement lié à la résilience du projet) est passée en revue. Le but est d'identifier les indicateurs utilisés pour évaluer la résilience organisationnelle et pour encourager le développement d'indicateurs de résilience de projet (2e article publié).

Des entretiens semi-structurés avec dix gestionnaires de projets, appartenant à de différents domaines, sont conduits, puis dix études de cas ont été explorées et analysées. À partir de ces données empiriques, dix indicateurs sont proposés pour évaluer deux dimensions de la résilience du projet: l'attention vigilante et la capacité d'adaptation (3e article publié).

Ces indicateurs ont par la suite été validés dans le domaine des technologies de l'information (TI) avec une étude exploratoire; 167 observations ont été collectées et analysées statistiquement (analyse factorielle exploratoire et confirmatoire). De ces analyses, huit indicateurs sont proposés et validés empiriquement pour évaluer la résilience des projets TI.

Une discussion vient clore cette thèse en mettant en évidence les contributions théoriques et pratiques de la recherche. Les implications pour la gestion de projets, et en particulier les projets en technologies de l'information, y sont discutées. Les limites de la recherche et des pistes futures de développement sont proposées.

Mots clés : Gestion de projet TI, évaluation de la résilience projet, résilience organisationnelle, indicateurs de résilience projet, attention vigilante, capacité d'adaptation

ABSTRACT

From a project management perspective dealing with disruptive events is a challenge for practitioners and an interesting research topic for academics. These events lead to severe deviations from a project's objectives during its life-cycle (e.g., delay, budget overruns, low quality, incomplete scope, client dissatisfaction, etc.).

Approaches proposed in the project management literature to deal with these events involve managing risks and vulnerabilities and facing clients and stakeholders needs and demands in the project's environment (e.g., the concept of agility). However, despite the importance and applicability of these approaches, they still face many challenges when events that are unforeseen, unknown or even considered impossible to occur. In this context, the concept of resilience in project management is becoming an interesting research topic. A resilience perspective focuses on being aware of possible disruptive events and adapting in order to successfully recover from such events.

This dissertation by articles aims to advance knowledge on the emergent concept of project resilience and contribute to a more profound and integrative comprehension of resilience in project management.

First, the project management literature on dealing with risks and disruptive events is reviewed from four different concepts: management of risks, management of vulnerabilities, project agility, and resilience. The goal is to present the objectives and limitations of each concept and to introduce this dissertation's main research topic.

In the first published article, a definition of and a conceptual framework for project resilience are presented. Specifically, project resilience is defined as the project system's capacity to be aware of its surroundings and to adapt in order to recover from disruptive events. The dimensions of project resilience are awareness and adaptive capacity. In addition, five relationships between project resilience, known and unknown risks, and current practices in risk management are discussed.

Once project resilience is conceptualized, indicators to assess it are developed. The empirical literature on organizational resilience (a concept closely related to project resilience) is reviewed.

The goal is to identify the indicators employed to evaluate organizational resilience and to encourage the development of project resilience indicators (second published article).

Semi-structured interviews with ten senior project managers from different fields were conducted and then ten case studies were explored and analyzed. As a result, inspired by the indicators used to assess organizational resilience, ten indicators are proposed to assess two dimensions of project resilience: awareness and adaptive capacity (third published article).

These indicators were validated in the information technology (IT) field with an exploratory study; 167 observations were collected and statistically analyzed (exploratory and confirmatory factor analysis). Consequently, eight indicators are proposed and empirically validated to assess IT project resilience.

In the conclusion, the theoretical and practical contributions of this research and of project resilience to project management, especially IT projects, are explained. Then limitations and avenues for future studies are discussed.

Keywords: IT project management, assessment of project resilience, organizational resilience, project resilience indicators, awareness, adaptive capacity, IT projects

TABLE OF CONTENTS

DEDICATION III

ACKNOWLEDGEMENTS IV

RÉSUMÉ V

ABSTRACT VII

TABLE OF CONTENTS IX

LIST OF TABLES XIII

LIST OF FIGURES XV

LIST OF SYMBOLS AND ABBREVIATIONS XVI

LIST OF APPENDICES XVII

CHAPTER 1 INTRODUCTION 1

CHAPTER 2 LITERATURE REVIEW 4

2.1 Management of Risks 4

2.2 Management of Projects' Vulnerabilities 10

2.3 Project Agility 12

2.4 Project Resilience 16

2.5 Critical Analysis of The Literature 24

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY 32

3.1 Research Objectives 32

3.2 Research Approach 35

3.2.1 Definition of An Indicator 35

3.2.2 The Choice of Methodology 37

3.2.3 Step 1: Item Generation 39

3.2.4 Step 2: Questionnaire Administration 43

3.2.5 Step 3: Initial Item Reduction 53
3.2.6 Step 4: Confirmatory Factor Analysis 55
3.2.7 Step 5: Convergent/Discriminant Validity 57
3.2.8 Step 6: Replication 57
3.3 Ethics Certificates 57
3.4 Dissertation Structure 58
CHAPTER 4 ARTICLE 1 - PROJECT RESILIENCE: A CONCEPTUAL FRAMEWORK 62
4.1 Introduction 63
4.2 Literature Review 64
4.2.1 Project Risk Management 64
4.2.2 Limitations of Project Risk Management 66
4.2.3 Resilience and Its Definitions 67
4.2.4 Project Resilience 72
4.3 Methodology 75
4.4 Project Resilience: A General Definition and Conceptual Framework 76
4.4.1 Project as a System 76
4.4.2 Project Resilience: Conceptual Framework 78
4.5 Conclusion 81
CHAPTER 5 ARTICLE 2 - INDICATORS TO ASSESS ORGANIZATIONAL RESILIENCE - A REVIEW OF EMPIRICAL LITERATURE 83
5.1 Introduction 84
5.2 Background on Organizational Resilience 85
5.3 Methodology 87
5.4 Results 88

5.5 Discussion 91
5.5.1 Awareness 95
5.5.2 Adaptive Capacity 97
5.6 Conclusions and Future Research 100
CHAPTER 6 ARTICLE 3 - BENCHMARKING PROJECT RESILIENCE 102
6.1 Introduction 103
6.2 Literature review 105
6.2.1 Resilience 105
6.2.2 Organizational Resilience 105
6.2.3 Project Resilience 108
6.2.4 Assessment of Project Resilience 109
6.3 Methodology 110
6.4 Results & Discussion 115
6.4.1 Awareness 115
6.4.2 Adaptive Capacity 118
6.5 Conclusion 124
CHAPTER 7 EMPIRICAL VALIDATION RESULTS OF THE INDICATORS 125
7.1 Population Overview 125
7.2 Results of Factor Analysis 128
7.2.1 Principal Component Analysis (PCA) 129
7.2.2 Confirmatory Factor Analysis (CFA) 139
CHAPTER 8 GENERAL DISCUSSION 154
8.1 Theoretical Contributions to Project Management 154
8.2 Practical Contributions to Project Management 164

8.3 Research Limitations 167

8.4 Future Studies 169

CHAPTER 9 CONCLUSION AND RECOMMENDATIONS 171

REFERENCES 173

APPENDICES 200

LIST OF TABLES

Table 2.1: Approaches to deal with known and unknown sources of disruptions summarized from the work of (Blay, 2017) 9

Table 2.2: Approaches to evaluate resilience in several domains (adapted from (Borisoglebsky et al., 2019)) 20

Table 2.3: Concepts to deal with risks/disruptions, their objectives and limitations 30

Table 3.1: Dates of signing the consent form and the dates of the interviews 41

Table 3.2: The indicators, their items, and their coding 45

Table 3.3: the pretest characteristics of the respondents 50

Table 3.4: Dates, strategies adopted, and number of observations collected 52

Table 3.5: Rules of thumbs for exploratory factor analysis (EFA) as proposed by (Hair et al., 2010) 54

Table 3.6: Rules of thumbs for CFA as suggested by (Hair et al., 2010) 56

Table 4.1: Definitions of resilience 69

Table 4.2: Definitions of project resilience 74

Table 5.1: Keywords used to search for empirical literature on organizational resilience 87

Table 5.2: Details of the 33 papers—authors (AU); type of empirical studies (TES) (Qualitative (QL), Quantitative (QN)); industry (IN); type of publication (TOP) (Journals Articles [JA], Grey literature [GL]) 90

Table 5.3: Definitions of organizational resilience 93

Table 5.4: Indicators to assess organizational awareness 97

Table 5.5: Indicators to assess an organization's adaptive capacity 100

Table 6.1: Definitions of project resilience found in the literature 109

Table 6.2: Information on the interviewee and the case studies discussed 111

Table 6.3: The indicators and their items to assess the awareness and the adaptive capacity dimensions of project resilience 120

Table 7.1: PCA final results for awareness 132

Table 7.2: PCA final results for adaptive capacity 136

Table 7.3: Test Mono-Method Bias Harman's single factor 138

Table 7.4: Items removed for awareness after CFA 139

Table 7.5: CFA results for awareness 141

Table 7.6: 2nd Order factor analysis for awareness 144

Table 7.7: Discriminant validity for awareness 145

Table 7.8: Final validated set of indicators to assess awareness 146

Table 7.9: Items removed for adaptive capacity after CFA 147

Table 7.10: CFA results for adaptive capacity 148

Table 7.11: CFA for adaptive capacity – 2nd Order 151

Table 7.12: Discriminant validity for adaptive capacity 152

Table 7.13: Final validated set of indicators to assess adaptive capacity 153

Table 8.1: Final validated set of indicators to assess project resilience, for IT projects, in terms of awareness and adaptive capacity 160

Table 8.2: Extract from a sample questionnaire to assess resilience of IT projects 165

LIST OF FIGURES

Figure 2.1 – Relationship between risk management, vulnerability management, resilience and agility from a project management perspective (inspired by Mochizuki et al., 2018).....24

Figure 3.1 – Links between the research question, the specific objectives and the articles 60

Figure 3.2 – The dissertation structure.....61

Figure 4.1 – Representation of the project system and its interaction with its environment 77

Figure 4.2 – Conceptual framework of project resilience.....81

Figure 5.1 – The number of empirical scientific documents on organizational resilience from January 2007 to April 2017.....89

Figure 7.1 – Distribution of observations by project's type.....126

Figure 7.2 – Distribution of observations by project's schedule and budget.....127

Figure 7.3 – Distribution of observations by role and years of experience 128

Figure 8.1 – Example of a radar chart for project resilience indicators. 166

Figure 8.2 – Example of a radar chart for the "Efficiency of External Resources" indicator.....167

LIST OF SYMBOLS AND ABBREVIATIONS

PRM	Project Risk Management
IT	Information Technology
ERP	Enterprise Resource Planning
PCA	Principal Component Analysis
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
KMO	Kaiser-Meyer-Olkin
AVE	Average Variance Extracted
CFI	Comparative Fit Index
IFI	Incremental Fit Index
GFI	Goodness of Fit Index
AGFI	Adjusted Goodness of Fit Index
RMSEA	Root Mean Square Error of Approximation
RP	Research Proposition

LIST OF APPENDICES

Appendix A Invitation for the semi-structured interview in French 200

Appendix B Invitation for the semi-structured interview in English 201

Appendix C Consent Form for qualitative study in French 202

Appendix D Consent Form for qualitative study in ENGLISH 206

Appendix E The questions for the semi-structured interview in French.....210

Appendix F The questions for the semi-structured interview in EngLISH.....212

Appendix G Questionnaire in french 213

Appendix H Questionnaire in english 221

Appendix I The respondent and the project characteristics and their values in the data file 228

Appendix J Ethics certificate for the qualitative study 229

Appendix K Ethics certificate for the quantitative study 230

Appendix L Principal component analysis for awareness – First attempt 231

Appendix M Principal component analysis for awareness – Second attempt.....232

Appendix N Principal component analysis for awareness – Third attempt 233

Appendix O Principal component analysis for awareness – Fourth attempt 234

Appendix P Principal component analysis for awareness – Fifth attempt 235

Appendix Q Principal component analysis for Adaptive Capacity – First attempt 236

Appendix R Principal component analysis for adaptive capacity – Merged factors 237

CHAPTER 1 INTRODUCTION

From a project management perspective, the management of disruptive events represents a great challenge for practitioners and an interesting research topic for academics. Disruptive events are circumstances leading to severe deviations from a project's objectives (e.g., delay, budget overruns, low quality, incomplete scope, client dissatisfaction, etc.). They can affect a project's cost, budget, strategic goals, introduction to market, financial performance, etc., and, if not managed effectively, may lead to the project's failure (Bannerman, 2008; Brady & Davies, 2014; De Bakker, Boonstra, & Wortmann, 2010; Schneider, Wickert, & Marti, 2017; Thamhain, 2013; L.-A. Vidal, 2009).

Many approaches have been suggested in the literature to deal with such events (Ward & Chapman, 2003; Zhang, 2011). For instance, risk management is concerned with the identification, analysis, prioritization and mitigation of risks. Risks are uncertain events that can have a negative or positive impact on a project's objectives if they occur (De Bakker et al., 2010; Project Management Institute, 2017). Alternatively, vulnerability management seeks to identify, analyze, and mitigate project weaknesses, limits, and its susceptibility to disruptive events (L. Vidal & Marle, 2012; Zhang, 2007). As for the concept of agility in project management, its aim is to build the project's capacity to update the project's plan based on changes in its environment. These changes are mainly generated by customers and/or stakeholders (Conforto et al., 2016).

However, despite the advancement in the development of approaches to deal with disruptive events, the success rates of project management (cost, budget, quality) in different domains remain very low. For example, a study done in 2015 by the Standish Group (2015) found the success rate for information technology (IT) projects to be 29%. That report was written following an empirical study of 50,000 IT projects of different sizes from around the world. IT is not the only domain of activity with low project success rates. A study conducted by the Construction Industry Institute (2012) showed that only 5.4% of the 975 construction projects analyzed complied with schedules and budgets with an acceptable margin of ±10%.

These low success rates show that projects still face many challenges when dealing with events that were unpredicted, unknown or even deemed impossible in specific circumstances (Turner & Kutsch, 2015). Consequently, approaches to deal with disruptive events must include strategies that aim to develop a project's capacity to recover successfully when faced with disruptive events,

regardless of whether these events were known or not before they occurred (Schroeder & Hatton, 2012).

That is why recent academic research has started exploring the concept of resilience in project management (Turner & Kutsch, 2015). Despite the varied definitions of this concept in different research fields, resilience mainly denotes a system's capacity (e.g., psychological, organizational, ecological) to recover from disruptions (Blay, 2017; Geambasu, 2011; Zhu, 2016).

In this regard, the originality of this dissertation resides in the proposal of a definition and a conceptual framework for project resilience, and in the development of indicators to assess this new and novel concept. This dissertation builds on the suggestions of Thomé et al. (2016), Geambasu (2011) and Blay (2017), who emphasized the need for ongoing research on project resilience and the proposal of indicators to measure observable processes, methods, structures, etc., that contribute to a project's capacity to successfully deal with disruptive events.

In the following chapter (Chapter 2), the literature on four different concepts to deal with disruptive events is reviewed: management of risks, management of vulnerabilities, project agility and resilience. The goal is to introduce the main research topic of this dissertation.

Next, the research design and methodology are presented, and the exploratory nature of this study is explained, given the scarcity of studies on resilience in project management (Chapter 3).

This research resulted in three published scientific articles and an additional chapter in which the exploratory study results are presented. In the first published article, the literature on project risk management is first reviewed to identify current research efforts and limitations on dealing with disruptive events. Then, the broader concept of resilience is explored, and two dimensions are derived: awareness and adaptive capacity. The literature on the new concept of project resilience is also scrutinized, and its novel nature, the lack of scientific studies to conceptualize it, and its significance for project management are demonstrated. These facts helped lead to a definition of and a conceptual framework for project resilience. A set of relationships are examined, which constitute a baseline to perform further studies to assess their validity (Chapter 4).

In the second published article, the empirical literature on organizational resilience is explored. The goal is to identify and understand the indicators used to evaluate organizational resilience and instigate the development of indicators to assess project resilience (Chapter 5).

Inspired by the indicators derived from the empirical literature on organizational resilience, the third published article sets out the development of indicators to assess project resilience. The third article's objectives were accomplished by conducting semi-structured interviews with 10 senior project managers from different industries; the 10 case studies were explored and analyzed. As a result, the definition from the first article was confirmed, and 10 indicators were established to assess the two dimensions of project resilience: awareness and adaptive capacity (Chapter 6).

The proposed indicators were then subject to an exploratory study through a project resilience questionnaire in the IT field to ensure their internal validity. After collecting the data (167 observations), exploratory and confirmatory factor analyses were conducted. The outcome was a proposed set of validated indicators to assess IT project resilience. The validation results are presented in a separate chapter (Chapter 7).

In the discussion chapter (Chapter 8), a general overview of project resilience is presented in which the theoretical and practical contributions of the concept for project management, especially IT projects, are summarized. That chapter also presents the limitations of this study and provides some suggestions for future research on the novel concept of project resilience. This chapter is followed by a conclusion that summarizes the main contributions of this dissertation (Chapter 9).

CHAPTER 2 LITERATURE REVIEW

Projects are temporary organizations in which human and non-human resources are pulled together to achieve specific goals (Cleland & Kerzner, 1985; Hanisch & Wald, 2013; Janoqicz-Panjaitan, Cambre, & Kenis, 2009). They are unique (Project Management Institute, 2017; L.-A. Vidal, 2009); they have a beginning and an end that vary depending on their type (e.g., Information Technology (IT), construction, production, etc.) and goals (Shenhar, 2001); and they involve specific deliveries (e.g., a specific product, a specific service, etc.). People gather to work together on specific objectives and are then dispersed at the end of the project (Bakker & Janowicz-Panjaitan, 2009).

The management of a project always represents a challenge "*since it interacts with time pressures and uncertainty of the results due to the fact that the project completion is something new or/and revolutionary, transient teams, and has risks*" (Geambasu, 2011, p. 29).

In this chapter, a literature review is conducted in which four concepts are presented that allow for an understanding of how risks/disruptive events and their management are perceived in project management, and where resilience fits within the current scientific research. These concepts are:

1. Management of risks;
2. Management of projects' vulnerabilities;
3. Project agility;
4. Project resilience.

2.1 Management of Risks

Risks are events or conditions that may or may not occur (they have a certain probability); if they do occur, they will have negative (threats, adverse effects) or positive (opportunities) consequences for the project's endeavors (Project Management Institute, 2017; Tomanek & Juricek, 2015; Ward & Chapman, 2003). Therefore, from a project management perspective, the main objective of risk management is to reduce the gravity of negative risks while taking advantage

of positive risks in order to respect the project objectives (Chapman & Ward, 2007; Project Management Institute, 2017).

Zhang (2011) argued that there are two main schools of risk analysis: risk perceived as an objective fact and risk perceived as a subjective construct.

The first school of risk analysis – "risk as an objective fact" – considers that risk exists outside free of people's minds and perceptions. Risks involve negative impacts, scientific methods, and clear processes are adopted to identify, quantify, mitigate and control them (Zhang, 2011). Therefore, the management of this type of risk can be classified into two categories. The first category perceives the project as a system with clear and precise objectives, free from stakeholders' perceptions. Consequently, systematic and rational risk management processes and methods are adopted to deal with the logical and objective consequences of risks (e.g., the works of Baccarini, 1996; Huchzermeier & Loch, 2001; Williams & Thompson, 2004; etc.). The second category considers the management of risks to depend on individual perception. In other words, different individuals can have different ways of managing objective risks. These ways are often based on the individual's personal experience, skills and expertise, along with psychological and organizational factors (Ward & Chapman, 2003; Zhang, 2007). One of the most important methods of dealing with this type of risk is the method proposed by Ward and Chapman (2003), who focus on managing uncertainty instead of risks because "*Uncertainty management is not just about managing perceived threats, opportunities and their implications. It is about identifying and managing all the many uncertainty sources which give rise to and shape our perceptions of threats and opportunities*" (Ward & Chapman, 2003, p. 98).

The second school of risk analysis – "risk as a subjective construct" – perceives risk as a subjective construction. Individuals identify risks based on their perceptions and put in place policies to manage these risks. Moreover, different people with different emotional and moral reactions may identify different risks and put in place different strategies to manage them. Therefore, the interaction between events, circumstances, and individual reactions contributes to the identification and analysis of risks (Zhang, 2011). This perspective ("risks as a subjective construction") is explained well by Kutsch and Hall (2005, who find that project stakeholders do not identify risks rationally because they intentionally or unintentionally tend to ignore, deny or

avoid risks. These acts (ignoring, denying, avoiding) are associated with environmental conditions that affect stakeholders' judgment of risks, the effectiveness of risk mitigation plans, and their impact on the project's objectives.

From this perspective, the consequences of risks are extended to include secondary impacts such as shame, fairness, justice, etc.: "*These secondary impacts can be understood as subjective overlays over external phenomena laid by the people who are encountering those phenomena*" (Zhang, 2011, p. 7). Therefore, the analysis of subjective risks aims to understand the perception and cultural identity of risks by reinforcing the strength of economic, social, and technological systems (Renn, 1998).

Various practices, processes, methods and approaches exist to assess and manage project risks; but it has not been confirmed if these practices, methods, processes and approaches are effective or essential for project management success (Besner & Hobbs, 2012b; De Bakker et al., 2010; Sanchez, Robert, Bourgault, & Pellerin, 2009). For example, De Bakker et al. (2010) tried to understand the relationship between risk management and IT project success. After evaluating 29 articles published from 1997 to 2009, they concluded that neither the evaluation approach nor the management approach has led to conclusive evidence regarding the relation between risk management and IT project success, regardless of the context in which the project is conducted. In fact, they concluded that "*the empirical knowledge is still anecdotal and largely based on how risk management is assumed to work instead of how it is actually used in project practice*" (De Bakker et al., 2010, p. 501). In addition, projects exist where the project managers did not apply risk management strategies but the project succeeded nonetheless, while other managers properly applied risk management methods and yet their projects failed (De Bakker et al., 2010; Hall, 2014). In other words, while projects continue to fail in some circumstances, it is not known whether the problem involves inappropriate risk management practices or inappropriate use of risk management practices by project managers (Hall, 2014). Another interesting fact noticed by researchers is that the majority of project managers implement risk management processes less rigorously than the project management institutions and risk management standards suggest (Besner & Hobbs, 2012b; De Bakker et al., 2010). In fact, "*only 29 percent of the project offices studied consider managing a risk database to be an important function*" (Sanchez et al., 2009, p.

19). This was also observed by Taylor (2006), who indicated that project managers do not analyze risks by applying the traditional methods. They use four main strategies to deal with risks: control, negotiation, research and monitoring. He argues that this tendency can be perceived from two points of view: *"(a) the extent to which IT project managers do not adhere to formal risk management prescriptions, and (b) the inability of the formal prescriptions to provide practical guidance in the situations faced by project managers*" (Taylor, 2006, p. 61).

Besner & Hobbs (2012a) empirically identify a toolset for risk management composed of 5 tools; risk management document, ranking of risks, contingency plans, assignment of risk ownership, and graphic presentation of risk information. They noticed that the level of use of these tools is close to average which can be explained by the sequence of actions related to risk management. For instance, *"Risk identification and documentation is a prerequisite to ranking risks and planning contingency"* (Besner & Hobbs, 2012a, p. 30). In addition, they noticed a tendency to use less arduously complex tasks such as assigning owners to specific risks, and graphically presenting risk information. These tools are used to better address specific organizational contexts and management problems. For instance, contexts such as large projects, important novelty, significant amount of resources, high level of uncertainty, require a detailed risk management process. In addition, these risk management tools are needed in all the stages of the project life-cycle, more especially at the beginning of the project, to mainly address high levels of uncertainty. Besides, risk management tools are used in specific contexts (e.g. pharmaceutical industry), because they are simply an important requirement to approve the project plan.

In addition, these authors highlighted that the relationship between risk management and project success still not clear. In fact, many risk professionals "*reported that despite the high visibility and favorable perception of risk management in their organizations, an important gap exists between interest for risk management and resource allocation and staff training; a lot of people talk about risk, but not so many do something about it.*" (Besner & Hobbs, 2012b, p. 233). Therefore, after reviewing the literature on the relationships between risk, risk management, uncertainty, and the context in which the projects are carried out, Besner & Hobbs (2012b) explored the extent of use of risk management in relation to the level of project uncertainty. Their study was completed through a quantitative analysis among 1296 experienced practitioners. Logically, they were

supposed to get results where risk management should be used extensively when managing highly uncertain projects, because risk management processes are supposed to improve project performance. However, an interesting paradoxical fact discovered by these authors is that risk management methods are often used when the project is well defined, and uncertainty is at its lowest level. Conversely, the higher the uncertainty, the less risk management is adopted. "*It is indeed easier to recognize that project analysis, planning, control, estimation or evaluation are easier to do and consequently done more, for well-defined projects.*" (Besner & Hobbs, 2012b, p. 239). This fact is the reason why risk management tools do not give the desired results, because these tools are mainly applied on well-defined projects and used to manage well known risks. In addition, their analysis suggests that other, more flexible, practices are needed to deal with unexpected uncertainty because actual risk management practices are not appropriate for this type of event.

Despite these facts, approaches to deal with risks mainly include processes to identify risks, plan responses and control risks throughout the project life-cycle.

The first set of processes allows the identification of risks that have an impact on the project's objectives. As discussed by Vidal (2009), the methods of identifying risks fall into two categories: direct risk identification and indirect risk identification. Direct identification serves to evaluate both the present situation, while analyzing its context in order to identify possible risks, and the future situation in the sense that the risks that can affect a project have to be imagined. On the other hand, retaining lessons learned, by collecting data on the causes of past problems, is part of indirect risk identification (Raz & Michael, 2001). In addition, once risks are identified, they are prioritized according to their likelihood and impact (Project Management Institute, 2017).

The second set of risk management processes aims to plan responses to risks. This phase aims to choose measures to reduce overall risk exposure at the least cost. Project risks are handled based on their priority by determining the resources needed to address them in a timely and cost-effective manner (Boehm & Turner, 2003). As mentioned by Bannerman (2008), all methods in this phase communicate the same possible treatment strategies: avoid risk, reduce risk's impact, transfer risk, and accept risk. Each strategy is achieved by many methods, depending on the risk and its impact on the project (Chapman & Ward, 2007).

The third and final set of risk management processes consists of keeping track of recognized risks while identifying new ones, assessing the effectiveness of risk processes in order to improve the risk approach's efficiency, and continuing the optimization of risk mitigation plans (Ahmed, Kayis, & Amornsawadwatana, 2007; Chapman & Ward, 2007). This phase is known as the monitoring and control of risks.

Other approaches also exist to manage risks. For example, Blay (2017) reviewed the literature on four management approaches to deal with disruptions, explaining their main objectives and limitations (Table 2.1). She concluded that "*The challenge of these approaches is the inability to fully manage shock, develop capabilities and ensure overall project recovery. This is because the approaches focus on increasing abilities to predict the threat or opportunity in order to manage them to avoid shock"* (Blay, 2017, p. 12).

Table 2.1: Approaches to deal with known and unknown sources of disruptions summarized from the work of (Blay, 2017)

Approaches	**Objectives**	**Limitations**
	Known sources	
Risk management	Predict the occurrence of a threat or opportunity and develop a mitigation plan to cope with it	1. Risk identification is influenced by people's subjective interests and experiences 2. Limited to known risk – unforeseen risks do not have mitigation plans
Opportunity management	Focus on positive consequences of the risk instead of negative consequences	1. Suffers from the inability to deal with disruptions 2. It is not oriented on developing project capacities to deal with disruptive events

Table 2.1: Approaches to deal with known and unknown sources of disruptions summarized from the work of (Blay, 2017) (Continued and end)

Approaches	**Objectives**	**Limitations**
	Unknown sources	
Change management	Focus on renewing the project's direction and structure to cope with disruptions by forecasting possible changes	1. Use of generic process to manage change without focusing on project development to recover from disruptions 2. It will not succeed in managing disruptions if unknown sources of disruption are outside those allowed or accepted
Uncertainty management	This approach incorporates strategies to understand or ignore uncertainties or react upon occurrence	1. Uncertainties are ignored if the impact on the project is insignificant, which leads to the adoption of risk and opportunity management approaches 2. Uncertainties tend to be high at the beginning of a project, which makes it vulnerable
Crisis management	This approach focuses on handling issues that disrupt the execution of the project's tasks	1. This approach is criticized because it oversimplifies the severity of the crisis. 2. This approach tends to ignore special problems due to crisis such as behavioral instability, information management, etc.

2.2 Management of Projects' Vulnerabilities

The concept of vulnerability emerged from social science and it is applied to economics, information systems, organizational management, politics, project management, etc. (Füssel & Klein, 2006; McManus, 2008; Zhang, 2007).

Füssel and Klein (2006) distinguished among three main models for conceptualizing and defining vulnerability: (1) the "risk-hazard framework," where vulnerability represents the relationship between hazard and its adverse effects on a system; (2) the "social constructivist framework," where vulnerability is a prior condition of a system determined by socio-economic and political factors; and (3) a school of thought that considers vulnerability as a system function represented by the degree to which this system is susceptible to, or unable to address, the negative consequences of disturbances.

Inspired by the third school of thought presented by Füssel and Klein (2006), from the project management perspective, Zhang (2007) discusses vulnerability as a redefinition of the project risk process. He illustrates two dimensions that represent a project's vulnerability: exposure and capacity. The first dimension denotes the influence of organizational activities in the creation of risk events. The second dimension means that the higher the project's capacity to deal with risk events is, the lower its vulnerability will be. The notion of vulnerability can cause a project to better mediate risks. In this process, "*the nested interactions and feedback between risk events and project systems are omitted in order to improve its ability of explanation and clarification*" (Zhang, 2007, p. 696).

Vulnerability is defined as the characteristic of a project that makes it susceptible to disruptive events (L. Vidal & Marle, 2012; Zhang, 2007). Therefore, the existence of vulnerabilities is independent of the presence of risks. For instance, within a project, not having the right qualified human resources to work on a specific task is considered a vulnerability. This vulnerability may (or may not) lead to poor-quality work. Therefore, a risk ("poor-quality work") can be caused by a vulnerability ("not having a qualified person"), but a vulnerability does not necessarily lead to a disruptive event (a risk that actually materialized). In other words, the lower the vulnerability, the less likely it is that disruptions will occur during the project life-cycle. Conversely, the higher the vulnerability, the more exposed the project is to disruptions that may lead to its failure (Aleksic, Puskaric, Tadic, & Stefanovic, 2017; Zhang, 2007).

Based on the work of Zhang (2007) and his perspective on the concept of vulnerability, L. Vidal and Marle (2012) reviewed the literature on the concept of vulnerability in many scientific domains and defined this concept, from the project management perspective, as "*the characteristic of a project which makes it susceptible to be subject to negative events and, if occurring, which makes it non-capable to cope with them, which may in the end allow them to degrade the project values*" (L. Vidal & Marle, 2012, p. 10). They also proposed a project vulnerability management process composed of four steps (which are very similar to the phases of the project risk management presented in the previous section): project vulnerability identification, project vulnerability analysis, project vulnerability response plan, and project vulnerability monitoring and control. Vidal and Marle's (2012) perspective on vulnerabilities complements Zhang's (2007) approach.

As in Zhang's perspective, vulnerability denotes a characteristic of the project that makes it susceptible to negative/disruptive events. In addition, vulnerability is related to the project's ability to cope with disruptive events. Therefore, adapting to and recovering from disruptions is also considered part of vulnerability. This point was also argued by Proag (2014), who mentioned that "*the concept of vulnerability implies a measure of risk associated with the physical, social and economic aspects and implications resulting from the system's ability to cope with the resulting event*" (Proag, 2014, p. 375).

2.3 Project Agility

The notion of agility in project management evolved from the Agile Manifesto for software development issued in 2001, which focused on lightweight methods to develop software applications (Lehnen, Schmidt, & Herstatt, 2016). In that manifesto, 17 software development practitioners proposed 4 values and 12 principles that made up agility in software project management. The values emphasize:

1. The importance of interactions between individuals over methods;
2. Functional and working software over extensive documentation;
3. Effective collaboration between stakeholders over negotiation of contracts;
4. Coping with change over following a specific plan (Lehnen et al., 2016).

The principles include processes that emphasize being closer to the client, the iterative approach to better deal with risks, daily meetings between team members to keep everyone updated on the status of the project, etc. (Cockburn & Highsmith, 2001).

From a software project management perspective, the Agile method remains the main replacement of the waterfall methodology (Cockburn & Highsmith, 2001), which emphasizes the execution of the project's phases sequentially. For instance, the first phase is to gather requirements; once that is finished, the development of the application starts, followed by the testing phase and finally the deployment phase.

An interesting Agile framework that has developed since 1995 is SCRUM (Hobbs & Petit, 2017). This framework features a product owner that works in a close collaborative environment with a

development team to deliver specific pre-defined software pieces in an iterative manner (S. Lee & Yong, 2010). SCRUM is one of the most widely used frameworks for Agile development. Other frameworks include Lean, Kanban, Extreme programming (XP) and others. In fact, as defined by Ambler (2009),

> *Agile software development is an evolutionary (iterative and incremental) approach which regularly produces high quality software in a cost-effective and timely manner via a value-driven life-cycle. It is performed in a highly collaborative, disciplined, and self-organizing manner with active stakeholder participation to ensure that the team understands and addresses the changing needs of its stakeholders. Agile software development teams provide repeatable results by adopting just the right amount of ceremony for the situation they face.* (Ambler, 2009, p. 6)

Following the 2001 manifesto, the term Agile was adopted in many publications on project management (Coram & Bohner, 2005; S. Lee & Yong, 2010). However, research on this concept is still mostly related to the software development sector (Hobbs & Petit, 2017; Werder & Maedche, 2018).

Nevertheless, as mentioned by Conforto et al. (2016), after a systematic literature review on the concept of agility in project management, "*Definitions of agility found in the project management (PM) and agile project management (APM) disciplines are inconsistent, incomplete and lack clarity*" (Conforto et al., 2016, p. 660).

Therefore, Conforto et al.'s (2016) goal was to clearly define the concept of agility in project management. To achieve this objective, they surveyed 171 projects and, as a result, defined this construct in project management as "*the project team's ability to quickly change the project plan as a response to customer or stakeholders needs, market or technology demands in order to achieve better project and product performance in an innovative and dynamic project environment*" (Conforto et al., 2016, p. 667).

Several points emerge from this definition. First, agility is defined as an ability (a quality or a skill). Second, the project team is the main entity, and the project plan is the primary element that needs to be modified or adapted. Finally, agility requires a transformation in response to the

customers or stakeholders needs or market and technology demands, which is not necessarily a disruptive event.

Werder and Maedche (2018) argued that agility relies on two concepts: flexibility and leanness. Flexibility is defined as the capacity to initiate and to respond quickly to change (not necessarily a disruptive event). Leanness, on the other hand, aims to provide additional value based on the outcome of responding to a change. Like Conforto et al. (2016), these authors emphasize the importance of customers, users and stakeholders, which are, in many cases, the sources of changes. Therefore, agility is also about taking advantage of a change, embracing it, and learning from it to increase customer satisfaction. In fact, as mentioned by Morgan & Conboy (2010) "*agile approaches continually involve the customer in the development process…while the customer plays an essential part in the agile process, this practice could be extended to include multiple stakeholders*" (Morgan & Conboy, 2010, p. 2)

As noticed by the definitions of the agility's concept. Agility is less about proactivity (actions before the occurrence of a disruptive event) and more about reactivity (actions during or after the occurrence of a disruptive event) (Baweja & Venugopalan, 2015; Wieland et al., 2013). It focuses on rapid response to change, mainly customers and stakeholders needs and demands. In relation to risk management, agile approaches manage risks that might be caused by the customers and stakeholders needs and demands in a implicit way. As mentioned by Nelson et al. (2008) important steps of risk management are neglected in agile approaches such as defining guidelines and procedures, mitigation plans, risk repositories for tracking risks, etc. This shows the lack of proactive actions within the agile approaches.

Despite these developments in the concept of agility, several further research avenues can be explored. For instance, it would be interesting to explore the applicability of agility to large-scale projects. In fact, agility has been shown to be effective for small projects, where the client can easily participate to deal with changes and be closely involved (may be physically present). However, as argued by Hobbs and Petit (2017), "*there are a number of impediments to the scaling of these practices (Agile practices) in large multi-site, multi-customer, and multi-project organizations*" (Hobbs & Petit, 2017, p. 5). This perspective remains largely overlooked in the literature.

Another interesting research avenue is related to scaling agility from the project to the organization. Many frameworks exist to achieve such scaling, mainly developed by consultants (Hobbs & Petit, 2017). Of the existing frameworks (e.g., Agile Scaling Model (ASM), Disciplined Agile Deliver (DAD), etc.), the most commonly adopted is the Scaled Agile Framework (SAFe). This framework aims to maintain the benefits of the Agile method at the organization level and consists of a set of processes and workflow patterns to guide organizations in scaling Agile practices beyond a single team with a single project (Leffingwell, 2015). Like applying agile at the project level, scaling agility focus on providing value to the customer, on improving quality and efficiency of the organization's product and services through incremental, small implementation of changes, on developing organized, co-located teams through a design-thinking approach, and on focusing on transparency and visibility (Reifer, Maurer, & Erdogmus, 2003).

However, as Leffingwell (2007) mentions, scaling Agile practices is very challenging at the organization level. The challenges can be grouped into two categories. The first is related to the Agile methodology itself and its principles (e.g., difficulty of continuous involvement by the client, difficulty of analyzing needs and demands, etc.). The second category is related to the company: rigid culture and high resistance to change, among other factors, prevent the application of novel methodologies such as Agile. In conclusion on scaling agility, this concept still requires improvement and additional development to efficiently scale agility at the organization level.

In conclusion, from a project management perspective, focusing only on agility can, to a certain extent, make a project vulnerable (Berglund, 2012; Werder & Maedche, 2018), because it does exist other events, outside the scope of customers and stakeholders needs and market and technology demands, that may disrupt a project. Therefore, it would be interesting to explore new avenues that focus on dealing with disruptive events and building a project's capacity to manage events that may cause a deviation from its main objectives. These avenues describe this study's objective of making projects more resilient.

2.4 Project Resilience

The concept of resilience[1] has existed for decades and applied in many disciplines. Consequently, its definition varies depending on the entity involved (an organization, a project, etc.); even when the focus is on a specific entity, definitions of resilience can vary substantially (Carlson et al., 2012).

Holling (1996) introduced two of the foundations of resilience: "engineering resilience" and "ecological resilience." Engineering resilience refers to a focus on resisting and absorbing a specific force. It is a system's capacity to maintain its functions and controls and the relationships between its various entities (Bhamra, Dani, & Burnard, 2011; Ponomarov & Holcomb, 2009). A system based on engineering resilience has limited possible states and tends to return to equilibrium quickly after a disruption. As a result, it focuses on stability (Holling, 1973; Ponomarov & Holcomb, 2009).

Conversely, ecological resilience refers to a capacity for change and reorganization and is measured by "*the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior*" (Holling, 1996, p. 33). A system founded on ecological resilience can endure serious disruptions, tends to return to its equilibrium only gradually and, under certain conditions, will completely overhaul its structure and functions (Holling, 1996).

As noted by Florin and Linkov (2016, Chapter 3), two propositions form the basis for managing resilience from an ecological perspective:

1. Identify the conditions indicating a loss of a system's resilience. These conditions are different from one type of system to another.

[1] More detailed information on resilience and project resilience can be found in Chapters 4, 5 and 6.

2. Identify and foster conditions aiming to maintain a system in an acceptable/desirable state: "*Maintain the distribution of ecological functions within and across scales that contribute to system resilience*" (Florin & Linkov, 2016, Chapter 3, p. 20).
3. These original foundations of resilience have been refined over the years and have influenced subsequent studies on resilience from many perspectives and in many fields (Bhamra et al., 2011; Geambasu, 2011; Ponomarov & Holcomb, 2009).

The operationalization of resilience is still a matter for discussion among practitioners and scholars. Many dimensions and attributes are used, which "*demonstrates that resilience assessment is still emerging*" (Florin & Linkov, 2016, Chapter 15, p. 92). For instance, the earthquake engineering community has proposed four dimensions of resilience: robustness, redundancy, resourcefulness, and rapidity. On the other hand, the National Academy of Sciences defines resilience as a set of six dimensions "*(1) prepare and (2) plan for, (3) absorb, (4) recover from, (5) adapt to actual or (6) potential adverse events*" (Cutter et al., 2013, p. 27). Argonne National Laboratory, which worked on the concept of resilience to help prevent and manage turbulences in critical infrastructure and communities, argues that "*in describing the components or determinants of resilience, several of the definitions considered here focus on what happens 'after the adverse event' (i.e., an adverse natural or man-made event), whereas others include one or more 'before the adverse event' components, including resistance, protection, anticipation, and preparedness*" (Carlson et al., 2012, p. 12). They conclude that resilience includes actions to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance.[2]. In fact, as highlighted by (Carlson et al., 2012), the system is initially in equilibrium. Therefore, anticipation, resistance and absorption actions are executed before the occurrence of an event that may disrupt this equilibrium. Alternatively, after the occurrence of a disruptive event, actions to respond, adapt and recover are undertaken. As a result, the resilience of the system "*determines both the amount*

[2] This perspective of resilience is also used in more recent reports from the Argonne National Laboratory (e.g., Phillips, Finster, Pillon, Petit, & Trail, 2016). For instance, studies on energy resilience adapted this perspective to the context of energy.

by which the activity/well-being declines and the amount of time required to return to the pre-event equilibrium (or some other new equilibrium)" (Carlson et al., 2012, p. 18).

According to this definition of resilience, recovery includes a set of activities or programs to effectively return to an acceptable state. This is debated in the literature, as some authors consider recovery to be a natural consequence of successful adaptation, which means that recovery and resilience are separate concepts. For instance, Stephenson (2010)[3] argues "*that the resilience of organizations directly contributes to the speed and success of community recovery following a crisis or disaster*" (Stephenson, 2010, p. 3). This perspective (recovery as a consequence of resilience) is also adopted in the work of Blay (2017), who viewed recovery as a positive impact of resilience. She defined it as "*the improvement to the same or new set of objectives to ensure a successful completion of project endeavours*" (Blay, 2017, p. 218).[4]

Many approaches do exist to assess resilience in different fields, mainly in natural disaster, critical infrastructure, communities, etc. Very recently (august 2019), the National Infrastructure Commission issued a report in which several approaches to resilience are presented (Borisoglebsky et al., 2019). Some of these approaches are presented in Table 2.2. The authors conclude that "*further work may be related to an ecosystem of approaches covering the complete set of needs for resilience and a method for design a holistic approach for the objectives and constraints of an organization*" (Borisoglebsky et al., 2019, p. 51) . This indicates that the concept of resilience is still under development even within the most mature fields like infrastructure, communities and organizations. Also, there is a lack of standardization on the concept of resilience and its assessment approaches. This has been observed by Petit (2019) who claims that "*Even if the concept of resilience is defined in national policies, discussions are still ongoing about the resilience components, the relationship between risk and resilience, and the characterization of resilience metrics. One of the main concerns is the absence of industry or government initiative to*

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[3] Stephenson (2010) based her work on the work of McManus (2008). Later on, many authors working on organizational resilience adopted Stephenson's (2010) work in their studies (e.g., Brown, Seville, & Vargo, 2017; Hatton et al., 2018; Lee, Vargo, & Seville, 2013).

[4] For more on recovery and resilience, see Chapter 4.

develop a consensus on or to implement standardized assessment approaches" (Anholt et al., 2018, Chapter 18, p. 119).

From a project management perspective, the concept of resilience is still new and largely overlooked. It is new because, based on our research, there is no common understanding on the main elements that compose the concept of project resilience given the fact that any new field of research leads to a variety of definitions, methods, tools and processes (Gibson & Tarrant, 2010). To illustrate this fact, and in reference to the definitions provided for this concept (Table 4.2), sometimes resilience is referred to as an ability, a capacity, or a capability to "restore capacity", to "evolve", to "maintain purpose and integrity", to "notice, interpret, contain", to "overcome", to "cope", or to "reduce the impact". All these terms can be defined in many ways based on the project's context and characteristics. Also, the type of event that resilience is trying to deal with needs to be well defined. For example, some authors refer to resilience as the ability to deal with changes, others to emerging risks, to shocks, to unexpected events, or to uncertainties. Thus, the type of event that project resilience is trying to deal with needs as well to be well exposed. Therefore, a rigorous conceptualization is needed to well define the concept of project resilience. The other fact that indicates the novelty of project resilience is what was mentioned by (Thomé et al., 2016) who suggest that "*Resilience is absent from most research in PM*" (Thomé et al., 2016, p. 1340). Therefore, the absence of resilience in project management is a powerful sign of the novelty of this concept. It is also to mention that (Thomé et al., 2016) found that *"the lack of coverage of the concept of resilience in both SCM and PM literatures deserves more attention by scholars and is an opportunity to aid project and SC management, as resilience mitigates risk"* (Thomé et al., 2016, p. 1342).

Alternatively, based on our research, no indicators are available to evaluate project resilience. This is because a concept needs to be well defined and well conceptualized in order to develop or propose indicators to assess it. As mentioned by (Hinkin, 1998, p. 105) "*The key to successful item generation is the development of a well-articulated theoretical foundation that would indicate the content domain for the new measure*".

Table 2.2: Approaches to evaluate resilience in several domains (adapted from (Borisoglebsky et al., 2019))

Approach name	Publisher	Purpose	Unit of analysis	Aspects covered
City Resilience Index	Rockefeller Foundation and Arup	Assess city resilience.	City	4 dimensions (health & wellbeing, economy & society, infrastructure & ecosystem, leadership & strategy), and 7 characteristics (reflective, resourceful, inclusive, integrated, robust, redundant, flexible) Resilience is measured based on: - 12 goals (**e.g.** Minimal human vulnerability, Diverse livelihoods and employment, Collective identity and mutual support, Sustainable) - 52 indicators (**e.g.** Effective emergency response services, Cohesive communities, Proactive corruption prevention, competent policing, emergency medical care)
City Water Resilience Approach	The Rockefeller Foundation and The Resilience Shift and Arup	Assess water system resilience.	Infrastructure	In water research: basic service provision, flood risk, environment, economic, sociocultural Resilience is measured through a hierarchy of quantitative indices: - 4 dimensions (Leadership and strategy, planning and finance, Infrastructure and ecosystems, health and well-being); - 12 goals (**e.g.** effective asset management, effective disaster response and recovery, adaptive and integrated planning, Prosperous communities) - 53 sub-goals (**e.g.** Active community engagement and participation around water issues, Support for civil society institutions working on water issues, Long-term strategy development and action planning around water, Incorporation of local knowledge and culture into decision-making, Promotion of clear stakeholder roles and responsibilities, Dissemination of accurate data, effective regulation and enforcement around qualities of water service provision)

Table 2.2: Approaches to evaluate resilience in several domains (adapted from (Borisoglebsky et al., 2019)) (Continued)

Approach name	Publisher	Purpose	Unit of analysis	Aspects covered
Australian Natural Disaster Resilience Index	Australian Government	Assess disaster resilience at a national scale in Australia	Country, community	9 themes: Coping capacity (social character, economic capital, infrastructure and planning, emergency services, community capital, information engagement); adaptive capacity (governance, policy and leadership; social and community engagement). Resilience is measured based on - 35 indicator dimensions (**e.g.** Immigration, Internal migration, Sex, Age, Employment, Planning for natural hazards, Emergency response workforce) - 77 indicators divided by theme (**e.g.** leadership style, resource levels, Land use planning, Disaster management planning, local government financial status, Social health Atlas, strategic directions, presence of research organizations)
Resilience, Adaptation and Transformation Assessment	CSIRO, Australia	Understand resilience, adaptation and transformation of agro-ecosystems to meet the Sustainable Development Goals	Agro-ecosystems	Category specific indicators related to irrigated rice, fallowing, herbage intake, nutrient balance, etc. Resilience is measured based on 36 indicators (**e.g.** Levels of agrochemical use, Area cleared for upper catchment agriculture, Ability to change laws when new circumstances require it, Openness to criticism and new ideas, Strong feedback to research, governance and management, Gender roles, Money, Energy)

Table 2.2: Approaches to evaluate resilience in several domains (adapted from (Borisoglebsky et al., 2019)) (Continued)

Approach name	Publisher	Purpose	Unit of analysis	Aspects covered
Resilience Assessment Framework	The European Virtual Institute for Integrated Risk Management	Assess three types of resilience of critical infrastructure, structural, interrogative, transformative / adaptive.	Infrastructure	System/physical, information/data, societal/political, cognitive/decision-making, operation/business As of the 6th of February 2019, resilience assessment was based on 2723 approved indicators (**e.g.** "Can appropriate security controls requested in any case?", Completeness of investigation procedures, Test bed that mimics a production environment, KPI-Traffic public transport flow rail & light rail train flows).
Resilience Measurement Index	Argonne National Laboratory	Capture the fundamental aspects of resilience for critical infrastructure with respect to all hazards, support decision management related to risk management, disaster response, and maintenance of the business community	Infrastructure	Preparedness (awareness, planning), mitigation measures (mitigation construction, alternate site, resources mitigation measures), response capabilities (onsite capabilities, offsite capabilities, incident management & command center characteristics), recovery mechanisms (restoration agreements, recovery time) Resilience is evaluate based on 4 levels. For example, for level 1 "Response capabilities" exists - 3 "level 2" items (Onsite capabilities, Offsite capabilities, Incident management & command center (IMCC) characteristics) - 7 "level 3" items arranged by the "level 2" items (**e.g.** New response measures, Incident management capabilities, Resource service level agreements, Equivalent number of dependencies) - 11 "level 4" items arranged by the "level 3" items (**e.g.** Communications and notification, Immediate onsite response, Significant onsite response, Onsite visits, Communications. Contingency/business continuity plans)

Table 2.2: Approaches to evaluate resilience in several domains (adapted from (Borisoglebsky et al., 2019)) (Continued and end)

Approach name	Publisher	Purpose	Unit of analysis	Aspects covered
Flood Risk Measurement for Communities	Zurich Flood Resilience Alliance	Measure flood risks of communities (villages) and guide communities towards a higher resilience against flood risks	Community	Financial, human, natural, physical, political, social, process and institutions Resilience is measured based 64 indicators (**e.g.** Percent Agricultural occupations, % Member of savings or credit groups, Percent of HHs who borrowed, Percentage of 'vulnerable', % of HH w/ 5+ years education, % of Household Migrants, Average Months way per migrant / year, "Are bus services disrupted in the monsoon? Yes: 1, No: 0", "Condition of Bridges Very Poor: 1, Poor 2, OK: 3, Good: 4, Very Good: 5", "How many community managed boats?", % Households with cell phone, % of Households with access to LPG/cooking gas)

2.5 Critical Analysis of The Literature

This section offers a critical analysis of the literature on risk management, vulnerability management, agility, and resilience. It does so by reviewing the terminology and perspectives, and by highlighting the similarities and differences within the project management context. The analysis in this section will be conducted by thoroughly explaining Figure 2.1. This explanation will be supported by an example from the implementation of an IT application. An IT implementation project goes mainly through the following phases; launch, discovery (where the requirements and data are collected to better configure the application based on the client needs), configuration, tests, go-live, support. The project team for this type of project is mainly composed of the project manager, the implementation consultants, and subject matter experts from both the company side and the client side. The most important phase is the "go-live" phase where the client will stop using its legacy system and start using the newly configured application. Therefore, not respecting the go-live date (which is fixed at the end of the discovery phase) may engender additional costs and many internal and external frustrations.

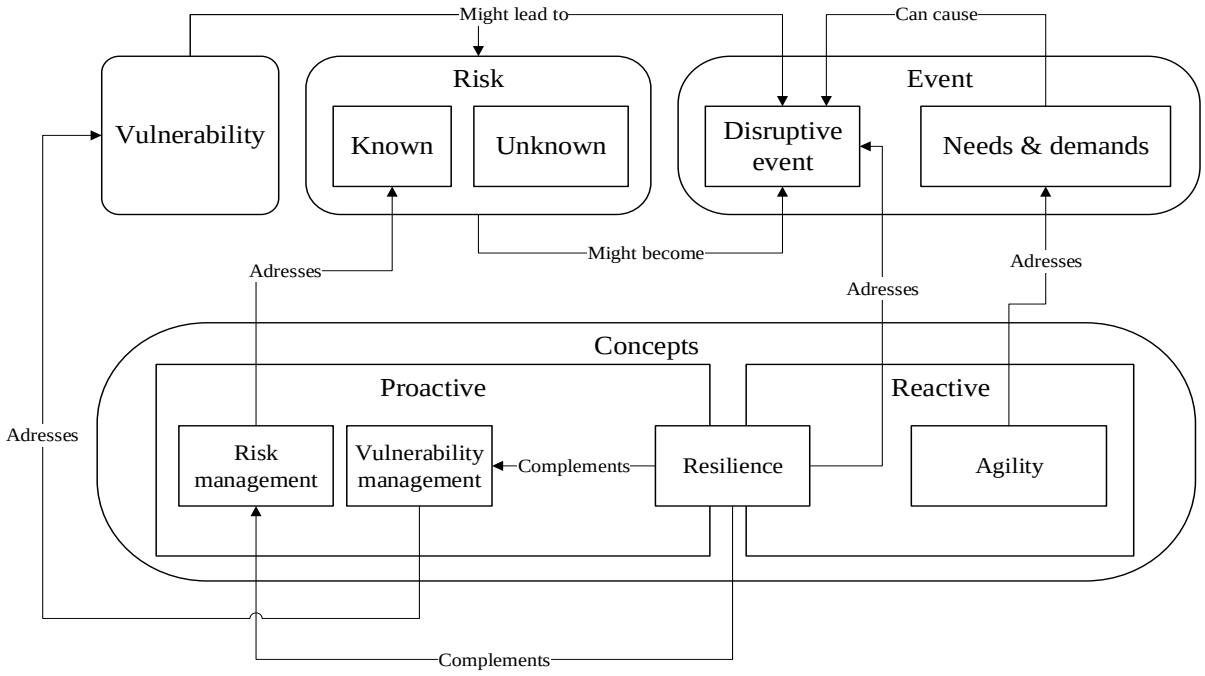

Figure 2.1 – Relationship between risk management, vulnerability management, resilience and agility from a project management perspective (inspired by Mochizuki et al., 2018)

The first concept is risk management. Despite the fact that risk management practices is less implemented and used in the industry (Besner & Hobbs, 2012; Sanchez et al., 2009), these practices work well in low uncertain environments where the project is well defined and disruptive events can be easily (to a certain extent) identified (known events), assessed, and analyzed (Besner & Hobbs, 2012b). Thus, as shown in Figure 2.1, risk management is considered a proactive concept that addresses known risks, but it encounters difficulties in addressing unknown or unpredicted events (De Bakker et al., 2010; Thamhain, 2013). These risks might become disruptive events at a certain point in time during the project life-cycle. Risk management practices focus on dealing with the sources of known events without emphasizing the management of their consequences on the project's objectives when these events occur (Blay, 2017). This is because the consequences of these events, if they occur, are hardly predictable in advance due to the dynamic continuous changes on the project's conditions. Also, it is hard with actual risk management practices to identify *all* threats that may cause negative impact to the project. Therefore, more flexible practices are needed that take into consideration the characteristics of a disruptive event upon occurrence, and that offer actions to limit losses caused by this disruptive event as much as possible (Anholt et al., 2018)[5]. For example, in IT implementation projects, inaccurate collection of requirements at the discovery phase is considered a risk that can impact the configuration phase and lead to delays. This is a known risk that can be mitigated through rigorous follow-up with the client to get accurate information, or by informing the client that a sign-off is required at the end of the discovery phase where any changes during the next phases (configuration, testing, etc.) will engender additional costs. These actions can encourage the client to provide accurate information. However, what would be the consequences of configuring the application based on data that is not accurate? How to manage issues caused by this inaccuracy during the go-live phase where the frustration level is extremely high? That is why, complementing practices are needed to cope with this type of disruptive events.

[5] To avoid repetition in this dissertation, more information on risk management and resilience is available in Chapter 4. More information on the limitations of project risk management is available at section 4.2.2

Vulnerability management is also a proactive concept that focuses on identifying, analyzing, and mitigating project weaknesses instead of risks as shown in Figure 2.1. In fact, dealing with project's weaknesses is important, it aims to reduce (to a certain extent) (1) the probability of having specific types of disruptive events, and (2) the susceptibility of the project to the disruptive events damaging effects (Mochizuki et al., 2018). For instance, having a senior implementation consultant may reduce the risk of poorly collecting requirements during the discovery phase, or the risk of having a poor configured application. However, for the system to withstand the effects of an event, not only should the event be known, but its context and the project's characteristics when the event occurred need to be understood and taken into consideration (McManus, 2008). Thus, it is of equal importance to develop context-specific capacities to cope and recover from disruptive events along with the capacities to identify, analyze, and mitigate project vulnerabilities. For example, a vulnerability can be the presence of a junior implementation consultant instead of a senior one for an IT implementation project that requires a senior implementation consultant. This vulnerability may lead to poor collection of requirements and/or poor quality of configuration. Thus, making the project more susceptible to disruptive events with a lack of expertise and knowledge to effectively deal with these events. Therefore, vulnerability management aims to understand this type of vulnerabilities (among other types) and to prepare a mitigation plan to overcome them. However, vulnerability management does not eliminate the fact of having poor collection of requirements or poor configuration that may lead, for example, to severe issues in the go-live phase. In addition, even if a senior implementation consultant is part of the project team, with enough knowledge and expertise to deal with the consequences of poor configuration or poor collection of requirements, this senior team member can be absent when an issue caused by a poor configuration occurs. So, what to do in this case? How to cope with this issue? That is why additional practices are needed to cope with this type of events upon occurrence. Therefore, resilience thinking complements vulnerability management by offering coping strategies to improve the project capacity to cope with disruptive events on occurrence.

The third concept is agility. Agility is mainly used in IT projects and offers an iterations-driven approach to better capture and address clients' needs and demands during the project life-cycle (Tomanek & Juricek, 2015). Four points aim to distinguish between agility and resilience. First, agility focus on coping with events generated from changes on needs and demands to satisfy clients

and stakeholders. These changes can cause disruptive events if not handled accurately. However, agility is not oriented toward coping with disruptive events on occurrence either caused by new needs or demands, or by other factors. For example, during an IT project life-cycle, having a technical difficulty with a software application used mainly by a software developer to produce an important deliverable, is a disruptive event that falls outside the scope of new needs from customers or stakeholders, or new technology or market demands. Therefore, other capacities are needed to cope with this type of disruptive events. Second, agility tends to ignore the organizational context in which the project is carried out (Hobbs & Petit, 2017). Alternatively, from a resilience perspective, the project is on continuous interaction with its environment. These continuous interactions play a significant role in promoting project resilience (Schroeder & Hatton, 2012). Third, agility focuses more on reactive actions and less on proactive actions (Baweja & Venugopalan, 2015). It focuses on changing specifically the project plan at the project level. This change is completed by the project team members (Ambler, 2009). Resilience, on the other hand, includes proactive and reactive capacities. It "*includes both the ability to "prevent or resist being affected by an event" and to "return to an acceptable level of performance in an acceptable period of time after being affected by an event"*" (Wieland et al., 2013, p. 301). Resilience focuses on adapting the project as a system (not only the project plan). The adaptation could affect the project plan along with other elements like, for example, the project management information systems, the resources database, external partnerships, etc. Fourth, from a resilience perspective, the adaptation is related to the behavior of the system and its relationship with its environment. Therefore, it could be completed at the project level and/or at the organization level to contribute to the resilience of the project. Scaling agility frameworks do exist to promote agility at the organization level, but these frameworks are still facing many challenges to improve the relationship between the organization and the project, and to contribute in making the project more agile (Leffingwell, 2007). In fact, these frameworks aim to learn from the application of agility at the project level and adopt this knowledge at the organization level. In addition, these frameworks still require testing and validation to verify their applicability at the organization level (Hobbs & Petit, 2017). As an example on agility, in an IT implementation project, agility offers strategies to keep the client and stakeholders involved through continuous meetings to quickly adapt to needs and demands. This adaptation can be achieved by updating the discovery document (a document

issued at the end of the discovery phase), by advising the concerned implementation consultants, who in turn, adjust the configuration in consequence. However, what strategies are offered by the agility concept to deal with a technical disfunction on the configured application when submitting your first official request through the application at the go-live phase? How to adapt to this kind of disruptive event? Therefore, additional practices and strategies are needed to cope with this type of events and to ensure as much as possible a successful delivery of the project's objectives.

The concept of resilience complements risk management and vulnerability management by (1) imbricating functional attributes relevant to practices aiming to deliver a system service when the system is in an acceptable state, and (2) by introducing a shift in the system to a desirable state when faced with disruptive events. In the second case, it is of equal importance to manage the system to benefit from the new desirable state once the shift is completed (Florin & Linkov, 2016). From a project management perspective, it is not only important to have the right tools to deal with risks (at the event level), with vulnerabilities (at the system level), or to deal with changes from the customers or stakeholders needs and requirements (at the stakeholders, clients and team members level). It is of equal importance to work on the project behavior and to have the toolkit to think, act, and manage efficiently the consequences of disruptive events (Klein et al., 2015). This behavioral work is important because it allows projects to adapt through a series of activities and actions when faced with disruptive events. Resilience helps focus on the project behavior and on the efficient utilization of resources once faced with disruptive events. In other words, resilience is concerned with how processes, methods, organizational structure, etc. evolve and realign to face all types of disruptive events. It offers insights to which elements mostly contribute to maintain an acceptable project functioning at a specific point in time (the time once the project is faced with a disruptive event). The concept of project resilience neither eliminates the need nor denies the relevance of risk management, vulnerability management or project agility. Instead, these perspectives contribute to project resilience, among other factors. Table 2.3 summarizes these objectives and limitations of the four concepts presented in this chapter.

In conclusion, this dissertation aims to advance knowledge on the concept of project resilience by proposing a definition, a conceptual framework, and a set of indicators to assess it through literature reviews and qualitative and quantitative studies[6].

[6] More details on the methodology and objectives of this dissertation are provided in the 3rd chapter.

Table 2.3: Concepts to deal with risks/disruptions, their objectives and limitations

Type of method	**Proactive or reactive strategy**	**Deal with**	**Objective**	**Limitations**
Management of risks	Proactive	Threat and opportunities	Identify and analyze risks, prepare mitigation plans, and control risks during the project life-cycle.	1- Limited due to uncertainties, ambiguities and interdependencies between the project's elements (Hillson, 2014; Thamhain, 2013; Ward & Chapman, 2003).[7] 2- Focus on risk sources rather than their consequences (Schroeder & Hatton, 2012). 3- Not oriented toward empowering a project's capacity to deal with disruptive events (Blay, 2017; Crawford et al., 2013).
Management of projects' vulnerabilities	Proactive	Project's weaknesses	Reduce a project's vulnerabilities by managing weaknesses. These weaknesses may lead to disruptive events.	1- Focus on the disruptive events' sources rather their consequences (Blay, 2017; Crawford et al., 2013). 2- Reducing vulnerabilities may reduce the occurrence of risks, but do not necessarily manage them effectively if they occur (Geambasu, 2011; Schroeder & Hatton, 2012). 3- Not oriented toward empowering a project's capacity to deal with disruptive events (Blay, 2017; Zhu, 2016).

[7] More details on uncertainties, ambiguities and interdependencies between a project's elements are provided in Chapter 4.

Table 2.3: Concepts to deal with risks/disruptions, their objectives and limitations (Continued and end)

Type of method	Proactive or reactive strategy	Deal with	Objective	Limitations
Project agility	Reactive	New customer or stakeholders needs, or technology or market demands	Develop a project's capacity to change the project plan in response to customers' or stakeholders' needs, market or technology demands.	1- Does not necessarily focus on disruptive events; emphasizes the importance of customers and stakeholders. Focusing only on agility may make a project more vulnerable (Berglund, 2012; Werder & Maedche, 2018). 2- Agility **as a concept** is still new; focuses mainly on the individual project, mainly in IT, and ignores the organizational context in which the project is carried out (Hobbs & Petit, 2017).
Project resilience	Proactive and reactive	Disruptive events	Foster a project's capacity to deal with disruptive events. [8]	1- Resilience is still a new concept in project management that requires a clear conceptualization (Hillson, 2014; Turner & Kutsch, 2015). 2- Lack of empirical studies of this concept (Thomé et al., 2016) 3- Lack of indicators to assess resilience in project management (Blay, 2017; Geambasu, 2011). 4- Studies of resilience in project management are mainly within the construction field (e.g., Blay, 2017; Geambasu, 2011).

[8] Further explanations and development of the concept of project resilience and its implications for project management are provided in Chapter 4.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

This chapter presents the research design and methodology adopted in this dissertation. This is an exploratory study given the scarceness of the literature on resilience in project management. In fact, to the extent of the researcher's knowledge very few scientific studies have been actuated on the concept of project resilience. Thus, the methodology adopted in this dissertation aims to advance knowledge on resilience from a project management perspective and is organized in three main subsections that help meet this dissertation objectives.

The first subsection presents this research objectives. The second subsection illustrates the approach that will be used to answer the research objectives. Finally, the third subsection presents this dissertation structure.

3.1 Research Objectives

Even though the literature on project resilience is still scarce, two main elements were noticed:

1. There is a new significant interest in project resilience (Geambasu, 2011; Hillson, 2014; Kutsch, Hall, & Turner, 2015; Schroeder & Hatton, 2012; Thomé et al., 2016).
2. There is a need to develop indicators to assess project resilience (Blay, 2017; Geambasu, 2011; Thomé et al., 2016). As mentioned by (Blay, 2017, p. 246) "…*future work on developing or adapting measurement scales to measure capabilities identified which could be used to measure the level of resiliency of a project and thus identify areas of strength and weakness are recommended.*"

Based on these two elements and on the literature reviewed in the previous chapter, the main research question of this study is:

How can resilience be conceptualized in the project management domain, and how project resilience can be empirically assessed?

The methodological approach used to answer the main question developed during the doctoral project, based on an iterative process between the analysis of the literature and the work of conceptualization. The methodological aspects to be deployed were therefore not firmly fixed at the beginning of the research. Thus, the articulation of the theoretical/conceptual dimension, on one hand, and the empirical dimension of the research, on the other hand, was the subject of a long reflection process and proved to be the right way, as the conceptualization of resilience from a project management perspective progressed.

In fact, the initial research work was devoted to conceptualization and led to the proposal of a theoretical framework linking various concepts necessary for the understanding of resilience in project management (see Objective 1 below and Article 1). These initial results made it possible to re-examine the choices made in terms of the overall approach (objectives, deliverables, methodology), so that the choice to study the resilience indicators more specifically became obvious. Indeed, an experimental approach would have been inappropriate or even impossible, given the scarcity of operational definitions of constructs related to the proposed conceptual model. This argument is also supported by recent studies on resilience in project management, which emphasized the importance of developing indicators to assess project resilience (Blay, 2017; Geambasu, 2011; Thomé et al., 2016; etc.). The formulation of objectives 2, 3, and 4 should therefore make it possible to fill this gap and make a significant scientific contribution. To achieve this contribution, a scale development approach is adopted in order to propose indicators to assess project resilience by following the guidelines from Hair et al. (2010) and Hinkin (1998). The work of Hinkin (1998) and Hair et al. (2010) has been adopted in many scientific studies on project management (e.g., Besner & Hobbs, 2012; Lehnen et al., 2016) and organizational resilience (e.g., Lee et al., 2013; Stephenson, 2010), and in scientific research on management.

That being said, the above stated question will be addressed by the following objectives:

1. <u>Propose a conceptual framework of project resilience:</u> Given the scarcity of the literature on resilience in project management, the proposed framework is established through a theorizing effort (theory building) (Burnard & Bhamra, 2011; Lynham, 2002; Meredith, 1993). This effort is supported by various literature on the concept of resilience from

diverse perspectives. In addition, this effort adds value to the existing theories in project management, more specifically risk management. Consequently, the dimensions of the novel concept of project resilience are established and the relationships between project resilience, current risk management practices, and known and unknown risks are proposed.

2. Develop an understanding of resilience indicators and measurement in organizational settings: Most projects exist in an organizational context to meet the strategic objectives of the latter (Aubry, Hobbs, & Thuillier, 2007; Thakurta, 2015). Consequently, several phenomena observed traditionally in the project's contexts share several similarities with the issues raised by authors who are interested in organizations. (Anbari, 1985; Sydow & Braun, 2018; Thakurta, 2015). In addition, indicators to assess organizational resilience exist and are validated empirically by many authors (e.g. [Hatton et al., 2018; Lee, Vargo, & Seville, 2013; McManus, 2008; Stephenson, 2010]). Therefore, exploring organizational resilience can help in the conceptualization of project resilience, and in the proposition of indicators to assess it.

3. Develop a set of indicators to assess project resilience: This Objective aims to propose a set of indicators to evaluate project resilience. Based on the achievement of the 1st and the 2nd objectives, a qualitative study is conducted among senior project managers, from different fields, to understand how disruptive events are successfully managed. Case studies are also discussed and analyzed. Therefore, the indicators proposed to assess project resilience are the result of a conceptual work both theoretical and empirical, since the literature are crossed with the qualitative study.

4. Validate the indicators to assess project resilience: After achieving the 3rd objective, the indicators derived are therefore validated using principal component analysis, confirmatory factor analysis, and convergent and discriminant validity (Hair, Black, Babin, & Anderson, 2010; Hinkin, 1998). Based on the researcher expertise and knowledge of the sector,

information technology[9] (IT) projects have proven to be a relevant choice when conducting the quantitative analysis. Unlike the qualitative study where different fields were taken into consideration, for the quantitative study only one field (IT) is considered to ensure first the internal validity (Hair et al., 2010).

3.2 Research Approach

In this dissertation several approaches are adopted depending on the objectives presented in the previous section. However, before explaining how the objectives of this dissertation will be fulfilled, it is important to define first the term "indicator." Then explain why the focus in this dissertation is on adopting a methodology that aims on proposing new indicators for project resilience instead of improving existing indicators of other, close, fields.

3.2.1 Definition of An Indicator

An indicator is an "*observable trait of a thing (physical, biological, social, or other) that is rightly or wrongly assumed to point to the value of some other trait, usually an unobservable one, of either the same or a different thing*" (Bunge, 1975, p. 66). An indicator aims to associate a value or a symbol to a part of a concept, and helps a researcher in choosing the right type of data to collect (Thietart, 2014). It represents a particular facet of a concept (Hair et al., 2010). In social science or in management, an indicator is considered in a broader perspective than in physics of biology. Therefore, a research can use/develop an indicator even if its value is not represented in a number (Thietart, 2014).

In the particular area of resilience indicators, Carpenter et al. (2005) present four empirical approaches that can be used by researchers to propose indicators. The first approach is to

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[l]IT is defined as "*a field of engineering, which is derived from combination of computers and telecommunications science and employed in order to, retrieve, transmit and manipulate data. It is related to the study, design, development, application, implementation, support or management of computer-based information systems*" (Shabanesfahani & Tabrizi, 2012, p. 43)

understand the history of a system (e.g. an organization) and analyze its coping capabilities when faced with disruptions (Historical profiling). The second approach is to build an understanding on disruptions management, through workshops with stakeholders (Stakeholders assessments). The third approach is to simulate scenarios to explore the potential thresholds of a system. By using this approach measurable aspects are identified that have direct relationship with the thresholds modeled (Model exploration). The final approach is to compare case studies to understand how systems with many similarities react differently to disruptions. These case studies can be examined to detect observable properties related to the systems' resilience (Case study comparison).

In their work on measuring safety climate, Flin et al. (2000) distinguish between two types of indicators; the lagging indicators and the leading indicators. The lagging indicators are measures based on retrospective data. For instance, causes of certain fatalities are used as predictors to better deal with future crises. Alternatively, the leading indicators measure observable processes, methods, structures, etc. that contribute to the system continuous functioning. Therefore, leading indicators allow the identification of the system weakness to take proactive actions (Flin et al., 2000; A. V. Lee et al., 2013).

Each approach has its strengths and weakness. For instance, lagging indicators, historical profiling and case study comparisons allow an interesting understanding of the system's abilities to cope with future disruptions having similar characteristics as those already identified and analyzed. However, the applicability of these coping abilities on future disruptions is not guaranteed due to changes on the context of the disruption and the environment of the system. On the other hand, model's exploration is criticized for simplifying the reality due to key model parameters (Linnenluecke & Griffiths, 2011).

In this dissertation, leading indicators are proposed in order to build an understanding on disruptive events management. This choice is made based on the uniqueness of projects which diminish the appropriateness of indicators based on retrospective data (lagging indicators, historical profiling, or case study comparison). In fact, the same disruptive event can have different context and characteristics from one project to another. For example, even when working on IT implementation projects where the same modules and software applications are configured and deployed, the same

disruptive events can be managed differently from one implementation project to another. Therefore, it is more interesting to understand observable processes, methods, structures, etc. that contribute to effective and efficient coping when faced with disruptive events, and to project resilience.

3.2.2 The Choice of Methodology

For the first objective, a theory building approach is adopted. As mentioned by (Burnard & Bhamra, 2011) "*The basis of theory building is drawing conclusions through establishing and developing definitions, domains, relationships and predictions. Theory building research thereby forms an iterative process that cycles through phases of description, explanation and testing*" (Burnard & Bhamra, 2011, p. 5585) [10].

As for the second objective, a literature review of recent empirical studies is conducted to collect information on the indicators used to assess organizational resilience[11].

The third and the fourth objectives of this research are achieved by following the scale development processes suggested by Hinkin (1998). In fact, based on Thietart (2014) when there is a lack of indicators to assess a specific concept, a researcher can adopt one of two strategies. The first strategy is to improve what already exists, within the field or from closely related fields. The second strategy is to innovate by developing new indicators specific to the context being studied.

In the case of this research, it was decided to adopt the second strategy and to develop indicators to assess project resilience by exploring the project management reality, and by taking into account the following observations:

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[10] To avoid redundancy of information, more details on the adopted methodology to achieve the first objective can be found in the 1st article – section 4.3 Methodology)

[11] To avoid redundancy of information, more details on the adopted methodology to achieve the second objective can be found in the 2nd article – section 5.3 Methodology)

1. Based on our research, and as concluded and proposed by scientific authors who worked on the concept of resilience in project management (e.g. Blay (2017); Thomé et al. (2016); Crawford et al. (2013); Geambasu, (2011)) there is a lack of studies on indicators to assess resilience in project management;
2. Indicators to assess resilience in other fields, such as organization, critical infrastructure, climate, community, etc. do exist. However, as clarified in chapter 2 (the literature review) there is no consensus on a definition for resilience, and on a specific set of indicators to assess it even within the same field (Anholt et al., 2018, Chapter 18). Therefore, choosing a specific set of indicators among many others, in order to improve and adapt them to the project management context, is very hard to justify.

This choice of strategy is also supported by Hair et al. (2010) who mentioned "*Scale development is appropriate when a researcher is studying something that does not have a rich history of previous research*" (Hair et al., 2010, p. 567). Therefore, applying scale development in this research is appropriate because resilience, as already mentioned in previous sections, is a new and novel concept in project management (Thomé et al., 2016). In addition, Hinkin's work is adopted by many studies on scale development research in management studies (e.g. Holt, Armenakis, Feild, & Harris [2007]; Slavec & Drnovsek [2012]; Swanson [2009]) including disquisitions that aimed to propose indicators to assess organizational resilience (e.g. McManus [2008]; Stephenson [2010]). Therefore, Hinkin's scale development process is used in this dissertation. This process goes through 6 steps; (1) items generation, (2) Questionnaire administration, (3) Initial item reduction, (4) Confirmatory factor analysis, (5) Convergent/discriminant validity, (6) Replication (Hinkin, 1998). All these steps and their relationship with this dissertation will be explained in detail in the next sections.

Central to the process of developing indicators is the concept of validation. In this particular context, it is defined as the process by which one can establish the relevance and reliability of a particular purpose (Worth & Balls, 2002). From the scale development perspective adopted in the current research, the validation process refers to the relationship between project resilience and the indicators proposed to measure it (Edwards, 2003). It is related to "*the extent to which the scale*

measures what it is purported to measure" (Hinkin, 1998, p. 105). Therefore, project resilience validity concerns the degree to which project resilience proposed indicators represent the concept of project resilience. It is an ongoing process where every application of the indicators to assess project resilience offers additional evidence regarding project resilience validity, and may result in generating additional indicators. Thus, the validation is a matter of cumulative evidence on the relationship between project resilience and its indicators (Edwards, 2003). Many techniques can be used for validation purposes, however, as argued by Swanson (2009) *"…although researchers can use another related technique, item analysis, in developing reliable and valid measurement items, factor analysis should be considered as a better tool for the development and validation of measurement tools in organizational study, particularly for the measurement of multidimensional constructs*" (Swanson, 2009, Chapter 11, p. 183). Factor analysis is represented in steps 3 to 6 in Hinkin's scale development process and will be used in this dissertation to validate the indicators proposed to assess project resilience.

3.2.3 Step 1: Item Generation

In this step the inductive approach was adopted. This approach uses empirical data to propose and formulate novel theoretical propositions (Swanson, 2009). It is mainly used "*when the conceptual basis for a construct may not result in easily identifiable dimensions for which items can then be generated*" (Hinkin, 1998, p. 107). This seems particularly relevant to project resilience as a new topic, and where very few theoretical contributions have been made in the literature (Thomé et al., 2016). Such approach allows generating a set of indicators from a grounded empirically-based research aiming at collecting shared understanding amongst a group of relevant organizational actors.

Specifically, the data collection was carried out through a series of semi-structured interviews for it helped gather, as stated by (Eisenhardt & Graebner, 2007, p. 28) "*…rich, empirical data, especially when the phenomenon of interest is highly episodic and infrequent."* It is also to mention that interviews were also adopted by many studies to develop indicators to assess organizational resilience (e.g. Lee, Vargo, & Seville, 2013; McManus, 2008; Stephenson, 2010).

As suggested by (Yin, 2014) a sample size between 1 and 10 is recommended for qualitative studies. The number of participants is determined based on the data saturation level and the satisfaction of the researcher on the answers of the research questions (Yin, 2014).

A total of 10 semi-structured interviews were conducted between September and October 2018 (Table 3.1 presents the dates of signing the consent form and the dates of the interviews) with senior project managers belonging to different industries[12].

[12] To avoid redundancy of information, the characteristics of respondents who participated in the interviews can be found in Table 6.2 – 3rd article (Chapter 6)

Table 3.1: Dates of signing the consent form and the dates of the interviews

Interviewee[13] #	**Date of signing the consent form**	**Date of the interview**
1	22nd of September 2018	22nd of September 2018
2	22nd of September 2018	22nd of September 2018
3	22nd of September 2018	23rd of September 2018
4	23rd of September 2018	23rd of September 2018
5	24th of September 2018	24th of September 2018
6	25th of September 2018	25th of September 2018
7	27th of September 2018	27th of September 2018
8	1st of October 2018	1st of October 2018
9	2nd of October 2018	3rd of October 2018
10	4th of October 2018	4th of October 2018

These projects managers were selected based on the following criteria:

1. Males or females at least 18 years of age
2. Project managers with more than 3 years of experience[14], currently practicing project management in private and public organizations, and who have dealt with unforeseen and unknown risks in the course of their projects
3. Located within the greater Montreal area

[13] The interviewee names will not be revealed for confidentiality reasons

[14] Previous studies on project management suggested that project managers with more than 3 years of experience are considered seniors (e.g. (Hamersly, 2015; Harvett, 2013; Napier, Keil, & Tan, 2009)). However, and as suggested by Bluhm et al., (2011) and Schultze & Avital, (2011), it is during the interview process that the researcher examines how the interviewees interpret the research questions based on their experiences.

The purposive sampling technique is used to recruit project managers based on their availability, and the subjective judgment of the researcher given his rich experience in project management. This technique targets a specific group of respondents. It can be used to learn from "*unusual manifestations of the phenomenon of interest, such as outstanding success/notable failures*" (Swanson, 2009, p. 51). The project managers were solicited via phone or email from the personal researchers contact. Upon recruitment, the researcher sent a letter of invitation (Appendix A for French, Appendix B for English) containing the objectives of the project, the conditions of the interview, as well as the main directives related to confidentiality and data processing. The same (more detailed) information is provided in the consent form (Appendix C for French, Appendix D for English), before starting the interview. The questions of the semi-structured interviews are available in Appendix E for French and Appendix F for English.

The goal was to understand how project managers are aware of, address, and manage disruptive events that occur during the project life-cycle. During the semi-structured interviews, two series of questions were asked. The first series of questions is related to the current methods used by the respondent, in most common projects, to identify project weaknesses and be prepared to deal with disruptive events. The second series of questions is related to the identification and the management of a specific major disruptive event (a case study). Each interview lasted between 30 and 45 min, either in person or over the phone, and were recorded after getting the consent of the interviewees[15]. It was decided to stop interviewing respondents after noticing the same pattern of answers from one interview to another, also called "data saturation" in qualitative studies. (Hinkin, 1998)

As for the number of items Hinkin argues that "*there are no hard-and-fast rules guiding this decision, but keeping a measure short is an effective means of minimizing response biases caused by boredom or fatigue*" (Hinkin, 1998, p. 109). Based on this fact and to stay in line with social science literature (Stephenson, 2010), it was decided to produce at least 3 items per indicator.

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[15] Details on the interviewees and the case studies can be found in Table 6.2, 3rd article (Chapter 6).

Additionally, a 5-point Likert-scale was used as the research instrument. The scale reads from strongly disagree to strongly agree with a neutral mid-point.

3.2.4 Step 2: Questionnaire Administration

In this section the design of the survey questionnaire, the sample size, the pre-test validation, and the questionnaire launch will be discussed. Based on the results from the third article (Chapter 6), twenty-six items were proposed to measure six indicators of awareness, and twenty-two items were suggested to measure four indicators of adaptive capacity. Awareness and adaptive capacity are the two suggested dimensions of project resilience[16].

3.2.4.1 Survey Questionnaire Design

The survey questionnaire was designed in two languages; French (Appendix G) and English (Appendix H) and consists of four pages.

The first page is an introductory page in which the respondent is introduced to the objectives of the survey questionnaire.

The second page aims to gather information on the respondents and on the project in which a disruptive event is managed successfully. The information on the respondent includes the respondent's role in the project where a disruptive event was successfully addressed. Thus, the respondent can choose from the following 2 options; project manager and project team member. Project managers were chosen because they mainly deal with disruptions during the project life-cycle (Thamhain, 2013). Additionally, project team members collaborate with project managers to stay aware to possible disruptions and to help the project adapts when faced with disruptive events (Amaral, Fernandes, & Varajão, 2015). Therefore, project's team members inputs are also highly valuable. In addition, the respondent's years of experience is demanded as previous studies on risk/disruptive event management have shown that more experienced team members have

[16] The project resilience's dimensions, indicators and items are presented in Table 6.3, 3rd article (Chapter 6)

different perspective to deal with disruptive events (e.g. Harvett [2013]; Thamhain [2013]). Thus, the respondents' years of experience is considered valuable for the context of this study.

The information on the project include the type of the project in which a disruptive event is managed successfully, its initial budget and its initial schedule. These projects' characteristics are chosen because "*the majority of publications that relate risk management to project success refer to the traditional time–budget–requirements definition of project success*" (De Bakker et al., 2010, p. 501). In addition this information were used in empirical studies in which risk/disruptive events management methods were examined (Blay, 2017; Geambasu, 2011; Harvett, 2013).

All the respondents and the project's characteristics can be used in future studies to test if the project resilience indicators can have significant differences in their means within and between the different characteristics (e.g. ANOVA[17]) (Hair et al., 2010; Swanson, 2009). Appendix I presents the respondent and the project characteristics and the values of their elements in the data file.

In the third page the questions on awareness were asked. This page is organized by the awareness's indicators *(e.g. 1. Clarity of roles and responsibilities, 2. Availability of project & risk management methods).*

Finally, in the fourth page the questions on adaptive capacity were asked. This page is organized by the adaptive capacity's indicators (*e.g. Accessibility & Mobilization of Resources, 2. Responsiveness of Team Members).*

The indicators, their respective items, and the coding for each item are presented in Table 3.2. ***These indicators are the results from the third article "Benchmarking project resilience" (Chapter 6)***. The coding will be used to facilitate understanding the factor analysis results (Chapter 7).

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[17] ANOVA : "*Statistical technique used to determine, on the basis of one dependent measure, whether samples are from populations with equal means*" (Hair, Black, Babin, & Anderson, 2010, p. 3)

Table 3.2: The indicators, their items, and their coding

Indicator	Items	Coding
Awareness		
Clarity of Roles & Responsibilities **(CRR)**	1. I have a clear understanding of my tasks during the project life-cycle.	CRR1
	2. I continuously use my expertise to identify project risks.	CRR2
	3. I continuously use my expertise to assess (probability vs. impact) projects' risks.	CRR3
	4. I work in collaboration with other team members to remain alert to disruptive events.	CRR4
	5. I use field-specific practices (e. g. safety measures, protocols and certifications, etc.) to ensure tasks are completed based on field-specific regulatory compliance.	CRR6
Availability of Project & Risk Management Methods **(APRMM)**	1. Based on the project type, project management methods (e.g. project plan template, Agile, etc.) are employed to capture all project's requirements and potentially avoid possible disruptive events.	APRMM1
	2. Based on the project type, risk management methods (e.g. risk register template, Monte Carlo analysis, etc.) are used to avoid possible disruptive events.	APRMM2
	3. Lessons learned from previous similar projects are analyzed to identify project weaknesses.	APRMM3
	4. Field-specific methods (e.g. field-specific checklists, equipment installation guides and procedures, etc.) are used to remain alert to project weaknesses.	APRMM4
Alertness to Scope & Performance Deviations **(ASPD)**	1. Scope changes are continuously monitored through the project life-cycle.	ASPD1
	2. Project requirements are properly gathered from the beginning of the project.	ASPD2
	3. KPIs for the budget are continuously monitored to detect any budget performance deviation through the project life-cycle.	ASPD3
	4. KPIs for the schedule are continuously monitored to detect any schedule performance deviation through the project life-cycle.	ASPD4
	5. Quality control is continuously achieved to detect any discrepancies that may lead to disruptive events through the project life-cycle.	ASPD5

Table 3.2: The indicators, their items, and their coding (Continued)

Indicator	Items	Coding
Awareness		
Sensitivity to Environmental Changes **(SEC)**	1. External changes (e.g. changes in laws, regulations and field-specific trends, etc.) are proactively monitored (e.g. by participation with industry-specific groups or associations, etc.) to have early warnings of possible disruptive events.	SEC1
	2. Internal organizational changes (e.g. new project management processes, updates to existing methods, etc.), that may impact the project, are clearly communicated to avoid possible disruptive events.	SEC2
	3. When needed, access to resources within the organization is available to help identify project weaknesses.	SEC3
	4. When needed, access to resources within the organization is available to help assess project weaknesses.	SEC4
Efficiency of External Resources **(EER)**	1. Partnerships with external parties that have the field-specific knowledge are continuously developed.	EER1
	2. Current partnerships with external parties are continuously reinforced.	EER2
	3. Access to external resources through partnerships is possible to help identify project weaknesses.	EER3
	4. Access to external resources through partnerships is possible to help assess project weaknesses.	EER4
Leadership & Involvement of Stakeholders **(LIS)**	1. Senior managers are transparent regarding any organizational changes that may cause disruptive events during the project life-cycle.	LIS1
	2. All detected issues through the project life-cycle are communicated to senior managers, to keep them alert to possible disruptive events.	LIS2
	3. Expectations are continuously set to reinforce trust and avoid surprises.	LIS3
	4. Follow-ups (regular meetings, status calls, etc.) take place regularly to remain alert to possible disruptive events.	LIS4

Table 3.2: The indicators, their items, and their coding (Continued)

Indicator	Items	Coding
Adaptive Capacity		
Accessibility & Mobilization of Resources **(AMR)**	1. When needed, resources can be mobilized from different departments to face disruptive events.	AMR1
	2. When needed, resources can be mobilized through partnerships to face disruptive events.	AMR2
	3. Information systems are available to provide quick access to information to solve an issue.	AMR3
	4. Information systems are available to log disruptive events.	AMR4
	5. Departments can provide feedback on possible solutions to face disruptive events through information systems.	AMR5
	6. External partners can provide feedback on possible solutions to face disruptive events through information systems.	AMR6
	7. When the budget contingency is completely consumed, leadership can release additional funds to face disruptive events.	AMR7
Responsiveness of Team Members **(RTM)**	1. I tend to adopt creative solutions to face disruptive events.	RTM1
	2. I am encouraged to think outside of the box to find solutions to face disruptive events.	RTM2
	3. I have the expertise to deal with disruptive events.	RTM3
	4. When faced with disruptive events, it is a priority to find the best ways to avoid them.	RTM4
Effectiveness of Communications & Relationships **(ECR)**	1. Clear explanations of issues and possible solutions are provided to all stakeholders through transparent communications.	ECR1
	2. Stakeholders, including the client, are encouraged to take ownership of the issue and any possible solutions.	ECR2
	3. Stakeholders are involved through continuous follow-ups (e.g. regular meetings, status calls, etc.) to ensure proper management of disruptive events.	ECR3
	4. Stakeholders are open to reassess project objectives (e.g. new ways of doing things, new roadmap, new strategies, etc.), if needed, to face disruptive events.	ECR4
	5. A clear escalation plan is available to face disruptive events.	ECR5

Table 3.2: The indicators, their items, and their coding (Continued and end)

Indicator	Items	Coding
Adaptive Capacity		
Adapted & Responsible Decision Making **(ARDM)**	1. Senior managers plot a course of actions to face disruptive events.	ARDM1
	2. Senior managers ensure actions are implemented in the right way and at the right time to effectively face disruptive events.	ARDM2
	3. Senior managers adapt their strategies to face disruptive events based on the project's importance to the organization.	ARDM3
	4. Stakeholders' satisfaction is taken into consideration when finding solutions to face disruptive events.	ARDM4
	5. Clauses in the contract can be bypassed, to a certain extent, to find solutions to face disruptive events.	ARDM5
	6. Qualified team members are encouraged to make critical decisions without the need for senior managers' approval.	ARDM6

3.2.4.2 Sample Size Calculation

Based on the guidelines of (Hair et al., 2010) the following data was used to determine the number of respondents required to conduct this quantitative study:

1. The number of factor loadings and the residuals in factor analysis. In the case of project resilience 2 factors exists; Awareness and adaptive capacity.
2. Awareness has 6 indicators measured by 26 items
3. Adaptive capacity has 4 indicators measured by 22 items
4. $\binom{6}{2} = 15$ pairwise correlations between the six indicators of awareness
5. $\binom{4}{2} = 6$ pairwise correlations between the four indicators of adaptive capacity
6. 5 is the minimum ratio (respondents by item) according to scientific studies (e.g. (Hair et al., 2010; Hinkin, 1998))

The formula to calculate the number of respondents as suggested by Hair et al. (2010) is

$$Nb\ of\ respondents = (A\ \times B\ + C) \times D$$

A: *Number of factor loadings and the residuals in factor analysis*

B: *The highest number of items between the project resilience's dimensions (in this case it is Awareness)*

C: *The highest pairwise correlation between the indicators of a specific project resilience's dimensions (in this case it is the pairwise correlation between the awareness's indicators)*

D: *the minimum number of respondents by item suggested in scientific studies (Hair et al., 2010; Swanson, 2009)*

Therefore, the number of observations required for factor analysis is: $(2 \times 26\ + 15)\ \times 5 = 335$ respondents

3.2.4.3 Pre-test Launch

Once the survey questionnaire designed and deployed on www.surveyhero.com, it was launched for a pre-test among project managers and project team members to get as much feedback as possible to improve its quality and clarity. Table 3.3 presents socio-demographic information on the respondents who participated in the pretest.

Table 3.3: the pretest characteristics of the respondents

#	**Role in the project**	**Industry**	**Years of experience**	**Project's budget**	**Project schedule**
1	Project manager	Telecommunication	11 to 15 years	$50M to $100M	Between 13 months and 3 years
2	Project manager	Government	6 to 10 years	$50K to $100K	Less than 6 months
3	Project manager	IT – Application implementation	6 to 10 years	$100K to $500K	6 to 12 months
4	Project manager	Construction	6 to 10 years	$50K to $100K	12 months and 3 years
5	Project team member	IT – Application implementation	6 to 10 years	$50K to $100K	6 and 12 months

After getting insights from the respondents, changes on the questionnaire have been done. First, options for the project schedule have been trimmed to be easier to assimilate (e.g. Between 12 months, exclusive and 3 years inclusive *TO* Between 13 months and 3 years). Second, some questions have been rephrased to make them easier to read and understand. For instance, some words in some questions were highlighted to distinguish them (*e.g. 3. Access to external resources*

through partnerships is possible to help ***identify*** *project weaknesses. 4. Access to external resources through partnerships is possible to help* ***assess*** *project weaknesses.*). Third, the time required to complete the survey questionnaire was discussed and was judged acceptable (around 10 minutes). Finally, the introductory message was adjusted to better explain the objectives of the survey questionnaire.

3.2.4.4 Questionnaire Launch

After doing the changes due to the pre-test, the survey was launched confidentially among IT project managers and project team members. The sample is a convenience sample[18] because IT practitioners were solicited in general without aiming a specific firm or the practitioners' special activities. Project managers and project team members that work in IT were invited to participate in the survey questionnaire by using social network platforms such as LinkedIn. The researcher background in IT facilitate the access to a pool of respondents. Table 3.4 presents the strategies adopted to launch the survey, the dates and the results obtained.

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[18] A Convenience sampling "*involves selecting haphazardly those cases that are easiest to obtain for your sample*" (Saunders, Lewis, & Thornhill, 2009, p. 241)

Table 3.4: Dates, strategies adopted, and number of observations collected

Date from	**Strategies**	**# of observations collected**

2/3/2019 – 8/3/2019	• 226 private messages
	• Posting on the LinkedIn private wall of the researcher. The post is shared by 4 people
	• Posting on the following LinkedIn groups:
	  ○ Agile Project Management Group
	  ○ Montreal Technology Network - Technologie de l'information du Montreal
	  ○ Software Implementation Consultants Group
	  ○ Project Management 2.0
	  ○ Project Management Passion
	  ○ IT Project Management Professionals
	  ○ Polytechnique Montréal - Groupe officiel
	  ○ PMI Montreal
		97

9/3/2019 – 15/3/2019	• 13 private messages • Soliciting a CEO of a medical IT application development company • Soliciting a Sr. VP from a telecommunication company • Posting on the LinkedIn private wall of the researcher • Soliciting PMI Toronto, and PMI Los-Angeles	32
16/3/2019 – 22/3/2019	• 4 private messages • Posting on the LinkedIn private wall of the researcher. The post is shared by 4 people	31
23/3/2019 – 7/4/2019	• Posting on the LinkedIn private wall of the researcher • Soliciting senior manager at a financial institution	19
Total		**179**

From the 179 responses received, a total of 167 were considered in the exploratory analysis. 12 responses were ignored due to the following two reasons:

1. 4 participants only responded to the respondent information (The first page);
2. 8 participants abandoned the questionnaire after responding to the first page (the respondent information) and the second page (questions on awareness).

The researcher stopped soliciting IT project managers and IT project team members when no additional responses were received after the above several tentative. (Hair et al., 2010). Because it was not possible to achieve the 335 responses threshold as discussed in section 3.2.4.2, it was decided to launch the exploratory analysis on both dimensions of project resilience; awareness and adaptive capacity, independently (Swanson, 2009; Winter, Dodou, & Wieringa, 2009). The sample of 167 responses is considered suitable for principal component analysis and confirmatory factor analysis if the two dimensions of project resilience are analyzed separately. All the results were after downloaded on a excel file (.csv) to begin principal component analysis with SPSS V24 for windows, and confirmatory factor analysis with EQS 6.1 for windows.

3.2.5 Step 3: Initial Item Reduction

For item reduction, Hinkin (1998) first recommends carrying out exploratory factor analysis (EFA) using principal component analysis (PCA). EFA is recommended when there is a lack of evidence on the factor structure. It helps reduce the number of observed variables. This reduction "*creates a more parsimonious representation of the original set of observations providing evidence of construct validity*" (Hinkin, 1998, p. 112). Additionally, PCA helps ensure that the items are unidimensional by grouping variables into related and reliable components. Hair et al. (2010) argues that "*Items are unidimensional meaning that they are strongly associated with each other and represent a single concept. PCA plays a pivotal role in making an empirical assessment of the dimensionality of a set of items by determining the number of factors and the loading of each variable on the factor(s)*" (Hair et al., 2010, p. 123). Within PCA, *Varimax* rotation is used to ensure the elimination as much as possible of intermediate values (coefficients are either large or close to zero), and to make the factors orthogonal (Hair et al., 2010). Therefore, the selected items are those that displayed saturation levels of ≥ 0.5 (factor loading score) as suggested by Hair et al. (2010).

Second, to measure the appropriateness of factor analysis, Bartlett sphericity test and Kaiser-Meyer-Olkin (KMO) are used. The Bartlett's test of sphericity is used to ensure that there is enough correlation between the variables to continue with PCA. Having a significance of less than 0.05 (represents 95% confidence) indicates that factor analysis can be achieved as the items seems to

relate to each other and they can be grouped to become factors (Hair et al., 2010). On the other hand, KMO test is used to measure the consistency and adequacy of data for factor analysis. It evaluates sampling adequacy of every variable in the model and for the model as a whole. KMO returns a value between 0 and 1, and a value greater than 0.6 indicates that the sample is adequate for PCA (Hair et al., 2010).

Third, α Cronbach is used to measure the reliability of the factor. An acceptable reliability index is basically ≥ 0.7, however, in exploratory studies a value of ≥ 0.6 is tolerated (Hinkin, 1998; Yin, 2014). Table 3.5 presents the rule of thumbs for exploratory factor analysis (EFA) proposed by Hair et al. (2010).

Table 3.5: Rules of thumbs for exploratory factor analysis (EFA) as proposed by (Hair et al., 2010)

Measure	**Rules of thumb for EFA**
Factor loadings for each PCA items	≥ 0.5
Variance explained by the PCA	≥ 0.6
Bartlett's test of sphericity	≤ 0.05
Kaiser-Meyer-Olkin (KMO)	≥ 0.5
α Cronbach	≥ 0.6

Finally, Harman's single-factor test is conducted to ensure that the problem of common method bias is reduced. This problem occurs when two constructs share common methods that "*may exert a systematic effect on the observed correlation between the measures. Thus, at least partially, common method biases pose a rival explanation for the correlation observed between the measures*" (Podsakoff et al., 2003, p. 879). This test is done by constraining the number of factors derived from the PCA analysis to be just one. Then the unrotated solution is examined to determine if one single factor accounts for most of the total variance for awareness, adaptive capacity and project resilience (Podsakoff et al., 2003).

Therefore, having a percentage of variance on the main component less than 50% means that the problem of common method bias has a minimum effect on the correlation distinguished between the measures (Podsakoff et al., 2003; Wickramasinghe & Liyanage, 2013).

3.2.6 Step 4: Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) is used to validate models by specifying which variable should load into which factor. It helps measure the consistency between the variables and the factor (Norris & Lecavalier, 2010) and "*assesses the quality of the factor structure providing further evidence of the construct validity of the new measure*" (Hinkin, 1998, p. 116). CFA calculate the validity through the factorial contributions of each item (λ) along with their level of significance. Thus, CFA is verified by the average variance extracted (AVE) and a series of fit indices that can be categorized into two groups: absolute fit indices and incremental fit indices. Absolute fit indices validate the extent to which the theoretical model reproduces the observed data (e.g. χ^2/df, RMSEA, GFI, AGFI). Alternatively, the incremental fit indices "*assess how well the estimated model fits relative to some alternative baseline model*" (Hair et al., 2010, p. 580) (e.g. CFI, IFI, Bentler-Bonett-Index). Table 3.6 presents the rule of thumbs for CFA as suggested by (Hair et al., 2010).

Table 3.6: Rules of thumbs for CFA as suggested by (Hair et al., 2010)

Measure	**Rules of thumb for CFA**
CFA standardized loadings	≥ 0.63 representing 40% of the variance in exploratory analysis
Average Variance Extracted (AVE)	≥ 50%
Fit indexes	– χ^2/df [19]: ≤ 3 – Bentler-Bonett[20] : ≥ 0.90 – CFI[21]: ≥ 0.95 can tolerate 0.90 in exploratory analysis – IFI[22]: ≥ 0.90 can tolerate 0.85 in exploratory analysis – GFI[23]: ≥ 0.90 can tolerate 0.85 in exploratory analysis – AGFI[24]: ≥ 0.90 can tolerate 0.85 in exploratory analysis – RMSEA[25]: ≤ 0.07

[19] χ^2 : Chi-Square test indicates the differences between expected and observed set of values. It is sample size sensitive. Df = degree of freedom: Sample size – number of estimated parameters (Hair et al., 2010)

[20] **Bentler-Bonett or Normed Fit Index (NFI):** "*It is a ratio of the difference in the χ2 value for the fitted model and a null model divided by the χ2 value for the null model. It ranges between 0 and 1, and a model with perfect fit would produce an NFI of 1. One disadvantage is models that are more complex will necessarily have higher index values and artificially inflate the estimate of model fit.*" (Hair et al., 2010, p. 580)

[21] **Comparative Fit Index (CFI):** An improved version of the NFI. "*The CFI is normed so that values range between 0 and 1, with higher values indicating better fit. Because the CFI is among the most widely used indices.*" (Hair et al., 2010, p. 580)

[22] **Incremental Fit Index (IFI):** This index is considered non-normed, therefore, on occasion it can has values larger than 1 or slightly below 0. (Hair et al., 2010)

[23] **Goodness of Fit Index (GFI):** "*The GFI was an early attempt to produce a fit statistic that was less sensitive to sample size. Even though N is not included in the formula, this statistic is still sensitive to sample size due to the effect of N on sampling distributions*" (Hair et al., 2010, p. 579)

[24] **Adjusted Goodness of Fit Index (AGFI):** AGFI "*tries to take into account differing degrees of model complexity. It does so by adjusting GFI by a ratio of the degrees of freedom used in a model to the total degrees of freedom available.*" (Hair et al., 2010, p. 581)

[25] **Root Mean Square Error of Approximation (RMSEA):** "*One of the most widely used measures that attempts to correct for the tendency of the χ2 GOF test statistic to reject models with a large sample or a large number of observed variables is the root mean square error of approximation*" (Hair et al., 2010, p. 579)

3.2.7 Step 5: Convergent/Discriminant Validity

Two main forms of validity can be used to gather additional evidence on the validity of a construct; Convergent validity and Discriminant validity. Convergent validity evaluates the degree of correlation between two measures where high correlations indicates that the intended concept is well measured by the scale (Hair et al., 2010). The convergent validity is calculated through the factorial contributions of each item (λ) along with their level of significance.

On the other hand, discriminant validity tends to validate the degree to which a dimension is distinct from other dimensions (Hair et al., 2010).

Therefore, the discriminant validity can be evaluated by comparing, "*the average variance-extracted values for any two constructs with the square of the correlation estimate between these two constructs. The variance extracted estimates should be greater than the squared correlation estimate.*" (Hair et al., 2010, p. 619)

Both convergent and discriminant content validity can be achieved through confirmatory factor analysis (Dunn, Seaker, & Waller, 1994; Fornell & Larcker, 1981; Hair et al., 2010).

3.2.8 Step 6: Replication

This step consists of using a new sample to validate the applicability of the new scale developed. Therefore, a new set of data is collected and steps four to six are re-executed. It is to mention that "t*o avoid the common source/common method problem, it is recommended that data from sources other than the respondent, such as peers or superiors, be collected where possible to provide evidence for construct validity.*" (Hinkin, 1998, p. 118). This step is not covered in this dissertation because it was outside the scope of this study to get another sample for additional construct validity.

3.3 Ethics Certificates

Two ethics certificates were requested during this Ph.D. The first one was used to conduct the qualitative analysis which led to the published article titled "*Benchmarking project resilience*"

(The 3rd article). This Ethics Certificate from the Polytechnique Montreal Research Ethics Board (CER) was granted on the 18th of September 2018 (file CER-1819-04 – Appendix J).

The second ethics certificate was necessary to conduct the quantitative study. It was used to design the survey questionnaire and to collect data for exploratory analysis (results are available in Chapter 7). This Ethics Certificate from the Polytechnique Montreal Research Ethics Board (CER) was granted on the 1st of Mars 2019. It has the same file name because it was requested as an amendment to the first ethics certificate. (Appendix K).

3.4 Dissertation Structure

The content of this dissertation is presented in three articles along with a validation chapter. Each article has a specific research objective and adds an important value to the research in the project and organizational management.

It was decided to publish these articles in scientific journals that:

1. Address specifically the topics of project management and organizational resilience;
2. Are open to publish literature reviews especially for the second article where indicators to assess organizational resilience were derived from empirical studies;
3. Are open to contributions aiming to the development of new and emerged concepts or new perspectives such as the integration of the concept of resilience in project management.

Rahi, K. (2019). Project resilience: a conceptual framework. International Journal of Information Systems and Project Management, (7), 69–83

This **first published article** *aims to respond to the first specific objective of this dissertation*. Its main objective is to demonstrate the relevance of the resilience concept to address current project risk management challenges. This is achieved by exhibiting existing knowledge on resilience, and by advancing an interdisciplinary understanding of the concept of project resilience. To achieve this article's objectives the literature on project risk management is first reviewed to identify current research effort and limitations of dealing with disruptions. Consecutively, the concept of resilience in its broader applicability is explored where two dimensions are derived; awareness and

adaptive capacity. The literature on the new concept of project resilience is also scrutinized where its novel nature, the lack of scientific studies to conceptualize it, and its significance to project management are demonstrated. These facts helped propose a definition and a conceptual framework of project resilience, where a set of relationships are instigated, which constitute a base line to perform further disquisitions to assess their validity. The main research question of this article is ***what is the link between project resilience and project risk management in dealing with disruptive events?***

Rahi, K. (2019). Indicators to assess organizational resilience – a review of empirical literature. International Journal of Disaster Resilience in the Built Environment, 10(2/3), 85–98

The **second published article** *aims to respond to the second specific objective of this dissertation*. It explores the empirical literature on organizational resilience. The goals consist of identifying and understanding the indicators used to evaluate organizational resilience and instigating the development of indicators to assess resilience in other areas; such as project management and critical infrastructure. This literature review has shown that there is a range of interrelated indicators aiming to measure organizational resilience in two dimensions is shown in this literature review: awareness and adaptive capacity. Awareness is the ability of an organization to assess its environment and interpret the changes in its surroundings, both now and in the future, to be proactive and better manage possible disruptive events. On the other hand, adaptive capacity is the organization's capacity to transform its structure for recovering once faced with a disruptive event. Awareness forms the main base of the organization's adaptive capacity. The main research question of this article is ***what are the indicators that were used in empirical studies to evaluate organizational resilience?***

Rahi, K., Bourgault, M., & Robert, B. (2019). Benchmarking Project Resilience. Journal of Modern Project Management, 7(1), 8

The outputs from the first article and the second article inspired the work conducted in the third article. Therefore, the core objective of the **third published article** *is to respond to the third specific objective of this dissertation.* It aims to develop indicators to assess project resilience. The progression is achieved after conducting semi-structured interviews with 10 senior project

managers, from different industries, where 10 case studies were explored and analyzed. In total, 10 indicators are proposed to assess two dimensions of project resilience; awareness and adaptive capacity. The main research question of this article is: ***What indicators can be used to assess project resilience?***

The validation of the proposed project resilience's indicators is the subject of an independent chapter in this dissertation. Figure 3.1 presents the links between the research question, the specific objectives and the articles. Figure 3.2 presents the dissertation structure by chapters. Chapter 4 is directly linked to chapter 6 because, like chapter 5, the results derived from chapter 4 set the foundation for the development of the indicators to assess project resilience (results from chapter 6). Alternatively, chapters 4 and 5 are unrelated, because the results of chapter 4 did not contribute to the advancement of chapter 5. Chapter 4 and 5 discuss different topics.

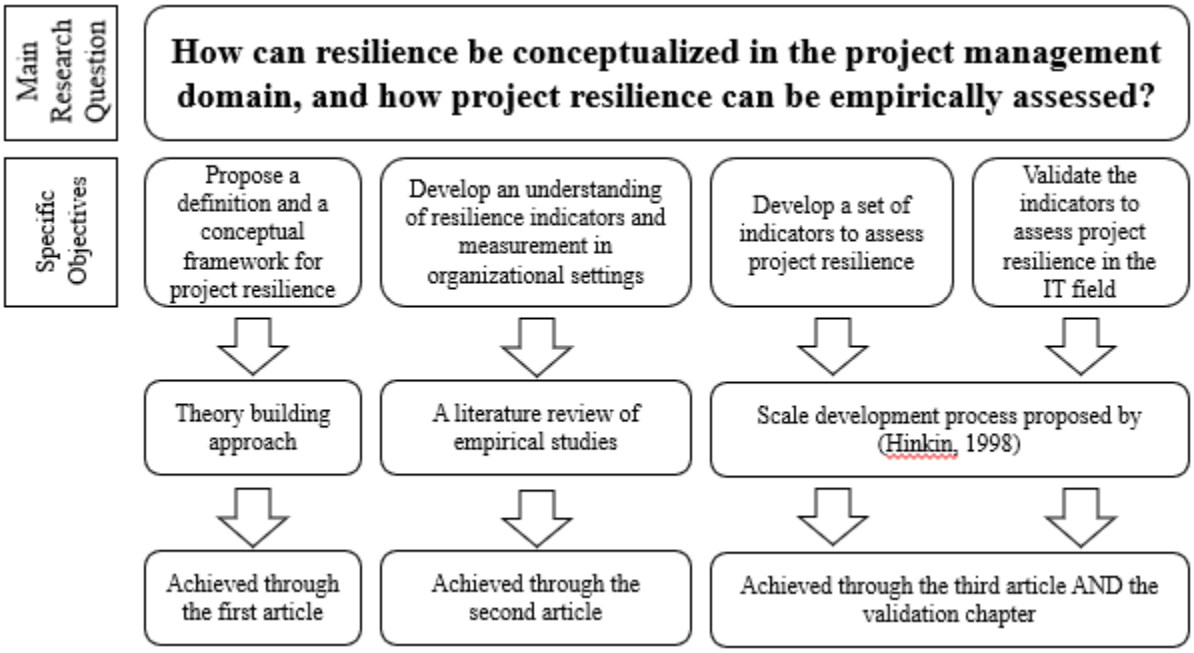

Figure 3.1 – Links between the research question, the specific objectives and the articles

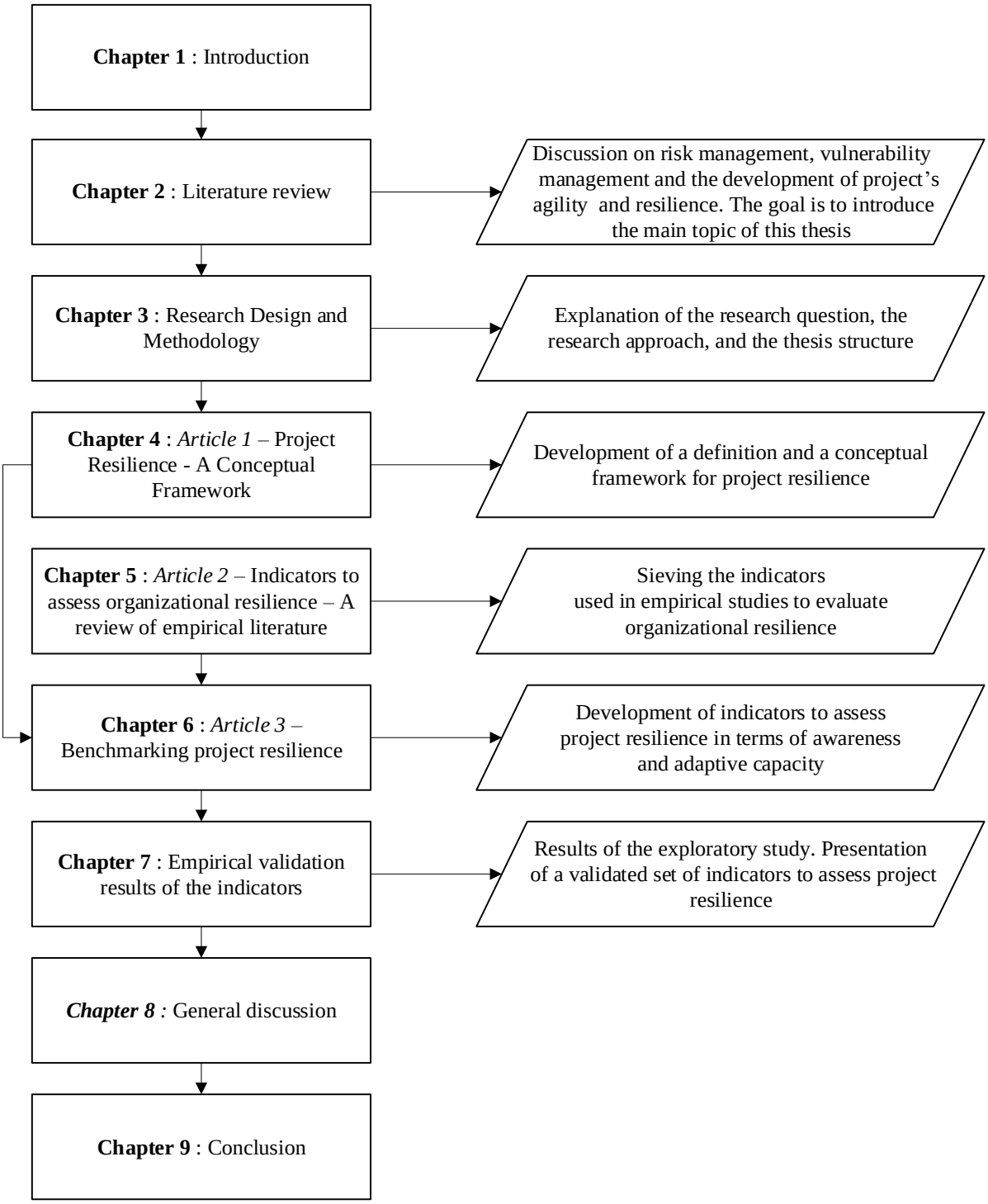

Figure 3.2 – The dissertation structure

CHAPTER 4 ARTICLE 1 - PROJECT RESILIENCE: A CONCEPTUAL FRAMEWORK

RAHI, K. (2019). PROJECT RESILIENCE: A CONCEPTUAL FRAMEWORK. INTERNATIONAL JOURNAL OF INFORMATION SYSTEMS AND PROJECT MANAGEMENT, (7), 69–83

Abstract:

Resilience is a novel but promising concept in project management studies. Resilience thinking can help projects maintain their performance through flexible, systemic and context-specific approaches once faced with disruptive events. That said, the main goal of this paper is to advance an interdisciplinary understanding of project resilience by proposing a definition and a conceptual framework of this concept. To achieve this article's objectives, the literature on project risk management is first reviewed to identify current research efforts and limitations of dealing with disruptions. Consecutively, the concept of resilience in its broader applicability is explored, where two dimensions are sieved; awareness and adaptive capacity. The literature on the new concept of project resilience is also scrutinized, where its novel nature, the lack of scientific studies to conceptualize it, and its significance to project management are demonstrated. These facts helped propose a definition and a conceptual framework of project resilience, where a set of relationships are instigated, which constitute a base line to perform further disquisitions to assess their validity.

Implications for future contributions advocate conceptual exchanges with more advanced research fields (e.g. organizational resilience). These exchanges can assist in the development of indicators to evaluate the ability of projects to deal with disruptive events and enhance their resilience.

Keywords:

project risk management, resilience, project resilience, awareness, adaptive capacity, recovery.

4.1 Introduction

A project is a temporary organization, where diverse and skilled resources work together, on a specific endeavor, for a limited period of time, in order to achieve unique objectives (Stringer, 1967). During the project life-cycle, disruptive events, either known or unknown at the beginning of the project, can cause interruption of planned tasks, and, in many cases, the whole project to fail (Blay, 2017; Geambasu, 2011). These events can affect "*everything from technical feasibility to cost, market timing, financial performance, and strategic objectives*" (Thamhain, 2013, p. 1). Thus, responding to these disruptions is considered a major challenge for practitioners as well as a relevant research topic (Zhu, 2016; Thamhain, 2013; Geambasu, 2011; Ward & Chapman, 2003).

Project risk management (PRM) is the knowledge area responsible for dealing mainly with disruptions. It aims to reduce the impact of negative risks (disruptive events that may or may not occur (Ward & Chapman, 2003)) while taking advantage of positive risks to help ensure project success (Project Management Institute, 2017; L.-A. Vidal, 2009). However, current PRM practices are often described as time-consuming and inflexible under high-uncertainty conditions (Crawford et al., 2013). These practices tend to focus on sources of disruptions, to reduce vulnerabilities, without developing a general capacity to recover from their negative consequences (Schroeder & Hatton, 2012). Therefore, these practices " … *should incorporate the capacity for projects to evolve in response to the consequences of unexpected risks"* (Schroeder & Hatton, 2012, p. 410).

To overcome the PRM limitations, recent studies have suggested integrating the concept of resilience into project management (Blay, 2017; Geambasu, 2011; Turner & Kutsch, 2015; Zhu, 2016). Resilience can be broadly defined by the system's ability (e.g. ecological, organizational, psychological, etc.) to be aware of its surroundings and to adapt for recovering once faced with disruptions (Bhamra, Dani, & Burnard, 2011). This multidimensional concept has been the subject of several research studies over time in many disciplines and domains. The concept of resilience helps recognize the inherent fallibility of a project so it can successfully recovers, when confronted with disruptive events (Zhu, 2016).

Therefore, the aim of this study is to define the concept of resilience from a project management perspective, which requires an in-depth analysis of its various components. A conceptual framework of project resilience is formulated to set the foundations for future studies of resilience in project management. This article tackles Thomé et al.'s challenge when they recently suggested that (Thomé et al., 2016, p. 1342)*:* "*the lack of coverage of the concept of resilience project management literature deserves more attention by scholars and is an opportunity to aid project management*."

Consequently, this paper is organized into four parts. First, the literature on PRM, resilience and project resilience is reviewed. The objectives are to explore the limitations of PRM practices, to sieve the resilience dimensions in their broader applicability, and to understand the current research efforts on the concept of project resilience. Second, the methodology adopted to achieve this study is discussed. Third, a definition and the conceptual framework of project resilience are presented where the relationships between its building blocks are exposed. Finally, implications for future disquisitions are proposed.

4.2 Literature Review

4.2.1 Project Risk Management

The knowledge area of project risk management includes the processes to identify risks, analyze risks, plan risks' responses, and control risks through the project life-cycle (Project Management Institute, 2017; L.-A. Vidal, 2009). It adds value to other project management methods by helping in the mitigation of uncertain conditions (Sanchez et al., 2009; Ward & Chapman, 2003). Project risk management has a direct effect on project success because it maximizes the efficiency of processes such as decision-making and communication among others (Marcelino-Sádaba, Pérez-Ezcurdia, Echeverría Lazcano, & Villanueva, 2013).

Many approaches have been proposed to manage project risks. The latter often refer to complex and sophisticated concepts and architectures. To name few examples among others, Lee and Baby (2013) (O.-K. D. Lee & Baby, 2013) developed a conceptual framework for risk management

based on the principles of service-oriented architecture (SOA). According to these researchers, this framework helps identifying risks related to the dynamic interactions that exist between human resources, processes and technology. Alternatively, López & Salmeron (2014) (López & Salmeron, 2014) have proposed a fuzzy logic system to mathematically model the risks associated with the maintenance of ERP implementation projects. This system makes it possible to analyze the impacts of risks on the objectives of the project with a reasonable degree of precision.

Despite this advancement, PRM still faces several challenges when dealing with disruptive events mostly due to the project increased complexity (Aven, 2012; Thamhain, 2013). This complexity is caused by many varied and interrelated elements operationalized in terms of differentiation and interdependence (Baccarini, 1996). It mainly leads to "*uncertainties, ambiguities, and arrays of risk factors that are often intricately connected*" (Thamhain, 2013, p. 21). Uncertainty is defined as the inability to evaluate the project's objectives and characteristics, as well as the consequences of actions and decisions on the entire project environment (Geraldi, Maylor, & Williams, 2011). It tends to be high at the beginning of a project and is supposed to diminish when approaching the closure phase (Sicotte & Bourgault, 2008; Ward & Chapman, 2003).

Alternatively, ambiguity is "*associated with lack of clarity because of the behavior of relevant project players, lack of data, lack of detail, lack of structure to consider issues, working and framing assumptions being used to consider the issues, known and unknown sources of bias, and ignorance about how much effort it is worth expending to clarify the situation.*" (Ward & Chapman, 2003, p. 99). Ambiguity often derives from cultural differences and optimism levels by stakeholders (Jaafari, 2001) consequently increasing the probability of project failure (Sanchez et al., 2009).

Finally, As mentioned by Vidal (L.-A. Vidal, 2009), non-linear and dynamic interdependencies exist between the components of the project and between the project and its environment. So, every change in any facet of the project may propagate through the other elements and therefore lead to additional, unforeseen and unpredictable risks (Hillson, 2014).

4.2.2 Limitations of Project Risk Management

As noted by Crawford et al. (2013), PRM practices are criticized for being time consuming and inflexible when dealing with disruptive events that require quick response. Geambasu (2011) explains this inflexibility by referring to the "hard" theories behind these practices. "*These theories emphasize the planning and control dimensions of a project anchored in a system of engineering methods and related tools*" (Geambasu, 2011, p. 19)

She also mentions that in many cases the poor performance of projects is due to the optimism bias and strategic misrepresentation of the projects' scope, budget and schedule. The latter lead stakeholders to ignore or underestimate risks (Geambasu, 2011).

On the other hand, Blay (2017) notes that current PRM practices focus on the source of the disruptive events in order to minimize the level of vulnerability. For instance, risk management helps manage known sources, whereas uncertainty management and crisis management focus on unknown sources [7], (Ward & Chapman, 2003), [11]. This vulnerability-reduction perspective is limiting because the "*focus is on identifying strategies to implement on disruptions perceived and also work towards predicting threat, without critically developing the general capacity (response and preparedness) for dealing with shock (sudden distress) these disruptions cause.*" (Blay, 2017, p. 1)

To address these challenges, the following avenues are proposed:

1. More flexible and context-specific methods need to be integrated in PRM. This adds a dynamic and proactive perspective to PRM where the focus is on the evolution of the project, and its ability to deal with disruptive events during its life-cycle (Crawford et al., 2013).

2. PRM practices necessitate progressing beyond the common and simplistic perspective of detecting obvious risks during the project planning phase and monitoring and controlling them on a regular basis. New methods are required to cope with unknown, unpredictable and completely unexpected disruptive events (Schroeder & Hatton, 2012).

3. The focus should not only be on vulnerability reduction, but also on factors and conditions' identification that enables a successful response to disruptive events (Geambasu, 2011). Recognizing the inherent fallibility of projects helps understand how projects maintain and recover their performance once faced with disruptive events (Zhu, 2016).

That is why recent academic research is exploring the concept of resilience in project management. In fact, "*responding to emerging unknown unknowns requires that we make our systems—and, by extension, our development projects located within these systems—more resilient. Resilient projects are nimble, flexible, and adaptable.*" (Schroeder & Hatton, 2012, p. 412)

4.2.3 Resilience and Its Definitions

Resilience is a concept widely used in many domains including ecology (Holling, 1973), psychology (Coutu, 2002), climate change (Hallegatte & Engle, 2018), critical infrastructure (Hémond, 2013; Therrien, 2010) and organization science (Sapeciay, Wilkinson, & Costello, 2017; Ortiz-de-Mandojana & Bansal, 2016; Somers, 2007). Its definitions vary depending on the subject to be analyzed whether it's a community, an organization, a project, an engineering system or others (Bhamra et al., 2011).

In 1973, Holling (Holling, 1973) pioneered studies in resilience from the ecological perspective. He differentiates between stability and resilience. Stability is the ability to emphasize the presence of a unique steady state for a system, and to conserve equilibrium around it. Resilience, on the other hand, focuses on maintaining existence of function. It is related to a complete change of the system's state into another regime of behavior.

Later, in 1996, Holling (Holling, 1996) advanced his research and distinguished between engineering and ecological resilience. Engineering resilience accentuates efficiency, constancy, rigidity and predictability of a system as measured by resistance to disturbance and speed of recovery (Bhamra et al., 2011; Holling, 1996). Consequently, a system that follows this perspective of resilience is designed to recover quickly from small disruptive events with difficulties to recover from the large ones. It is a highly controlled system that works within limited possible states (Fiksel, 2003).

Alternatively, ecological resilience focuses on the persistence, change, renewal, reorganization and unpredictability of a system. It is measured by the levels of disturbance that can be absorbed before necessitating changes to the system's structure (changes are made on variables and processes that operate the system behavior). Hence, the system that follows this perspective of resilience endures larger disruptive events through adaptation and evolution. It functions within an expansive spectrum of possible states and tends to return gradually to its equilibrium point. Under certain circumstances this system may switch to a new equilibrium point with major changes to its requirements and structure (Fiksel, 2003).

The differentiation between engineering resilience and ecological resilience shaped the studies on resilience from many perspectives (Bhamra et al., 2011; Ponomarov & Holcomb, 2009).

Table 4.1 presents a summary of the resilience's definitions in diversified contexts. From these definitions, key words and key activities are observed. First, resilience usually refers to a specific unit of analysis (a system, an organization, an individual, etc.). Second, it often corresponds to a function (capacity, ability, capability, etc.) of the unit to be aware of its surroundings (proactive activities) and adapt (reactive activities) to recover following a disruptive event. Therefore, resilience is composed of two dimensions: awareness and adaptive capacity (Aburn, Gott, & Hoare, 2016; Barasa, Mbau, & Gilson, 2018; Bhamra et al., 2011; Fontes & Neri, 2015; Tukamuhabwa, Stevenson, Busby, & Zorzini, 2015).

Table 4.1: Definitions of resilience

Context	**Definition**	**Reference**
Ecological systems	Measure of resistance of systems, and ability to absorb shocks, while maintaining relationships among state variables.	(Holling, 1973)
Ecological systems	The capacity of a system to absorb a disturbance and reorganize itself while retaining its functionality and structure.	(Walker et al., 2004)
Engineering systems	The ability to sense, recognize, adapt and absorb disruptions.	(Hollnagel, 2011)
Organizational	The ability of firms to develop specific responses to disruptions and engage in transformative activities.	(Akgün & Keskin, 2014)
Organizational	The ability of an organization to adapt to changes and maintain its operation.	(Murray, 2013)
Organizational	The capacity to adapt to changes in the environment to prevent disruptions.	(Mafabi et al., 2013)
Psychology	The ability to improvise, accept reality, and maintain the belief that life is meaningful.	(Coutu, 2002)
Socio-ecological systems	Ability to maintain functionality of a system under perturbations, or ability to maintain elements when disturbances alter system structure or function.	(Walker et al., 2004)
Psychology	Acquired capacity to rebound from adversity.	(Luthans et al., 2006)
Disaster management	The application of learning, innovation, and development skills at individuals, communities and operational level to recovery from disasters.	(Crawford et al., 2013)
Disaster management	The ability to function at a higher psychological level based on individual abilities and experiences.	(Paton & Johnston, 2001)
Engineering systems	The ability to anticipate, adapt and recover from disruptions.	(Madni & Jackson, 2009)

Table 4.1: Definitions of resilience (Continued and end)

Context	Definition	Reference
Engineering systems	The ability of a system to adjust function to disturbances and maintain operations under certain conditions.	(Saurin et al., 2014)
Ecological systems	The magnitude of disturbance absorbed by a system before its structure and behavior are transformed.	(Gunderson, 2000)
Supply chain	The ability of the supply chain to prepare for unexpected events, adapt to and recover from disruptions.	(Ponomarov & Holcomb, 2009)
Supply chain	The ability of a system either to return to its original state or to shift to a superior state desirable following disturbance.	(Carvalho et al., 2012)

4.2.3.1 Awareness

Awareness is a holistic understanding of the system's internal and external elements (McManus, 2008; Stephenson, 2010). This understanding enhances responsiveness to disruptive events due to effective monitoring of the changes in the system environment (Coutu, 2002; Luthans et al., 2006). Responsiveness means knowing the actions and/or the modes of functioning that need to be adopted in order to face future disruptions, while monitoring, is knowing what to look for and what can affect the system's performance (Hollnagel, 2011).

So, awareness requires proactive behavior towards disruptive events and knowledge of the system inputs, outputs and vulnerabilities (Hémond, 2013). Vulnerability can be represented by a system's disturbance thresholds that can potentially prevent it from maintaining an acceptable functioning (Proag, 2014). Hence, deficiencies links in system internal connectivity, and lack of available resources, among other factors, are internal and external threats that increase susceptibility to disruptive events (Hémond, 2013). So, the longer the system is vulnerable, the most likely it will face disruptions, and its probability to fail increases (Zhang, 2007). Therefore, the level of the system's vulnerability is measured by the gap between available versus required resources to operate (McManus, 2008).

4.2.3.2 Adaptive Capacity

The concept of adaptive capacity has its origins in biology and denotes structural and functional changes in species as a result of an environmental change (Smit & Wandel, 2006). It refers to structural and behavioral transformation (Bernal, Jiménez-Chafey, & Domenech Rodríguez, 2009). Therefore, adaptive capacity requires a specific system (ecological, organizational, etc.) to be aware of its surroundings in order to alter its structure, operations, and strategies and to cope with disruptive events (Dalziell & McManus, 2004).

From the engineering perspective, adaptive capacity is the ability of the system to return quickly to its equilibrium point once faced with a disruptive event. Therefore, the speed to return to the equilibrium point is a main characteristic of the system. On the other hand, adaptive capacity from the ecological perspective, also includes the ability to transform its structure and behavior when a return to its equilibrium point is no longer viable (Holling, 1996).

Woods & Wreathall (Woods & Wreathall, 2008) and Vogus & Sutcliffe (Vogus & Sutcliffe, 2007) also observe this by distinguishing two types of adaptive capacity. The first type is when the system bounces back using existing predetermined planning and strategies. The second type is when the system develops new capacities to respond to events that are outside of its preconfigured design. Accordingly, as proposed by Hémond (Hémond, 2013), a system can adapt by the application of existing available responses, of an existing response in a new context, or of a novel response to address a disruptive event.

However, regardless of the adaptive capacity's types and the perspective from which it is perceived, the main objective of the adaptation, once faced with a disruptive event, is to recover. This recovery can be achieved by returning to a steady state or by changing to a new equilibrium point (a new state) (Ponomarov & Holcomb, 2009; Sahebjamnia, Torabi, & Mansouri, 2015). Therefore, learning through adaptation is essential to reinforce what worked well, and change or adjust what was considered a failure (Hollnagel, 2011; van der Beek & Schraagen, 2015). Thus, knowing what happened to acquire the right lessons can improve the system's global awareness and its capacity to adapt to future disruptive events (Sahebjamnia et al., 2015). This learning can also be achieved through negative feedback [34], which allows systems to cross boundaries,

explore alternative new situations and collect information to avoid potentially non-viable states. Negative feedback is also the main principle of the cybernetics theory, which is mainly concerned with the functioning of self-regulating systems. To this matter, learning through negative feedback loop "*minimizes discrepancies between environmental characteristics and relevant reference criteria*" (Edwards, 1992, p. 238). Thus, resilience is linked to the cybernetic theory through the adaptive capacity dimension especially from the "engineering resilience" perspective (Müller, 1997).

4.2.4 Project Resilience

The concept of project resilience is still new and largely undefined and ambiguous despite the growing recognition of this concept within academic publications (Thomé et al., 2016).

Geambasu (Geambasu, 2011) was the first to introduce the concept of project resilience after an empirical study on major infrastructure projects. The author defines it as "*1) the project system's ability to restore capacity and continuously adapt to changes 2) to fulfill its objectives in order to continue to function at its fullest possible extent, in spite of threatening critical events.*"(Geambasu, 2011, p. 133). Geambasu proposed a framework for project resilience composed of 3 levels; Strategy, culture and structure. For each level, a set of resilience enablers (project resilience facilitators) is suggested. For instance, the legitimacy and clear vision of the project objectives facilitate the strategic level of resilience. On the other hand, partnerships, risk attitude, safety culture, effective communication, proactive planning, positive work relationships, and the diversity of skills and expertise are enablers for the cultural level of resilience. Finally, having a flat organizational structure to facilitate communication, having a financial structure, using technology to reduce complexity, and having flexible contracting practices are all enablers for the structural level of resilience.

In 2017, Blay (Blay, 2017) conducted an empirical study to conceptualize project resilience. Thus, the author defines this concept as the capacity to respond to, prepare for, and reduce the disruptions' impact to recover and ensure successful completion of project objectives. Her conceptual framework of project resilience is composed of 4 dimensions; proactivity, coping

ability, flexibility, and persistence. Each dimension has several antecedents (similar to enablers in Geambasu's conceptual framework of resilience). First, project management procedures, project management mechanisms and experience are antecedents for proactivity. Second, contract, training, contingency and experience are antecedents to the coping ability dimension. Third, open-mindedness, planning, continuous monitoring and continual identification of ideas are antecedents for flexibility. Finally, the continuous monitoring, planning, and negotiation are the antecedents for the persistence dimension.

Turner & Kutsch (2015) (Turner & Kutsch, 2015) proposed another interpretation of project resilience. These authors elaborated on the meaning of project resilience and defined it as the art of detecting changes in the project environment, understanding these changes, planning answers, minimizing damage when a change occurs, and adapting to a new reality.

Prevention, response, and adaptation were also present in the definition of project resilience proposed by Giezen et al. (2015) (Giezen, Salet, & Bertolini, 2015). These researchers mentioned the presence of two types of project resilience; reactive resilience and proactive resilience. Reactive resilience takes into consideration that the project is in a stable situation that allows it to protect itself against disruptive events. On the other hand, proactive resilience emphasizes the project's environment and considers that an unstable environment requires some form of adaptation. For these authors "*Resilience related to the availability of a redundancy of options, alternatives, and recombinant pathway*s" (Giezen et al., 2015, p. 171).

Alternatively, being a significant part of a project, the resilience of the project team is an important aspect of the project's resilience as a system (van der Beek & Schraagen, 2015). Amaral et al. (2015) (Amaral et al., 2015), and after conducting a quantitative study among project teams, define the team's resilience as the team's ability to deal with issues, bypass obstacles, or resist to adverse cases without being ruptured. They suggest 10 actions to improve the team's resilience. These actions emphasize the collaboration and solidarity between project team members, the recognition, appreciation and efficient use of the team members' competences, the ability to learn from mistakes, the stimulation of a positive team environment, and the capability to be creative,

innovative, and to develop project team building. Table 4.2 presents the definitions of project resilience found in the literature.

Table 4.2: Definitions of project resilience

Definitions	**Reference**
The ability to restore capacity and continuously adapt to changes, and to achieve its objectives in the face of disruptive events.	(Geambasu, 2011)
The capacity to evolve in response to risks emerging after the project planning stage.	(Schroeder & Hatton, 2012)
The capacity to maintain purpose and integrity under external or internal shocks.	(Hillson, 2014)
The art of noticing, interpreting, containing, preparing for and recovering from disruption.	(Turner & Kutsch, 2015)
The capacity to overcome unexpected events.	(Giezen et al., 2015)
The ability to cope with uncertainty.	(Zhu, 2016)
The capability to respond to, prepare for and reduce the impact of disruptions caused by changes in the project environment.	(Blay, 2017)

As noticed and already discussed, the concept of project resilience is still new and largely undefined and ambiguous despite the growing recognition of this concept within academic publications (Thomé et al., 2016). In fact, resilience, in project management, can help projects maintain their performance through flexible, systemic and context-specific approaches (Crawford et al., 2013; Shishodia, Verma, & Dixit, 2019). Resilience helps focus on the project behavior, and the efficient utilization of resources once faced with disruptive events or conditions (Sansavini, 2016). In other words, resilience is concerned with how processes, methods, organizational structure, etc. evolve and realign to face disruptive events. This is achieved through continuous monitoring of the project complexity and uncertainty levels during the project life-cycle (Zhu, 2016). As mentioned by Schroeder and Hatton (2012) (Schroeder & Hatton, 2012), the focus should be on redundancy, diversity, transparency, decentralization in processes and structures, decreased connectivity between methods, and increasing communication and sharing of

information. In fact, unlike the critical success factors that do not take into consideration the context of the project once faced with the disruptive event, resilience offers insights to which elements mostly contribute to maintain an acceptable project functioning at a specific point in time (the time once the project is faced with a disruption) (Geambasu, 2011).

4.3 Methodology

This theoretical article aims to develop a clear understanding of the concept of project resilience. Therefore, a theory building approach is adopted to develop the project resilience conceptual framework and to set the foundation for future research studies. The main characteristic of theory building is to develop definitions and relationships, and to compare existing emergent key concepts, constructs and theories in order to draw conclusions (Burnard & Bhamra, 2011; Lynham, 2002; Meredith, 1993).

Accordingly, the importance of developing a conceptual framework is to provide a general understanding of the main elements of a concept (Burnard & Bhamra, 2011). Therefore, the proposed conceptual framework of project resilience will set the basis for future research activities on this newly emergent concept by borrowing the previously discussed dimensions of resilience; awareness and adaptive capacity. Consecutively, this framework will also describe the link that exists between current project risk management practices and the concept of resilience to successfully respond to disruptive events during the project life-cycle.

The development of the project resilience conceptual framework is achieved by following the same process as many authors (e.g. the works of (Kantur & Iseri-Say, 2012; Ponomarov & Holcomb, 2009)) who utilized literature review to establish a conceptual framework. As noted by Burnard and Bhamra (2011) (Burnard & Bhamra, 2011) "*conceptual frameworks aid in not only providing construct validity, but also provide an outline for future research activities*" (Burnard & Bhamra, 2011, p. 5585). Therefore, to build this conceptual framework, the literature was reviewed to identify current research efforts and limitations of project risk management. Consecutively, the concept of resilience in its broader applicability was reviewed where two main dimensions were sieved; awareness and adaptive capacity. The literature on the newly introduced concept of project

resilience was also reviewed where its novel nature, the lack of scientific studies to conceptualize it, and its significance to project management were demonstrated. This confirmation will help propose a definition and a conceptual framework of project resilience where a set of relationships will be instigated. The definition and the conceptual framework, proposed in this paper, constitute a base line to perform further studies to assess their validity.

4.4 Project Resilience: A General Definition and Conceptual Framework

In this section, a definition and a conceptual framework for project resilience are presented. Thus, given the plethora of definitions and perspectives summarized in the previous literature review, a generalized definition of project resilience is proposed; It is *the capacity of the project system to be aware of its surroundings and vulnerabilities, and to adapt in order to recover from disruptive events and achieve its objectives.* This definition borrows the dimensions from the previously reviewed literature on resilience; awareness and adaptive capacity. It also emphasizes the visualization of the project as a system.

4.4.1 Project as a System

The main unit of analysis in studies on resilience is the system (Bhamra et al., 2011; McManus, Seville, Vargo, & Brunsdon, 2008; Ponomarov & Holcomb, 2009). Systems are delimited by spatial and temporal boundaries, determined by structure and objectives, and influenced by their surrounding environment (Senge & Sterman, 1992; Von Bertalanffy, 1951). Two types of systems are distinguished: while open systems constantly interact with their environments by exchanging information, resources, or energy, closed systems are isolated from their environments. As a result, closed systems are more autonomous and able to self-adapt (Checkland, 1994; Sheffield, Sankaran, & Haslett, 2012), whereas open systems are required to adapt to changes imposed by the environment in order to preserve its equilibrium. Therefore, either self-adaptation or adaptation to environmentally imposed changes are crucial to the survival and functionality of systems (Senge & Sterman, 1992).

Applications of systems thinking in project management have been proposed for a number of years (Anbari, 1985; Morris, 1983; Sheffield et al., 2012; L.-A. Vidal, 2009; Zhu, 2016). From the system perspective, projects are composed of several interdependent subsystems including processes, activities, tangible and intangible resources, and information. Those elements or activities convert inputs into outputs, which are mostly resources such as tangible and intangible assets, and knowledge (Hémond, 2013). The project system's environment is the main provider of inputs and the main receptor of outputs. It is where the project goes through its life-cycle to fulfill its objectives. Given its continuous interaction with the environment, it must be concluded that project systems are open systems. Figure 4.1 presents the project system and the interaction with its environment.

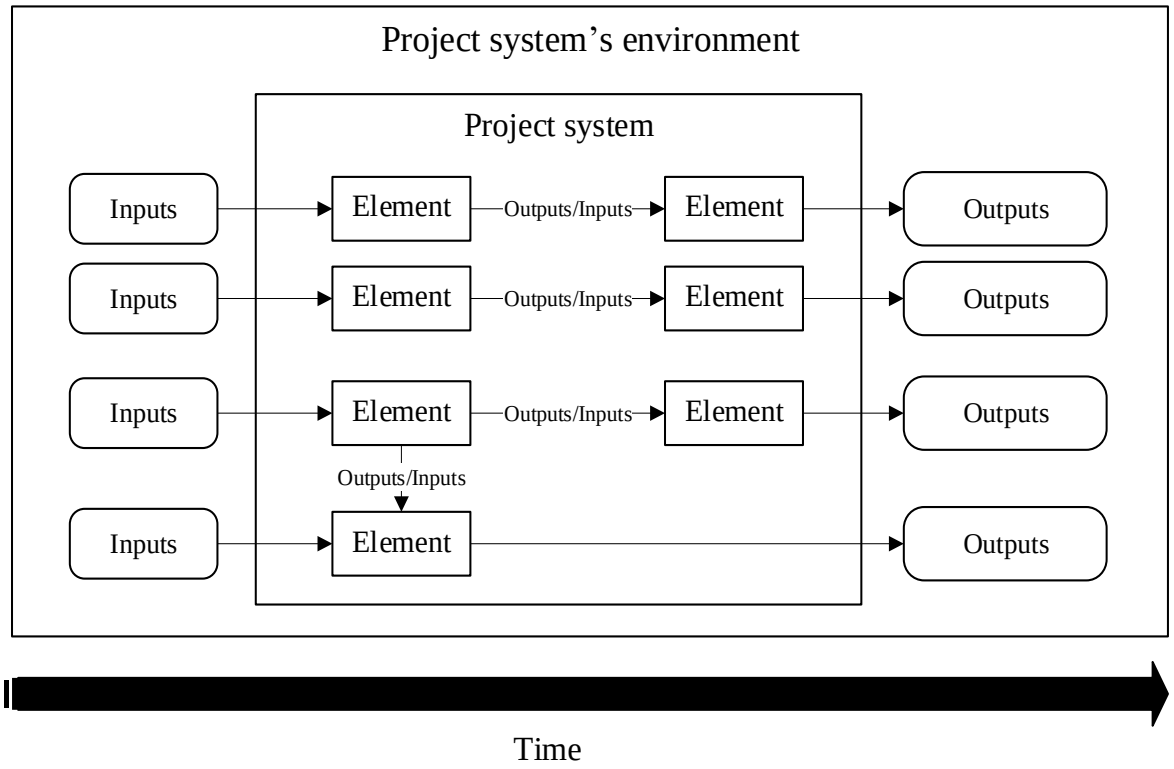

Figure 4.1 – Representation of the project system and its interaction with its environment

4.4.2 Project Resilience: Conceptual Framework

The framework provided by the concepts of awareness and adaptive capacity related to resilience also applies to the specific context of project management. Project resilience depends on awareness of disruptive events and of the gap between available versus required resources; projects' vulnerabilities.

Adaptive capacity is also central to the transformation (e.g. changes on structure, processes, methods, etc.) of the project system to recover from negative known or unknown risks (*disruptive events or conditions that may or may not occur*) (Geambasu, 2011; Zhu, 2016). Therefore, recovery is the result of a successful adaptation. For instance, when unpredicted changes related to budget or schedule contingencies, critical paths, or client satisfaction provoke modifications in the project trajectory and development, project systems can either adapt and restore the original baseline, or, after approval of main stakeholders, create a new baseline (Sheffield & Lemétayer, 2013). Both cases exemplify successful recovery as they avoid a terminal or dead state where the project can no longer achieve its original objectives (Sanchez et al., 2009). Thus, shifting from a state to another while avoiding the "death state" is a main attribute of a project system. Furthermore, project resilience should be classified as an example of ecological resilience, as projects exhibit multiple baselines or equilibrium points over time (possible multiple baselines).

To this matter, three adaptation strategies are suggested at the elements level of the project's system: deploying new inputs recruited from other project elements or environments, changing input-output conversion mechanisms, or changing outputs after consultation with stakeholders. The relationship between awareness and adaptive capacity is essential to ensure an efficient recovery once faced with a disruptive event. In fact, awareness is the force driving the project's capacity to adapt when facing a disruptive event. Thus, the following relationship between awareness and adaptive capacity is proposed:

RP1: the greater the project's awareness, the better it adapts and successfully recovers once faced with disruptive events.

Developing project awareness and its capacity to adapt when facing disruptive events, increases the project's capacity to assess the impact of events, actions and decisions as to predict and control the project evolution (Geraldi et al., 2011). This is done by evaluating the project elements' objectives and characteristics, as well as the actions and decisions' consequences on the entire project environment (Sicotte & Bourgault, 2008). In other words, developing project resilience helps manage the consequences of uncertainties over the project life-cycle and efficiently deal with unpredictable or unknown risks (Besner & Hobbs, 2010; Schroeder & Hatton, 2012). Therefore, the following relationship between project resilience and managing uncertainties is proposed:

RP2: The greater the project's resilience, the better is the management of uncertainties during the project life-cycle

Developing project resilience helps deal with ambiguities. It improves the stakeholders' knowledge about the elements of the project and their characteristics. It helps eliminate the bias of the stakeholders' perception about the project and its environment. This perception is influenced by the stakeholders' mental representations and cultural differences (Jaafari, 2001). Therefore, a project without well-developed awareness and adaptive capacity will have great challenges to face risks related to factors such as change management and user resistance, requirements management, project planning (budget, schedule, quality, communication, etc.), organizational structure, etc. (D. Laurie Hughes, Nripendra P. Rana, & Antonis C. Simintiras, 2017). Therefore, the following relationship between project resilience and managing ambiguities is proposed:

RP3: The greater the project's resilience, the better is the management of ambiguities during the project life-cycle

Focusing on the development of project awareness and its capacity to adapt when dealing with disruptive events, helps manage the risks caused by the interdependencies that exist between the elements of the project and between the project and its environment. These interdependencies can be strong enough to modify the characteristics of certain, already identified, risks and potentially lead to additional unknown risks (Schroeder & Hatton, 2012). Therefore, the following relationship between project resilience and managing risks caused by non-linear and dynamic interdependencies is proposed:

RP4: The greater the project's resilience, the better is the management of risks caused by non-linear and dynamic interdependencies during the project life-cycle

The continuous evolution of the project environment increases the likelihood that contingency and risk response plans, which were developed at the beginning of the project, become ineffective for managing known risks (Geambasu, 2011; Cicmil, Cooke-Davies, Crawford, & Richardson, 2009). Therefore, developing project resilience empowers current PRM practices to better deal with known risks by continuously monitoring changes to their characteristics during the project life-cycle. To this matter, the following relationship between project resilience and the management of known risks is proposed:

RP5: The greater the project's resilience, the better is the management of already identified and analyzed risks by current PRM practices.

Figure 4.2 presents the overall conceptual framework underlying project resilience and including the capacity to learn from successful recoveries. This capacity enhances project resilience by developing, context specific, new strategies, processes and practices to better deal with future disruptions. The learning aspect provides the means for project resilience to continuously evolve, advance and grow (Ponomarov & Holcomb, 2009).

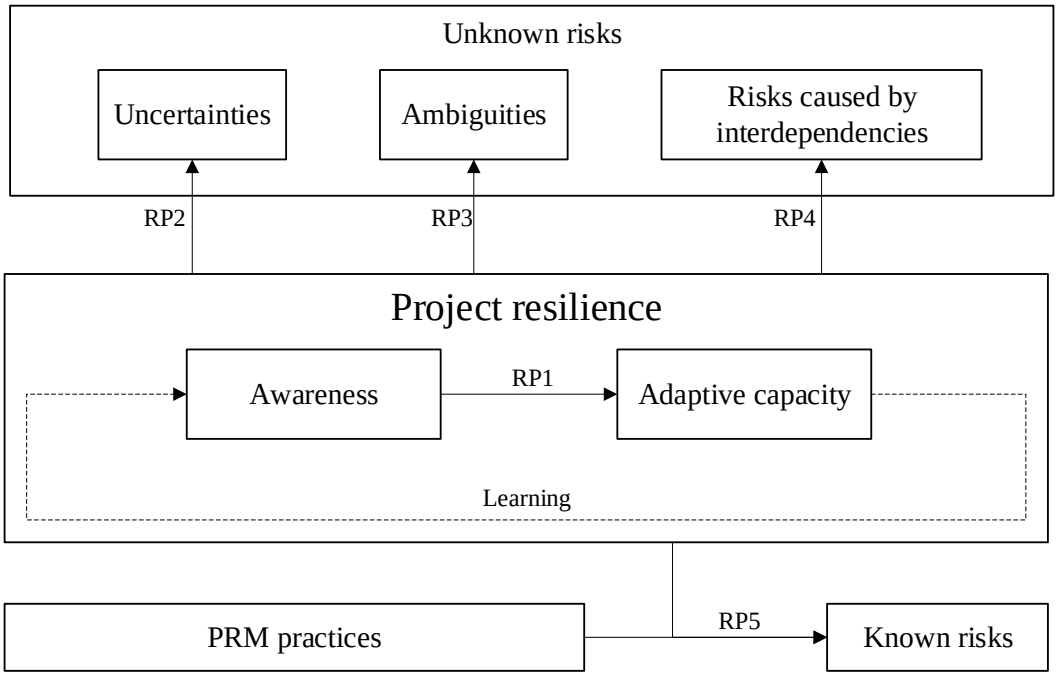

Figure 4.2 – Conceptual framework of project resilience

4.5 Conclusion

The presented framework of project resilience provides a new conceptual methodology to identify intrinsic risks of project systems and to accelerate project adaptation to known and unknown risks, thereby reinforcing risk management approaches and enhancing risk management strategies.

However, project resilience is still a very recent field of research that needs to be reinforced by qualitative and quantitative academic studies. From this perspective, the main objective of this paper is to propose a conceptual definition and framework of project resilience. Therefore, project resilience is defined by the capacity of the project system to be aware of its surroundings and vulnerabilities, and to adapt in order to recover from disruptive events and achieve its objectives. Also, a conceptual framework of project resilience is presented that potentially can set the basis for additional research on this new, very promising, concept.

However, as any new research concept, what is presented is one of many possible ways to define project resilience. As such, this is considered an obvious limitation. Thus, to continue reinforcing what was presented in this paper, the following agenda is suggested.

Next steps should firstly include conceptual exchanges with more advanced research fields. For example, organizational resilience is a more established concept among researchers and could catalyze the conceptual development on project resilience.

Second, a set of indicators to estimate the ability of projects to manage disruptive events should be developed. The goal of this development is to provide project stakeholders with a diagnostic tool to assess the impact of efforts required to improve current and future projects resilience. This tool can help determine the project's strengths and weaknesses as well as suggest action plans to improve its resilience.

Third, once a validated set of indicators is developed to assess project resilience, rigorous empirical studies are required to validate the propositions and the developed conceptual framework of project resilience.

Finally, the concept of project resilience neither eliminates the need nor denies the relevance of current PRM practices and may, instead, redirect and strengthen them. Project resilience strategies should coexist with the current PRM practice to promote more efficient project management.

CHAPTER 5 ARTICLE 2 - INDICATORS TO ASSESS ORGANIZATIONAL RESILIENCE - A REVIEW OF EMPIRICAL LITERATURE

RAHI, K. (2019). INDICATORS TO ASSESS ORGANIZATIONAL RESILIENCE – A REVIEW OF EMPIRICAL LITERATURE. INTERNATIONAL JOURNAL OF DISASTER RESILIENCE IN THE BUILT ENVIRONMENT, 10(2/3), 85–98

Abstract

Purpose - This paper aims to explore the empirical literature on organizational resilience. The goal consists of identifying and understanding the indicators used to evaluate organizational resilience and instigating the development of indicators to assess resilience in other areas, such as project management and critical infrastructure.

Design/methodology/approach - A review of recent empirical studies is conducted to collect information on the indicators used to assess organizational resilience.

Findings - A range of interrelated indicators aiming to measure organizational resilience in two dimensions is shown in this literature review: awareness and adaptive capacity. Awareness is the ability of an organization to assess its environment and interpret the changes in its surroundings, both now and in the future, to be proactive and better manage possible disruptive events. On the other hand, adaptive capacity is the organization's capacity to transform its structure, processes, culture, etc. for recovering once faced with a disruptive event. Awareness forms the main base of the organization's adaptive capacity.

Originality/Value - Organizational resilience contributes to the safe development of the built environment. This concept helps organizations to cope with disruptions. However, little research has been conducted on the indicators to assess organizational resilience, in different fields. Moreover, these indicators' credibility is based on empirical studies.

Keywords - Resilience, Organizational resilience, Indicators, Empirical studies, Awareness, Adaptive capacity.

Paper type - Literature Review

5.1 Introduction

Organizational resilience describes how well-prepared organizations are to overcome or react to disruptions. This increasingly popular concept has been examined attentively in recent years following several international events (e.g. the Hyogo framework for action in 2005, the financial crisis of 2008, etc.). These events prompted organizations to review their business processes, so as to effectively manage the impact of events that could potentially disrupt their operations (Bhamra et al., 2011).

Despite the interest in organizational resilience, this topic is still predominantly conceptual (Barasa et al., 2018). Academic studies continue to focus on developing theories, and proposing evaluation approaches, with scarce empirical evidence. Yet, an understanding of what makes organizations resilient in the real world is significant to develop and promote resilience strategies and frameworks that deal better with disruptive events. Therefore, scientific studies need to evaluate organizational resilience, across multiple industries. This assessment aims to understand the behavior of organizations and the prevention and safety measures that they have put in place to manage disturbances (Ortiz-de-Mandojana & Bansal, 2016; Price, 2012; Sapeciay et al., 2017; Somers, 2007; Sonnet, 2016; Tillement, Cholez, & Reverdy, 2009).

That being said, this paper reviews empirical studies on organizational resilience to explore how it was conceptualized, with the goal of identifying and understanding the indicators used to evaluate it. These indicators measure observable methods (e.g. processes, actions, etc.) that may help evolve the resilience of an organization (Flin et al., 2000), and "*provide organizations with information on their resilience strengths and weaknesses before a crisis happens.*" (Lee et al., 2013, p. 30).

Therefore, this study is organized by multiple sections. Section 2 provides a general background on the concept of organizational resilience and its assessment. Section 3 describes the methodology used to find the scientific studies where organizational resilience was empirically examined. Section 4 presents the results, and Section 5 presents discussion of the indicators used in empirical studies to evaluate organizational resilience. Section 6 concludes the paper.

5.2 Background on Organizational Resilience

According to the well-cited article of Handy et al. (2002), the built environment includes specific patterns of human activities (e.g. use of land and transportation systems, urban design, etc.) within a well-defined physical environment. This built environment: "*is constantly changing in countless ways; some changes are fast (e.g., the drop in pedestrians on a downtown street from noon to midnight) and some are slow (e.g., the deterioration of building exteriors over decades or more).*" (Handy et al., 2002, p. 65). To this matter, organizations contribute significantly to the development of this environment because they exist primarily to provide products and services to individuals, communities, countries and societies (McManus et al., 2008). Therefore, improving and assessing the resilience of organizations are critical steps towards creating more prepared communities and societies to deal with disruptions. Consequently, strengthening organizational resilience contributes to the safe development of the built environment (Sonnet, 2016).

Many definitions exist for the concept of organizational resilience, employed in various disciplines. They mainly focus on two types of resilience, proposed by (Holling, 1996); "*engineering resilience*" and "*ecological resilience*".

From the "*engineering resilience*" perspective, organizations are perceived as systems with simple cause and effect dynamics (Barasa et al., 2018). Moreover, they are supposed to return quickly to the functional "acceptable" state (bounce back) from disruptions (Darrow & Eseonu, 2016; Le Coze, 2016; Madni & Jackson, 2009). The systems engineering academy mainly adopts this perspective.

In contrast, from the "*ecological resilience*" perspective, organizations tend to adapt (recognition of the adaptive nature of the organization) by changing their structure, processes, culture, etc., to thrive in times of crisis (Bosher & Dainty, 2011; McManus et al., 2008). From this perspective, developing the organization's adaptive capacity helps promote learning and development of responses, in a timely manner, to cope with disruptions (Engle, 2011; Linnenluecke & Griffiths, 2011). Thus, this capacity is achieved through proliferated interactions between humans and the environmental components of the organization (Walker et al., 2004). It facilitates the

organization's transformations by moving to a new state (changes on the structure, processes, etc., of the organization) when the current state is no longer viable (Engle, 2011). Mainly, the environment and the business academies endorse this perspective.

Consecutively, it is essential to assess organizational resilience, regardless of the perspective it is derived from (Lee et al., 2013). This assessment helps an organization in dressing a portrait on its capacity to become more resilient, to link improvements with competitiveness, and to demonstrate a business case for resilience investments (Stephenson, 2010). For instance, the method proposed by Hollnagel (2011) consists in analyzing four essential abilities of an organization:

(1) the ability to respond;
(2) the ability to anticipate;
(3) the ability to monitor; and
(4) the ability to learn.

His method entails three steps. The first step is to properly define the system by taking into consideration the organizational structure, the resources involved, the thresholds for normal operations, etc. The second step is to identify the most relevant elements for the analysis of each ability. Finally, the third step is to define a scale for the evaluation of each ability. Always, from the engineering resilience perspective, Madni and Jackson (2009) proposed an approach based on four key pillars of system resilience; system attributes, methods, disruptions and metrics. Indicators such as system functionality, system complexity, system performance, analytical methods and single agent were proposed to measure each key pillar. On the other hand, the "Resilient Organizations and the Ministry of Civil Defense and Emergency Management," in New Zealand, developed an organizational resilience assessment tool consisting of 13 indicators that are divided into three independent attributes: leadership and culture, networks and change (Sapeciay et al., 2017). Likewise, Bruneau et al. (2003) proposed indicators to assess two dimensions of organizational resilience; impact resistance and rapidity. Their indicators assess the redundancy of organizational systems, the availability of resources and supplies and the existence of planning and decision-making systems. Similarly, Longstaff et al. (2010) proposed indicators that measure the resource's robustness (performance, diversity, redundancy) and the adaptive

capacity (institutional memory, innovative learning, connectedness) of resilient communities from five perspectives; ecological, economic, physical infrastructure, civil society and governance.

However, despite the availability of many approaches and indicators developed to assess organizational resilience, to date, these approaches and indicators were rarely used in the real world. They have rarely been subject to empirical studies (Barasa et al., 2018; Petit et al., 2013). Therefore, the goal of this paper is to sieve indicators used in empirical studies that were tested in the real world to determine how resilient an organization is.

5.3 Methodology

As empirical studies on organizational resilience are limited, to get a reasonable sample size the literature reviewed included all types of industries. The literature in databases that deal mainly with scientific studies in the field of management and science of organizations was searched. In fact, all types of studies, published in the gray literature and in scientific journals, where indicators are used to evaluate empirically organizational resilience, were retained. Based on the definition of Mahood et al. (2014) grey literature is defined as follows: "*magazine articles, trade press articles, academic dissertations, institutional reports, consultant reports, book chapters and conference proceedings*" (Mahood et al., 2014, p. 223).

Table 5.1 shows the keywords used to search the empirical literature on organizational resilience.

Table 5.1: Keywords used to search for empirical literature on organizational resilience

Items	**Keywords**
Resilience	Resilien*
Organization	Organisation* OR enterpri* OR firm* OR organization* OR compan*
Empirical studies	Empiri* OR (cas study*) OR qualitat* OR quantitat*
Indicator	Indicator* OR measure* OR metric*

The selection criteria were as follows:

1. ***Research options*:** Although the term "resilience" appears frequently in studies dealing with management and science of organizations, it is often the case that the concept of

"organizational resilience" is not the one being researched. So, to keep the number of scientific documents within a manageable amount, the search was carried out only in abstracts and titles.

2. ***Choice of language*:** Only scientific documents written in English and French were selected.
3. ***The publication date*:** As part of Hyogo in 2005 (United Nations, 2005), several countries agreed to strengthen the resilience of their critical infrastructure and organizations to protect their people. Based on the assumption that organizations need two years to develop resilience strategies, 2007 was chosen as the year in which researchers were likely to begin the empirical assessment of organizational resilience. Accordingly, this study encompasses scientific articles and dissertations that were published from January 2007 to April 2017.

Based on these criteria, 1,470 items were extracted from the databases and saved in Microsoft Excel. The next step was to identify and remove any duplicate items. The original total of 1,470 items was reduced to 1,323 because 147 duplicate items were found. Then, a preliminary analysis of the titles and abstracts was carried out to select the relevant articles for this literature review. Based on this analysis, and because the terms "resilience" and "organization" are used in many contexts without really having a link to the purpose of this research, the 1,323 articles were reduced to 91.

Then, a thorough and detailed reading of the 91 articles enabled the selection of 33 scientific documents corresponding exactly to this study's purposes.

5.4 Results

Of the 33 papers, 27 per cent were qualitative studies and 79 per cent were quantitative studies (the total of qualitative and quantitative studies does not equal 100 per cent because some researchers used both techniques). Interviews mainly conduct qualitative studies (Dewald and Bowen, 2010; Witmer and Mellinger, 2016). Whereas psychometric tools conduct the quantitative ones (the majority of the studies) such as the Likert scale, or simply yes/no questions (Lee et al., 2013; McManus et al., 2008; Stephenson, 2010).

Figure 5.1 shows the number of scientific documents per year. From which, it is seen that the number of scientific documents that addressed empirically the topic of organizational resilience increased dramatically from 2010 onwards; 91 per cent of scientific documents were published from then on.

Table 5.2 below contains information about the 33 documents selected for analysis.

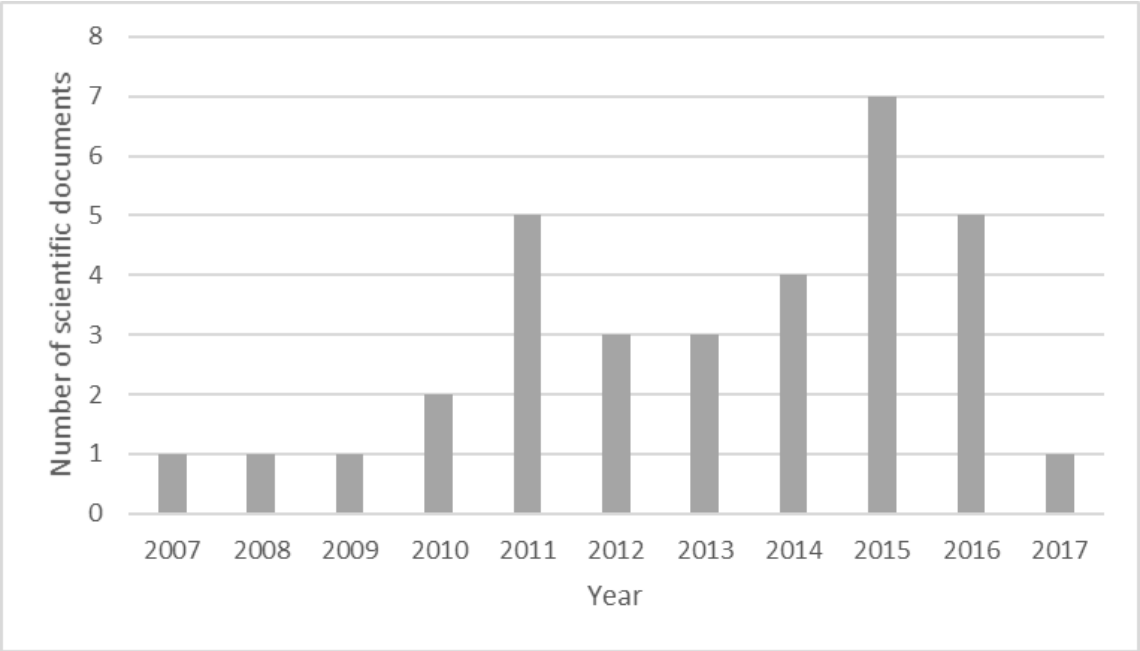

Figure 5.1 – The number of empirical scientific documents on organizational resilience from January 2007 to April 2017

Table 5.2: Details of the 33 papers—authors (AU); type of empirical studies (TES) (Qualitative (QL), Quantitative (QN)); industry (IN); type of publication (TOP) (Journals Articles [JA], Grey literature [GL])

AU	***TES***		***IN***	***TOP***	
	QL	***QN***		***JA***	***GL***
Sapeciay et al., (2017)		√	Construction	√	
Kim et al., (2016)		√	Social network	√	
Ortiz-de-Mandojana and Bansal, (2016)		√	Multiple industries	√	
Witmer and Mellinger, (2016)	√		Non-profit organisation	√	
Pettit et al., (2016)	√		Military	√	
Sonnet, (2016)		√	Manufacturing		√
Castellacci, (2015)		√	Multiple industries	√	
Duarte Alonso and Bressan, (2015)		√	Wine industry	√	
Mafabi et al., (2015)		√	Parastatal	√	
Sawalha, (2015)		√	Insurance	√	
Borekci et al., (2015)		√	Textile	√	
Jones, (2015)		√	Multiple industries		√
Jung, (2015)		√	Multiple industries		√
Pal et al., (2014)		√	Textile	√	
Borekci et al., (2014)		√	Services	√	
Bauweraerts and Colot, (2014)		√	Family business	√	
Akgün and Keskin, (2014)		√	Multiple industries	√	
Murray, (2013)		√	Hospital		√
Mafabi et al., (2013)		√	Public sector	√	
Lee et al., (2013)		√	Multiple industries	√	
Mafabi et al., (2012)		√	Parastatal	√	
Salanova et al., (2012)	√		Multiple industries	√	
Price, (2012)	√	√	University		√
Sullivan-Taylor and Branicki, (2011)	√		Multiple industries - SME	√	
Vargo and Seville, (2011)	√		Multiple industries - SME	√	
Demmer et al., (2011)		√	Machinery	√	
Gunasekaran et al., (2011)		√	Multiple industries - SME	√	
Otulana, (2011)	√	√	Multiple industries		√
Dewald and Bowen, (2010)		√	Real estate	√	
Stephenson, (2010)		√	Multiple industries		√
Tillement et al., (2009)	√		Rail transport	√	
McManus et al., (2008)	√		Multiple industries	√	
Somers, (2007)		√	Public sector		√

5.5 Discussion

Organizational resilience is, in essence, the ability of an organization to deal with disruptive events that cause alteration, degradation or cessation of organizational operations (Somers, 2007). Thus, the key terms used when defining resilience are: ability, capacity and capability (the definitions of organizational resilience are presented in Table 5.3). Ability refers to actual skills that are either native or acquired. Alternatively, capacity refers to the potential of developing a skill. This potential is a native characteristic that cannot be developed or acquired. Capability is closer to ability in meaning, but refers to the unique skill of accomplishing a specific task with a high degree of precision (Sonnet, 2016).

Moreover, a disruptive event could be: a crisis (Sapeciay et al., 2017), an uncertainty (Borekci et al., 2014; Sapeciay et al., 2017), a disaster (Kim et al., 2016; Price, 2012), a disturbance (Akgün & Keskin, 2014; Duarte Alonso & Bressan, 2015; Jones, 2015; Murray, 2013; Pettit et al., 2016; Salanova et al., 2012; Witmer & Mellinger, 2016), a risky event (Sonnet, 2016), an incident (Sawalha, 2015), an adverse event (Borekci et al., 2014), an emergency (Jung, 2015), a shock (Bauweraerts & Colot, 2014), a threat (Mafabi et al., 2013), or business failure (Mafabi et al., 2012); it is an event that prevents an organization from delivering its products or services properly, has a negative impact on its operational environment and causes an interruption in its normal workflow (McManus et al., 2008). In other words, it is an event that prevents an organization from continuing its normal operations and subsequently failing to accomplish properly its mission and strategic objectives (Stephenson, 2010).

Furthermore, sensing the arrival of disruptive events (Ortiz-de-Mandojana & Bansal, 2016), avoiding them (Pettit et al., 2016; Mafabi et al., 2015, 2013, 2012), and building a culture of resilience to prepare for them (Sawalha, 2015), are examples of proactive actions that organizations need to take to better prepare for future disruptive events. This requires a continuous rebuilding of values, processes and behaviors by transforming individuals' actions into a collective source of strategic advantage: one that empowers over time to manage future disruptive events (Jung, 2015; Sonnet, 2016; Sullivan-Taylor & Branicki, 2011). Therefore, having a global awareness of the organization's surroundings, vulnerabilities and the inputs and outputs that drive

its operations, along with the development of proactive activities to deal with future disruptive events, is a dimension of organizational resilience. Alternatively, the following are actions that organizations can take when facing a disruptive event:

- Survive it (Bauweraerts & Colot, 2014; Borekci et al., 2015; Sapeciay et al., 2017);
- Respond productively to it (Mafabi et al., 2013; Otulana, 2011; Pal et al., 2014);
- Absorb its negative consequences (Borekci et al., 2015; Otulana, 2011);
- Thrive after its occurrence (Demmer et al., 2011; Dewald & Bowen, 2010; Somers, 2007);
- Recover from it (Borekci et al., 2015; Kim et al., 2016; Pettit et al., 2016);
- Restructure management strategies after it happens (Mafabi et al., 2012; Pal et al., 2014);
- Maintain organizational operations (Murray, 2013; Salanova et al., 2012);
- Adapt by adjusting the functions of the organization (Castellacci, 2015; Murray, 2013; Otulana, 2011);
- Bounce back to a normal operating state (Borekci et al., 2014; Jung, 2015; Price, 2012; Sawalha, 2015).

Therefore, the organization's adaptive capacity for recovering, once faced with a disruptive event, is another dimension of organizational resilience.

Table 5.3: Definitions of organizational resilience

Definition	**Reference**
The ability of an organization to survive and thrive changes and uncertainties	(Sapeciay et al., 2017)
The ability of an organization to maintain its operations, adapt, and recover from a disaster	(Kim et al., 2016)
The ability of an organization to be aware of disturbances and to cope positively with unexpected events	(Ortiz-de-Mandojana & Bansal, 2016)
The ability to respond to disruptions and transform challenges into opportunities	(Witmer & Mellinger, 2016)
The ability of an organization to avoid disruptions, and if unsuccessful recover quickly	(Pettit et al., 2016)
The capability to cope with risk events, and enhance rates of change success	(Sonnet, 2016)
The ability of an organization to adapt to changes in its environment	(Castellacci, 2015)
The organizations' capacity to adapt and recover when facing disruptions	(Duarte Alonso & Bressan, 2015)
The ability of the organization to cope with change, and adapt its structure to prevent disturbances	(Mafabi et al., 2015)
The ability of an organization to establish a culture of resilience and adapt to recover when facing an incident	(Sawalha, 2015)
The ability to be aware and prepared, adapt and recover from undesirable events	(Borekci et al., 2015)
To adapt and successfully manage disruptive challenges	(Jones, 2015)
The capability of an organization, to manage emergency events in order to recover to its original condition	(Jung, 2015)
The ability of an organization to respond and adapt rapidly to unexpected events	(Pal et al., 2014)
The ability to improve organizational awareness and adapt from unexpected events	(Borekci et al., 2014)
The capacity of family businesses to adapt and recover from structural shocks	(Bauweraerts & Colot, 2014)

Table 5.3: Definitions of organizational resilience (Continued and end)

Definition	**Reference**
A firm's ability to improve its awareness and adapt effectively in response to disruptive surprises	(Akgün & Keskin, 2014)
The ability of an organization to transform its structure prior to, during, or following disturbances	(Murray, 2013)
The capacity to adapt to threats and opportunities and avoid disturbances	(Mafabi et al., 2013)
The capacity of an organization to enhance its awareness and its adaptive capacity in a complex environment	(Lee et al., 2013)
Organizations' obligation to adapt its strategies in order to avoid business failure	(Mafabi et al., 2012)
The development of a healthy workforce able to improve its awareness and adapt successfully during disruption periods	(Salanova et al., 2012)
The ability to improve awareness, to analyze the situation, to adapt and recover from errors to continue operations	(Price, 2012)
The capability of an organization to prepare for, and respond to disturbances	(Sullivan-Taylor & Branicki, 2011)
The ability of an organization to survive and thrive through negative and positive changes	(Vargo & Seville, 2011)
The ability of an organization to improve its awareness and adapt in the face of adverse circumstances	(Demmer et al., 2011)
The ability to adapt and stay competitive in evolving markets	(Gunasekaran et al., 2011)
The capacity of an organization to stay aware of the changes in its environment and to adapt to changes amidst disruptions	(Otulana, 2011)
The capacity of an organization to improve its awareness and its adaptive capacity in a complex and dynamic environment	(Stephenson, 2010)
The managers' challenge to adapt its strategies and survive the changes in the organization's environment	(Dewald & Bowen, 2010)
The capacity of an organization to be aware of irregular variations and disruptions in order to manage the unexpected	(Tillement et al., 2009)
The capacity of an organization to improve its awareness and its adaptive capacity in a complex and dynamic environment	(McManus et al., 2008)
The ability of an organization to identify risks and thrive in the face of adversity	(Somers, 2007)

On the other hand, the indicators used by researchers to assess organizational resilience are numerous and vary from one area of activity to another. In some scientific studies, indicators were developed to respond to a very specific area of activity such as the wine industry (Duarte Alonso & Bressan, 2015). While other indicators were more oriented to address organizational values, responsiveness, adaptability, internal and external knowledge, networks, etc.

However, although no consensus on a specific framework to assess organizational resilience exists, the indicators found in this literature review aim to evaluate the two main dimensions of organizational resilience, discussed previously: “awareness” and “adaptive capacity”. It was also noted that there is no consensus on the measures used to evaluate these indicators. In some cases, different measures were used to evaluate the same indicator (e.g. Murray, [2013] vs Otulana,[2011] to measure adaptive capacity).

5.5.1 Awareness

From an organizational perspective, awareness is the organization’s ability to assess its environment and interpret the changes in its surroundings, now and in the future, to be proactive and better manage possible disruptive events (Lee et al., 2013; Stephenson, 2010). Awareness consists of understanding the entire organization’s operational environment, the resources available to perform its minimum operating requirements, and the obligation that the organization has towards its internal and external stakeholders (McManus et al., 2008).

To achieve this understanding, organizations need to be conscious of their surroundings and to establish prevention and protection measures to better respond to disruptions, and therefore reduce vulnerabilities. This requires a deep knowledge of the organization’s aspects entirely, in order to target the intervention priorities and to assess the resources required vs. those available to achieve operational activities (Borekci et al., 2015, 2014). It also requires a continuous monitoring of the organization’s financial and economic situation, together with the latest trends in the market, and the behavior of the competition and of customers, etc. Constant updates on the organization’s internal structure, culture and strategic objectives should be continuously monitored (Gunasekaran et al., 2011; Otulana, 2011). This will also require the continuous planning of mechanisms,

practices, skills, strategies and processes in order to stay alert and to ensure business continuity and minimize risks (Somers, 2007).

On the other hand, achieving awareness requires the minimization of communication barriers between an organization's departments. These barriers are often related to the employee's cognitive behaviors, cultural backgrounds and work experiences, and cause detrimental working ways (Coutu, 2002; Sonnet, 2016). In fact, it is important that employees have access to opportunities that help them develop the skills they need to do their jobs properly. In addition, a work environment that promotes knowledge sharing and good relations with the management team allows employees to encourage and support management to embark on organizational changes that aim to achieve strategic objectives(McManus et al., 2008; Sonnet, 2016; Stephenson, 2010). This will also encourage employees to think "out of the box" and use their knowledge in an innovative way to stay competitive. So, the ability of an organization to develop the knowledge and skills of its employees, to provide the necessary technological interfaces that encourage the sharing of information and knowledge across the various organizational departments, and to keep its employees informed, warned and alerted to manage unexpected events, are important elements that increase the organization's global awareness (Demmer et al., 2011; McManus et al., 2008; Sapeciay et al., 2017; Stephenson, 2010).

Furthermore, awareness requires a continuous development of an organization's external networks. These networks consist of those parties with whom the organization does business (e.g. suppliers, customers, government agencies, trade associations, etc.). In other words, in order to increase organizational awareness, it is important to have agreements with external organizations that enable the mobilization and exchange of resources when disruptive events occur (McManus et al., 2008; Stephenson, 2010). It is also important to maintain these agreements and to keep the communication links open by continuously understanding the different laws, regulations and other public or private organizations' involvement(Jones, 2015; Pettit et al., 2016; Sapeciay et al., 2017).

Table 5.4 summarizes the indicators used in the empirical studies to assess organizational awareness.

Table 5.4: Indicators to assess organizational awareness

Indicators	**Explanation**
Efficiency of organizational networks	The management and the continuous development of organizational networks to exchange and immobilize resources to face future disruptive events efficiently, now and in the future.
Clarity of roles and responsibilities	The development of expertise, and the right assignment of roles and responsibilities, help prevent the occurrence of disruptive events. This increases the global awareness of the organization and helps employees remain alert to possible disruptive events
Alertness to the organization's health	The continuous monitoring of the organization's financial and economic situation, its competitors, its customers, the updates on laws and regulations, etc., and making internal changes to avoid disruptive events, increase the organization's global awareness.
Minimization of organizational barriers	Minimizing the communications' barriers between an organization's departments helps keep its employees alert to future disruptive events. These barriers are often related to employees' cognitive behaviors, cultural backgrounds and work experiences, and are often the cause of detrimental working methods.
Adoption of an innovation culture	Building an innovation culture and encouraging the employees to think outside of the box is essential to stay competitive, and therefore achieve the organization's strategic objectives. This prepares to deal creatively with future disruptive events.

5.5.2 Adaptive Capacity

The concept of adaptive capacity is not new in the science of organizations, neither its relationship with resilience (Engle, 2011; McManus et al., 2008). In fact, in the literature on resilience, adaptive capacity influences resilience. Therefore, the more adaptive a system, the more resilient it is

(Engle, 2011). Thus, adaptive capacity is an essential dimension leading to organizational resilience to help preserve organizational missions, operations, etc. once faced with disruptive events (Dutra et al., 2015). It allows long-term sustainability of an organization (efficient use of resources to reduce the negative impact of changes and improve long-term organizational performance [Folke et al., 2002; Keenan, 2016]) because it empowers rapid and significant responses to disruptions (Keenan, 2016; 2015b).

Consequently, an organization's adaptive capacity is vital for its survival. Organizations that do not adapt will, at some point, collapse under the consequences of unsuccessfully managed disruptive events and will therefore cease to exist (Demmer et al., 2011).

Adaptive capacity is defined as the capacity of an organization to transform its structure, processes, culture, etc. to recover once faced with a disruptive event (Lee et al., 2013; McManus et al., 2008; Stephenson, 2010). An organization that adapts well to disruptive events is one that allows proper decision-making and appropriate resource mobilization, in a timely manner.

However, the development of the adaptive capacity is related to the disruptive events, their causes, their impacts and the alternatives to overcome them (Pettit et al., 2016; Sawalha, 2015). In fact, some researchers mention that a disruptive event may occur as a result of some internal or external changes to the organization. These changes can be caused by: the loss of a financing source, increased spending, an economic crisis, difficulty finding new customers, competition, threats of terrorism and continuous updates on laws and government regulations (Duarte Alonso & Bressan, 2015; Pettit et al., 2016; Sawalha, 2015). Consequently, it is necessary to analyze the disruptive events, and to realign the organizational priorities carefully, to be able to develop the most suitable adaptation strategy to overcome these events. Hence, having the right tools, processes and mechanisms can facilitate access to information, accelerate the analysis of the situation and allow an efficient and effective adaptation (Gunasekaran et al., 2011; McManus et al., 2008; Sapeciay et al., 2017; Stephenson, 2010).

Thus, the ability to deal with disruptive events in innovative and creative ways, the possession of above-average quality control processes and the existence of maintenance plans, are crucial for the organization to adapt once faced with disruptive events (Borekci et al., 2015, 2014).

Furthermore, a successful adaptation cannot be achieved without an effective contribution from both the leaders and other employees of an organization. In fact, the ability of managers to identify potential problems, to ensure availability of resources needed, to avoid damage caused by a disruption, and to take right decisions and actions to reduce negative impact of disturbances, are important qualities of leadership that increase the organization's overall adaptive capacity(Sullivan-Taylor & Branicki, 2011). In addition, employees' cognitive behaviors, work experiences, attitudes to disruptive events, psychological safety and ability to innovate and to be creative, are important elements that help organizations adapt to survive disruptive events (Akgün & Keskin, 2014; Pal et al., 2014; Sonnet, 2016; Tillement et al., 2009).

Table 5.5 summarizes the indicators used in empirical studies to assess the adaptive capacity of an organization. It is to mention that some of these indicators interrelate with the indicators used to assess the organization's awareness. For instance, the development of external networks and the capacity to immobilize internal and external resources, facilitate the leadership decisions when facing disruptive events.

In fact, as previously mentioned, the relationship between awareness and adaptive capacity is essential to ensure an efficient recovery from disruptive events(Lee et al., 2013; McManus et al., 2008; Sapeciay et al., 2017; Stephenson, 2010). The importance of this relationship is clearly explained by Keenan (2015a) when proposing a framework for adaptive capacity. Keenan argues that having the right beliefs, perceptions, learning capacities and processes for detecting changes for organizations (Keenan's definition of awareness), is crucial to improve the organizations' adaptive capacity and avoid shortening their economic and technical lifetime.

Table 5.5: Indicators to assess an organization's adaptive capacity

Indicators	**Explanation**
Mobilization of resources	The capacity to mobilize resources, from both the inside and the outside of the organization (e.g. through networks and partnerships), to help face disruptive events.
Employees' engagement	The engagement and involvement of employees in ensuring the success of organizational operations help reinforce its resilience. This includes understanding the link between their own daily tasks and the tasks required to adapt in the face of disruptive events. Also, the presence of employees that adopt innovative and creative solutions, in response to disruptive events, is a key factor in reinforcing the organization's adaptive capacity.
Leadership	The degree to which leadership has decision-making capabilities to strike a balance between daily and special operations during the occurrence of disruptive events. The focus on a leadership style that empowers employees to use their skills and expertise to solve issues.
Access to information	The degree to which information is quickly acquired, and stored in secure locations, to facilitate the management of disruptive events.
Decentralized decision-making	The extent to which employees are encouraged to make decisions by taking advantage of their specific knowledge and expertise to manage the challenges that may occur from a specific disruptive event.
Organizational analytical capabilities	The extent to which the organization can accurately analyze the consequences of disruptive events, and continuously adjust its priorities. This help guides organizations in the adaptation process to face disruptive events.

5.6 Conclusions and Future Research

This literature review has shown a range of indicators that are not part of a formal organizational resilience assessment approach or framework. Indicators were measured qualitatively and/or quantitatively, according to the context of each empirical study. However, after a thorough analysis

of the results, a set of indicators was extracted. These indicators measure two dimensions of resilience: awareness and adaptive capacity.

Awareness is the ability of an organization to evaluate its environment and interpret the changes in its surroundings, both now and in the future, to be proactive and better manage possible disruptive events. On the contrary, adaptive capacity is the organization's capacity to transform its structure for recovering once faced with a disruptive event. Awareness is essential to ensure a successful adaptation.

Consequently, the efficiency of organizational networks, the clarity of roles and responsibilities, the alertness to the organization's health, the minimization of organizational barriers and the adoption of an innovation culture are indicators used to explore organizational awareness. On the other hand, the mobilization of resources, employees' engagement, leadership, access to information, presence of a decentralized decision-making and organizational analytical capabilities are indicators used to examine the organization's adaptive capacity.

As for future research, it is suggested that the proposed indicators be part of a formal organizational resilience assessment approach, which should be flexible enough to adjust to any organizational context and environment. This assessment approach should be the subject of empirical studies needing to focus on evaluating continuously the resilience of organizations.

CHAPTER 6 ARTICLE 3 - BENCHMARKING PROJECT RESILIENCE

RAHI, K., BOURGAULT, M., & ROBERT, B. (2019). BENCHMARKING PROJECT RESILIENCE. JOURNAL OF MODERN PROJECT MANAGEMENT, 7(1), 8

Abstract

Projects still suffer from low project management success rates, mainly due to events that occur during their life-cycles, which cause deviations from their main objectives. That is why, recent studies have begun exploring the concept of resilience in project management. These studies aim to reinforce current project risk management practices and improve the capacity of a project to deal with disruptive events. Therefore, this paper reviews first the literature on the concepts of resilience, and of organizational resilience in order to propose a definition of project resilience and to set its dimensions. Second, the development of indicators to assess project resilience is achieved by conducting semi-structured interviews with 10 senior project managers from different industries, in which, 10 case studies were explored and analyzed. As a result, a definition is proposed, and 10 indicators are established to assess two dimensions of project resilience: awareness and adaptive capacity. In future research, these indicators would require a rigorous validation in different project types. This provides project team members with a robust set of indicators with which they would be able to assess their project's capacity to effectively and efficiently deal with disruptive events.

Keywords: project risk management, resilience, organizational resilience, project resilience, awareness, adaptive capacity

6.1 Introduction

Projects are becoming more and more complex. This literature reflects this complexity, and reports several examples of projects marked with difficulties and failures (Schneider et al., 2017; Brady & Davies, 2014; De Bakker et al., 2010; L.-A. Vidal, 2009; Bannerman, 2008). Members of project teams, and other stakeholders, still face many challenges when dealing with risks that occurred, which were unpredicted, unknown or even considered impossible to occur in specific circumstances: "*These are uncertainties, ambiguities, and arrays of risk factors that are often intricately connected*" (Thamhain, 2013, p. 21).

Traditional project risk management (PRM) practices have been ineffective in dealing with these risks(Albert, Balve, & Spang, 2017). In fact, these practices are criticized for being very time consuming, because they focus on 'hard theories and processes', without taking into consideration the dynamic changes in the project's environment (Crawford et al., 2013; Geambasu, 2011). On the other hand, PRM practices tend to identify, analyze, mitigate, and control, sources of quantifiable and predictable risks, without emphasizing the importance of dealing with risks 'consequences upon occurrence (Blay, 2017).

For those reasons, among others, it has been recognized that practices that are more flexible and context-specific can empower PRM practices to deal more effectively with disruptive events (Crawford et al., 2013). The focus should be on recognizing the inherent fallibility of the project, and developing response strategies to cope efficiently with disruptive events (Geambasu, 2011). These events are circumstances leading to severe deviations from the project's objectives (e.g. delay, over budget, low quality, incomplete scope, client dissatisfaction, etc.). They are known or unknown risks that occurred and caused distress during the project life-cycle (Blay, 2017; Zhang, 2007).

Undoubtedly, it is important to spend time trying to identify all possible and imaginable risks, and to prepare mitigation plans to deal with them. However, it is of equal importance to strengthen a project's 'immune system' to deal with any event that may arise during the project lifecycle. A comparison may be drawn with medicine: vaccination is important, for it makes the human body

immune to specific viruses. However, what is also important is to reinforce the human immune system itself, through specific behavior, so that it can deal with any virus, regardless of whether or not it is known.

That is why recent research has started to explore the concept of resilience as a path towards empowering PRM practices to effectively and efficiently face disruptive events during the project life-cycle (Schroeder & Hatton, 2012). Therefore, the goal of this article is to build on the suggestions of Thomé et al. (2016), Geambasu (2011) and Blay (2017), and to propose a definition, and a set of indicators to assess project resilience through a qualitative study.

First, the literature on resilience, and on organizational resilience is reviewed in order to propose a definition of project resilience and to set its dimensions. Second, the importance of assessing project resilience is explained. Third, the methodology used to develop the indicators is described. Finally, the results are analyzed and refined in order to propose a set of indicators to assess this novel concept of project resilience and validate its definition and dimensions.

It is to mention that organizational resilience was chosen because of the close link that exists between projects and organizations. Moreover, projects exist in an organizational context in order to meet the strategic objectives of the latter (Aubry et al., 2007; Thakurta, 2015). In addition, there is a line of research that defines projects as temporary organizations due to the similarity between the structure of a project and the structure of an organization (Anbari, 1985; Hanisch & Wald, 2013; Son JeongWook & Rojas Eddy M., 2011; Sydow & Braun, 2018; Thakurta, 2015). Therefore, the concept of organizational resilience, its definition, and the strategies sieved from the literature to improve it, have a guiding role in the definition of project resilience and the development of indicators to assess it.

6.2 Literature review

6.2.1 Resilience

The concept of resilience has been used for decades, in many disciplines and from many perspectives. Therefore, defining it varies depending on the entity involved (an individual, a critical infrastructure, an organization, a project, etc.), and even when the focus is on a specific entity, the definitions of resilience can vary in a substantial way (Carlson et al., 2012).

Two main foundations of resilience were introduced by Holling in (1996): 'engineering resilience' and 'ecological resilience'. The term 'engineering resilience' describes a focus on resisting and absorbing a specific force. It is the capacity of a system to maintain its functions, controls, and the relationships between its entities (Bhamra et al., 2011; Ponomarov & Holcomb, 2009). Therefore, a system based on engineering resilience works within limited possible states and tends to return quickly to its equilibrium state, after a disruption. Consequently, it focuses on stability (Holling, 1973; Ponomarov & Holcomb, 2009)

On the other hand, 'ecological resilience' is defined as the capacity for change and reorganization, and is measured by: "*the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior*" (Holling, 1996, p. 33). Therefore, a system founded on ecological resilience endures large disturbances, tends to return gradually to its equilibrium state and, under certain conditions, can change its structure and functions completely (Holling, 1996).

These original foundations of resilience have improved over the years, and have influenced subsequent studies on resilience from many perspectives and in many fields (Bhamra et al., 2011; Geambasu, 2011; Ponomarov & Holcomb, 2009).

6.2.2 Organizational Resilience

Despite the various definitions of organizational resilience, it can be stated unequivocally that this concept is related to the ability of an organization to deal with disruptive events that may cause cessation of organizational operations (Lee et al., 2013; McManus, 2008; Somers, 2007; Sonnet,

2016; Stephenson, 2010). It is mainly related to the capacity of the organization to be alert and prepared, via a set of cognitive behaviors, to successfully adapt and recover from disruptive events (Mafabi et al., 2015; Stephenson, 2010). This requires a continuous rebuilding of values, processes and mechanisms to proactively and reactively deal with disruptive events (Jung, 2015; Sonnet, 2016). Therefore, the concept of organizational resilience has mainly two dimensions that can be sieved from the literature: awareness and adaptive capacity.

Awareness is related to the organization's capacity to evaluate its surroundings and to be alert to changes that may cause disruptive events (Lee et al., 2013; McManus, 2008; Sapeciay et al., 2017). This requires a deep knowledge of the organization's inputs and outputs in order to identify the resources (e.g. tangible and intangible assets, knowledge, etc.) needed vs those available to maintain its operations (Borekci et al., 2014).

Many strategies can be used to improve the awareness of an organization. To this matter, the management and the continuous development of organizational networks is needed to exchange and immobilize external resources to face future disruptive events (Jones, 2015; McManus, 2008; Petit et al., 2013). Also, the development of expertise, and the right assignment of roles and responsibilities help prevent the occurrence of disruptive events. This increases the global awareness of the organization and helps employees remain alert to possible disruptive events (Lee et al., 2013; McManus, 2008). On the other hand, the continuous monitoring of the organization's financial and economic situation, its competitors, its customers, the updates on laws and regulations, etc., and making internal changes to avoid disruptive events, increase the organization's global awareness (Gunasekaran et al., 2011; Otulana, 2011). Another strategy that can be adopted is by minimizing the communications barriers between the organization's departments which helps keep its employees alert to future disruptive events. These barriers are often related to employees' cognitive behaviors, cultural backgrounds and work experiences, and are often the cause for detrimental ways of working (Sapeciay et al., 2017; Sonnet, 2016). Finally, building an innovation culture and encouraging the employees to think outside of the box is essential to stay competitive and help achieving the organization's strategic objectives, and to be prepared to deal creatively with future disruptive events (Demmer et al., 2011; Stephenson, 2010).

The second dimension of organizational resilience is adaptive capacity. It describes the capacity of an organization to transform itself in response to disruptive events (Otulana, 2011; Sonnet, 2016; Stephenson, 2010). As mentioned by Stephenson (2010): "*An organization's ability to adapt is at the heart of its ability to display resilient characteristics*" (Stephenson, 2010, p. 99).

To this matter, strategies can also be adopted to improve the organization's adaptive capacity. Thus, the mobilization of resources from both the inside and the outside of the organization (e.g. through networks and partnerships), help face disruptive events (Duarte Alonso & Bressan, 2015; Pettit et al., 2016; Sawalha, 2015). On the other hand, the engagement and involvement of employees in ensuring the success of organizational operations help improve its adaptive capacity. This includes understanding the link between their own daily tasks and the tasks required to adapt in the face of disruptive events. Also, the presence of employees that adopt innovative and creative solutions in response to disruptive events is a key factor in emphasizing the organization's adaptive capacity (Akgün & Keskin, 2014; Pal et al., 2014; Sonnet, 2016; Tillement et al., 2009). Consequently, adapting when faced with a disruptive event requires strong leadership and decision-making capabilities to strike a balance between daily operations and special operations. Leadership that focuses on empowering employees to use their skills and expertise to solve issues, reinforces the organization's adaptive capacity to better face disruptive events (Lee et al., 2013; Stephenson, 2010). So, employees are encouraged to make decisions by taking advantage of their specific knowledge and expertise to manage the challenges that may occur from a specific disruptive event. This includes allowing qualified employees to take decisions in critical situations, without the necessity of senior management approval (Borekci et al., 2015, 2014; Sullivan-Taylor & Branicki, 2011). Finally, improving the organization's adaptive capacity requires quick access to information stored in secure locations, to facilitate dealing with disruptive events (Gunasekaran et al., 2011; Sapeciay et al., 2017; Stephenson, 2010). It also requires accurate analysis of the consequences of disruptive events, and the continuous adjustment of organizational priorities (Demmer et al., 2011; Price, 2012).

6.2.3 Project Resilience

In project management, the concept of resilience is still new and largely overlooked (Thomé et al., 2016). The need for resilience emerged as a new way of dealing with disruptive events that may occur during the project lifecycle (Geambasu, 2011). These events can potentially lead to the project failure, because they can affect: "*everything from technical feasibility to cost, market timing, financial performance, and strategic objectives*" (Thamhain, 2013, p. 1).

There are few definitions of project resilience, and based on our knowledge, those that do exist are presented in Table 4.2. From these definitions, key words and key activities are observed. Project resilience refers to a function (ability, capacity, capability, etc.) of the project to be proactive (notice, interpret, prepare, etc.) and reactive (restore capacity, evolve in response, overcome, cope, etc.) when facing disruptive events. In fact, the project should be aware of its surroundings and adapt when faced with disruptive events, regardless of whether or not these events are known at the beginning of the project. So, the resilience of the project is reinforced by monitoring the project system's inputs, outputs and vulnerabilities (a measure of the gap between resources needed to complete a task and resources available (Proag, 2014)), and by being prepared and able to acquire the resources needed to deal with disruptive events.

Therefore, project resilience can be defined by the capacity of the project system to be aware of its surroundings, and to adapt in order to recover from disruptive events. Accordingly, project resilience has two dimensions; awareness and adaptive capacity. Awareness is a continuous understanding of the project system's elements and vulnerabilities, and an incessant monitoring of changes in its environment. On the other hand, adaptive capacity is the capacity of the project system to transform itself in order to cope with disruptive events.

From the system perspective, the project is defined by a set of elements that, in a changing environment, transform inputs into outputs. Thus, the project environment is both the main provider of inputs and the main receptor of the final outputs (the outputs that shape the final deliverables of the project), where inputs and outputs are resources (e.g. tangible and intangible assets, knowledge, etc.) (Anbari, 1985; Kopczyński & Brzozowski, 2015).

Table 6.1: Definitions of project resilience found in the literature

Definitions	**Reference**
The ability to restore capacity and continuously adapt to changes, and to achieve its objectives in the face of disruptive events.	(Geambasu, 2011)
The capacity to evolve in response to risks emerging after the project planning stage.	(Schroeder & Hatton, 2012)
The capacity to maintain purpose and integrity under external or internal shocks.	(Hillson, 2014)
The art of noticing, interpreting, containing, preparing for and recovering from disruption.	(Turner & Kutsch, 2015)
The capacity to overcome unexpected events.	(Giezen et al., 2015)
The ability to cope with uncertainty.	(Zhu, 2016)
The capability to respond to, prepare for and reduce the impact of disruptions caused by changes in the project environment.	(Blay, 2017)

6.2.4 Assessment of Project Resilience

Based on prior research and our knowledge of the new concept of project resilience, it would appear that there is both a need for, and an interest in, developing indicators to assess project resilience (Geambasu, 2011; Thomé et al., 2016). In fact, assessing project resilience, by the project team members, aims to validate the state of knowledge on the ability of the project to deal with disruptive events (Blay, 2017). This refers to the progress of the knowledge's acquisition about the project, and its environment, to deal with events that can potentially lead to its failure. Therefore, these indicators, when developed, can be used as a diagnostic tool to assess the impact of the efforts required to support the resilience of current and future projects. These indicators can potentially help determine the project’s strengths and weaknesses regarding its capacity to deal with disruptive events, as well as to suggest action plans to improve its resilience.

6.3 Methodology

The inductive approach was employed to achieve the objectives of this study and to propose a set of indicators to assess project resilience. This approach is appropriate, because it allows the generation of a set of indicators to assess project resilience by exploring the reality. This approach is mainly used: "*when the conceptual basis for a construct may not result in easily identifiable dimensions for which items can then be generated*" (Hinkin, 1998, p. 6), which is well suited to the context of this study.

Therefore, semi-structured interviews were conducted with 10 senior project managers from different industries. The goal was to understand how project managers become aware of, deal with, and manage disruptive events that occur during the project life-cycle. Two series of questions were asked during these interviews. The first series of questions was related to the current methods used by the respondent, in their most common projects, to identify project weaknesses (where the project is most vulnerable), and to deal with disruptive events in general. The second series of questions was related to the identification and the management of a specific major disruptive event (a case study). Each interview lasted between 30 min and 45 min. Table 6.2 provides the characteristics of respondents who participated in the interviews (while ensuring the confidentiality of their names and the companies that they work for), and the case studies that were discussed with the interviewees. The interviews' transcripts were analyzed by QDAMiner Lite to propose a set of indicators that can potentially be used to assess this concept. It is to mention that the word 'resilience' was deliberately not used during the interviews, because it is still a new concept in project management, and project managers are not used to it. So, phrases such as: "unforeseen and unknown risks", "project management processes and practices," and "are aware, deal with, and manage" were used instead. It was during the analysis phase that these phrases were transposed to 'resilience', in order to fulfill the objective of this study.

On the other hand, the literature reviewed, in the previous sections, on organizational resilience inspired the development of the interview questions and helped in the development of indicators to assess project resilience.

Table 6.2: Information on the interviewee and the case studies discussed

Interviewee #	**Years of experience in PM**	**Industry**	**Range of projects' budgets ($ CAD)**	**Key deliverables**	**Range of projects' schedules**	**Brief description of the case study discussed**
1	5	IT[26] consulting	500K to 2M	Software applications and enterprise shared services modules in a SOA[27] environment	3 to 12 months	A migration project from Windows XP to Windows 7 in a Canadian Bank in which, based on an executive decision during the execution phase of the project, 80% of the team was changed. This decision led to serious compatibility issues between the team members and tensions with senior management.
2	18	Financial services	10K to 500K	System upgrades to various organizations' payroll platform	2 to 18 months	During the go-live date of the implementation of a payroll application, the client decided to make important changes to a specific interface. This issue caused all processing in the application to fail and, consequently, the main provider did not receive accurate information related to his employees' payroll on time.

[26] Information Technology

[27] Service Oriented Architecture

Table 6.2: Information on the interviewee and the case studies discussed (Continued)

Interviewee #	**Years of experience in PM**	**Industry**	**Range of projects' budgets ($ CAD)**	**Key deliverables**	**Range of projects' schedules**	**Brief description of the case study discussed**
3	7	Software development and implementation	10K to 70K	Software payroll platforms	4 to 6 months	During the implementation of a technological system, and before the go-live date, the main resource (the resource that owns the most critical information on the application and the data) from the client's side left the project. This change was followed by a new requirement that has never been implemented before.
4	8	Construction	25K to 3M	Electrical construction related	1 to 4 years	During the commissioning, delivery and integration of 8 critical electrical generators for a hospital, a team member forgot to trigger the ventilation system. This led to the explosion of some pieces within the electrical generators which caused delays, and additional, unforeseen cost.
5	6	Wood industry and production	100K to 1M	Plant/factory development, installation of assembly lines in factories	4 to 5 months	During the assembly of a production line, the senior management decision to purchase a cheaper machine led to many issues in the piping system. This issue led to delays and additional costs.

Table 6.2: Information on the interviewee and the case studies discussed (Continued)

Interviewee #	**Years of experience in PM**	**Industry**	**Range of projects' budgets ($ CAD)**	**Key deliverables**	**Range of projects' schedules**	**Brief description of the case study discussed**
6	8	IT and payroll services	50K to 400K	Payroll system including benefits, and time & attendance	4 to 18 months	After signing the contract with the client and gathering the initial requirements to start the implementation of a software application, it was noticed, during the project life-cycle, that the application did not meet, at all, the client's needs.
7	5	Construction / transportation	300M to 400M	Constructed establishments	Around 5 years	For a big construction project, the design was completed, and a specific engineering firm was hired to execute specific task. However, an opposition from a specific municipality prevented the company from getting the license to move forward with the project, because of the presence of a dog park.
8	7	Construction	25K to 4M	Buildings renovations and small constructed establishments	6 to 24 months	A general strike in the construction industry stopped 30 construction projects at the same time due to the lack of resources. This led to delays and an unhappy customer.

Table 6.2: Information on the interviewee and the case studies discussed (Continued and end)

Interviewee #	**Years of experience in PM**	**Industry**	**Range of projects' budgets ($ CAD)**	**Key deliverables**	**Range of projects' schedules**	**Brief description of the case study discussed**
9	7	Decontamination and construction	20M to 80M	Installation and extension of gas networks	2 years	A change in a law within the committee on standards, equity, health and safety at work led to a major change on a construction project. This change cost millions of dollars and delays.
10	5	IT	10K to 250K	Hardware installation and support. SAAS[28], cloud-based, implementation projects.	3 to 12 months	While working with a client that purchased a software application with many interrelated components, he decided, during the testing phase, to withdraw a specific component which led the whole application to crash.

[28] Software as a Service

6.4 Results & Discussion

Based on the findings from the qualitative study, project resilience is indeed the capacity of the project system to be aware of its surroundings and to adapt in order to recover from disruptive events. The evidence emphasized the importance of recognizing the project system's vulnerabilities, of analyzing potential threats, and on being prepared to deal with them on occurrence. On the other hand, the analysis of the case studies provided evidence of positive adjustments when facing disruptive events. These positive adjustments are transformations that occurred in order to cope with the disruptive events and recover successfully.

Therefore, 10 indicators and 48 items are proposed to measure the two dimensions of project resilience: awareness and adaptive capacity. Table 6.3 presents the indicators, and the items to measure them, along with their link to awareness and adaptive capacity. As suggested by Hinkin (1998), Likert-type scales are the most useful in behavioral research. Therefore, it is suggested that a 5-point Likert scale would be appropriate to evaluate the indicators, by rating the correspondent items from 'strongly disagree' to 'strongly agree', with a neutral midpoint.

6.4.1 Awareness

The awareness dimension of project resilience is measured by 6 indicators and 26 items. These indicators are presented and explained in the following sections.

6.4.1.1 Clarity of Roles & Responsibilities

Increasing awareness, and accomplishing successfully project objectives, require a clear understanding of the functions assumed, the accountability and collaboration needed, and the right skills, expertise, physical and mental states demanded by team members, during the project life-cycle. As mentioned by a senior project manager, whose project suffered from severe consequences due to the negligence of an experienced team member: "*Having the experience and skills to complete a specific task is important but not enough: physical and mental states are of equal importance*". It must also be mentioned that this indicator is in line with the indicators used

to assess organizational resilience. The latter refers to the work of Lee et al. (2013), McManus (2008), and Stephenson (2010).

6.4.1.2 Availability of Project & Risk Management Methods

The availability of project management and risk management tools and applications to keep stakeholders updated on project performance, and informed about project weaknesses, during the project life-cycle, increases awareness. As noted by the majority of the respondents, having clear processes, together with risk and project management templates, including field-specific methods, helped the project team to capture project weakness, and remain alert to possible disruptive events.

6.4.1.3 Alertness to Scope & Performance Deviations

Remaining alert to disruptive events demands continuous monitoring, throughout the project life-cycle, of project Key Performance Indicators (KPIs), and of changes to the project's scope. This indicator is in line with the studies of Geambasu (2011) and Zhu (2016), in which it was noted that deviations in KPIs can lead project managers and project team members to the potential occurrence of disruptive events. These KPIs are related to the budget, the schedule and the quality of work (if quality insurance is continuously performed). Thus, the positive adjustment of these KPIs increases the project's ability to remain alerted to possible disruptive events.

6.4.1.4 Sensitivity to Environmental Changes

External events can have a huge impact on the project's objectives. These external events can be, among others: a change in laws and regulations, a general strike, critical weather conditions, etc. These events can happen anytime during the project life-cycle. Therefore, the continuous monitoring and assessment of events or conditions in the project's environment will help in the identification and assessment of possible threats.

Therefore, and as suggested by one respondent, participating more actively and frequently in the meetings of associations, and staying aware of changes on laws and regulations can help the project avoid the negative effects of external disruptive events. On the other hand, learning from history, in a specific field, can also improve the general awareness of the project. For example, a senior

project manager in the construction industry suffered from a lack of resources on his projects, because of a general strike in the province of Quebec. He mentioned: "*It is important to verify the frequency of having strikes in Quebec. Strikes in this province are not rare. This lack of verification caused serious delays on the projects, and unsatisfied customers*".

6.4.1.5 Efficiency of External Resources

A project's global awareness may be increased by the continuous development and updates of partnerships and networks, so as to better identify and assess possible threats through external resources. Many respondents emphasized the importance of developing and maintaining partnerships with external parties, to help in the identification and assessment of project weaknesses. A specific example that occurred in the construction industry, where consultants were encouraged at the beginning of the project, to participate in risk analysis sessions and project planning, especially that those consultants are typically the ones who execute the work.

The importance of networks is also discussed in studies on organizational resilience, such as the work of Jones (2015), Pettit et al. (2016), and Sapeciay et al. (2017).

6.4.1.6 Leadership & Involvement of Stakeholders

Awareness requires that leaders embrace transparency when dealing with all stakeholders, by continuously setting expectations, providing updates on changes, and having the optimal visibility of issues that may lead to disruptive events. As mentioned by one of the respondents: "*A lack of an open and transparent communication between senior managers and the team members caused a major change in the project's main resources (80% of the team members were changed without any notice), which creates tension between team members and delays on the project".*

It is to mention that the role of leadership is also discussed in studies on organizational resilience, as part of developing strategies and supporting employees to deal with disruptive events (e.g. Sullivan-Taylor & Branicki (2011)).

6.4.2 Adaptive Capacity

The adaptive capacity dimension of project resilience is measured by 4 indicators and 22 items. These indicators are presented and explained in the following sections.

6.4.2.1 Accessibility & Mobilization of Resources

A project's adaptive capacity to recover, and to continue fulfilling its objectives, is increased by having access to accurate information, and by being able to mobilize external (e.g. through partnerships) and internal (e.g. from different organizational departments) resources to face disruptive events. As mentioned by one of the respondents in the IT industry: "*mobilizing a qualified internal resource, which was not part of the project, helped hand-holding the client on site until he recovered from the loss of its key resource*". Another respondent from the construction industry received help from external resources, through partnership, to redesign a whole solution that allowed the project to recover from a major disruptive event.

The importance of accessing qualified internal and external resources, and being able to mobilize them, is also discussed in studies on organizational resilience (e.g. Lee et al. (2013), McManus (2008), Stephenson (2010))

6.4.2.2 Responsiveness of Team Members

To increase the adaptive capacity of the project system, team members are encouraged and rewarded for adopting innovative and creative solutions, through their managerial and technical skills, and expertise when faced with disruptive events. Many examples given by the respondents show how team members' responsiveness enabled quick recovery from disruptive events. For example, as mentioned by one respondent in the IT industry: "*another resource, that was not even supposed to work on the project, showed diligence, filled in the job required by both ill resources, and continued the project by himself for two weeks*".

This indicator is also discussed in studies on organizational resilience, where the organization's adaptive capacity is increased by its employees' cognitive behaviors and their innovative attitude

to face disruptive events (Akgün & Keskin, 2014; Pal et al., 2014; Sonnet, 2016; Tillement et al., 2009)

6.4.2.3 Effectiveness of Communications and Relationships

Continuous follow-ups, with honest and transparent communications, in which stakeholders take ownership of the issues and suggest possible solutions, enable an efficient management of disruptive events. As mentioned by one of the respondents: "*It is very important to report the disruptive event with great honesty and transparency and take ownership to deal with it. Therefore, when the external consultant and the client took ownership and had the commitment to deliver according to the new plan, the disruptive event was successfully managed*". As also mentioned by another respondent: "*during a disruptive event, projects may fail because of a lack of effective communication*". The adoption of effective, transparent and honest communication is also discussed in studies on organizational resilience. In fact, as mentioned by Stephenson (2010): "*during crisis, organizations often fail (or the crisis is escalated) because of their lack of effective communication.*"

6.4.2.4 Adapted & Responsible Decision-Making

To better adapt when facing disruptive events, the devolution of decision making is encouraged by leadership. In fact, leadership must acts strategically to face disruptive events, by taking into account the project importance, by always ensuring stakeholders' satisfaction, and by respecting signed contracts and agreements. Additionally, the delegation of authority to qualified team members, to make decisions related to their tasks, can help in dealing with disruptive events. However, this expansion of decision-making needs to be well controlled to avoid, as much as possible, the 'silo mentality' effect (Geambasu, 2011; Zhu, 2016). This effect occurs when project team members adopt an individualistic approach when making decisions (McManus, 2008). In fact, if there is a lack of understanding of a disruptive event, and without coordinating with other team members and senior management, individual decisions can lead to additional risks that may cause the project to deviate from its main objectives (Schroeder & Hatton, 2012).

Table 6.3: The indicators and their items to assess the awareness and the adaptive capacity dimensions of project resilience

Indicator	**Items**
	Awareness
Clarity of Roles & Responsibilities	1. I have a clear understanding of my tasks during the project life-cycle. 2. I continuously use my expertise to identify project risks. 3. I continuously use my expertise to assess (probability vs impact) projects' risks. 4. I work in collaboration with other team members to remain alert to disruptive events. 5. I use field-specific practices (e. g. safety measures, protocols and certifications, etc.) to ensure tasks are completed based on field-specific regulatory compliance.
Availability of Project & Risk Management Methods	1. Based on the project type, project management methods (e.g. project plan template, Agile, etc.) are employed to capture all project's requirements and potentially avoid possible disruptive events. 2. Based on the project type, risk management methods (e.g. risk register template, Monte Carlo analysis, etc.) are used to avoid possible disruptive events. 3. Lessons learned from previous similar projects are analyzed to identify project weaknesses. 4. Field-specific methods (e.g. field-specific checklists, equipment installation guides and procedures, etc.) are used to remain alert to project weaknesses.
Alertness to Scope & Performance Deviations	1. Scope changes are continuously monitored through the project life-cycle. 2. Project requirements are properly gathered from the beginning of the project. 3. KPIs for the budget are continuously monitored to detect any budget performance deviation through the project life-cycle. 4. KPIs for the schedule are continuously monitored to detect any schedule performance deviation through the project life-cycle. 5. Quality control is continuously achieved to detect any discrepancies that may lead to disruptive events through the project life-cycle.

Table 6.3: The indicators and their items to assess the awareness and the adaptive capacity dimensions of project resilience (Continued)

Indicator	**Items**
	Awareness
Sensitivity to Environmental Changes	1. External changes (e.g. changes in laws, regulations and field-specific trends, etc.) are proactively monitored (e.g. by participation with industry-specific groups or associations, etc.) to have early warnings of possible disruptive events. 2. Internal organizational changes (e.g. new project management processes, updates to existing methods, etc.), that may impact the project, are clearly communicated to avoid possible disruptive events. 3. When needed, access to resources within the organization is available to help identify project weaknesses. 4. When needed, access to resources within the organization is available to help assess project weaknesses.
Efficiency of External Resources	1. Partnerships with external parties that have the field-specific knowledge are continuously developed. 2. Current partnerships with external parties are continuously reinforced. 3. Access to external resources through partnerships is possible to help identify project weaknesses. 4. Access to external resources through partnerships is possible to help assess project weaknesses.
Leadership & Involvement of Stakeholders	1. Senior managers are transparent regarding any organizational changes that may cause disruptive events during the project life-cycle. 2. All detected issues through the project life-cycle are communicated to senior managers, to keep them alert to possible disruptive events. 3. Expectations are continuously set to reinforce trust and avoid surprises. 4. Follow-ups (regular meetings, status calls, etc.) take place regularly to remain alert to possible disruptive events.

Table 6.3: The indicators and their items to assess the awareness and the adaptive capacity dimensions of project resilience (Continued)

Indicator	**Items**
	Adaptive Capacity
Accessibility & Mobilization of Resources	1. When needed, resources can be mobilized from different departments to face disruptive events. 2. When needed, resources can be mobilized through partnerships to face disruptive events. 3. Information systems are available to provide quick access to information to solve an issue. 4. Information systems are available to log disruptive events. 5. Departments can provide feedback on possible solutions to face disruptive events through information systems. 6. External partners can provide feedback on possible solutions to face disruptive events through information systems. 7. When the budget contingency is completely consumed, leadership can release additional funds to face disruptive events.
Responsiveness of Team Members	1. I tend to adopt creative solutions to face disruptive events. 2. I am encouraged to think outside of the box to find solutions to face disruptive events. 3. I have the expertise to deal with disruptive events. 4. When faced with disruptive events, it is a priority to find the best ways to avoid them.
Effectiveness of Communications & Relationships	1. Clear explanations of issues and possible solutions are provided to all stakeholders through transparent communications. 2. Stakeholders, including the client, are encouraged to take ownership of the issue and any possible solutions. 3. Stakeholders are involved through continuous follow-ups (e.g. regular meetings, status calls, etc.) to ensure proper management of disruptive events. 4. Stakeholders are open to reassess project objectives (e.g. new ways of doing things, new roadmap, new strategies, etc.), if needed, to face disruptive events. 5. A clear escalation plan is available to face disruptive events.

Table 6.3: The indicators and their items to assess the awareness and the adaptive capacity dimensions of project resilience (Continued and end)

Indicator	**Items**
	Adaptive Capacity
Adapted & Responsible Decision Making	1. Senior managers plot a course of actions to face disruptive events. 2. Senior managers ensure actions are implemented in the right way and at the right time to effectively face disruptive events. 3. Senior managers adapt their strategies to face disruptive events based on the project's importance to the organization. 4. Stakeholders' satisfaction is taken into consideration when finding solutions to face disruptive events. 5. Clauses in the contract can be bypassed, to a certain extent, to find solutions to face disruptive events. 6. Qualified team members are encouraged to make critical decisions without the need for senior managers' approval.

6.5 Conclusion

Project resilience is still a novel and an interesting concept to be explored in scientific studies. It empowers current project management methods, to better deal with events that may cause severe deviations from a project's objectives. Following an inductive approach, in which 10 senior project managers were interviewed, and 10 case studies were carefully examined, 10 indicators were mined from this empirical study to assess the two dimensions of project resilience: awareness and adaptive capacity.

The clarity of roles and responsibilities, the availability of project and risk management methods, the alertness to scope and performance deviations, the sensitivity to environmental changes, the efficiency of external resources, and the leadership and involvement of stakeholders measure the continuous understanding of the project system's elements and vulnerabilities, and the incessant monitoring of changes in its environment (awareness).

On the other hand, the accessibility and mobilization of resources, the responsiveness of team members, the effectiveness of communication and relationships, and adapted and responsible decision-making, measure the capacity of the project system to efficiently acquire resources in order to transform itself (adaptive capacity).

It is suggested that future research should seek to validate these indicators (e.g. exploratory and confirmatory factor analysis) in different project types (e.g. IT, Construction, Pharmaceutical, etc.), in order to give project team members more robust indicators to help them assess the project's capacity to deal effectively and efficiently with disruptive events.

CHAPTER 7 EMPIRICAL VALIDATION RESULTS OF THE INDICATORS

This chapter details the validation results based on the data obtained from the survey questionnaire

This chapter aims to present an examination of the proposed indicators for the two dimensions of project resilience; awareness and adaptive capacity. It is organized in three subsections designed to facilitate the interpretation of the results. The first subsection presents information on the population from which the data was collected. The second sub-section reveals the results of the principal component analysis. The third subsection uncovers the results of the confirmatory factor analysis. The reliability of the indicators is also discussed.

It is very important to remember, when reading this chapter, that in this dissertation an exploratory approach is used to validate, for the first time, indicators developed through qualitative study to assess project resilience. Therefore, having imprecise or incomplete results is considered acceptable, and opens the door for additional investigation and research avenues (DeVellis, 2012; Hair et al., 2010; Wymer & Alves, 2012).

7.1 Population Overview

The sample for this research was 335 observations, of which 167 observations[29] were collected. The majority of the 167 respondents participated in IT projects that aim to *develop* (39% of the survey population's) or to *implement* IT applications (32% of the survey's population). Alternatively, 14% of the respondents participated in IT infrastructure projects[30], 10% in telecommunications project, and finally 5% of the participants chose other types of IT projects

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[29] More details on the number of observations required vs. those collected are available in the 3rd Chapter: Research Design and Methodology

[30] IT infrastructure "*includes the hardware, operating software, communications, other equipment and support required to enable business applications*" (Weill, 1992, p. 4). IT infrastructure projects require a large and long-term investments (Weill, 1992).

than those pre-defined in the questionnaire (Applications implementation, Applications development, Infrastructure, Telecommunications). These new types of projects are:

1. Product development
2. Smart factory (app development, infrastructure and IT/OT implementation)
3. Transformation
4. Database and data entry
5. Student information system
6. Computer science
7. Data science
8. "Portage d'application" (type of project in French)

Figure 7.1 presents the distribution of the survey's population by type of project. Other information on the projects selected by the respondents, where disruptive events occurred and were managed successfully, include the budget and the schedule of the project.

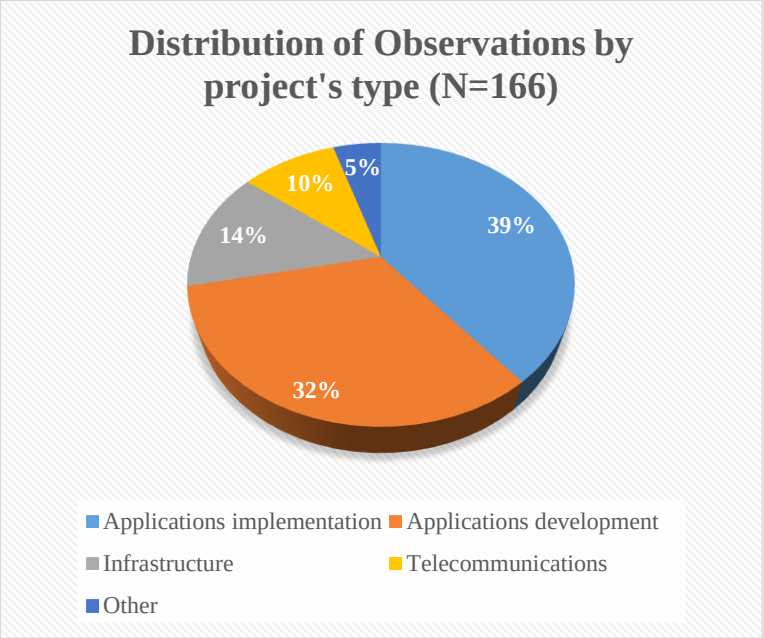

Figure 7.1 – Distribution of observations by project's type

In fact, it was also noticed that 77% of the participants worked on projects with a schedule between 6 months and 3 years (40% between 6 months and 12 months, 37% between 13 months and 3 years). Additionally, 18% of the participants worked on projects with a schedule less than 6 months. On the other hand, it was also noted that 68% of the projects had a budget less than 1 M$ (13% less than 50 K$, 15% between 50 K$ and 100 K$, 26% between 100 K$ and 500 K$, 14% between 500 K$ and 1 M$). From these results it can be conclude that IT projects are considered projects with relatively a short time frame and a low budget. Figure 7.2 presents the distribution of survey's population by the projects' budget and schedule.

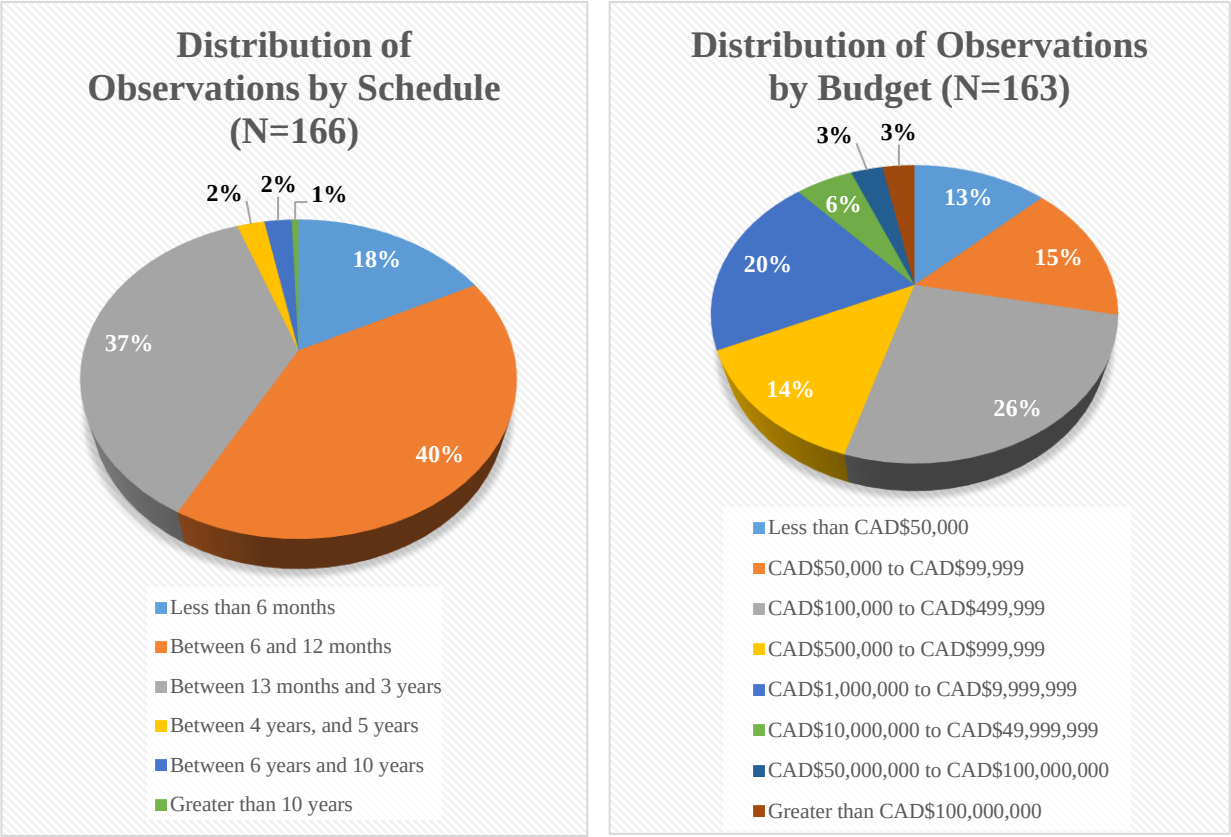

Figure 7.2 – Distribution of observations by project's schedule and budget

The empirical data analyzed in this research were collected from project managers and project team members (55% were project managers and 45% were project team members). Their years of experience varied from less than 2 years of experience (8%) to greater than 20 years of experience

(16%). Most of the participants had 11 to 15 years of experience (26%) and 6 to 10 years of experience (23%). In fact, 76 % of the participants have more than 5 years of experience. Therefore, based on these results, we can suppose that a certain level of maturity and accumulated knowledge exist within the participants. Figure 7.3 presents the distribution of survey's population by role and years of experience.

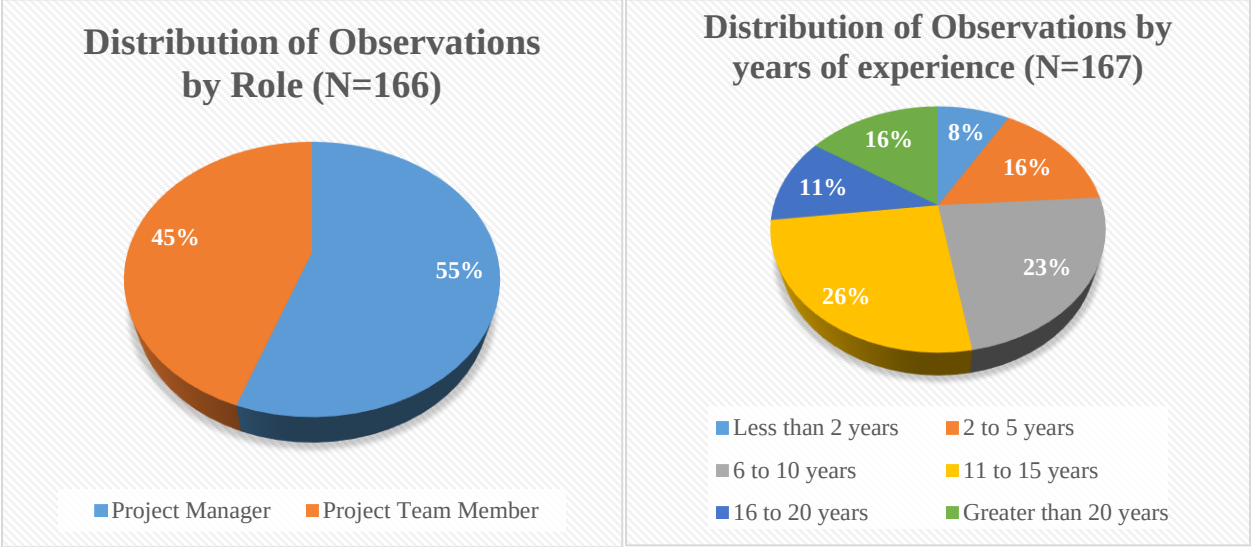

Figure 7.3 – Distribution of observations by role and years of experience

7.2 Results of Factor Analysis

As already discussed, because the number of respondents (N=167) is lower than the suggested sample for this study (N of 335), it was decided to run principal component analysis (PCA) on the current data to analyze separately the two dimensions of project resilience; awareness and adaptive capacity. Analyzing separately the two dimensions of project resilience has an impact on accurately validating the effectiveness of the two dimensions (awareness and adaptive capacity) when measuring the main concept (project resilience) (Hair et al., 2010). As explained in Chapter 8 this is considered a research limitation, and future research avenues are suggested.

7.2.1 Principal Component Analysis (PCA) [31]

7.2.1.1 PCA for Awareness

In this section PCA for awareness is presented. The awareness dimension is composed of 6 indicators and 26 items.

First, PCA was launched to derive the number of components with eigenvalues greater than 1. As a result, 7 components were retrieved. Consequently, PCA was launched with 7 factors including all the awareness indicators and their items. Based on the results (presented in Appendix L) a Kaiser-Meyer-Olkin (KMO) of 0.807 and a Bartlett's Test of Sphericity of 0.000 were registered. This implies that the data is suitable for factor analysis (Hair et al., 2010). However, ASPD5 was removed, because it did not load on any factor with a value higher than 0.5, thus tainting the convergent validity.

Again, PCA without ASPD5 was executed. Results (presented in Appendix M) show a KMO of 0.789 and a Bartlett's Test of Sphericity of 0.000. However, ASPD2 loaded on factors 1 and 6 with a value of 0.558, thus tainting the discriminant validity. Therefore, it was decided to omit it. LIS4 loaded 0.498 on the 1st factor (very close to the rule of thumb of 0.5). But, it was decided to retain it because in exploratory studies, some authors can tolerate factor loadings up to 0.475 (Hinkin, 1998). LIS2 did not load on any factor with a value greater than 0.5, but it was decided to retain it for two reasons:

1. It loaded high (0.688) in the first attempt, which means it might load high again if ASPD2 is omitted;
2. Even if it was decided to keep LIS4, it loaded close to 0.5. Therefore, if LIS2 is removed, LIS4 might load even lower when repeating PCA for the 3rd time. If LIS4 loaded lower

[31] As explained in the 3rd chapter (Research Design and Methodology), several PCA attempts are executed to ensure that the convergent validity (items not loading on any factor with a value greater than 0.5) and the discriminant validity (items loading on multiple factors with a value greater than 0.5) are not tainted (Hair et al., 2010; Hinkin, 1998).

than 0.5, it will be removed and this will violate the rule of thumb of having a least three items to measure an indicator (Hinkin, 1998). Therefore, the whole LIS indicator will be jeopardized.

As a third attempt (presented in Appendix N), PCA without ASPD2 was executed. This results of two items (APRMM4 and ASPD5) loading respectively on two factors (APRMM4 loaded 0.546 on the 3rd factor and 0.574 on 6th factor, and ASPD4 loaded 0.539 on 2nd factor and 0.543 on the 3rd factor), thus tainting the discriminant validity. Yet, it was decided to omit only APRMM4, because removing ASPD4 violates the rule of thumb of having a least three items to measure an indicator (Hinkin, 1998). LIS2[32] loaded 0.484 on the 2nd factor (very close to the rule of thumb of 0.5). However, it was decided to retain it, because in exploratory studies, some authors can tolerate factor loadings up to 0.475 (Hinkin, 1998).

Accordingly, the 4th attempt eventuates (presented in Appendix O) a KMO of 0.781 and a Bartlett's Test of Sphericity of 0.000. No item loaded on two factors, but CRR1 and LIS2 did not load on any factor with a value greater to 0.5, thus tainting the convergent validity. Therefore, it was decided to remove them and rerun PCA.

In the fifth attempt (presented in Appendix P) all items loaded on one factor with a value greater than 0.5, but only two unrelated items loaded on the 6th factor. Consequently, it was decided to execute PCA with 5 factors and omit CRR5 and SEC1 (the two items that loaded on the 6th factor). This decision was taken, because as suggested in the literature at least 3 items are needed to evaluate an indicator. The 6th factor violates this rule because only two items are available to assess it (DeVellis, 2012; Hinkin, 1998). In addition, it was not possible to interpret or rename this factor after reviewing the results from the qualitative analysis.

As a result, the final attempt presented acceptable results. All items loaded with values greater than 0.5 and the combination of items by factors matched with the results from the qualitative study.

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[32] Higher than the loadings of LIS2 after executing PCA for the 2nd time. This reinforced the choice of keeping LIS2 after the 2nd attempt.

The final PCA results for awareness are presented in Table 7.1 . This includes 5 indicators and 19 items to assess the awareness dimension of project resilience.

This is a summary of the PCA results for the awareness dimension and their respective meanings:

1. A KMO of 0.757 (greater than the rule of thumb of 0.5) and a Bartlett's Test of Sphericity of 0.000 (less than the rule of thumb of 0.05) were registered which means that the data is suitable for factor analysis;
2. Items from the APRMM and ASPD indicators were mixed in a new indicator as they loaded on the same factor. It was decided to name the new indicator "*Alertness to Performance Deviations*" (code APD). This combination of items was completed after reviewing the results from the qualitative analysis. In fact, the availability of project management and risk management methods aims to remain alerted to performance deviations. These methods provide clear information on the status of tasks and risks to keep the project team updated (Ahmed et al., 2007; Bannerman, 2008);
3. It is also to mention that the cumulative variance explained for awareness is equal to 64.504% which is higher than the rule of thumb of 60%. In other words, indicators for awareness explain 64.504% of the variance which means they are worth including in the awareness model;
4. for the assessment of the internal coherence and the consistency of the scale, values of α Cronbach for each factor are higher than the rule of thumb of 0.6 (0.62 for LIS, 0.879 for EER, 0.761 for SEC, 0.778 for APD, and 0.764 for CRR). This means that the reliability of the factors is achieved.

Table 7.1: PCA final results for awareness

Code	**Clarity of Roles & Responsibilities (CRR)**	**Factor**
CRR2	I continuously use my expertise to identify project risks	0.828
CRR3	I continuously use my expertise to assess (probability vs. impact) projects' risks	0.826
CRR4	I work in collaboration with other team members to remain alert to disruptive events	0.717
α Cronbach		***0.764***
% Var.		***11.596***
Code	**Alertness to Performance Deviations (APD)**	**Factor**
APRMM1	Based on the project type, project management methods (e.g. project plan template, Agile, etc.) are employed to capture all project's requirements and potentially avoid possible disruptive events	0.642
APRMM2	Based on the project type, risk management methods (e.g. risk register template, Monte Carlo analysis, etc.) are used to avoid possible disruptive events	0.538
APRMM3	Lessons learned from previous similar projects are analyzed to identify project weaknesses	0.610
ASPD1	Scope changes are continuously monitored through the project life-cycle	0.671
ASPD3	KPIs for the budget are continuously monitored to detect any budget performance deviation through the project life-cycle.	0.673
ASPD4	KPIs for the schedule are continuously monitored to detect any schedule performance deviation through the project life-cycle.	0.663
α Cronbach		***0.778***
% Var.		***14.388***

Table 7.1: PCA final results for awareness (Continued and end)

Code	**Sensitivity to Environmental Changes (SEC)**	**Factor**
SEC2	Internal organizational changes (e.g. new project management processes, updates to existing methods, etc.), that may impact the project, are clearly communicated to avoid possible disruptive events	0.548
SEC3	When needed, access to resources within the organization is available to help identify project weaknesses	0.863
SEC4	When needed, access to resources within the organization is available to help assess project weaknesses	0.850
α Cronbach		***0.761***
% Var.		***11.286***
Code	**Efficiency of External Resources (EER)**	**Factor**
EER1	Partnerships with external parties that have the field-specific knowledge are continuously developed	0.821
EER2	Current partnerships with external parties are continuously reinforced	0.809
EER3	Access to external resources through partnerships is possible to help identify project weaknesses	0.847
EER4	Access to external resources through partnerships is possible to help assess project weaknesses	0.863
α Cronbach		***0.879***
% Var.		***16.081***
Code	**Leadership & Involvement of Stakeholders (LIS)**	**Factor**
LIS1	Senior managers are transparent regarding any organizational changes that may cause disruptive events during the project life-cycle	0.739
LIS3	Expectations are continuously set to reinforce trust and avoid surprises	0.607
LIS4	Follow-ups (regular meetings, status calls, etc.) take place regularly to remain alert to possible disruptive events	0.627
α Cronbach		***0.620***
% Var.		***11.154***

PCA analysis for awareness has shown that the items were grouped by indicators as already derived from the qualitative study (the analysis of the interviews with senior project managers). This reinforces the fact that the strategy adopted to generate the indicators and their respective items is suitable (Hinkin, 1998).

7.2.1.2 PCA for Adaptive Capacity

In this section PCA for adaptive capacity, the second dimension of project resilience, is presented. In fact, the adaptive capacity dimension is composed of 4 indicators and 22 items.

First, PCA was launched to derive the number of components with eigenvalues greater than 1. As a result, 6 components were retrieved. Consequently, PCA was launched with 6 factors including all the adaptive capacity indicators and their items. Based on the results (presented in Appendix Q) a KMO of 0.805 and a Bartlett's Test of Sphericity of 0.000 were registered. This implies that the data is suitable for factor analysis (Hair et al., 2010). However, it was noticed that ECR5 and ARDM4 did not load on any factor with a value higher than 0.5, thus tainting the convergent validity. Consequently, it was decided to remove them. AMR1 loaded 0.484 on the 4th factor (very close to the rule of thumb of 0.5). But, it was decided to retain it because in exploratory studies, some authors can tolerate factor loadings up to 0.475 (Hinkin, 1998).

As a result, the final attempt presented acceptable results. All items except AMR1 (0.477 very close to the rule of thumb of 0.5) loaded with values greater than 0.5. In addition, the combination of items by factors matched with the results from the qualitative study conducted to propose indicators for project resilience.

The final PCA results for adaptive capacity are presented in Table 7.2. This includes 4 indicators for adaptive capacity and 20 items to assess these indicators. These are a summary of the results and their respective meanings:

1. A KMO of 0.788 (greater than the rule of thumb of 0.5) and a Bartlett's Test of Sphericity of 0.000 (less than the rule of thumb of 0.05) were registered. This indicates that the data is suitable for factor analysis;

2. A combination was made between the 1st and the 4th factors, and between the 2nd and 6th factors. In fact, items from the combined factors are intended to measure the same indicators based on the results of the qualitative study (Appendix R)[33].
3. Cumulative variance explained for adaptive capacity is equal to 63.696% which is higher than the rule of thumb of 60%. In other words, indicators for adaptive capacity explain 63.696% of the variance which means they are worth including in the adaptive capacity model;
4. For the assessment of the internal coherence and the consistency of the scale, values of α Cronbach for each factor are higher than the rule of thumb of 0.6 (0.783 for AMR, 0.661 for RTM, 0.759 for ECR, 0.627 for ARDM). This means that the reliability of the factors is achieved.

[33] More details on the development of the indicators and their respective items, resulted from the qualitative analysis, are presented in the 3rd article (Chapter 6)

Table 7.2: PCA final results for adaptive capacity

Code	**Accessibility & Mobilization of Resources (AMR)**	**Factor**
AMR1	When needed, resources can be mobilized from different departments to face disruptive events.	0.477
AMR2	When needed, resources can be mobilized through partnerships to face disruptive events.	0.768
AMR3	Information systems are available to provide quick access to information to solve an issue.	0.795
AMR4	Information systems are available to log disruptive events.	0.816
AMR5	Departments can provide feedback on possible solutions to face disruptive events through information systems.	0.708
AMR6	External partners can provide feedback on possible solutions to face disruptive events through information systems.	0.706
AMR7	When the budget contingency is completely consumed, leadership can release additional funds to face disruptive events.	0.637
α Cronbach		***0.783***
% Var.		***24.076***
Code	**Responsiveness of Team Members (RTM)**	**Factor**
RTM1	I tend to adopt creative solutions to face disruptive events.	0.793
RTM2	I am encouraged to think outside of the box to find solutions to face disruptive events.	0.468
RTM3	I have the expertise to deal with disruptive events.	0.666
RTM4	When faced with disruptive events, it is a priority to find the best ways to avoid them.	0.629
α Cronbach		***0.661***
% Var.		***9.700***

Table 7.2: PCA final results for adaptive capacity (Continued and end)

Code	**Effectiveness of Communications & Relationships**	**Factor**
ECR1	Clear explanations of issues and possible solutions are provided to all stakeholders through transparent communications.	0.600
ECR2	Stakeholders, including the client, are encouraged to take ownership of the issue and any possible solutions.	0.760
ECR3	Stakeholders are involved through continuous follow-ups (e.g. regular meetings, status calls, etc.) to ensure proper management of disruptive events.	0.745
ECR4	Stakeholders are open to reassess project objectives (e.g. new ways of doing things, new roadmap, new strategies, etc.), if needed, to face disruptive events.	0.674
α Cronbach		***0.759***
% Var.		***11.311***
Code	**Adapted & Responsible Decision Making**	**Factor**
ARDM1	Senior managers plot a course of actions to face disruptive events.	0.849
ARDM2	Senior managers ensure actions are implemented in the right way and at the right time to effectively face disruptive events.	0.843
ARDM3	Senior managers adapt their strategies to face disruptive events based on the project's importance to the organization.	0.736
ARDM5	Clauses in the contract can be bypassed, to a certain extent, to find solutions to face disruptive events.	0.689
ARDM6	Qualified team members are encouraged to make critical decisions without the need for senior managers' approval.	0.684
α Cronbach		***0.627***
% Var.		***18.610***

PCA analysis for adaptive capacity has shown that the items were grouped by indicators as already derived from the qualitative study (the analysis of the interviews with senior project managers).

This reinforces the fact that the strategy adopted to generate the indicators and their respective items is suitable (Hinkin, 1998).

7.2.1.3 Common Method Bias

Harman's single factor test was executed to ensure that the problem of common method bias[34] does not exist. This was completed by constraining the number of factors derived from the PCA analysis to be just one. Then the unrotated solution was examined to determine if one single factor accounts for most of the total variance for awareness, adaptive capacity, and project resilience.

The values (presented in Table 7.3) show a 28.590% of total variance explained for awareness, 26.988% for adaptive capacity, and 24.460% for all the indicators tended to assess project resilience. These values are less than the rule of thumb of 50% and therefore, the common method bias problem does not exist with the observations collected.

Table 7.3: Test Mono-Method Bias Harman's single factor

Extraction Sums of Squared Loadings		
Total	**% of Variance**	**Cumulative %**
Total Variance Explained for Awareness		
5.432	28.590	28.590
Total Variance Explained for Adaptive Capacity		
5.398	26.988	26.988
Total Variance Explained for Project Resilience (both dimensions)		
9.539	24.460	24.460

[34] As explained in the 3rd Chapter (Research Design and Methodology), This problem occurs when two constructs share common methods that "*may exert a systematic effect on the observed correlation between the measures. Thus, at least partially, common method biases pose a rival explanation for the correlation observed between the measures*" (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003, p. 879).

7.2.2 Confirmatory Factor Analysis (CFA)[35]

In this section, CFA will be presented based on the final results from the PCA. CFA has been conducted to measure the consistency between the indicators and the items to assess them. It aims to validate the awareness and adaptive capacity models for unidimensionality, internal consistency, convergent validity, and discriminant validity. Convergent and discriminant validity will be verified because both approaches use CFA (Hair et al., 2010).

7.2.2.1 CFA for Awareness

Many CFA repetitions were done to ensure consistency between the indicators and their respective items to assess the awareness dimension. In the process, 5 items were dropped because they did not capture 40% of the variance (CFA standardized loadings ≥ 0.63). The items removed are presented in Table 7.4, and the CFA standardized loadings for all remaining items are presented in Table 7.5.

The item CRR2 has a CFA standardized loading of 0.623 (very close to the rule of thumb of 0.63). But, it was decided not to remove it, because it will jeopardize the significance of the CRR indicator (minimum 3 items are required to assess efficiently an indicator (Hair et al., 2010; Hinkin, 1998)). Additionally, removing it will not increase significantly the internal consistency of the awareness's indicators.

Table 7.4: Items removed for awareness after CFA

Code	**Alertness to Performance Deviations**
APRMM3	Lessons learned from previous similar projects are analyzed to identify project weaknesses
ASPD1	Scope changes are continuously monitored through the project life-cycle
Code	**Leadership & Involvement of Stakeholders**
LIS1	Senior managers are transparent regarding any organizational changes that may cause disruptive events during the project life-cycle

[35] More details and explanation on CFA are available in the 3rd Chapter (Research Design and Methodology)

Table 7.4: Items removed for awareness after CFA (Continued and end)

Code	Leadership & Involvement of Stakeholders
LIS3	Expectations are continuously set to reinforce trust and avoid surprises
LIS4	Follow-ups (regular meetings, status calls, etc.) take place regularly to remain alert to possible disruptive events

After removing the 5 items and re-executing CFA the measurement results suggested a good fit of the final awareness model (χ^2/df of 1.427; p-value of 0.014; Bentler-Bonett of 0.998; CFI of 0.999; IFI of 0.999; GFI of 0.931; AGFI of 0.889; RMSEA of 0.05). These results indicate that the unidimensionality of the awareness indicators is achieved.

Table 7.5: CFA results for awareness

	EER		**APD**		**CRR**		**SEC**	
	λ & Sign[(1)]	**t**	**λ & Sign[(1)]**	**t**	**λ & Sign[(1)]**	**t**	**λ & Sign[(1)]**	**t**
EER1	0.847****	12.571						
EER2	0.881****	13.272						
EER3	0.672****	9.321						
EER4	0.676****	9.386						
APRMM1			0.910****	5.211				
APRMM2			0.995****	18.274				
ASPD3			0.834****	9.111				
ASPD4			0.857****	9.278				
CRR2					0.623****	8.986		
CRR3					0.991****	17.991		
CRR4					0.703****	7.118		
SEC2							0.994****	18.157
SEC3							0.717****	7.720
SEC4							0.995****	9.264
AVE	**60.075**		**81.200**		**62.167**		**83.133**	
α Cronbach	**0.879**		**0.717**		**0.764**		**0.761**	
χ^2/df								1.427
p Value								0.014
Bentler-Bonett								0.998
CFI								0.999
IFI								0.999
GFI								0.931
AGFI								0.889
RMSEA								0.050

[(1)] *All correlations are significant at the p < 0.001 level. If 1.28 < t < 1.64 then *p<0.10; if 1.64 < t < 2.32 then **p<0.05; if 2.32 < t < 3.29 then ***p<0.01 and if t >= 3.29 then ****p<0.001*

Additionally, convergent validity is achieved because:

1. Average Variance Extracted (AVE)[36] loaded greater than the rule of thumb of 50% on all factors (60.075% for EER; 81.200% for APD; 62.167% for CRR; 83.133% for SEC)
2. α Cronbach is also greater than the rule of thumb of 0.6 for all factors (0.879 for EER; 0.717 for APD; 0.764 for CRR; 0.761 for SEC). This means that the reliability of the factors is achieved.

On the other hand, CFA results have shown that within the same indicator, some items are more important (does not mean that the other items are **not** important, but they are **less** important) than others because they capture a higher percentage of the variance.

First, for the indicator EER, it seems that EER1 and EER2 are more important than EER3 and EER4 because they capture respectively 72% (0.847^2) and 78% (0.881^2) of the variance. This means that, in IT and for the awareness dimension, developing and reinforcing partnerships are more important than having access to external resources through partnerships to help identify and assess project weaknesses.

Second, for the indicator APD all items capture more than 70% of the variance (APRMM1 83%; APRMM2 99%; ASPD3 70%; ASPD4 73%), but more particularly APRMM1 and APRMM2 captured more than 80% of the variance. This means that in IT, awareness necessitates the usage of project and risk management methods to capture the project's requirements and avoid possible disruptive events.

Third, for the indicator CRR, only CRR3 captured more than 70% of the variance (98% of the variance). Therefore, CRR3 is more important than CRR2 and CRR4. This means that IT project team members count on their expertise to assess, more than to identify, project's risk. Additionally, the assessment of IT project's risks is more important than working in collaboration with other team members to remain alert to disruptive events.

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[36] More explanation on the AVE are presented in the 3rd Chapter (Research Design and Methodology)

Fourth, for the indicator SEC, SEC2 and SEC4 capture both 99% the variance. This implies that the communication of internal organizational changes that may negatively impact the project, and the usage of internal resources to assess project weaknesses are more important than using internal resources to identify project weaknesses. Always from an IT perspective and for the awareness dimension.

Furthermore, 2nd order factor analysis for awareness (results presented in Table 7.6) was conducted to validate convergent validity between the awareness's indicators. The results provided a good fit as well (χ^2⁄df of 1.406; p-Value of 0.016; Bentler-Bonett of 0.998; CFI of 0.999; IFI of 0.999; GFI of 0.931; AGFI of 0.890; RMSEA of 0.49).

However, only APD showed a CFA standardized loading greater than 0.63, and SEC showed a value very close to the rule of thumb of 0.63 (0.611). Therefore, it seems that APD and SEC are the most important indicators to the awareness dimension. This conveys that the alertness to performance deviation through KPIs, and project and risk management methods along with the sensitivity to environmental changes are more important, in IT, than the efficiency of external resources and the clarity of roles and responsibilities among team members.

Additionally, the AVE had a value of 31.225% (less than the rule of thumb of 50%), and a α Cronbach of 0.584 very close to the rule of thumb of 0.6. This means that additional indicators are probably required to assess the awareness dimension of project resilience. This opens the door for additional research on indicators to assess the awareness dimension from an IT perspective (the field from where the data was collected). As already mentioned at the beginning of this chapter, it is normal in exploratory studies to have imprecise results especially that this is the first attempt to propose indicators for the assessment of project resilience (Hair et al., 2010; Hinkin, 1998; Wymer & Alves, 2012). Furthermore, collecting additional observations to approach 335 (the number of observations required to run exploratory analysis on the whole concept of project resilience) might improve the results.

Table 7.6: 2nd Order factor analysis for awareness

Awareness		
	λ & Sign(1)	**t**
EER	0.457****	3.903
APD	0.694****	4.935
CRR	0.430****	4.179
SEC	0.611****	3.587
AVE	31.225	
α Cronbach	0.584	
Internal Consistency	0.362	
χ^2⁄df	1.406	
p Value	0.016	
Bentler-Bonett	0.998	
CFI	0.999	
IFI	0.999	
GFI	0.931	
AGFI	0.890	
RMSEA	0.049	

(1) *Level of significance for Student's t-test: * p<0,10; **p<0,05; ***p<0,01; ****p<0,001; bilateral test.*

As for the discriminant validity, the outputs presented in Table 7.7 shows that discriminant validity is achieved. In fact, the diagonal (0.775; 0.901; 0.788; 0.912) represents the squared root of the variance extracted for each dimension. The lower diagonals ([0.312; 0.302; 0.256] , [0.196; 0.205], [0.288]) represents the correlations between the awareness indicators. To achieve discriminant validity all the values of the first diagonal must be higher than the correlations between the indicators (based on Fornell & Larcker [1981] criteria). In addition, all correlations between the awareness indicators are significant at the $p < 0.01$ level.

Table 7.7: Discriminant validity for awareness

	EER	**t**	**APD**	**t**	**CRR**	**t**	**SEC**
EER	**0.775**						
APD	0.312****	5.159	**0.901**				
CRR	0.196***	2.512	0.302****	5.392	**0.788**		
SEC	0.288****	4.334	0.205****	3.926	0.256****	4.132	**0.912**

As a conclusion Table 7.8 presents the final validated set of indicators and their respective items to assess awareness; the first dimension of project resilience.

It was decided to rename some indicators to better reflect their respective remaining items. The indicator “Clarity of Roles and Responsibilities” was renamed to “Clarity of Responsibilities”, and the indicator “Sensitivity to Environmental Changes” was renamed to “Sensitivity to Internal Organizational Changes”.

Table 7.8: Final validated set of indicators to assess awareness

Indicator	Items
Clarity of Responsibilities	I continuously use my expertise to identify project risks
	I continuously use my expertise to assess (probability vs impact) projects' risks
	I work in collaboration with other team members to remain alert to disruptive events
Alertness to Performance Deviations	Based on the project type, project management methods (e.g. project plan template, Agile, etc.) are employed to capture all project's requirements and potentially avoid possible disruptive events
	Based on the project type, risk management methods (e.g. risk register template, Monte Carlo analysis, etc.) are used to avoid possible disruptive events
	KPIs for the budget are continuously monitored to detect any budget performance deviation through the project life-cycle.
	KPIs for the schedule are continuously monitored to detect any schedule performance deviation through the project life-cycle.
Sensitivity to Internal Organizational Changes	Internal organizational changes (e.g. new project management processes, updates to existing methods, etc.), that may impact the project, are clearly communicated to avoid possible disruptive events
	When needed, access to resources within the organization is available to help identify project weaknesses
	When needed, access to resources within the organization is available to help assess project weaknesses
Efficiency of External Resources	Partnerships with external parties that have the field-specific knowledge are continuously developed
	Current partnerships with external parties are continuously reinforced
	Access to external resources through partnerships is possible to help identify project weaknesses
	Access to external resources through partnerships is possible to help assess project weaknesses

7.2.2.2 CFA for Adaptive Capacity

Many repetitions were conducted to ensure consistency between the indicators and their respective items proposed to assess the adaptive capacity dimension. In the process, 5 items were dropped

because they did not explain 40% of the variance (CFA standardized loadings ≥ 0.63). The items removed are presented in Table 7.9. The CFA standardized loadings for all remaining items are presented in Table 7.10.

Table 7.9: Items removed for adaptive capacity after CFA

Code	**Accessibility & Mobilization of Resources**
AMR7	When the budget contingency is completely consumed, leadership can release additional funds to face disruptive events.
Code	**Responsiveness of Team Members**
RTM4	When faced with disruptive events, it is a priority to find the best ways to avoid them.
Code	**Effectiveness of Communications & Relationships**
ECR4	Stakeholders are open to reassess project objectives (e.g. new ways of doing things, new roadmap, new strategies, etc.), if needed, to face disruptive events.
Code	**Adapted & Responsible Decision Making**
ARDM5	Clauses in the contract can be bypassed, to a certain extent, to find solutions to face disruptive events.
ARDM6	Qualified team members are encouraged to make critical decisions without the need for senior managers' approval.

After removing the 5 items, the measurement results suggested a good fit of the final adaptive capacity model (χ^2/df of 1.550; p-value of 0.002; Bentler-Bonett of 0.992; CFI of 0.997; IFI of 0.997; GFI of 0.916; AGFI of 0.866; RMSEA of 0.058). These results indicate that the unidimensionality of the adaptive capacity indicators is achieved.

Table 7.10: CFA results for adaptive capacity

	AMR		**ARDM**		**ECR**		**SEC**	
	λ & Sign[(1)]	**t**	**λ & Sign[(1)]**	**T**	**λ & Sign[(1)]**	**t**	**λ & Sign[(1)]**	**t**
AMR1	0.994****	17.982						
AMR2	0.750****	7.741						
AMR3	0.887****	10.408						
AMR4	0.742****	9.719						
AMR5	0.780****	9.512						
AMR6	0.647****	7.958						
ARDM1			0.734****	10.075				
ARDM2			0.922****	13.561				
ARDM3			0.646****	8.648				
ECR1					0.888****	10.294		
ECR2					0.643****	8.063		
ECR3					0.796****	8.851		
RTM1							0.651****	7.634
RTM2							0.642****	7.439
RTM3							0.640****	7.416
AVE	**65.267**		**60.200**		**61.167**		**41.500**	
α Cronbach	**0.807**		**0.795**		**0.764**		**0.678**	
χ^2/df								1.550
p Value								0.002
Bentler-Bonett								0.992
CFI								0.997
IFI								0.997
GFI								0.916
AGFI								0.866
RMSEA								0.058

[(1)] *All correlations are significant at the p < 0.001 level. In fact, if 1.28 < t < 1.64 than *p<0.10; if 1.64 < t < 2.32 than **p<0.05; if 2.32 < t < 3.29 than ***p<0.01 and if t >= 3.29 than ****p<0.001.*

Additionally, convergent validity is achieved because:

1. Average Variance Extracted (AVE) loaded greater than the rule of thumb of 50% on all factors except for the "*Responsiveness of Team Members*" (65.267% for AMR; 60.200% for ARDM; 61.167% for ECR; 41.500% for RTM).
2. The reliability is verified by α Cronbach, because all factors loaded greater than the rule of thumb of 0.6 (0.807 for AMR; 0.795 for ARDM; 0.764 for ECR; 0.678 for RTM).

Even though it scored an AVE of 41.5%, it was decided to keep the indicator RTM for two reasons:

a. It shows an α Cronbach of 0.678 which indicates that this indicator is reliable;
b. CFA standardized loadings for its items are significant and higher than of 0.63;
c. This is an exploratory study aiming to validate for the first-time indicators to assess the adaptive capacity dimension of project resilience.

On the other hand, CFA results have shown that within the same indicator, some items are more important (does not mean that the other items are **not** important, but they are **less** important) than others, because they capture a higher percentage of the variance.

First, for the indicator AMR, it seems that AMR1 and AMR3 are more important than AMR2, AMR4, AMR5, AMR6 because they capture respectively 98% and 79% of the variance. This means that, in IT and for the adaptive capacity dimension, the internal (from different departments) mobilization of resources to effectively face disruptive is more important than having access to external (through partnerships) resources. Also, having quick access to information through information systems is more important than being able to log disruptive events using information systems and to give external partners the possibility to provide feedback on possible solution through information systems. The less important item is the possibility of leadership releasing additional funds to face disruptive events if the budget contingency is completely consumed.

Second, for the indicator ARDM, ARDM2 is the more important than ARDM1 and ARDM3 because it captures 85% of the variance. This means that, in IT and for adaptive capacity, making sure that the corrective actions are implemented in the right way is more important than plotting a

course of actions to face disruptive events, and adapting strategies to face disruptive events based on the project's importance to the organization.

Third, for the indicator ECR, ECR1 is more important than ECR2 and ECR3 because it captures 79% of the variance. This means that, having a clear explanation of issues and possible solution through transparent communications is more important than encouraging stakeholders to take ownership of the issue and possible solution, and involving stakeholders through continuous follow-ups to ensure proper management of disruptive events. Always from an IT perspective and for the adaptive capacity dimension.

Fourth, for the RTM indicator, all items are of equivalent importance because they all capture around 42% of the variance. Therefore, adopting creative solutions, being encouraged to think outside of the box, and having the right expertise to deal with disruptive events are of equivalent importance from an IT perspective to effectively adapt when faced with disruptive events.

Furthermore, CFA of the 2nd order factor analysis model (results presented in Table 7.11) showing the convergent validity between the adaptive capacity's indicators, provided a good fit as well (χ^2⁄df of 1.542; p-Value of 0.002; Bentler-Bonett of 0.992; CFI of 0.997; IFI of 0.997; GFI of 0.917; AGFI of 0.865; RMSEA of 0.58) . However, only ECR showed a CFA standardized loading greater than 0.63 along with very close CFA standardized loadings for the other indicators (0.586 for AMR; 0.618 for RTM; 0.594 for ARDM). This means that, from an IT perspective, the effectiveness of communications and relationships and the responsiveness of team members when faced with disruptive events are more important than having an adapted and responsible decision-making by senior managers, and being able to access and mobilize resources to face disruptive events.

Additionally, the AVE had a value of 41.525% (less than the rule of thumb of 50% but considered close (Colwell, Aung, Kanetkar, & Holden, 2008)) and a α Cronbach of 0.693 (higher than the rule of thumb of 0.6). This implies that the indicators to assess the adaptive capacity's dimension of project resilience are considered acceptable, but additional indicators are probably required to assess the adaptive capacity dimension of project resilience. This opens the door for additional research on indicators to assess the adaptive capacity dimension from an IT perspective. As already

mentioned at the beginning of this chapter, it is normal in exploratory studies to have imprecise results especially that this is the first attempt to propose indicators for the assessment of project resilience (Hair et al., 2010; Hinkin, 1998; Wymer & Alves, 2012). Furthermore, collecting additional observations to approach 335 (the number of observations required to run exploratory analysis on the whole construct of project resilience) might improve the results.

Table 7.11: CFA for adaptive capacity – 2nd Order

Adaptive Capacity		
	λ & Sign(1)	**t**
AMR	0.586****	7.328
RTM	0.618****	5.620
ECR	0.763****	7.570
ARDM	0.594****	4.910
AVE	41.525	
α Cronbach	0.693	
Internal Consistency	0.541	
χ^2/df	1.542	
p Value	0.002	
Bentler-Bonett	0.992	
CFI	0.997	
IFI	0.997	
GFI	0.917	
AGFI	0.865	
RMSEA	0.058	

(2) *All correlations are significant at the p < 0.001 level. In fact, if 1.28 < t < 1.64 than *p<0.10; if 1.64 < t < 2.32 than **p<0.05; if 2.32 < t < 3.29 than ***p<0.01 and if t >= 3.29 than ****p<0.001*

As for the discriminant validity, the output presented in Table 7.12 shows that discriminant validity is achieved. In fact, the diagonal (0.808; 0.776; 0.782; 0.644) represents the squared root of the variance extracted for each dimension. The lower diagonals ([0.364; 0.494; 0.456] , [0.440; 0.267], [0.383]) represents the correlations between the adaptive capacity indicators. To achieve discriminant validity all the values of the first diagonal must be higher than the correlations between the indicators (based on Fornell & Larcker [1981] criteria). In addition, all correlations between the adaptive capacity indicators are significant at the $p < 0.01$ level.

Table 7.12: Discriminant validity for adaptive capacity

	AMR	**t**	**ARDM**	**t**	**ECR**	**t**	**RTM**
AMR	**0.808**						
ARDM	0.364****	6.005	**0.776**				
ECR	0.440****	7.513	0.494****	6.907	**0.782**		
RTM	0.383****	5.523	0.267***	2.676	0.456****	5.383	**0.644**

As a conclusion Table 7.13 presents the validated final set of indicators and their respective items to assess the second dimension of project resilience; adaptive capacity.

Table 7.13: Final validated set of indicators to assess adaptive capacity

Indicator	**Accessibility & Mobilization of Resources**
Accessibility & Mobilization of Resources	When needed, resources can be mobilized from different departments to face disruptive events.
	When needed, resources can be mobilized through partnerships to face disruptive events.
	Information systems are available to provide quick access to information to solve an issue.
	Information systems are available to log disruptive events.
	Departments can provide feedback on possible solutions to face disruptive events through information systems.
	External partners can provide feedback on possible solutions to face disruptive events through information systems.
Responsiveness of Team Members	I tend to adopt creative solutions to face disruptive events.
	I am encouraged to think outside of the box to find solutions to face disruptive events.
	I have the expertise to deal with disruptive events.
Effectiveness of Communications & Relationships	Clear explanations of issues and possible solutions are provided to all stakeholders through transparent communications.
	Stakeholders, including the client, are encouraged to take ownership of the issue and any possible solutions.
	Stakeholders are involved through continuous follow-ups (e.g. regular meetings, status calls, etc.) to ensure proper management of disruptive events.
Adapted & Responsible Decision Making	Senior managers plot a course of actions to face disruptive events.
	Senior managers ensure actions are implemented in the right way and at the right time to effectively face disruptive events.
	Senior managers adapt their strategies to face disruptive events based on the project's importance to the organization.

CHAPTER 8 GENERAL DISCUSSION

This chapter highlights the main contributions of this dissertation. It is organized in three sections. The first section presents the main contributions of this dissertation to project management. The second section discusses the limitations on this research limitations. Finally, in the third section suggestions for future research are presented.

8.1 Theoretical Contributions to Project Management

As demonstrated in the first literature review and in the first published article (Chapter 4), current project risk management practices focus mainly on identifying, analyzing, and preparing mitigation plans for known risks. These practices focus on reducing vulnerabilities by detecting the project's weaknesses and trying to mitigate them (Thamhain, 2013; Zhang, 2007). They do not emphasize the development of the project's capacity to deal with disruptive events, whether if these events are known or unknown, or detected or not overlooked by current risk management methods. In addition, mitigation plans are not context- specific (Crawford et al., 2013). These plans may not function properly due to the lack of unclarity and unpredictability of the disruptive event's environment and characteristics.

Agility aims to develop project capacities to respond to changes mainly requested by stakeholders and customers, and therefore, require quick updates to the project plan to achieve better performance (Conforto et al., 2016). However, agility does not explicitly focus on events that may cause the project to deviate from its main objectives and does not develop proactive capacities. Consequently, investing in agility without investing in developing capacities to deal with disruptive events, which can cause project's failure, makes the project more vulnerable during its life-cycle (Werder & Maedche, 2018).

In this dissertation, project resilience, which is a novel concept in project management (Thomé, Scavarda, Scavarda, & Thomé, 2016) is explored. Despite the applicability of resilience in many domains (ecology, psychology, climate change, critical infrastructure, etc.), the definition proposed for this concept in this dissertation is specific for the project management domain. In this

dissertation, the concept of resilience is introduced to project management. Thus, project resilience is the capacity of the project system to be aware of its surroundings, and to adapt in order to recover from disruptive events. It emphasizes the importance of recognizing the project's vulnerabilities, of analyzing potential threats, and on being prepared to deal with them on occurrence. Additionally, it denotes the development of the project's capacity to adapt in order to recover from disruptive events whether these events are known or unknown during the project life-cycle. Therefore, it emphasizes the importance of positive adjustments to efficiently cope with disruptive events in order to recover successfully and continue fulfilling the project's objectives. Thus, project resilience includes actions and activities to remain aware of possible future disruptive events and to adapt in order to recover when faced with disruptive events.

Consequently, project resilience has two dimensions: awareness and adaptive capacity. Awareness is a continuous understanding of the project system's elements and vulnerabilities and constant monitoring of changes in its environment. On the other hand, adaptive capacity is the project system's capacity to transform itself in order to cope with disruptive events.

From a system perspective, a project is defined by a set of elements that, in a changing environment, transform inputs into outputs. Thus, the project environment is both the main provider of inputs and the main recipient of the final outputs (the outputs that shape the final project deliverables). Inputs and outputs are resources that includes tangible and intangible assets, knowledge, etc. (Anbari, 1985; Kopczyński & Brzozowski, 2015). For example, a software developer uses software applications and a laptop to transform client requirements (inputs) into software modules (outputs). On the other hand, a project manager transforms data and information (inputs) into decisions (outputs) after deep analysis as part of the project management activities. Therefore, it is important to focus on project resilience as a whole, and not just on the resilience of project management. That is because efficient project management (represented in many project resilience indicators and items), like risk management, contributes to project resilience. The availability of resources also contributes to project resilience. In fact, an efficient project manager is vulnerable if adequate resources to perform his/her job and efficiently and effectively manage his/her project are not available.

In addition to a definition of project resilience, indicators to assess this concept are developed in this dissertation. In fact, following the scale development process suggested by Hinkin (1998), 4 indicators and 14 items are suggested to assess the awareness dimension of project resilience, while 4 indicators and 15 items are proposed to assess the adaptive capacity dimension. These indicators are suitable for IT projects because they are the results of internal validity testing with this type of project.

Therefore, enhancing awareness within IT projects requires that responsibilities be clear and precise and that project team members use their skills and expertise to identify and analyze potential threats and work in collaboration with other team members to remain alert to possible disruptive events. In addition, staying alert to project performance deviations by means of project management methods, risk management methods, and KPIs for the budget and schedule improves the project's overall awareness of disruptions. Awareness requires being sensitive to internal organizational changes. That includes having access to internal resources to help assess a project's weaknesses and remaining vigilant for internal organizational changes. Finally, developing partnerships might increase project awareness through access to external resources to help identify and assess project weaknesses.

Having access to resources and being able to mobilize them in a timely manner, whether from different departments or through partnerships, improves the capacity to adapt when faced with disruptive events. Information systems can also play an important role in the adaptation process. They help present information on disruptive events and gather possible internal and external solutions to deal with them. In addition, adopting creative solutions and encouragement by senior management to think outside of the box improve responsiveness to disruptive events. Clear communications about disruptive events, encouragement to take ownership of these events and provide possible solutions, and keeping stakeholders updated through continuous follow-ups increase the effectiveness of adaptation to disruptive events. Finally, senior managers play a vital role in the adaptation process by plotting a clear course of action to deal with disruptive events and ensuring that these actions are followed rigorously without compromising the project's importance to the organization.

These leading indicators[37] can be used to validate conceptual frameworks when the concept of project resilience is addressed from an IT perspective. As suggested by Hinkin (1998), Likert-type scales are the most useful in behavioral research. Therefore, it is suggested that a 5-point Likert scale would be appropriate to evaluate these indicators, rating the corresponding items from "strongly disagree" to "strongly agree."

In addition, assessing project resilience using the indicators proposed in this dissertation aims to validate the state of knowledge of the IT project's ability to deal with disruptive events. It refers to the progress of the knowledge acquisition about the project and its environment, to deal with events that could potentially lead to its failure. These indicators can therefore be used as a diagnostic tool to assess the impact of the efforts required to support the resilience of current and future IT projects. They can potentially help determine a project's strengths, weaknesses and capacity to deal with disruptive events, as well as to suggest action plans to improve its resilience. Obviously, using these indicators cannot guarantee that project success rates or project management success rates would near 100%, as these rates are subject to multiple factors. Rather, these indicators provide an understanding of the project's weaknesses and strengths. Thus, applying corrective actions as a result of using these indicators should improve project resilience, awareness and adaptive capacity.

In fact, the indicators used to assess the awareness dimension of project resilience are intended to validate current knowledge of the project. That is why the present tense is used to assess the items of each indicator under this dimension. Thus, using these indicators at a specific point in time aims to assess the project's capacity to understand the project system's elements and vulnerabilities and to monitor changes in its environment at this specific time. At another point, the assessment using these indicators could change. That is why acceptable values for awareness indicators, at a specific point in time, do not guarantee 100% that the project has reached its optimum awareness capacity.

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[37] Leading indicators measure observable processes, methods, structures, etc., that contribute to a system's continuous functioning (Lee et al., 2013).

However, acceptable values can indicate that the project has attained an acceptable capacity for awareness – again, at a specific point in time.

As for adaptive capacity, the situation is more complex. When using the indicators developed in this dissertation to assess a project's adaptive capacity, a future ability to adapt when faced with disruptive events is evaluated (which is why expressions such as "can be" and "can provide" are used). Again, this does not guarantee that the project will definitely adapt to any disruptive event that may occur in the future. But, acceptable values for the adaptive capacity indicators indicate that the project is more likely to be adaptable when faced with disruptive events in the future. However, it would be incorrect to suggest that a score for adaptive capacity indicators of 100% means the project is 100% adaptable. This is also true of any assessment methodology for resilience, regardless of the field being assessed (project, organization, critical infrastructure, etc.). The reason is that every disruptive event has its own specific context and its own specific characteristics. In many cases, the latter are unpredictable and unexpected, even when disruptive events are well identified and assessed, and mitigation plans are available to cope with them. For instance, in high-reliability organizations,[38] disruptive events still cause irreparable damages. Planes still fall from the sky even when the greatest precautions are taken with extremely strict procedures, and nuclear plants still suffer meltdowns.

The indicators presented in this dissertation were proposed for the field of project management after an analysis of several situations in which disruptive events were successfully managed. This initial analysis was conducted among project managers who worked on different project types (IT, construction, government, etc.). Trends and best practices were identified that should ensure better awareness and adaptive capacity for projects, and indicators were developed based on these trends and best practices. In addition, the proposed indicators were validated in the context of IT projects to ensure their reliability and unidimensionality. These indicators assess the awareness and

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[38] *"High reliability organizations (HROs) are those that exist in such hazardous environments where the consequences of errors are high, but the occurrence of error is extremely low"* (Baker et al., 2006).

adaptive capacity dimensions of project resilience. They measure observable processes, methods, structures, practices, etc., that contribute effectively and efficiently to project resilience.

In conclusion, the originality of this dissertation resides in the following three points:

1. Explaining in detail the concept of project resilience by proposing a definition and a conceptual framework. This point answers the first part of the main research question (*How can resilience be conceptualized in the project management domain?*).
2. Developing a set of indicators to assess project resilience through a qualitative study. This point answers the second part of the main research question (*How can project resilience be empirically assessed?*).
3. Validating the project resilience indicators within the context of IT projects to ensure their internal validity. Therefore, the final set of indicators (Table 8.1) is suitable to measure IT projects' resilience.

Table 8.1 presents the final set of indicators, their definitions and items to assess the resilience of IT projects in terms of awareness and adaptive capacity.

Table 8.1: Final validated set of indicators to assess project resilience, for IT projects, in terms of awareness and adaptive capacity

Indicator	Definition	Items
Awareness		
Clarity of Responsibilities	Clear understanding of the accountability and collaboration required and the right skills, and expertise needed by team members during the project life-cycle to successfully accomplish project objectives.	I continuously use my expertise to identify project risks.
		I continuously use my expertise to assess (probability vs. impact) project risks.
		I work in collaboration with other team members to remain alert to disruptive events.
Alertness to Performance Deviations	Availability of project management and risk management methods, and continuous monitoring of project KPIs, throughout the project life-cycle, to remain alert to any performance deviations that may lead to disruptive events.	Based on the project type, project management methods (e.g., project plan template, Agile, etc.) are employed to capture all project requirements and avoid possible disruptive events.
		Based on the project type, risk management methods (e.g., risk register template, Monte Carlo analysis, etc.) are used to avoid possible disruptive events.
		KPIs for the budget are continuously monitored to detect any budget performance deviation throughout the project life-cycle.
		KPIs for the schedule are continuously monitored to detect any schedule performance deviation throughout the project life-cycle.

Table 8.1: Final validated set of indicators to assess project resilience in terms of awareness and adaptive capacity (Continued)

Indicator	Definition	Items
Awareness		
Sensitivity to Internal Organizational Changes	Continuous monitoring and assessment of internal organizational changes to better identify and assess project weaknesses.	Internal organizational changes (e.g., new project management processes, updates to existing methods, etc.) that may impact the project are clearly communicated to avoid possible disruptive events.
		When needed, resources within the organization are accessible to help identify project weaknesses.
		When needed, resources within the organization are accessible to help assess project weaknesses.
Efficiency of External Resources	Continuous development and updates of partnerships to better identify and assess project weaknesses.	Partnerships with external parties that have field-specific knowledge are continuously developed.
		Current partnerships with external parties are continuously reinforced.
		Access to external resources through partnerships is possible to help identify project weaknesses.
		Access to external resources through partnerships is possible to help assess project weaknesses.

Table 8.1: Final validated set of indicators to assess project resilience in terms of awareness and adaptive capacity (Continued)

Indicator	Definition	Items
		Adaptive Capacity
Accessibility and Mobilization of Resources	Quick access to accurate information, and the mobilization of external (through partnerships) and internal (from different organizational departments) resources to face disruptive events.	When needed, resources can be mobilized from different departments to face disruptive events.
		When needed, resources can be mobilized through partnerships to face disruptive events.
		Information systems are available to provide quick access to information to solve an issue.
		Information systems are available to log disruptive events.
		Departments can provide feedback on possible solutions to face disruptive events through information systems.
		External partners can provide feedback on possible solutions to face disruptive events through information systems.
Responsiveness of Team Members	The adoption by team members of innovative and creative solutions, through their managerial and technical expertise, to face disruptive events.	I tend to adopt creative solutions to face disruptive events.
		I am encouraged to think outside of the box to find solutions to face disruptive events.
		I have the expertise to deal with disruptive events.

Table 8.1: Final validated set of indicators to assess project resilience in terms of awareness and adaptive capacity (Continued and end)

Indicator	Definition	Items
		Adaptive Capacity
Effectiveness of Communications and Relationships	Continuous follow-ups, with honest and transparent communications, where stakeholders take ownership of the issues and possible solutions to better face disruptive events.	Clear explanations of issues and possible solutions are provided to all stakeholders through transparent communications.
		Stakeholders, including the client, are encouraged to take ownership of the issue and any possible solutions.
		Stakeholders are involved through continuous follow-ups (e.g., regular meetings, status calls, etc.) to ensure proper management of disruptive events.
Adapted and Responsible Decision-Making	Devolved decision-making where senior managers act strategically to face disruptive events.	Senior managers plot a course of action to face disruptive events.
		Senior managers ensure actions are implemented in the right way and at the right time to effectively face disruptive events.
		Senior managers adapt their strategies to face disruptive events based on the project's importance to the organization.

8.2 Practical Contributions to Project Management

From a practical perspective, these indicators can be used to validate conceptual frameworks where the concept of project resilience is involved. As suggested by Hinkin (1998), Likert-type scales are the most useful in behavioral research. Therefore, it is suggested that a 5-point Likert scale would be appropriate to evaluate the indicators, by rating the corresponding items from "strongly disagree" to "strongly agree."

In addition, the assessment of project resilience by the project team members validates the state of knowledge of the project's capacity to deal with disruptive events. This refers to the progress of knowledge acquisition about the project and its environment to deal with events that could potentially lead to its failure. Therefore, the indicators provided here can be used as a diagnostic tool to assess the impact of the efforts required to support the resilience of current and future projects. These indicators can potentially help determine the strengths and weaknesses of a project's capacity to deal with disruptive events, as well as to suggest action plans to improve its resilience.

Therefore, it is suggested that these indicators be part of a methodology to assess a project's resilience at any time during the project life-cycle. For instance, **as a suggestion**, a methodology could be based on the well-known Plan-Do-Check-Act cycle (Deming, 1986).

In the *plan* phase, the objectives and baselines for project resilience are established. For example, a value of 4 on the indicator "Efficiency of External Resources" could be considered acceptable as an agreed-upon threshold, so no corrective actions would be needed. In fact, in this phase it is important to recognize the opportunity of making the project more resilient, and establish specific baselines inspired by the indicators proposed in this dissertation, and by the context and characteristic of the IT project. Table 8.2 presents *part* (only one indicator) of an example to assess IT projects' resilience. The same type of questionnaire should be completed for all proposed indicators, both for awareness and for adaptive capacity. This questionnaire can be automated as part of the organization's project management information system to facilitate data collection and analysis.

Table 8.2: Extract from a sample questionnaire to assess resilience of IT projects

Efficiency of External Resources					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Partnerships with external parties that have field-specific knowledge are continuously developed **(EER1)**					
Current partnerships with external parties are continuously reinforced **(EER2)**					
Access to external resources through partnerships is possible to help identify project weaknesses **(EER3)**					
Access to external resources through partnerships is possible to help assess project weaknesses **(EER4)**					

In the *do* phase, the plan from the previous phase is executed. Project team members, including the project manager, are asked to respond to the questionnaire developed previously. Other stakeholders can also be invited to participate based on the IT project's context and characteristics.

Once the answers have been collected, the *check* phase begins: the data and results are gathered and evaluated. They are compared to the baselines established during the *plan* phase. Figure 8.1 presents an example of a radar chart that shows the results by indicators where the value for each indicator represents the average of the items aiming to evaluate this indicator.

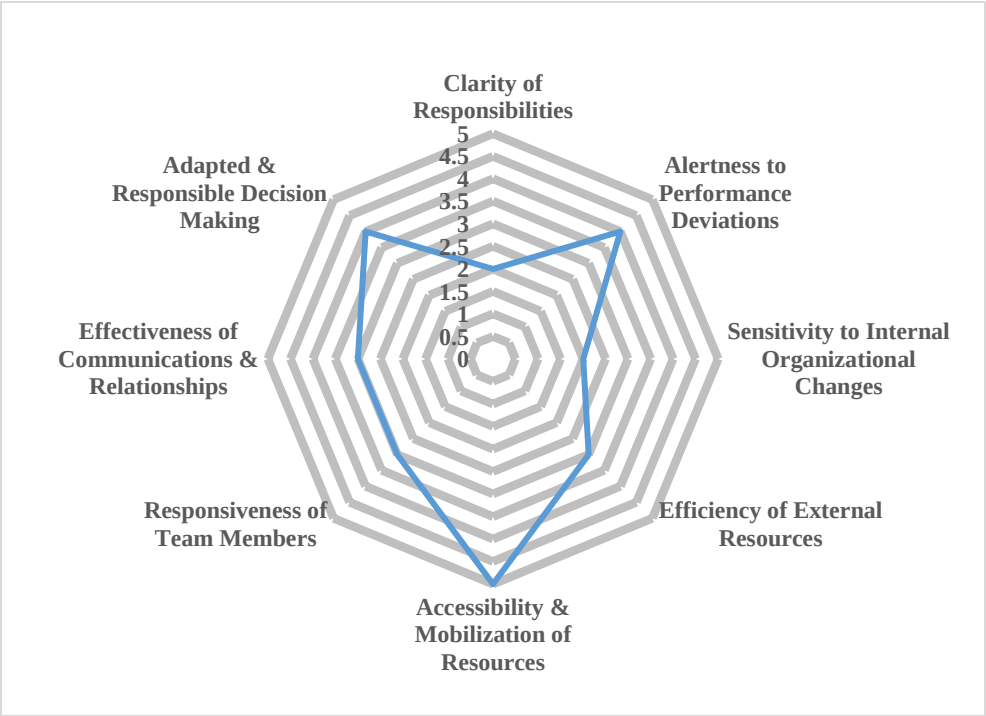

Figure 8.1 – Example of a radar chart for project resilience indicators.

For instance, the "Efficiency of External Resources" indicator received a value of 3, which is lower than the sample baselines established in the *plan* phase (value of 4). Therefore, it is important to dig deeper and find what led to this low value. Figure 8.2 shows the scores for every item (EER1 to EER4) aiming to evaluate the indicator "Efficiency of External Resources". It shows that EER1 and EER2 scored 2, which means that new external partnerships are not adequately developed, nor are existing ones reinforced. Therefore, a corrective action could be to incite senior management to develop and reinforce partnerships, because, over time, the lack of new partnerships and the weakness of existing ones may lead to a scarcity of external resources that could help to identify and assess project weaknesses. During this phase, all possible corrective actions are documented and prioritized.

In the *act* phase, corrective actions that contribute to project resilience are taken to improve the project's awareness and adaptive capacity. The corrective actions are implemented to reduce the weaknesses detected without compromising the strengths. After this phase, planning for the next "Plan, do, check, act" cycle can proceed with better baselines and the project resilience indicators

should score higher; if they do not, the corrective actions were not effective. In conclusion, the main goal of these cycles is to improve project resilience during the project life-cycle.

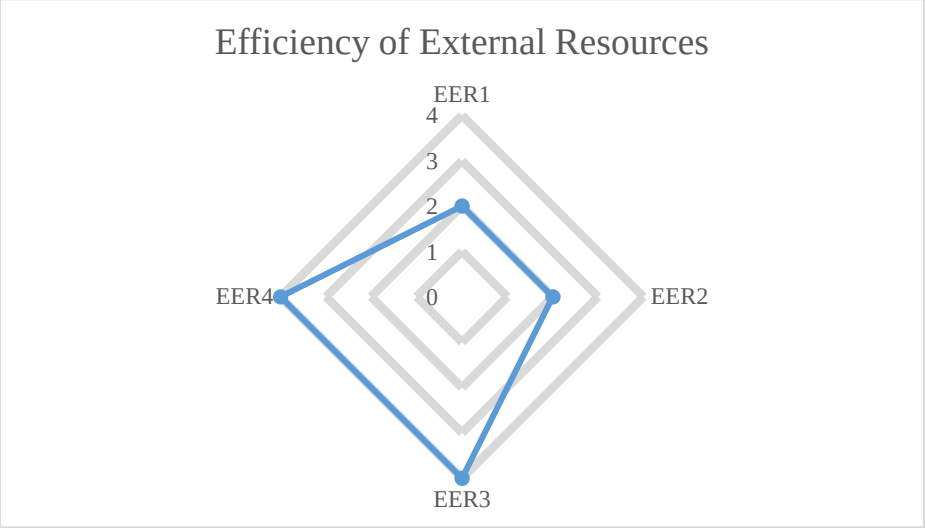

Figure 8.2 – Example of a radar chart for the “Efficiency of External Resources” indicator

8.3 Research Limitations

Integrating the concept of resilience into project management remains a new and emergent research theme that requires additional investigation and study (Thomé et al., 2016). In fact, as Gibson and Tarrant (2010) mentioned, any new field of research leads to a variety of definitions, methods, tools and processes, and the new concept of project resilience is no exception.

Despite the diversified nature of the methodology used in this dissertation (qualitative and quantitative studies), there are some limitations that should be mentioned.

First, the literature on the concept of project resilience is still sparse. Therefore, in this dissertation, studies of resilience from many perspectives were reviewed to propose a definition and a conceptual framework of project resilience. Although it was subsequently endorsed by a qualitative study (semi-structured interviews and analysis of case studies), additional future studies are needed to reinforce the topics developed in this dissertation and the importance of the concept of resilience in project management, which opens the door to many interesting research opportunities.

The second limitation is that the qualitative study was conducted among project managers from different fields, and the empirical literature on organizational resilience also came from different fields. However, the exploratory analysis (the validation process) was conducted on the field of information technology to achieve internal validity. So, at this stage, the generalizability of the results to other types of projects may be limited.

The third limitation is related to sample size. The sample size that was used for the exploratory analysis is considered small (it represents 50% of the sample needed). Therefore, even though the results of the EFA and CFA are considered acceptable and matched with the results obtained from the qualitative analysis, conducting an exploratory analysis on the dimensions of project resilience separately would have been too restrictive for the validation of the indicators on this concept as a whole.

The fourth possible limitation is related to gathering data through self-reports (predefined questionnaire) which is the case in this dissertation. Self-reports are highly used in studies on management, including project management, thus it is important to discuss the advantages and disadvantages of this data gathering method. First, self-reports are easy to interpret, are inexpensive, and offer a relatively quick way to gather data. Second, self-report can ensure the confidentiality of the respondent which gives him the necessary confidence and motivation to complete the questionnaire accurately. Third, self-reports offer good validity because opinions, thoughts, and actions are collected directly from the people involved deeply in a particular project (Byworth, 2008). Besides the advantages presented previously, self-reports are confronted to many weaknesses. First, the structure of the questionnaire can have an impact on measuring accurately the construct. Second, respondents tend to answer questions to their favor which may reduce credibility because of biased answering. Third, it is not guaranteed that the respondents have the right knowledge to answer the questions which may decrease the probability of having an accurate state of what the questionnaire is trying to measure. Fourth, answering some self-reports is considered a time-consuming activity subjected to cultural differences (Byworth, 2008). Most of these disadvantages can be bypassed through statistical analysis. For instance, KMO and Bartlett's Test of Sphericity help ensure that the data is suitable for factor analysis, Common Method Bias

can help provide evidence on a bad questionnaire structure, etc. (Hair et al., 2010; Podsakoff et al., 2003). However, it is important to recognize the limitations of self-reports and open the door for using a variety of methods (e.g. System behavioral measures by collecting behavioral data through lessons learned or by simulating scenarios, stakeholders' assessments through workshops with stakeholders) to improve assessing the concept of project resilience. This variety of methods can be subject to additional future research studies on project resilience.

That being said and taking into consideration the fact that this is among the first attempts to propose indicators to assess project resilience, more investigations are needed to better advance knowledge on this new and novel concept. Indeed, scientific research is a never-ending journey where there is always something to learn, regardless of the researcher's level of expertise. Therefore, it will be important and interesting for future studies to better conceptualize the concept of project resilience, validate its appropriateness and applicability in project management, and promote scientific knowledge of this concept. In fact, scientific studies are a "snapshot" of research at a particular moment in time. Thus, suggestions for future studies are discussed in the next section.

8.4 Future Studies

First, it is recommended that the "replication" step from Hinkin's (1998) scale development process be completed with an acceptable sample size to ensure the robustness of the indicators developed in this dissertation to assess project resilience in the IT field. This means that a new sample is necessary to diminish the bias due to sample-specific factors and "*enhance the generalizability of the new measures*" (Hinkin, 1998, p. 118). Once data from the new sample are available, exploratory and confirmatory factor analysis and convergent and discriminant validity are necessary so that we can be confident that the final set of indicators is suitable for use in future scientific studies.

Second, the same exploratory study, from the "item reduction" step to the "convergent and discriminant validity" step,[39] should be conducted in other project management fields such as construction, production, pharmaceutical, government, etc. External validation of the indicators derived from the qualitative study in other disciplines is recommended.

Third, the relationships from the proposed project resilience conceptual framework (results from Chapter 4) require validation. Statistical correlation and regression analysis are suggested for this purpose.

Fourth, as a practical contribution to project management, it is suggested that these indicators be part of a methodology to assess the resilience of a specific project at any time during its life-cycle. This methodology must take the project management's specific nature and characteristics into consideration and be context-specific.

Fifth, in this dissertation, leading indicators are proposed. This type of indicator allows system weaknesses to be identified so that proactive action can be taken (Flin et al., 2000; Lee et al., 2013). Another interesting research avenue would be to develop lagging indicators, where specific disruptive events within a specific project's contexts are analyzed and used as predictors to better deal with the same kind of disruptive events if they occur in the future (Flin et al., 2000). This process could be challenging, because the context and environment in which these events occur would change even if they shared the same characteristics at different points in time. Moreover, project types need to be taken into consideration, because lagging indicators can only be developed in projects that aim to generate the same deliverables repeatedly in order to bypass, to some extent, the uniqueness dimension. For instance, IT implementation projects where team members execute the same tasks in different projects could be an interesting research track for lagging indicators. Thus, disruptive events that occurred in past IT implementation projects, for the same application and in the same organizational environment, can be analyzed and specific indicators can be developed to deal with them in the future.

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[39] Referring to Hinkin's (1998) scale development process.

CHAPTER 9 CONCLUSION AND RECOMMENDATIONS

This dissertation's originality resides in the fact that the management of disruptive events in projects is viewed from a perspective of resilience. Consequently, it adds value to project risk management by concentrating not only on identifying, analyzing and preparing mitigation plans for risks and weaknesses but also on developing a project's capacity to be aware of its surroundings and to adapt in order to recover from disruptive events.

First, three literature reviews were conducted. The first literature review sets out the position of resilience in the project management domain: between risk management, vulnerability management and agility development. The second literature review sought to propose a definition and a conceptual framework for project resilience. Its objectives were achieved by reviewing the literature on the concept of resilience from many perspectives, including project management (Chapter 4). The third literature review dissects the indicators used in empirical studies to assess *organizational* resilience. The goal was to inspire the development of indicators to assess *project* resilience (Chapter 5).

Then qualitative and quantitative studies were conducted to propose a set of indicators to assess project resilience. In the qualitative study, 10 semi-structured interviews with senior project managers in to different fields were conducted. Inspired by the empirical literature on organizational resilience, 10 indicators to assess project resilience were suggested (Chapter 6). These indicators were subsequently examined in a quantitative exploratory study in which 167 observations in the IT field were statistically analyzed for internal validity.

Ultimately, 8 leading indicators, presented in Table 8.1, were suggested to assess awareness and adaptive capacity, the two dimensions of project resilience for IT projects. These indicators are intended to guide project team members to validate the knowledge acquired about the IT project and its environment in order to deal with events that could potentially lead to its failure. During the exploratory study, these indicators achieved acceptable Cronbach alpha scores and good fit results, indicating that they are reliable and have valid internal consistency and unidimensionality. Thus, they have been well received among project managers and project team members in the IT field for the assessment of project resilience.

In this dissertation, the main research question has been answered and the four objectives presented in section 3.1 have been satisfied. A definition and a conceptual framework for project resilience have been proposed and indicators to assess this concept were developed and validated through qualitative and quantitative studies. The scientific community's good reception of these results is indicated in the acceptance and publication of three scientific articles. In addition, these results open the door to a variety of research avenues and emphasize the importance of continuing to work on the novel, emergent and interesting concept of project resilience.

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APPENDIX A INVITATION FOR THE SEMI-STRUCTURED INTERVIEW IN FRENCH

Polytechnique Montréal
2900, boul. Édouard-Montpetit
Montréal, QC H3T 1J4

Monsieur, madame,

Je suis Khalil Rahi, étudiant au doctorat à l'École Polytechnique de Montréal, au département de mathématiques et de génie industriel.

Je vous écris pour vous demander si vous accepteriez de participer à un entretien semi-dirigé de 30 à 45 minutes, dans le cadre de mon projet doctoral. Cette recherche est sous la supervision du professeur Mario Bourgault et du professeur Benoit Robert.

Le but de cette étude est de comprendre comment les gestionnaires de projet, de différents domaines, identifient, traitent et gèrent les risques imprévus et inconnus qui, lorsqu'ils surviennent, perturbent le cycle de vie du projet. Ces risques sont ceux qui n'ont pas été détectés en utilisant les processus et les pratiques traditionnels de gestion de projet, ou ceux pour lesquels, même détectés, aucune stratégie adéquate n'a été mise en place pour les atténuer. En cas d'occurrence, ces risques ont un impact négatif sur le projet et peuvent nuire à l'atteinte des objectifs. Mon intention est de développer des indicateurs pour évaluer la capacité du projet, vu comme un système, de faire face à ce type de risque.

Dans le cadre de mes recherches, je sollicite des gestionnaires de projets ayant au moins 3 ans d'expérience et ayant traité des risques imprévus et inconnus. Compte tenu de votre expérience, de votre poste et de votre riche expérience professionnelle, votre participation serait très pertinente.

Cette démarche d'entrevues est réalisée selon les normes d'éthique de la recherche établies par Polytechnique Montréal. Conformément au Certificat d'éthique de la recherche qui encadre cette recherche, les informations recueillies resteront confidentielles, et ne seront utilisées qu'à des fins de recherche. À aucun moment votre identité ou celle du projet ne sera divulguée. Votre participation est volontaire et vous pourrez vous retirer de l'entretien à tout moment et sans justification..

Si vous souhaitez obtenir des précisions ou informations additionnelles relatives à l'étude, n'hésitez pas à communiquer avec moi par téléphone cellulaire au (514) 622-2266, ou par courriel à khalil.rahi@polymtl.ca

Je termine en vous remerciant de l'intérêt porté envers ma recherche, et en vous priant de communiquer avec moi dans le cas où vous seriez intéressé à participer aux entretiens.

Meilleures salutations,

Khalil Rahi

APPENDIX B INVITATION FOR THE SEMI-STRUCTURED INTERVIEW IN ENGLISH

POLYTECHNIQUE MONTRÉAL
LE GÉNIE EN PREMIÈRE CLASSE

Polytechnique Montreal
2900 Edouard Montpetit Blvd
Montreal, QC H3T 1J4

Dear <First_name>, <Last_name>

I am Khalil Rahi, a Ph.D. student at Polytechnique Montreal at the Department of mathematics and industrial engineering.

I am writing to ask you if you would agree to a semi-directed interview of 30-45 mins for my Ph.D. research. This research is under the supervision of Professor Mario Bourgault and Professor Benoit Robert.

The aim of this study is to understand how project managers, from different fields, are aware, deal with, and manage disruptive unforeseen and unknown risks that occur during the project life-cycle. These risks are those that were not detected when following traditional project management processes and practices, or when detected, no adequate strategies were put in place to mitigate them. On occurrence, these risks have a negative impact on the project and may prevent the project from fulfilling its objectives successfully. My intention is to develop indicators to assess the capacity of dealing with this type of risk, on occurrence, within a specific project environment.

As part of my research, I target project managers with at least 3 years of experience, and who have dealt with unforeseen and unknown risks. Therefore, your profile is very interesting for my study given your experience, position, and your rich professional background.

I assure you of the confidentiality of any information acquired which will be used for research purposes only. At no time will your identity or that of the project or anyone interviewed be disclosed. Your participation is voluntary and you will be able to withdraw at any time without justification, should you accept to participate in the interview.

In the meantime, if you do have any questions or require further clarification about this research study, please feel free to contact me on my cell phone: (514) 622-2266 or by email at khalil.rahi@polymtl.ca

I would like to thank you in advance for your time and for letting me know your interest in my research as well as your availability for an interview.

Best Regards,

Khalil Rahi

APPENDIX C CONSENT FORM FOR QUALITATIVE STUDY IN FRENCH

POLYTECHNIQUE MONTRÉAL

Formulaire d'information et de consentement

Titre du projet de recherche doctoral:

Conception des indicateurs pour évaluer la résilience des projets

Équipe de recherche :

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Préambule:

Par la présente, Nous vous invitions à participer à un projet de recherche visant à développer des indicateurs pour évaluer la résilience des projets. Vous avez été sélectionné pour ce projet

parce que vous êtes un gestionnaire de projet avec plus de 3 ans d'expérience en gestion de projet et que vous avez traité des risques imprévus et inconnus au cours de vos projets.

Cependant, avant d'accepter de participer à ce projet et avant de signer ce formulaire, veuillez prendre le temps de lire, de comprendre et d'examiner attentivement les informations fournies ci-dessous. Nous vous invitons à poser toutes les questions que vous pourriez avoir au chercheur responsable du projet ou aux autres membres de l'équipe de recherche et à leur demander de vous expliquer tout mot ou toute information qui n'est pas clair.

Présentation du projet de recherche et de ses objectifs:

Cette étude vise à comprendre comment les gestionnaires de projet, de différents domaines, identifient, traitent et gèrent les risques imprévus et inconnus qui, lorsqu'ils surviennent, perturbent le cycle de vie du projet. Ces risques sont ceux qui n'ont pas été détectés en utilisant les processus et les pratiques traditionnels de gestion de projet, ou ceux pour lesquels, même détectés, aucune stratégie adéquate n'a été mise en place pour les atténuer. En cas d'occurrence, ces risques ont un impact négatif sur le projet et peuvent nuire à l'atteinte des objectifs. Mon intention est de développer des indicateurs pour évaluer la capacité du projet, vu comme un système, de faire face à ce type de risque.

Nature et durée de votre participation à ce projet de recherche

Votre participation à ce projet consistera à répondre à une série de questions lors d'un entretien téléphonique ou en personne, en fonction de vos préférences personnelles. Toutes les réponses que vous fournissez seront confidentielles. Nous estimons que l'entretien semi-directif nécessitera 30 à 45 minutes de votre temps. Sur votre accord, vos réponses seront enregistrées pour permettre une meilleure analyse après l'entretien. L'enregistrement sera réalisé grâce à un enregistreur audio numérique. Le fichier audio sera copié sur l'ordinateur protégé de Khalil Rahi et une autre copie sera sauvegardée sur un disque dur externe protégé par un mot de passe (serveur MAGI). Le nom du fichier sera codé et le nom de la personne n'apparaîtra pas. Une fois le projet terminé, tous les enregistrements seront transférés aux professeurs Mario Bourgault et Benoît Robert de l'École Polytechnique de Montréal, et détruits sur l'ordinateur de Khalil Rahi.

Avantages et inconvénients résultant de votre participation au projet de recherche:

La participation au projet de recherche ne présente aucun inconvénient, sauf le temps nécessaire pour répondre à nos questions. Le principal avantage est d'avoir accès à un rapport-synthèse préparé au terme de la collecte de données. Le rapport-synthèse portera uniquement sur les entrevues, et retracera les grandes tendances observées.

Risques résultant de votre participation au projet de recherche:

Ce projet de recherche ne vous soumettra à aucun autre risque que ceux auxquels vous êtes soumis dans vos activités quotidiennes habituelles.

Compensation financière:

Vous ne recevrez aucune compensation financière pour votre participation à cette étude.

La participation et le retrait volontaire:

Votre participation à ce projet de recherche est totalement volontaire. Par conséquent, vous êtes libre de refuser d'y participer. Vous pouvez refuser d'être enregistré en le spécifiant au début de l'entretien. Vous pouvez également arrêter l'entretien à tout moment si vous le souhaitez. Dans ce cas, les informations collectées seront détruites et les réponses fournies par vous ne seront pas prises en compte.

Tout participant peut retirer son consentement à tout moment, même après l'entretien. Si le participant souhaite retirer son consentement après l'entretien, les données collectées seront détruites et ne seront utilisées d'aucune manière.

Le participant n'est pas obligé de répondre à toutes les questions, si certaines d'entre elles l'indispose pour diverses raisons (par exemple, la confidentialité).

Les résultats de la recherche pourraient mener à des publications scientifiques. Cependant, aucune donnée susceptible de mener à votre identification ou à votre entreprise n'apparaîtra dans ces publications.

Les participants peuvent être retirés sans leur consentement par les chercheurs ou le comité d'éthique de la recherche de Polytechnique Montréal s'ils ne suivent pas les instructions fournies ou s'il existe des raisons administratives d'abandonner le projet, notamment pour des raisons de sécurité ou de faisabilité.

Confidentialité:

Lors de votre entretien, le chercheur responsable du projet compilera les réponses aux questions posées. Seules les informations nécessaires à l'exécution du projet de recherche seront collectées.

Toutes les informations collectées dans le cadre de cette étude resteront strictement confidentielles dans les limites légales. Afin de préserver votre identité et la confidentialité des informations que vous nous fournissez, nous vous attribuerons un code. Les données recueillies par le chercheur responsable du projet seront conservées dans son bureau à Polytechnique Montréal.

Le chercheur responsable du projet utilisera toutes les données pour les seuls objectifs du projet de recherche décrit brièvement ci-dessus. Les données collectées dans le cadre du projet pourraient être publiées dans des articles scientifiques ou partagées avec d'autres personnes lors de conférences scientifiques. Cependant, aucune information susceptible de mener à votre identification ne sera contenue dans ces publications ou communications scientifiques.

À des fins de surveillance ou de contrôle, votre dossier de recherche pourrait être consulté par une personne mandatée par le comité d'éthique de la recherche de Polytechnique Montréal ou par une personne mandatée par les conseils de recherche. Toutes ces personnes adhèrent à des politiques de confidentialité strictes.

Vous avez le droit de consulter votre dossier de recherche pour vérifier l'exactitude des informations collectées aussi longtemps que le chercheur responsable du projet et l'institution possèdent ces informations. Cependant, pour préserver l'intégrité scientifique du projet de recherche, vous n'aurez accès à ces informations qu'à la fin de l'étude.

Les données collectées seront conservées pendant 7 ans, après quoi elles seront détruites.

Personnes de contact:

Si vous avez des questions concernant ce projet de recherche, vous pouvez communiquer avec Khalil Rahi, chercheur responsable du projet par courriel à: khalil.rahi@polymtl.ca

Si vous avez des questions concernant votre participation à ce projet de recherche, vous pouvez communiquer avec Mme Delphine Perié-Curnier, présidente du comité d'éthique de la recherche de Polytechnique Montréal au: (514) 340-4711, poste 4437 ou par courriel à: delphine.perie@polymtl.ca

Consentement:

J'ai lu attentivement ce document. On m'a clairement expliqué en quoi consistait ma participation. Un membre de l'équipe de recherche a répondu à toutes mes questions et j'ai eu suffisamment de temps pour décider si je voulais ou non participer à cette étude. J'accepte par la présente de participer à ce projet de recherche conformément aux conditions énoncées dans ce document. J'ai reçu une copie de ce document.

_____ _____

Nom et signature du participant à la recherche Date

Je certifie par la présente que j'ai soigneusement expliqué au participant en quoi consistera sa participation. J'ai répondu à toutes ses questions concernant ce projet et je lui ai clairement indiqué qu'elle / il a toujours le droit de se retirer du projet sans subir de préjudice. Je certifie par la présente que mon équipe de recherche et moi-même respecterons toutes les conditions énoncées dans ce document et attestons avoir remis une copie de ce document au participant.

_____ _____

Nom et signature du chercheur Date

APPENDIX D CONSENT FORM FOR QUALITATIVE STUDY IN ENGLISH

POLYTECHNIQUE MONTRÉAL

Informed Consent Form

Title of the research project:

Development of indicators to assess project resilience

Research Team :

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Preamble:

We hereby invite you to participate in a research project aimed at developing indicators to assess project resilience. You have been selected for this project because you are a project

manager with more than 3 years of experience in project management and you have dealt with unforeseen and unknown risks in the course of your projects.

However, before accepting to participate in this project and before signing this form, please take the time to read, understand and carefully consider the information provided below. We invite you to ask any question you might have to the researcher in charge of the project or the other members of the research team, and to ask them to explain to you any word or information that is not clear.

Presentation of the research project and its objectives:

This study aims to understand how project managers, from different fields, are aware, deal with, and manage disruptive unforeseen and unknown risks that occur during the project lifecycle. These risks are those that were not detected when following traditional project management processes and practices, or when detected, no adequate strategies were put in place to mitigate them. On occurrence, these risks have a negative impact on the project and may prevent the project from fulfilling its objectives successfully. My intention is to develop indicators to assess the capacity of dealing with this type of risk, on occurrence, within a specific project environment.

Nature and duration of your participation in this research project:

Your participation in this project will consist of answering a series of questions during a telephone interview or in person, based on your personal preference. All the answers you provide will be confidential. We estimate that the semi-directive interview will require 30 to 45 minutes of your time. Upon your agreement, your answers will be recorded to allow a better analysis after the interview. The recording will be on a digital audio recorder. This recording will be copied to Khalil Rahi's protected computer and another backup copy will be saved onto an external hard drive protected by a password. The file name will be coded and the person's name will not appear. Once the project is completed, all the recordings will be transferred to Professor Mario Bourgault from Poytechnique Montreal, and destroyed on Khalil Rahi's computer.

Benefits and disadvantages resulting from your participation in the research project:

There are no disadvantages to participate in the research project, except the time spent to answering our questions. The main advantage is to have access to a summary report prepared after the data collection. The summary report will focus solely on the interviews and will emphasize the major trends observed.

Risks resulting from your participation in the research project:

This research project will not subject you to any additional risks other than those you are subject to in your regular daily activities.

Financial compensation:

You will not receive any financial compensation for your participation in this study.

Voluntary participation and withdrawal:

Your participation in this research project is totally voluntary. Therefore, you are free to refuse to participate in it. You can refuse to be recorded by specifying it at the beginning of the interview. You can also stop the interview at any time if you wish. In this case, the information collected will be destroyed and the answers provided by you will not be considered.

Any participant may withdraw his/her consent at any time, even after the interview. If the participant wants to withdraw his/her consent after the interview, the data collected will be destroyed and will not be used in any manner whatsoever.

The participant is not obliged to answer all questions, if any makes them uncomfortable for various reasons (e.g. confidentiality).

The research results could lead to scientific publications. However, no data that could lead to your identification or your company will appear in those publications.

Participants may be withdrawn without their consent by the researchers or the Research Ethics Board of Polytechnique Montréal should they not follow the instructions provided or should there be some administrative reasons to abandon the project, notably for safety or feasibility reasons.

Confidentiality:

During your interview, the researcher in charge of the project will compile the answers to the questions asked. Only the information that is needed for the safe execution of the research project will be collected.

All the information collected within the framework of this study will remain strictly confidential within the legal limits. In order to preserve your identity and the confidentiality of the information you will provide us with, we will assign a code to you. The data collected by the researcher in charge of the project will be kept and locked up in his/her office at Polytechnique Montreal.

The researcher in charge of the project will use all the data for the sole objectives of the research project briefly described above. The data collected within the framework of the project could be published in scientific papers or be shared with other people during scientific conferences. However, no information that could lead to your identification will be contained in these publications or scientific communications.

For monitoring or control purposes, your research file could be consulted by a person mandated by the Research Ethics Board of Polytechnique Montreal or by a person mandated by the research councils. All these individuals adhere to strict confidentiality policies.

You are entitled to consult your research file to verify the correctness of the collected information for as long as the researcher in charge of the project and the institution possess this information. However, to preserve the scientific integrity of the research project, you will have access to this information only at the termination of the study.

The collected data will be kept for a 7-year period, after which it will be destroyed.

Contact people:

Should you have any questions pertaining to the research project, you can communicate with Khalil Rahi, researcher in charge of the project by e-mail at: khalil.rahi@polymtl.ca.

Should you have any questions pertaining to your participation in this research project, you can communicate with Ms. Delphine Perié-Curnier, Chair of Polytechnique Montreal's Research Ethics Board at: (514) 340-4711, Ext. 4437 or by e-mail at: delphine.perie@polymtl.ca.

Consent:

I have carefully read this document. I was clearly explained what my participation consisted of. A member of the research team answered all my questions and I was given enough time to decide whether I wanted to participate in this study or not. I hereby agree to participate in this research project in accordance with the conditions set out in this document. I have received a copy of this document.

_____ _____

Name and signature of the research participant Date

I hereby certify that I have carefully explained to the participant what his/her participation will consist of. I have answered all his/her questions pertaining to this project and clearly mentioned to him/her that he/she remains entitled to withdraw from the project at any time without suffering any prejudice. I hereby certify that my research team and I will respect all the conditions set out in this document and attest having given a copy of this document to the participant.

_____ _____

Name and signature of the researcher Date

APPENDIX E THE QUESTIONS FOR THE SEMI-STRUCTURED INTERVIEW IN FRENCH

Questions d'entretien

A) Questions relatives au répondant

1. Combien d'années d'expérience avez-vous en gestion de projet?
2. Quel est votre secteur d'activités professionnelles (industrie)?
3. Quelle est la valeur approximative des budgets de projets dont vous êtes responsable?
4. De quels types de livrables êtes-vous habituellement responsable au sein des projets que vous gérez?
5. Quelle est la durée approximative des projets dont vous êtes responsable?

B) Questions sur les processus actuels liées à vos projets les plus courants

1. Comment les faiblesses du projet (là où le projet est le plus vulnérable) sont-elles identifiées et évaluées durant le cycle de vie du projet?
2. Quels sont les éléments (mécanismes, processus, pratiques, compétences, etc.) qui aident à garantir une identification et une évaluation adéquate des faiblesses du projet?
3. Quels sont les éléments (mécanismes, processus, pratiques, compétences…) mis en œuvre pour maintenir une vigilance (anticiper) quant aux risques imprévus et inconnus?
4. En cas d'occurence, comment les risques imprévus et inconnus sont-ils gérés? Quelles seraient les premières mesures prises pour déclencher une réaction nécessaire à leur prise en charge?
5. Quels sont les éléments (mécanismes, processus, pratiques, compétences…) qui assurent une gestion adéquate des risques imprévus et inconnus perturbateurs?
6. Si un risque n'est pas géré adéquatement, comment les répercussions de ce risque sont-elles gérées?
7. En cas d'occurrence, à quel moment les risques imprévus et inconnus sont-ils considérés comme ayant été gérés adéquatement? En se basant sur quels critères? Comment une action / décision / stratégie est-elle évaluée quant à son niveau d'adéquation avec le risque imprévu et inconnu pouvant menacer le projet?
8. Selon vous, que signifie l'échec d'un projet?

C) Questions concernant un événement perturbateur spécifique

1. Pouvez-vous donner un exemple d'un événement perturbateur majeur survenu dans un projet spécifique?
2. Comment cet événement a-t-il été identifié et analysé (approche, méthodes, processus, etc.)?
3. Quel a été l'impact sur les objectifs du projet?
4. Quels sont les éléments (mécanismes, processus, pratiques, compétences, etc.) qui, à votre avis, peuvent améliorer l'identification de ce type d'événement?
5. Comment cet événement a-t-il été traité? Quelles sont les actions / décisions / stratégies adoptées pour y faire face?

6. Comment le projet a-t-il pu surmonter cet événement? Y a-t-il eu des changements sur les livrables, le calendrier, le budget, etc. du projet?

7. Y a-t-il eu des leçons tirées de la gestion de cet événement? Des mesures ont-elles été mises en place pour aider à surmonter de futurs événements perturbateurs similaires?

APPENDIX F THE QUESTIONS FOR THE SEMI-STRUCTURED INTERVIEW IN ENGLISH

Interview questions

A) Questions about the interviewee

1. How many years of experience do you have in project management?
2. What is your industry?
3. What is the range of your projects' budgets?
4. What are your regular key deliverables?
5. What is the range of your projects' schedules?

B) Questions about current processes related to your most common projects

1. How are project's weaknesses (where the project is most vulnerable) identified and assessed during the project life-cycle?
2. What are the elements (mechanisms, processes, practices, skills, etc.) that help ensure a successful identification and assessment of project's weaknesses?
3. What are the elements (mechanisms, processes, practices, skills ...) implemented to remain alert (to anticipate) to unforeseen and unknown risks?
4. On occurrence, how are unforeseen and unknown risks managed? what would be the first actions taken to initiate a reaction to manage them?
5. What are the elements (mechanisms, processes, practices, skills ...) that ensure a successful management of disruptive unforeseen and unknown risks?
6. If not managed successfully, how is the impact of these risks on the project managed?
7. On occurrence, when are disruptive unforeseen and unknown risks considered successfully managed? Based on what criteria? In fact, how is an action/decision/strategy evaluated to assess if it is satisfactory/adequate in relation to a disruptive unforeseen and unknown risk that threatens the project?
8. What does project failure mean to you?

C) Questions regarding a specific disruptive event

1. Can you give an example of a major disruptive event that occurred within a specific project?
2. How was this event identified and analyzed (approach, methods, processes, etc.)?
3. What was the impact on the project's objectives?
4. What are the elements (mechanisms, processes, practices, skills, etc.) that can, in your opinion, improve the awareness of this type of event?
5. How was this event handled? What were the actions/decisions/strategies adopted to deal with it?
6. How did the project recover from this event? Were there any changes on the project's deliverables, schedule, budget, etc.?
7. Were there any lessons learned from the management of this event? Were there any measures put in place to help recover from future similar disruptive events?

APPENDIX G QUESTIONNAIRE IN FRENCH

Cher répondant, je suis Khalil Rahi, doctorant à Polytechnique Montréal, au Département de mathématiques et de génie industriel.

Merci d'avoir accepté de participer à cette enquête sur la « résilience projet ». Ce terme est défini comme la capacité du projet à maintenir une attention vigilante ("awareness" en anglais) de son entourage, et à s'adapter afin de se remettre des événements perturbateurs.

En répondant aux questions, **pensez à un projet TI (ex. implantation des applications, développement des applications, infrastructure TI, etc.) dans lequel votre équipe a géré avec succès un événement ayant entraîné de graves écarts par rapport aux objectifs du projet (ex., retards, dépassements de budget, qualité médiocre, contenu incomplet, mécontentement de la clientèle, etc.)**

Le questionnaire n'exige aucune compétence particulière et il n'y a pas de bonne ou de mauvaise réponse.

Assurez-vous de disposer de 10 à 15 minutes pour remplir le questionnaire. Si vous avez des questions, n'hésitez pas à me contacter à khalil.rahi@polymtl.ca

Cordialement,

Khalil Rahi

PS: Veuillez laisser votre adresse courriel sur la page suivante si vous souhaitez recevoir un résumé des résultats de ce sondage.

Information sur les répondants

1. Quelle est votre adresse courriel si vous souhaitez recevoir un résumé des résultats de ce sondage?
2. Quel est/était votre rôle dans le projet?
   a. Gestionnaire de projet
   b. Membre de l'équipe
3. Quel est/était le type du projet TI?
   a. Implantation des applications
   b. Développement des applications
   c. Infrastructure
   d. Télécommunication
   e. *Autre (veuillez préciser)*
4. Combien d'années d'expérience avez-vous dans votre domaine d'expertise?
   a. Moins de 2 ans
   b. 2 à 5 ans
   c. 6 à 10 ans
   d. 11 à 15 ans
   e. 16 à 20 ans

   f. Plus de 20 ans
5. Quel est/était le budget prévu de votre projet?
   a. Moins de CAD$50,000
   b. CAD$50,000 à CAD$99,999
   c. CAD$100,000 à CAD$499,999
   d. CAD$500,000 à CAD$999,999
   e. CAD$1,000,000 à CAD$9,999,999
   f. CAD$10,000,000 à CAD$49,999,999
   g. CAD$50,000,000 à CAD$100,000,000
   h. Plus de CAD$100,000,000
6. Quelle est/était la durée prévue du projet?
   a. Moins de 6 mois
   b. Entre 6 et 12 mois
   c. Entre 13 mois et 3 ans
   d. Entre 4 ans et 5 ans
   e. Entre 6 ans et 10 ans
   f. Plus de 10 ans

Questions sur la résilience projet

Volet 1 : Attention vigilante (‘*Awareness’* en anglais)

Pour les éléments suivants, veuillez indiquer votre degré d’accord de “fortement en désaccord” à “fortement en accord”, en lien avec le contexte du projet sélectionné.

1. Clarté des rôles et des responsabilités					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Je comprends bien mes tâches pendant le cycle de vie du projet.					
J'utilise continuellement mon expertise pour identifier les risques du projet.					
J'utilise continuellement mon expertise pour analyser les risques (probabilité/impact) du projet.					
Je travaille en collaboration avec les autres membres de l'équipe pour rester vigilant face aux événements perturbateurs.					

J'utilise des pratiques spécifiques à mon domaine d'activité (p. ex. Mesures de sécurité, protocoles et certifications spécifiques, etc.) pour m'assurer que les tâches sont exécutées en fonction de la conformité aux réglementations en vigueur.					
2. Disponibilité des méthodes de gestion de projet et des risques					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Selon le type de projet, des méthodes de gestion de projet (p. ex., un modèle de plan de projet, une stratégie agile, etc.) sont utilisées pour capturer toutes les exigences du projet et éviter des événements perturbateurs.					
En fonction du type de projet, des méthodes de gestion des risques (p. ex., un modèle de registre des risques, une analyse de Monte-Carlo, etc.) sont utilisées pour éviter des événements perturbateurs.					
Les leçons tirées de projets similaires antérieurs sont analysées pour identifier les faiblesses du projet.					
Des méthodes spécifiques à mon domaine d'activité (p. ex., des listes de contrôle spécifiques au domaine d'activité, des guides et procédures d'installation des équipements, etc.) sont utilisées pour éviter des événements perturbateurs.					
3. Alerte aux écarts de portée et de performance					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Les modifications apportées à la portée du projet font l'objet d'une surveillance					

continue tout au long du cycle de vie du projet.					
Les exigences du projet sont convenablement recueillies dès le début du projet.					
Les indicateurs clés de performance concernant le budget sont contrôlés en continu pour détecter tout écart de performance budgétaire durant le cycle de vie du projet.					
Les indicateurs clés de performance concernant l'échéancier sont contrôlés en continu pour détecter tout écart calendaire durant le cycle de vie du projet.					
Le contrôle de la qualité est effectué en continu pour détecter toute anomalie pouvant conduire à des événements perturbateurs tout au long du projet de cycle de vie.					
4. Sensibilité aux changements environnementaux					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Les modifications externes (p. ex. modifications apportées aux lois, réglementations et tendances spécifiques au domaine d'activité, etc.) sont surveillées de manière proactive (p. ex., par le biais de la participation à des groupes ou associations sectoriels, etc.) afin de rester attentives aux possibles événements perturbateurs.					
Les changements organisationnels internes (p. ex., nouveaux processus de gestion de projet, mises à jour de méthodes existantes, etc.), pouvant avoir une incidence sur le projet, sont					

clairement communiqués pour éviter tout événement perturbateur.					
Lorsque cela est nécessaire, l'accès aux ressources au sein de l'organisation est possible pour aider à identifier les faiblesses du projet.					
Lorsque cela est nécessaire, l'accès aux ressources au sein des organisations est possible pour aider à évaluer les faiblesses du projet.					
5. Efficacité des ressources externes					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Le partenariat avec des parties externes, possédant des connaissances spécifiques au domaine d'activité, est continuellement développé.					
Les partenariats actuels avec des parties externes sont continuellement renforcés.					
L'accès à des ressources externes par le biais de partenariats est possible pour aider à identifier les faiblesses du projet.					
L'accès à des ressources externes par le biais de partenariats est possible pour aider à évaluer les faiblesses du projet.					
6. Leadership et participation des intervenants					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Les dirigeants sont transparents sur tous les changements organisationnels susceptibles de provoquer des événements perturbateurs au cours du projet de cycle de vie.					
Tous les problèmes détectés tout au long du cycle de vie du projet sont communiqués aux dirigeants pour les					

tenir au courant des perturbations éventuelles.					
Les attentes entre les parties prenantes sont constamment définies pour renforcer la confiance et éviter les surprises.					
Des suivis (p. ex. réunions régulières, appels d'état, etc.) sont effectués régulièrement pour rester alerter à des événements perturbateurs.					

Questions sur la résilience projet

Volet 2 : Capacité d'adaptation

Pour les éléments suivants, veuillez indiquer votre degré d'accord de "fortement en désaccord" à "fortement en accord", en lien avec le projet sélectionné.

1. Accessibilité et mobilisation des ressources					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Si nécessaire, des ressources peuvent être mobilisées auprès de différents départements pour faire face à des événements perturbateurs.					
Au besoin, des ressources peuvent être mobilisées par le biais de partenariats pour faire face à des événements perturbateurs.					
Des systèmes d'information sont disponibles pour fournir un accès rapide aux informations permettant de faire face à des événements perturbateurs.					
Des systèmes d'information sont disponibles pour enregistrer les événements perturbateurs.					
Les départements peuvent donner leur avis sur les solutions possibles pour faire face aux événements perturbateurs par le biais des systèmes d'information.					

Les partenaires externes peuvent donner leur avis sur les solutions possibles pour faire face aux événements perturbateurs via des systèmes d'information.					
Lorsque les imprévus budgétaires sont complètement consommés, les dirigeants peuvent dégager des fonds supplémentaires pour faire face aux événements perturbateurs.					
2. Réactivité des membres de l'équipe					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
J'ai tendance à adopter des solutions créatives pour faire face à des événements perturbateurs.					
Je suis encouragé à penser sans idées préconçues pour trouver des solutions face aux événements perturbateurs.					
J'ai l'expertise nécessaire pour faire face à des événements perturbateurs.					
Face aux événements perturbateurs, il est prioritaire de trouver les meilleurs moyens afin de les éviter.					
3. Efficacité des communications et des relations					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Des explications claires des problèmes et des solutions possibles sont fournies à toutes les parties prenantes au moyen de communications transparentes.					
Les parties prenantes, y compris le client, sont encouragées à s'approprier l'événement perturbateur et les solutions possibles.					
Les parties prenantes sont impliquées dans des suivis continus (p.ex. réunions régulières, appels d'état, etc.) pour					

assurer une gestion appropriée des événements perturbateurs.					
Les parties prenantes sont disposées à réévaluer les objectifs du projet (p. ex. nouvelles façons de faire, nouvelle feuille de route, nouvelles stratégies, etc.), si nécessaire, pour faire face aux événements perturbateurs.					
Un plan de recours hiérarchique clair est disponible pour faire face aux événements perturbateurs.					
4. Prise de décision adaptée et réactive					
	Fortement en désaccord	En désaccord	Neutre	En accord	Fortement en accord
Les dirigeants proposent un plan d'action pour faire face aux événements perturbateurs.					
Les dirigeants s'assurent que les actions sont mises en œuvre de la bonne manière et au bon moment pour faire face aux événements perturbateurs.					
Les dirigeants adaptent leurs stratégies pour faire face aux événements perturbateurs en fonction de l'importance du projet pour l'organisation.					
La satisfaction des parties prenantes est prise en compte lors de la recherche de solutions pour faire face à des événements perturbateurs.					
Les clauses du contrat peuvent être contournées, dans une certaine mesure, pour trouver des solutions face à des événements perturbateurs.					
Les membres qualifiés de l'équipe sont encouragés à prendre des décisions critiques sans obtenir l'approbation des dirigeants.					

APPENDIX H QUESTIONNAIRE IN ENGLISH

Dear respondent, I am Khalil Rahi, a Ph.D. student at the Department of Mathematics and Industrial Engineering of Polytechnique Montreal.

Thank you for agreeing to take part in this survey on project resilience. This concept is defined by the capacity of the project to be aware of its surroundings and to adapt in order to recover from disruptive events.

When answering these questions, please **think about an IT project (e.g. Application implementation, application development, infrastructure, etc.) in which your team successfully managed an event that caused severe deviations from the project's objectives (e.g. delay, over budget, low quality, incomplete scope, client dissatisfaction, etc.).**

The questionnaire requires no special skills, and there are no right or wrong answers.

Please make sure that you have 10-15 minutes to complete the questionnaire. If you have any questions, please do not hesitate to contact me at khalil.rahi@polymtl.ca

Best regards,

Khalil Rahi

PS: Please leave your email address on the next page if you are interested in receiving a summary of this survey.

Respondent Information

7. What is your email address if you are interested in receiving a summary of this survey?
8. What is/was your role in the project?
    a. Project manager
    b. Project team member
9. What is/was the type of the IT project?
    a. Applications implementation
    b. Applications development
    c. Infrastructure
    d. Telecommunications
    e. Other (Please specify)
10. How many years of experience do you have in your field?
    a. Less than 2 years
    b. 2 to 5 years
    c. 6 to 10 years
    d. 11 to 15 years
    e. 16 to 20 years
    f. Greater than 20 years

11. What is/was your project's initial budget?
    a. Less than CAD$50,000
    b. CAD$50,000 to CAD$99,999
    c. CAD$100,000 to CAD$499,999
    d. CAD$500,000 to CAD$999,999
    e. CAD$1,000,000 to CAD$9,999,999
    f. CAD$10,000,000 to CAD$49,999,999
    g. CAD$50,000,000 to CAD$100,000,000
    h. Greater than CAD$100,000,000
12. What is/was the project's initial schedule?
    a. Less than 6 months
    b. Between 6 and 12 months
    c. Between 13 months and 3 years
    d. Between 4 years, and 5 years
    e. Between 6 years and 10 years
    f. Greater than 10 years

Questions on Project Resilience

Part 1: Awareness

For the following items, please indicate your degree of agreement from strongly disagree to strongly agree, in the context of the project that you have selected.

1. Clarity of Roles & Responsibilities					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I have a clear understanding of my tasks during the project life-cycle.					
I continuously use my expertise to identify project risks.					
I continuously use my expertise to assess (probability vs impact) project's risks.					
I work in collaboration with other team members to remain alert to disruptive events.					
I use field-specific practices (e. g. safety measures, protocols and certifications, etc.) to ensure tasks are completed based on field-specific regulatory compliance.					
2. Availability of Project & Risk Management Methods					

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Based on the project type, project management methods (e.g. project plan template, Agile, etc.) are employed to capture all project's requirements and potentially avoid possible disruptive events.					
Based on the project type, risk management methods (e.g. risk register template, Monte Carlo analysis, etc.) are used to avoid possible disruptive events.					
Lessons learned from previous similar projects are analyzed to identify project weaknesses.					
Field-specific methods (e.g. field-specific checklists, equipment installation guides and procedures, etc.) are used to remain alert to project weaknesses.					
3. Alertness to Scope & Performance Deviations					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Scope changes are continuously monitored through the project life-cycle.					
Project requirements are properly gathered from the beginning of the project.					
KPIs for the budget are continuously monitored to detect any budget performance deviation through the project life-cycle.					
KPIs for the schedule are continuously monitored to detect any schedule performance deviation through the project life-cycle.					
Quality control is continuously achieved to detect any discrepancies that may lead to disruptive events through the project life-cycle.					
4. Sensitivity to Environmental Changes					

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
External changes (e.g. changes in laws, regulations and field-specific trends, etc.) are proactively monitored (e.g. by participation with industry-specific groups or associations, etc.) to have early warnings of possible disruptive events.					
Internal organizational changes (e.g. new project management processes, updates to existing methods, etc.), that may impact the project, are clearly communicated to avoid possible disruptive events.					
When needed, access to resources within the organization is available to help identify project weaknesses.					
When needed, access to resources within the organization is available to help assess project weaknesses.					
5. Efficiency of External resources					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Partnership with external parties that have the field-specific knowledge is continuously developed.					
Current partnerships with external parties are continuously reinforced.					
Access to external resources through partnerships is possible to help identify project weaknesses.					
Access to external resources through partnerships is possible to help assess project weaknesses.					
6. Leadership & Involvement of Stakeholders					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Senior managers are transparent regarding any organizational changes that may cause					

disruptive events during the project life-cycle.					
All detected issues through the project life-cycle are communicated to senior managers to keep them alert to possible disruptive events.					
Expectations are continuously set to reinforce trust and avoid surprises.					
Follow-ups (regular meetings, status calls, etc.) take place regularly to remain alert to possible disruptive events.					

Questions on Project Resilience

Part 2: Adaptive Capacity

For the following items, please indicate your degree of agreement from strongly disagree to strongly agree, in the context of the project that you have selected.

1. Accessibility & Mobilization of Resources					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
When needed, resources can be mobilized from different departments to face disruptive events.					
When needed, resources can be mobilized through partnerships to face disruptive events.					
Information systems are available to provide quick access to information to solve an issue.					
Information systems are available to log disruptive events					
Departments can provide feedback on possible solutions to face disruptive events through information systems.					
External partners can provide feedback on possible solutions to face disruptive events through information systems.					

When the budget contingency is completely consumed, leadership can release additional funds to face disruptive events.					
2. Responsiveness of Team Members					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I tend to adopt creative solutions to face disruptive events.					
I am encouraged to think outside of the box to find solutions to face disruptive events.					
I have the expertise to deal with disruptive events.					
When faced with disruptive events, it is a priority to find the best ways to avoid them.					
3. Effectiveness of Communications & Relationships					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Clear explanations of issues and possible solutions are provided to all stakeholders through transparent communications.					
Stakeholders, including the client, are encouraged to take ownership of the issue and any possible solutions.					
Stakeholders are involved through continuous follow-ups (e.g. regular meetings, status calls, etc.) to ensure proper management of disruptive events.					
Stakeholders are open to re-assess project objectives (e.g. new ways of doing things, new roadmap, new strategies, etc.), if needed, to face disruptive events.					
A clear escalation plan is available to face disruptive events.					
4. Adapted & Responsive Decision Making					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Senior managers plot a course of actions to face disruptive events.					

Senior managers ensure actions are implemented at the right way and the right time to effectively face disruptive events.					
Senior managers adapt their strategies to face disruptive events based on the project's importance to the organization.					
Stakeholders satisfaction is taken into consideration when finding solutions to face disruptive events.					
Clauses in the contract can be bypassed, to a certain extent, to find solutions to face disruptive events.					
Qualified team members are encouraged to make critical decisions without the need for senior managers' approval.					

APPENDIX I THE RESPONDENT AND THE PROJECT CHARACTERISTICS AND THEIR VALUES IN THE DATA FILE

Components		Element	Value in the data file
Respondent	Role	–	0
		Project manager	1
		Project team member	2
	Years of experience	–	0
		Less than 2 years	1
		2 to 5 years	2
		6 to 10 years	3
		11 to 15 years	4
		16 to 20 years	5
		Greater than 20 years	6
Project	Type of project	–	0
		Applications implementation	1
		Applications development	2
		Infrastructure	3
		Telecommunications	4
		Other	5
	Budget	–	0
		Less than CAD$50,000	1
		CAD$50,000 to CAD$99,999	2
		CAD$100,000 to CAD$499,999	3
		CAD$500,000 to CAD$999,999	4
		CAD$1,000,000 to CAD$9,999,999	5
		CAD$10,000,000 to CAD$49,999,999	6
		CAD$50,000,000 to CAD$100,000,000	7
		Greater than CAD$100,000,000	8
	Schedule	–	0
		Less than 6 months	1
		Between 6 and 12 months	2
		Between 13 months and 3 years	3
		Between 4 years, and 5 years	4
		Between 6 years and 10 years	5
		Greater than 10 years	6

APPENDIX J ETHICS CERTIFICATE FOR THE QUALITATIVE STUDY

POLYTECHNIQUE MONTRÉAL
LE GÉNIE EN PREMIÈRE CLASSE

CERTIFICAT DE CONFORMITÉ

Montréal, le 18 septembre 2018

M. Khalil Rahi
M. Mario Bourgault
Département de Mathématiques et génie industriel
Polytechnique Montréal

N/Réf : Dossier CÉR-1819-04

Messieurs,

J'ai le plaisir de vous informer que les membres du Comité d'éthique de la recherche avec des êtres humains (CÉR) ont procédé à l'évaluation en comité restreint du projet de recherche intitulé « *Conception d'indicateurs pour évaluer la résilience des projets* ».

Les membres du CÉR ayant examiné votre projet en ont recommandé l'approbation sur la base des précisions que vous nous avez fait parvenir ainsi que des réponses aux questions et commentaires du CÉR.

Veuillez noter que le présent certificat est valable pour une durée d'un an, soit du **18 septembre 2018 au 17 septembre 2019** pour le projet tel que soumis au Comité d'éthique de la recherche avec des êtres humains.

Veuillez noter que conformément aux exigences des organismes subventionnaires, il est de **votre responsabilité de nous soumettre un rapport annuel ou un rapport final avant l'expiration du présent certificat** afin de nous informer de l'avancement de vos travaux. Le formulaire à remplir est disponible à l'adresse suivante : (http://www.polymtl.ca/recherche/formulaires-et-guides).

La coordonnatrice du CÉR devra aussi être informée de toute modification qui pourrait être apportée ultérieurement au protocole expérimental, de même que de tout problème imprévu pouvant avoir une incidence sur la santé et la sécurité des personnes impliquées dans le projet de recherche (sujets, professionnels de recherche ou chercheurs).

Je vous souhaite bonne chance dans la poursuite de vos travaux.

Delphine Périé-Curnier, Présidente
Comité d'éthique de la recherche avec des êtres humains

cc: Céline Roehrig (DFR); Sylvie Proulx (Service des Finances)

Comité d'éthique de la recherche avec des êtres humains
Céline Roehrig; Coordonnatrice
Delphine Périé-Curnier, Présidente
Tél.: 514 340-4711 poste : 3755
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2900, boul. Édouard-Montpetit
2500, chemin de Polytechnique
Montréal (Québec) Canada H3T1J4

APPENDIX K ETHICS CERTIFICATE FOR THE QUANTITATIVE STUDY

POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

APPROBATION D'AMENDEMENT

Montréal, 1er mars 2019

M. Khalil Rahi
M. Mario Bourgault
Département de Mathématiques et génie industriel
Polytechnique Montréal

N/Réf : Dossier CÉR-1819-04

Messieurs,

J'ai le plaisir de vous informer que les membres du Comité d'éthique de la recherche (CÉR) ont procédé à l'évaluation en comité restreint de votre demande d'amendement au projet de recherche intitulé « *Conception d'indicateurs pour évaluer la résilience des projets* ».

Votre demande d'amendement relatif au protocole, au formulaire d'information et de consentement et au questionnaire est acceptée.

Nous vous rappelons que votre certificat arrive à échéance le **17 septembre 2019**. Veuillez noter que conformément aux exigences des organismes subventionnaires, **il est de votre responsabilité de nous soumettre un rapport annuel ou un rapport final avant l'expiration du présent certificat** afin de nous informer de l'avancement de vos travaux. Le formulaire à remplir est disponible à l'adresse suivante : (http://www.polymtl.ca/recherche/formulaires-et-guides).

Entre temps, je vous prierais de bien vouloir m'informer sans délai de toute modification qui pourrait être apportée à votre protocole expérimental, ou de tout problème imprévu pouvant avoir une incidence sur la santé et la sécurité des personnes impliquées dans votre projet.

Bonne continuation dans la poursuite de vos travaux de recherche.

Céline Roehrig, M.A., M.Sc.A.
Coordonnatrice administrative
Comité d'éthique de la recherche

cc: Sylvie Proulx (Service des Finances)

Comité d'éthique de la recherche avec des êtres humains
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APPENDIX L PRINCIPAL COMPONENT ANALYSIS FOR AWARENESS – FIRST ATTEMPT

Rotated Component Matrix[a]							
	Component						
	1	2	3	4	5	6	7
CRR1	0.217	0.180	-0.071	0.250	-0.101	**0.535**	0.221
CRR2	-0.027	-0.033	-0.103	**0.845**	0.002	0.206	0.083
CRR3	0.082	0.184	0.112	**0.813**	0.114	0.050	0.164
CRR4	0.009	0.192	0.139	**0.705**	0.120	-0.034	0.063
CRR5	0.315	0.059	-0.069	0.173	0.174	0.040	**0.652**
APRMM1	0.078	**0.628**	0.040	0.131	0.131	0.131	0.217
APRMM2	0.247	**0.505**	-0.021	0.309	0.194	-0.192	0.127
APRMM3	0.119	**0.613**	0.407	0.254	0.083	-0.120	0.012
APRMM4	0.092	0.474	0.048	0.093	-0.047	-0.100	**0.603**
ASPD1	-0.057	**0.607**	0.067	-0.001	0.252	0.276	0.186
ASPD2	0.083	0.340	0.055	-0.046	0.098	**0.653**	0.326
ASPD3	0.196	**0.675**	0.005	0.040	0.136	0.363	-0.119
ASPD4	0.170	**0.648**	-0.002	0.040	0.187	0.399	-0.196
ASPD5	0.189	0.332	0.265	0.226	0.365	0.121	0.343
SEC1	0.030	-0.087	0.269	0.135	0.031	0.278	**0.673**
SEC2	0.111	0.179	**0.592**	0.130	0.247	0.231	0.092
SEC3	0.160	-0.006	**0.862**	-0.050	0.039	-0.008	-0.003
SEC4	0.136	0.050	**0.824**	0.062	0.155	0.009	0.121
EER1	**0.812**	0.027	0.097	0.075	0.126	0.104	0.083
EER2	**0.814**	0.123	0.056	0.062	0.188	0.117	0.006
EER3	**0.830**	0.129	0.229	-0.071	-0.041	0.072	0.127
EER4	**0.845**	0.153	0.116	0.021	-0.033	0.069	0.145
LIS1	0.158	0.072	0.290	0.117	0.375	**0.574**	-0.163
LIS2	0.065	0.189	0.222	0.001	**0.688**	0.018	0.195
LIS3	0.190	0.226	0.126	0.078	**0.569**	0.400	0.010
LIS4	0.016	0.165	0.061	0.148	**0.772**	0.010	-0.024
KMO	0.807						
Bartlett's Test of Sphericity	0.000						
Eigenvalues	3.205	3.046	2.378	2.304	2.067	1.876	1.836
% Var.	12.328	11.717	9.146	8.861	7.952	7.214	7.060
% Var. Cumm.	12.328	24.044	33.190	42.051	50.003	57.217	64.278

APPENDIX M PRINCIPAL COMPONENT ANALYSIS FOR AWARENESS – SECOND ATTEMPT

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
CRR1	0.326	0.238	-0.173	0.033	0.206	0.444
CRR2	0.091	-0.018	-0.134	-0.051	**0.832**	0.185
CRR3	0.108	0.084	0.115	0.220	**0.805**	0.155
CRR4	0.083	0.007	0.151	0.231	**0.699**	0.032
CRR5	-0.020	0.296	0.037	0.210	0.208	**0.555**
APRMM1	0.348	0.073	0.029	**0.573**	0.108	0.198
APRMM2	0.130	0.232	0.028	**0.560**	0.314	-0.039
APRMM3	0.189	0.123	0.371	**0.606**	0.216	-0.084
APRMM4	-0.067	0.084	0.072	**0.628**	0.072	0.462
ASPD1	**0.518**	-0.059	0.058	0.471	-0.012	0.210
ASPD2	**0.558**	0.091	-0.002	0.148	-0.072	**0.558**
ASPD3	**0.617**	0.202	-0.075	0.436	0.001	0.003
ASPD4	**0.680**	0.176	-0.079	0.375	0.007	-0.055
SEC1	0.004	0.034	0.291	-0.002	0.136	**0.722**
SEC2	0.339	0.116	**0.587**	0.099	0.126	0.155
SEC3	0.014	0.176	**0.821**	-0.002	-0.074	0.001
SEC4	0.078	0.144	**0.826**	0.078	0.055	0.102
EER1	0.135	**0.809**	0.116	0.012	0.087	0.093
EER2	0.235	**0.809**	0.077	0.068	0.077	0.014
EER3	0.052	**0.834**	0.201	0.132	-0.089	0.140
EER4	0.057	**0.846**	0.097	0.162	0.007	0.152
LIS1	**0.672**	0.161	0.276	-0.193	0.130	0.077
LIS2	0.414	0.026	0.413	0.193	0.088	0.073
LIS3	**0.675**	0.170	0.210	0.044	0.127	0.104
LIS4	0.498	-0.026	0.261	0.116	0.248	-0.136
KMO	0.789					
Bartlett's Test of Sphericity	0.000					
Eigenvalues	3.263	3.158	2.459	2.282	2.248	1.832
% Var.	13.053	12.633	9.835	9.126	8.991	7.327
% Var. Cumm.	13.053	25.686	35.521	44.647	53.638	60.964

APPENDIX N PRINCIPAL COMPONENT ANALYSIS FOR AWARENESS – THIRD ATTEMPT

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
CRR1	0.279	0.269	0.129	0.227	-0.227	0.311
CRR2	-0.008	0.116	-0.034	**0.838**	-0.159	0.132
CRR3	0.076	0.134	0.206	**0.798**	0.096	0.187
CRR4	0.000	0.079	0.224	**0.712**	0.163	0.037
CRR5	0.295	0.028	0.135	0.181	-0.019	**0.632**
APRMM1	0.088	0.193	**0.639**	0.140	0.038	0.150
APRMM2	0.214	0.027	**0.562**	0.316	0.059	0.023
APRMM3	0.110	0.098	**0.621**	0.237	0.414	-0.045
APRMM4	0.072	-0.114	**0.546**	0.063	0.070	**0.574**
ASPD1	-0.050	0.440	**0.560**	-0.041	-0.014	0.237
ASPD3	0.221	0.455	**0.590**	0.005	-0.108	-0.059
ASPD4	0.192	**0.539**	**0.543**	-0.007	-0.133	-0.101
SEC1	0.050	0.138	-0.068	0.113	0.199	**0.759**
SEC2	0.115	0.445	0.126	0.089	**0.501**	0.216
SEC3	0.178	0.108	-0.019	-0.046	**0.834**	-0.008
SEC4	0.145	0.176	0.054	0.075	**0.821**	0.109
EER1	**0.810**	0.137	0.034	0.084	0.100	0.083
EER2	**0.808**	0.215	0.116	0.065	0.054	0.012
EER3	**0.832**	0.042	0.131	-0.087	0.202	0.152
EER4	**0.846**	0.019	0.166	0.017	0.107	0.145
LIS1	0.189	**0.728**	-0.037	0.101	0.154	-0.002
LIS2	0.017	0.484	0.223	0.034	0.321	0.169
LIS3	0.187	**0.694**	0.173	0.086	0.092	0.086
LIS4	-0.046	**0.576**	0.165	0.166	0.151	-0.006
KMO	0.783					
Bartlett's Test of Sphericity	0.000					
Eigenvalues	3.188	2.769	2.684	2.206	2.206	1.695
% Var.	13.282	11.536	11.185	9.194	9.190	7.064
% Var. Cumm.	13.282	24.818	36.003	45.197	54.387	61.451

APPENDIX O PRINCIPAL COMPONENT ANALYSIS FOR AWARENESS – FOURTH ATTEMPT

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
CRR1	0.255	0.195	0.224	-0.209	0.200	0.378
CRR2	-0.019	-0.034	0.146	-0.173	**0.815**	0.175
CRR3	0.075	0.188	0.126	0.096	**0.804**	0.188
CRR4	0.010	0.200	0.052	0.169	**0.721**	0.020
CRR5	0.284	0.166	-0.052	0.015	0.191	**0.640**
APRMM1	0.097	**0.636**	0.109	0.067	0.183	0.102
APRMM2	0.216	**0.564**	-0.075	0.082	0.339	0.019
APRMM3	0.120	**0.602**	-0.007	0.436	0.270	-0.070
ASPD1	-0.068	**0.659**	0.288	0.038	-0.035	0.276
ASPD3	0.206	**0.649**	0.381	-0.086	0.006	-0.023
ASPD4	0.170	**0.636**	0.451	-0.109	-0.018	-0.033
SEC1	0.031	-0.031	0.086	0.227	0.110	**0.776**
SEC2	0.111	0.162	0.413	**0.519**	0.093	0.214
SEC3	0.177	-0.032	0.100	**0.830**	-0.047	-0.005
SEC4	0.146	0.040	0.159	**0.824**	0.082	0.094
EER1	**0.819**	0.021	0.173	0.096	0.095	0.059
EER2	**0.821**	0.103	0.255	0.050	0.081	-0.024
EER3	**0.825**	0.149	-0.002	0.214	-0.091	0.176
EER4	**0.833**	0.201	-0.047	0.121	0.004	0.197
LIS1	0.160	0.049	**0.757**	0.141	0.067	0.053
LIS2	0.001	0.329	0.372	0.361	0.028	0.203
LIS3	0.170	0.302	**0.619**	0.127	0.066	0.138
LIS4	-0.031	0.191	**0.601**	0.163	0.194	-0.077
KMO	0.781					
Bartlett's Test of Sphericity	0.000					
Eigenvalues	3.138	2.831	2.308	2.288	2.232	1.512
% Var.	13.643	12.309	10.034	9.947	9.703	6.575
% Var. Cumm.	13.643	25.952	35.986	45.934	55.636	62.211

APPENDIX P PRINCIPAL COMPONENT ANALYSIS FOR AWARENESS – FIFTH ATTEMPT

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
CRR2	-0.027	-0.035	**0.805**	-0.157	0.152	0.142
CRR3	0.071	0.184	**0.800**	0.087	0.147	0.201
CRR4	0.016	0.179	**0.725**	0.152	0.060	0.020
CRR5	0.322	0.158	0.224	-0.051	-0.044	**0.643**
APRMM1	0.110	**0.634**	0.216	0.075	0.085	0.040
APRMM2	0.245	**0.533**	0.382	0.066	-0.094	-0.052
APRMM3	0.115	**0.594**	0.276	0.435	-0.015	-0.049
ASPD1	-0.068	**0.683**	-0.016	0.058	0.255	0.236
ASPD3	0.185	**0.676**	-0.008	-0.073	0.371	0.003
ASPD4	0.148	**0.668**	-0.036	-0.104	0.445	0.011
SEC1	0.045	-0.006	0.119	0.186	0.096	**0.821**
SEC2	0.091	0.195	0.078	**0.522**	0.429	0.275
SEC3	0.159	-0.021	-0.054	**0.864**	0.094	0.003
SEC4	0.140	0.046	0.085	**0.839**	0.152	0.097
EER1	**0.823**	0.016	0.094	0.083	0.188	0.051
EER2	**0.819**	0.102	0.081	0.057	0.265	-0.056
EER3	**0.824**	0.154	-0.091	0.214	0.005	0.174
EER4	**0.843**	0.196	0.014	0.107	-0.046	0.183
LIS1	0.144	0.084	0.055	0.164	**0.749**	0.035
LIS3	0.187	0.310	0.087	0.099	**0.607**	0.112
LIS4	-0.012	0.180	0.207	0.107	**0.615**	-0.055
KMO	0.767					
Bartlett's Test of Sphericity	0.000					
Eigenvalues	3.105	2.748	2.243	2.151	2.108	1.382
% Var.	14.783	13.087	10.682	10.241	10.036	6.580
% Var. Cumm.	14.783	27.870	38.552	48.793	58.829	65.408

APPENDIX Q PRINCIPAL COMPONENT ANALYSIS FOR ADAPTIVE CAPACITY – FIRST ATTEMPT

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
AMR1	0.363	0.269	0.249	**0.484**	0.136	-0.093
AMR2	0.272	0.055	0.155	**0.773**	-0.038	-0.014
AMR3	**0.793**	0.045	0.122	0.093	0.080	0.117
AMR4	**0.817**	-0.011	0.118	0.067	0.191	0.082
AMR5	**0.704**	0.212	0.140	0.233	0.130	0.037
AMR6	0.370	0.137	-0.031	**0.700**	0.040	0.136
AMR7	-0.170	0.169	0.085	**0.621**	0.051	0.110
RTM1	0.183	-0.017	0.026	0.007	**0.780**	0.030
RTM2	0.374	0.110	0.135	-0.156	**0.509**	0.336
RTM3	0.215	0.188	0.167	-0.028	**0.670**	0.065
RTM4	-0.131	-0.076	0.259	0.232	**0.617**	-0.042
ECR1	0.337	0.329	**0.630**	0.134	0.127	-0.151
ECR2	0.009	0.235	**0.754**	0.139	0.108	-0.012
ECR3	0.212	0.140	**0.717**	-0.077	0.213	0.002
ECR4	0.067	-0.040	**0.664**	0.119	0.047	0.392
ECR5	0.378	0.415	0.385	0.167	-0.019	0.017
ARDM1	0.027	**0.839**	0.078	0.056	-0.016	0.083
ARDM2	0.160	**0.836**	0.204	0.148	-0.021	0.041
ARDM3	0.034	**0.735**	0.197	0.172	0.153	0.048
ARDM4	0.094	0.339	0.441	0.230	0.229	-0.066
ARDM5	0.030	0.096	0.068	0.340	-0.158	**0.669**
ARDM6	0.146	0.046	-0.027	-0.072	0.247	**0.687**
KMO	0.805					
Bartlett's Test of Sphericity	0.000					
Eigenvalues	2.764	2.649	2.612	2.168	2.020	1.292
% Var.	12.563	12.043	11.874	9.854	9.180	5.872
% Var. Cumm.	12.563	24.606	36.480	46.334	55.514	61.386

APPENDIX R PRINCIPAL COMPONENT ANALYSIS FOR ADAPTIVE CAPACITY – MERGED FACTORS

Rotated Component Matrix[a]						
	Component					
	1	2	3	4	5	6
AMR1	0.382	0.268	0.226	**0.477**	0.120	-0.070
AMR2	0.282	0.052	0.135	**0.768**	-0.048	-0.003
AMR3	**0.795**	0.040	0.110	0.100	0.064	0.124
AMR4	**0.816**	-0.016	0.110	0.074	0.179	0.088
AMR5	**0.708**	0.219	0.150	0.239	0.114	0.034
AMR6	0.366	0.139	-0.027	**0.706**	0.039	0.122
AMR7	-0.187	0.170	0.081	**0.637**	0.084	0.084
RTM1	0.186	-0.022	0.006	0.005	**0.793**	0.057
RTM2	0.399	0.104	0.119	-0.175	**0.468**	0.383
RTM3	0.230	0.202	0.179	-0.028	**0.666**	0.061
RTM4	-0.112	-0.062	0.255	0.231	**0.629**	-0.053
ECR1	0.353	0.330	**0.600**	0.144	0.127	-0.144
ECR2	0.034	0.254	**0.760**	0.144	0.098	-0.026
ECR3	0.237	0.169	**0.745**	-0.067	0.199	-0.026
ECR4	0.037	-0.033	**0.674**	0.156	0.087	0.357
ARDM1	0.018	**0.849**	0.086	0.078	-0.001	0.060
ARDM2	0.173	**0.843**	0.197	0.155	-0.034	0.037
ARDM3	0.054	**0.736**	0.176	0.169	0.138	0.062
ARDM5	0.027	0.086	0.067	0.333	-0.186	**0.689**
ARDM6	0.145	0.045	-0.010	-0.073	0.225	**0.684**
KMO	0.805					
Bartlett's Test of Sphericity	0.000					
Eigenvalues	2.764	2.649	2.612	2.168	2.020	1.292
% Var.	12.563	12.043	11.874	9.854	9.180	5.872
% Var. Cumm.	12.563	24.606	36.480	46.334	55.514	61.386