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Risk and vulnerability management, project agility and resilience: a comparative analysis

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Abstract:
The main objective of this paper is to present a critical analysis of the project management literature on four concepts; risk management, vulnerability management, project agility and project resilience. The goal is to understand the strengths and weaknesses of these concepts to deal with disruptive events through the development of a conceptual framework that captures their differences and convergences. Therefore, a review of recent literature from international journals, specialized mainly in project risk management, vulnerability management, project agility, and project resilience has been conducted. A systematic literature review is adopted to compare the four key concepts of this study and to draw conclusions. A case from the information technology field is used to better illustrate the comparison. Results from this study show that risk management and vulnerability management are proactive concepts focusing on the management of known events or actions. Alternatively, project agility is a reactive concept that aims to adapt to changes, but not necessarily disruptive events. Project resilience is a mix concept – proactive and reactive – focusing on recovering from known and unknown disruptive events. In addition, this comparative analysis and the conceptual framework developed can be used to exploit future areas of research and exhibit new opportunities where project management best practices can be improved to deal with disruptive events.

Keywords:
risk management; vulnerability management; project agility; project resilience; critical analysis.

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1. Introduction

Projects are temporary organizations in which human and non-human resources are utilized to achieve specific goals [1]–[3]. Their management 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, involves transient teams, and has risks*" [4, p. 29]. It is a challenge because projects are on a regular basis confronted to disruptive events that, on occurrence, can cause severe deviations from the project main objectives [5], [6]. Therefore, it becomes a necessity, in project management, to deal effectively with these events through the development of new methods, tools and best practices [7]. In fact, as mentioned by Thamhain [8], project leaders must go beyond the mechanisms of examining the task and its contractual components of the "triple constraint," such as cost, schedules, and deliverables, to investigate and understand the sources of uncertainty before attempting to control them [8].

In this paper four topics are discussed that aim to deal with disruptive events during the project life-cycle. These events can lead the project to deviate from its main objectives (e.g., become delayed, run over budget, produce low quality, incomplete the scope, incur client dissatisfaction, etc.) [5]. The first topic is risk management that intends to manage possible future disruptive events through their identification, analysis, and mitigation during the project life-cycle [8], [9]. The second topic is vulnerability management that addresses the management of the project's characteristic that makes it susceptible to disruptive events [10], [11]. The third topic is project agility that is related to the capacity of the project team to quickly modify the project plans when faced with changes (i.e. disruptive events) [12]. Finally, the fourth concept is project resilience that correlate with the project's ability to be aware of and adapt when faced with disruptive events [6]. Therefore, the main subject that relates these four concepts is the management of disruptive events. Thus, analyzing these four concepts will allow the understanding of their strengths and weaknesses, and instigate the development of novel processes, tools and best practices to efficiently and effectively manage disruptive events during the project life-cycle.

The scope of this literature review was limited to scientific journals that covers risk management, vulnerability management and project agility in the project management field specifically. However, white papers and other popular media are considered when reviewing the concept of project resilience due to the novelty of the project resilience concept and the lack of scientific literature on this concept [7], [13]. It is also to mention that this review is mainly achieved through analysis of recent literature on these four concepts. Mainly because the main objective is to find new areas of opportunities for advanced development of new methods, tools and best practices.

That being said, this paper is organized in three distinct sections. In the first section, the methodology of the systematic literature review is explained. In the second section, the four main concepts of this study are explored independently to better understand their strengths and weaknesses. In the third section, a critical analysis of the literature on these four concepts is conducted to explore scientific areas of opportunities. This analysis is supported through a case of the implementation of Information Technology (IT) projects to better illustrate the main ideas. In addition, a conceptual framework linking these four concepts is also proposed to open the door for future research on new tools, methods and best practices to effectively and efficiently deal with disruptive events during the projects' life-cycles.

2. Methodology

This paper aims to develop a clear understanding of the strengths and weaknesses of four concepts that aim to deal with disruptive events. After a thorough analysis of the literature on these concepts, a conceptual framework is developed through the theory building approach to develop relationships and draw academic conclusions for future research [14], [15].

In addition, a case from the information technology field is used to better illustrate the relationships between these concepts. This aims to provide a real-world context in which the management of disruptive events occurs [16].

The proposition of conceptual frameworks to compare between concepts follows the same process that has been used by many authors (e.g., the works of [17]–[19]). As discussed by Burnard and Bhamra [20], "*conceptual frameworks aid in not only providing construct validity, but also provide an outline for future research activities*" [20, p. 5585].

The literature review aims to identify key elements of risk management, agility, vulnerability and resilience directly related to the field of project management. Therefore, a search of the literature in databases that deal specifically with research in management and science of organizations was conducted. Databases included Google Scholar, Web of Science, ProQuest, etc. The following keywords were used to complete the search: "concept", "resilience*", "agil*", "risk management", "project management", "vulnerability*". The main objective was to choose scientific documents (journal articles, thesis and dissertations), in the English language, that link two or more concepts (risk management, vulnerability, agility, resilience) to the project management field.

It is worth to mention that some concepts are widely used in the project management literature without referencing to their respective concept. These were excluded from this study. For instance, the word "agile" or "agility" is commonly used in project management, mainly in the IT sector. However, the literature on the concept of "agility", as a scientific progression, is not well defined and developed. Our goal was to identify the concepts not the words, such as "agile", "vulnerable", "risky", that are deployed in their general context.

So, a total of 18742 scientific documents were found in the first step of the literature search. After an examination of titles and abstracts, 18503 articles were eliminated because they did not focus on the main objective of the study. Eleven more articles were eliminated because they were duplicates. A review of the full-text formats of the remaining 228 publications resulted in the exclusion of another 192 scientific documents. Finally, a total of 36 studies were considered in the review (**Table 1**). The screening process for publications obtained from searches is depicted in **Figure 1**.

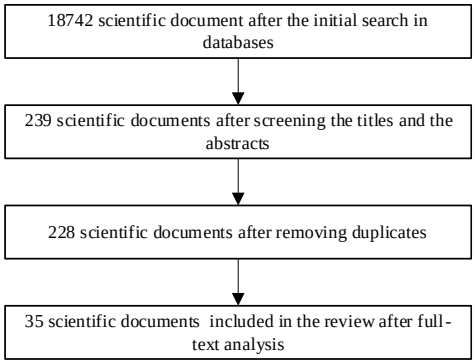

Fig. 1 – Screening process of scientific documents

Table 1: final list of scientific documents chosen for this review

Authors of Article/Thesis	Risk management	Resilience	Agility	Vulnerability	Field or research/Type of projects
(Huchzermeier & Loch, 2001)	√		√		Research and development
(Ward & Chapman, 2003)	√	√			General perspective
(Kutsch & Hall, 2005)	√	√			Information technology
(Coram & Bohner, 2005)	√		√		Information technology
(Taylor, 2006)	√		√		Information technology
(Ahmed et al., 2007)	√				Product development

Authors of Article/Thesis	Risk management	Resilience	Agility	Vulnerability	Field or research/Type of projects
(Zhang, 2007)	√			√	General perspective
(Nelson et al., 2008)	√		√		Information technology
(Sanchez et al., 2009)	√			√	General perspective
(Lee & Yong, 2010)	√		√		Information technology
(Geambasu, 2011)	√	√			Construction
(Zhang, 2011)	√			√	General perspective
(Vidal & Marle, 2012)	√			√	General perspective
(Besner & Hobbs, 2012)	√		√		General perspective
(Besner & Hobbs, 2012b)	√		√		General perspective
(Schroeder & Hatton, 2012)	√	√			Research and development
(Thamhain, 2013)	√				Product development
(Tomanek & Juricek, 2015)	√		√		Information technology
(Baweja & Venugopalan, 2015)			√		General perspective
(Turner & Kutsch, 2015)	√	√			General perspective
(Thomé et al., 2016)	√	√	√		General perspective
(Conforto et al., 2016)			√		General perspective
(Lehnen et al., 2016)	√		√		Product development
(Zhu, 2016)	√	√		√	Construction
(Blay, 2017)	√	√		√	Construction
(Aleksic et al., 2017)				√	General perspective
(Hobbs & Petit, 2017)	√		√		Large projects in large organizations
(Mochizuki et al., 2018)	√	√			General perspective
(Rahi, 2019)	√	√			General perspective
(Rahi et al., 2019)	√	√			Information technology
(Wang, 2019)	√			√	General perspective
(Naderpajouh et al., 2020)	√	√			General perspective
(Tam et al., 2020)	√		√		Information technology
(Bianchi et al., 2020)	√		√		Information technology
(Varajão et al., 2021)		√	√		Information systems
(Varajão & Amaral, 2021)	√		√		Information systems

3. Risk Management

Risks are possible future events 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 a project's endeavors [21]–[23]. Therefore, from a project management perspective, the main objective of risk management is to diminish the gravity of possible negative disruptive events in order to achieve the project objectives [21], [24].

The management of these disruptive events 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 [25]; Huchzermeier and Loch [26]; Williams and Thompson [27], etc.). The second category considers the management of these disruptive events to depend on individual perception. In other words, different individuals can have different perceptions on how to manage them. These ways are often based on the individual's personal experience, skills and expertise, along with psychological and organizational factors [11], [23]. One of the most important methods of dealing with these disruptive events is the method proposed by Ward and Chapman [23], who focus on managing uncertainty because managing perceived dangers, opportunities, and their consequences is not the only aspect of uncertainty management. It is about understanding and controlling all of the various sources of uncertainty that influence and affect perceptions of dangers and opportunities [23].

Additionally, challenges with the management of disruptive events from a risk management perspective is that 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 disruptive events and put in place different strategies to manage them. Therefore, the interaction between events, circumstances, and individual reactions contribute to the identification and analysis of risks [28]. This perspective is also discussed by Kutsch and Hall [29], 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 [29].

From this perspective, the consequences of possible future disruptive events are extended to include secondary impacts such as shame, fairness, justice, etc. These secondary effects might be thought of as subjective overlays placed by persons who are confronted with external phenomena [28]. Therefore, the analysis of this type of risk aims to understand the discernment and cultural identity of risks by reinforcing the strength of economic, social, and technological systems [30].

There are a variety of strategies, processes, methodologies, and approaches for assessing and managing project risks, however it is unclear if they are effective or necessary for project management success [31]–[33]. De Bakker et al. [32], for example, attempted to explore the relationship between risk management and the success of IT initiatives. They concluded that neither the evaluation technique nor the management strategy, regardless of the setting in which the project is conducted, has led to conclusive evidence about the relationship between risk management and IT project success. In reality, they concluded that empirical data is primarily anecdotal and focused on how risk management is intended to operate rather than how it is really employed in project practice [32]. Furthermore, there have been instances when project managers did not use risk management strategies yet the project still succeeded, whereas other managers used risk management methods but their projects failed [32], [34]. In other words, while projects continue to fail in some cases, it is unclear whether the problem stems from ineffective risk management procedures or from project managers' ineffective application of risk management practices [34]. Researchers have also discovered that most project managers do not follow risk management practices as thoroughly as project management organizations and risk management standards recommend [31], [32]. This was also observed by Taylor [35], who indicated that project managers do not analyze future possible disruptive events by applying the traditional methods. They use three main strategies to deal with risks: control and monitoring, negotiation, and research. 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*" [35, p. 61].

Besner and Hobbs [36] empirically identify a toolset for risk management composed of five tools to deal with disruptive events; risk management documents, positioning of risks, contingency plans, ownership of risk, and visualization of risk information. They noticed that the level of use of these tools is close to average which can be elucidated by the series of risk management actions. For instance, prior to rating risks and arranging contingencies, risk identification and documentation are required. In addition, they noticed a tendency to use less arduously complex tasks such as assigning

owners to specific risks, and graphically presenting risk information [36]. 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, and 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 the management of risks and project success still not clear. Many risk professionals emphasized that despite the great visibility and positive view of risk management in their businesses, there is a significant gap between interest in risk management and resource allocation and staff training; many people talk about risk, but few do something about it [31]. Therefore, after reviewing the literature on the relationships between risk, risk management, uncertainty, and the context in which the projects are carried out, Besner and Hobbs [31] discussed the scope of risk management usage in relation to the degree of project uncertainty. Their study was completed through a quantitative analysis among 1296 experienced practitioners [31]. 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. Thus, for well-defined projects, it is easy to realize that project analysis, planning, control, estimation, or evaluation are easier to do and thus done more frequently [31]. 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 possible disruptive events. In addition, their analysis suggests that other, more flexible, practices are needed to deal with unexpected disruptive events because actual risk management practices are not appropriate for this type of events.

Despite these facts, approaches to deal with risks mainly include processes to identify risks, plan responses and control risks throughout the project life-cycle [21]. As concluded by Blay the failure to effectively handle shock, create capacities, and assure overall project recovery is a problem with these approaches. This is because the methods emphasize improving the project's ability to forecast a threat or an opportunity in order to handle them and avoid being surprised without emphasizing adaptability actions to recover from negative consequences [5].

4. Vulnerability Management

The concept of vulnerability emerged from social science and it is applied to economics, information systems, organizational management, politics, project management, etc. [11], [37], [38]. The main objective of vulnerability management is to deal with the weaknesses in the system's (e.g., the project) characteristics to avoid facing possible future disruptive events [11]. It is defined as "*the characteristic of a project which makes it susceptible to be subject to negative events and, if occurring, which makes it non-capable of coping with them, which may in the end allow them to degrade the project values*" [10, p. 10].

Füssel and Klein [37] 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 [37].

Inspired by the third school of thought presented by Füssel and Klein, from the project management perspective, Zhang [11] discusses vulnerability as a redefinition of the project risks 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 disruptive events. The second dimension means that the higher the project's capacity to deal with disruptive events is, the lower its vulnerability will be. The notion of vulnerability can cause a project to better mediate

disruptive events. In fact, to improve his process ability to explain and clarify, the nested interactions and feedback between risk occurrences and project systems are eliminated [11].

Vulnerability is defined as the characteristic of a project that makes it susceptible to disruptive events [10], [11]. Therefore, the existence of vulnerabilities is independent of the presence of disruptive events. 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 disruptive event ("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. In other words, the lower the vulnerability, the less likely it is that disruptive events will occur during the project life-cycle. Conversely, the higher the vulnerability, the more exposed the project is to disruptive events that may lead to its failure [11], [39].

Vidal and Marle [10] reviewed the literature on the concept of vulnerability in many scientific domains and 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): the identification of project vulnerabilities, their analysis, the preparation of response plans to tackle them, and the processes of monitoring and controlling them [10]. Vidal and Marle's perspective on vulnerabilities complements Zhang's approach. This concept and the approach to manage it still require additional research and more clarifications.

5. 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 [40]. The Agile principles include processes that emphasize being closer to the client, the iterative approach to better deal with disruptive events, daily meetings between team members to keep everyone updated on the status of the project, etc. [41]. Following the 2001 manifesto, the term Agile was adopted in many publications on project management [42], [43]. However, research on this concept is still mostly related to the software development sector [44], [45]. As concluded by Bianchi et al. (2020), an agile methodology is more adequate, and can prevent deviations, when requirements and needs are little known or unstable, especially in fast-changing contexts (mainly in the information technology field) [46].

Nevertheless, Conforto et al. [12], after a systematic literature review on the concept of agility in project management, pointed the fact that the project management literature has conflicting, incomplete, and ambiguous definitions of agility [12]. Therefore, Conforto et al.'s 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 concept 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*" [12, 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 events that will deviate the project from its main objectives (disruptive events).

Werder and Maedche [45] 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 [45]. Like Conforto et al. [12], 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 and Conboy, customers are always involved in the development process using agile methodologies. While the client is an important aspect of the agile process, it is possible to expand this technique to include different stakeholders [47].

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) [48], [49]. It focuses on rapid response to change, mainly customers and stakeholders needs and demands. In relation to risk management, agile approaches manage possible future disruptive events that might be caused by the customers and stakeholders needs and demands in an implicit way (embedded in the way of perceiving and dealing with disruptive events). As mentioned by Nelson et al. [50] 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 [50].

Also, based on a study conducted by Tam et al. [51], these authors concluded to the fact that project success in agile projects strongly depends on the customer's collaboration and involvement. In addition, building the team capabilities through proper training and the development of teams composed of highly motivated individuals can also lead to successful projects from a time, cost and customer satisfaction perspective [51]. However, despite the importance of this study, emphasizing the type of change and its level of disruption needs to be analysed. Thus, additional items are needed to measure the ability of a project team to respond to change.

Therefore, from a project management perspective, focusing only on agility can, to a certain extent, make a project vulnerable [45], [52], 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.

6. Resilience in project management

The concept of resilience 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 [53].

Resilience is mainly related to the system's capacity to maintain its functions and controls and the relationships between its various entities [54], [55] when faced with disruptive events.

It refers to a capacity for change and reorganization helping the system to return to its balance only gradually and, under certain conditions, will completely overhaul its structure and functions [56]. Resilience includes actions to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance. In fact, as highlighted by Carlson et al. [53], 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 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)*" [53, p. 18].

According to these aspects of resilience, recovery from disruptive events 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 [57] argues that organizational resilience has a direct impact on the pace and success of recovery from a crisis or disaster [57]. This perspective (recovery as a consequence of resilience) is also adopted in the work of Blay [5], 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*" [5, p. 218].

From a project management perspective, the concept of resilience is still novel and largely ignored [6]. 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 [58]. To illustrate this fact, 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. Therefore, a rigorous conceptualization is needed. The shortage of resilience studies in project management is a powerful sign of the novelty of this concept. It is also to mention that Thomé et al. [7] found that scholars should pay more attention to the absence of coverage of the idea of resilience in the project management literature.

These statements among others encouraged academics to highlight resilience in project management. Naderpajouh et al. [59] proposed a conceptual framework that serves as a theoretical guide for additional research on the concept of resilience in project studies. From their perspective, resilience is defined as the analysis of how systems at various levels (individual, team, organization, project, industry, and society) function under a variety of circumstances, including disruptive events [59].

Varajão et al. [60] in their theoretical and practical study, emphasized the project team resilience. Thus, building a team composed of committed individuals that embrace conflicts and focus on results is key to face disruptive events. In addition, having an accountable leadership that formalize trust and solidarity through the right development of skills and the right acknowledgement of good behavior, improve work conditions and incite project teams to efficiently recover from disruptions [60].

Rahi [6] advanced the conceptualization on the concept of project resilience. After reviewing the literature on the resilience's concept from many perspectives and in many fields, he proposed a conceptual definition and framework of project resilience. Two dimensions of project resilience were exposed: awareness and adaptive capacity. Awareness is related to the capacity of the project to explore its surroundings in order to close the gap between available and required resources. Alternatively, adaptive capacity is related to the capacity of the project to transform its structure in order to successfully recover from disruptive events [6], [13]. However, Rahi [6] concludes that what is provided is one of many viable approaches to describe project resilience, as with any new research concept. As a result, this is regarded as a clear constraint. Thus, additional research and academic investigations are needed to reinforce any tentative of conceptualization on the new concept of project resilience [6].

7. Comparative Analysis and Discussion

This section offers a critical analysis of the literature on risk management, vulnerability management, agility, and resilience to develop a conceptual framework among these concepts. 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. This explanation will be supported by a case 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", 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.

The first concept is risk management. Despite the fact that risk management practices is less implemented and used in industry [33], [36], 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 [31]. Thus, as shown in Figure 2, risk management is considered a proactive concept that addresses known risks, but it encounters difficulties in addressing unknown or unpredicted events [8], [32]. 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 [5]. This is because the consequences of these events, if they occur, are hardly predictable in advance due to the

continuous dynamic 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 [62]. 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.

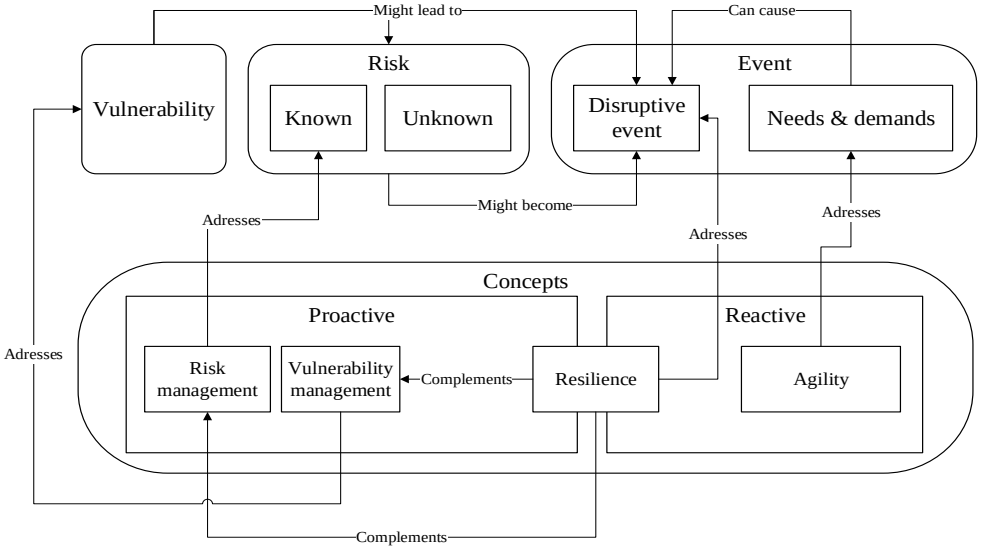

Fig. 2 – Conceptual framework between risk management, vulnerability management, resilience and agility from a project management perspective (inspired by Mochizuki et al. [61])

Vulnerability management is also a proactive concept that focuses on identifying, analyzing, and mitigating project weaknesses instead of risks as shown in Figure 2. 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 [61]. 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 [38]. 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 vulnerability (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 event 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 [22]. 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 [44]. 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 [63]. Third, agility focuses more on reactive actions and less on proactive actions [48]. It focuses on changing specifically the project plan at the project level. This change is completed by the project team members [64]. Resilience, on the other hand, includes proactive and reactive capacities. It involves the ability to avoid or resist being influenced by an event as well as the ability to return to an acceptable level of performance in a reasonable amount of time after being affected by an event [49]. 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's and/or the organization's level to contribute to the resilience of the project. Scaling agility framework does 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 [65]. 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 [44]. As an example of 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 dysfunction 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 event 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 [66]. 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 behaviour and to have the toolkit to think, act, and manage the consequences efficiently of disruptive events [67]. This behavioural work is important because it allows projects to adapt through a series of activities and actions when faced with disruptive events. Resilience helps reflect on the actions of the project and on the successful use of resources until adverse incidents are experienced. In other words, resilience is concerned with the development and realignment of

systems, strategies, organizational structure, etc., to face all sorts of disruptive events. It offers insights into which elements contribute primarily to maintaining an appropriate level of performance for the project at a specific point in time (the time once the project is faced with a disruptive event). The definition of project resilience neither removes the need for risk management, vulnerability management or project agility nor disputes their importance. Instead, these perspectives contribute to project resilience, among other factors. Table 2 summarizes these objectives and limitations of the four concepts presented in this paper.

Table 2: 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.	Limited due to uncertainties, ambiguities and interdependencies between the project's elements [8], [16], [67]. Focus on risk sources rather than their consequences [62]. Not oriented toward empowering a project's capacity to deal with disruptive events [5], [68].
Management of projects' vulnerabilities	Proactive	Project's weaknesses	Reduce a project's vulnerabilities by managing weaknesses. These weaknesses may lead to disruptive events.	Focus on the disruptive events' sources rather their consequences [5], [68]. Reducing vulnerabilities may reduce the occurrence of risks, but do not necessarily manage them effectively if they occur [4], [62]. Not oriented toward empowering a project's capacity to deal with disruptive events [5], [69].
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.	Does not necessarily focus on disruptive events; emphasizes the importance of customers and stakeholders. Focusing only on agility may make a project more vulnerable [38], [44]. 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 [37].
Project resilience	Proactive and reactive	Disruptive events	Foster a project's capacity to deal with disruptive events.	Resilience is still a new concept in project management that requires a clear conceptualization [67], [70]. Lack of empirical studies of this concept [7] Lack of indicators to assess resilience in project management [4], [5]. Studies of resilience in project management are mainly within the construction field (e.g., Blay [5]; Geambasu [4]).

8. Conclusion

This paper has provided a conceptual framework after reviewing the literature on risk and vulnerability management, project agility and resilience. It has applied the concepts specifically to implementation of IT projects.

As identified in the analysis, risk management is considered a proactive concept that addresses known risks, but it encounters difficulties in addressing unknown or unpredicted events. As stated, more flexible practices are needed that take into consideration the characteristics of a disruptive event upon occurrence, and that offer action to limit losses caused by this disruptive event as much as possible. Vulnerability management is also a proactive concept that focuses on identifying, analysing, and mitigating project weaknesses instead of risks. Resilience thinking complement

vulnerability management by offering coping strategies to improve the project capacity to cope with disruptive events on occurrence. From a project management perspective, it is not only important to have the right tools to deal with risks, with vulnerabilities, or to deal with changes from the customers or stakeholders needs and requirements. It is equally important to work on the project behaviour and to have the toolkit to think, act, and manage the consequences efficiently of disruptive events. This behavioural work is important because it allows projects to adapt through a series of activities and actions when faced with disruptive events. Resilience is concerned with the development and realignment of systems, strategies, organizational structure, etc., to face all sorts of disruptive events. It provides insights into which elements primarily contribute to sustaining an appropriate project at a particular 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.

The above-mentioned factors and issues identified through this work offer pointers for further empirical research which may also be analysed with respect to other project environments including health, education, construction, etc.

References

[1] D. I. Cleland and H. Kerzner, "A project management dictionary of terms," New York: Van Nostrand Reinhold, 1985.
[2] B. Hanisch and A. Wald, "Effects of complexity on the success of temporary organizations: Relationship quality and transparency as substitutes for formal coordination mechanisms," *Scandinavian Journal of Management*, vol. 30, no. 2, pp. 197–213, 2014.
[3] M. Janoqicz-Panjaitan, B. Cambre, and P. Kenis, "Introduction: Temporary Organizations – A Challenge and Opportunity for our Thinking About Organizations," in *Temporary Organizations*, Cheltenham, UK: Edward Elgar Publishing, 2009, pp. 121–141.
[4] G. Geambasu, "Expect the Unexpected: An Exploratory Study on the Conditions and Factors Driving the Resilience of Infrastructure Projects," Ph.D., École Polytechnique Fédérale de Lausanne, Switzerland, Lausanne, 2011.
[5] K. B. Blay, "Resilience in projects: definition, dimensions, antecedents and consequences," Ph.D., Loughborough University, United Kingdom, Loughborough, 2017.
[6] K. Rahi, "Project resilience: a conceptual framework," *International Journal of Information Systems and Project Management*, vol. 7, no. 1, pp. 69–83, 2019.
[7] A. M. T. Thomé, L. F. Scavarda, A. Scavarda, and F. E. S. de S. Thomé, "Similarities and contrasts of complexity, uncertainty, risks, and resilience in supply chains and temporary multi-organization projects," *International Journal of Project Management*, vol. 34, no. 7, pp. 1328–1346, 2016.
[8] H. Thamhain, "Managing Risks in Complex Projects," *Project Management Journal*, vol. 44, no. 2, pp. 20–35, 2013.
[9] A. Ahmed, B. Kayis, and S. Amornsawadwatana, "A review of techniques for risk management in projects," *Benchmarking: An International Journal*, vol. 14, no. 1, pp. 22–36, 2007.
[10] L. Vidal and F. Marle, "A systems thinking approach for project vulnerability management," *Kybernetes*, vol. 41, no. 1/2, pp. 206–228, 2012
[11] H. Zhang, "A redefinition of the project risk process: Using vulnerability to open up the event-consequence link," *International Journal of Project Management*, vol. 25, no. 7, pp. 694–701, 2007.
[12] E. C. Conforto, D. C. Amaral, S. L. da Silva, A. Di Felippo, and D. S. L. Kamikawachi, "The agility construct on project management theory," *International Journal of Project Management*, vol. 34, no. 4, pp. 660–674, 2016.
[13] K. Rahi, M. Bourgault, and B. Robert, "Benchmarking Project Resilience," *Journal of Modern Project Management*, vol. 7, no. 1, p. 7–21, 2019.
[14] S. A. Lynham, "The General Method of Theory-Building Research in Applied Disciplines," *Advances in Developing Human Resources*, vol. 4, no. 3, pp. 221–241, 2002.
[15] J. Meredith, "Theory Building through Conceptual Methods," *International Journal of Operations & Production Management*, vol. 13, no. 5, pp. 3–11, 1993.

[16] K. M. Eisenhardt and M. E. Graebner, "Theory Building From Cases: Opportunities And Challenges," *Academy of Management Journal*, vol. 50, no. 1, pp. 25–32, 2007.
[17] A. O. de Carvalho, I. Ribeiro, C. B. S. Cirani, and R. F. Cintra, "Organizational resilience: a comparative study between innovative and non-innovative companies based on the financial performance analysis," *International Journal of Innovation*, vol. 4, no. 1, pp. 58–69, 2016.
[18] B. A. Jones, "Benchmarking organizational resilience: A cross-sectional comparative research study," Ph.D., New Jersey City University, United States, New Jersey, 2015.
[19] S. Patel and K. Mehta, "Systems, Design, and Entrepreneurial Thinking: Comparative Frameworks," *Systemic Practice and Action Research*, vol. 30, no. 5, pp. 515–533, 2017.
[20] K. Burnard and R. Bhamra, "Organisational resilience: development of a conceptual framework for organisational responses," *International Journal of Production Research*, vol. 49, no. 18, pp. 5581–5599, 2011.
[21] Project Management Institute, 6th Ed., A Guide to the Project Management Body of Knowledge, 6th ed. *Newtown Square, PA: PMI*, 2017.
[22] M. Tomanek and J. Juricek, "Project Risk Management Model Based on PRINCE2 and Scrum Frameworks," *International Journal of Software Engineering & Applications*, vol. 6, no. 1, pp. 81–88, 2015.
[23] S. Ward and C. Chapman, "Transforming project risk management into project uncertainty management," *International Journal of Project Management*, vol. 21, no. 2, pp. 97–105, 2003.
[24] C. Chapman and S. Ward, *Managing Project Risk and Uncertainty: A Constructively Simple Approach to Decision Making*. John Wiley & Sons, 2007.
[25] D. Baccarini, "The concept of project complexity - a review," *International Journal of Project Management*, vol. 14, no. 4, pp. 201–204, 1996.
[26] A. Huchzermeier and C. H. Loch, "Project Management Under Risk: Using the Real Options Approach to Evaluate Flexibility in R… D," *Management Science*, vol. 47, no. 1, pp. 85–101, 2001.
[27] R. A. Williams and K. M. Thompson, "Integrated Analysis: Combining Risk and Economic Assessments While Preserving the Separation of Powers," *Risk Analysis*, vol. 24, no. 6, pp. 1613–1623, 2004.
[28] H. Zhang, "Two schools of risk analysis: A review of past research on project risk," *Project Management Journal*, vol. 42, no. 4, pp. 5–18, 2011.
[29] E. Kutsch and M. Hall, "Intervening conditions on the management of project risk: Dealing with uncertainty in information technology projects," *International Journal of Project Management*, vol. 23, no. 8, pp. 591–599, 2005.
[30] O. Renn, "The role of risk perception for risk management," *Reliability Engineering & System Safety*, vol. 59, no. 1, pp. 49–62, 1998.
[31] C. Besner and B. Hobbs, "The paradox of risk management; a project management practice perspective," *International Journal of Managing Projects in Business*, vol. 5, no. 2, pp. 230–247, 2012.
[32] K. De Bakker, A. Boonstra, and H. Wortmann, "Does risk management contribute to IT project success? A meta-analysis of empirical evidence," *International Journal of Project Management*, vol. 28, no. 5, pp. 493–503, 2010.
[33] H. Sanchez, B. Robert, M. Bourgault, and R. Pellerin, "Risk management applied to projects, programs, and portfolios," *International Journal of Managing Projects in Business*, vol. 2, no. 1, pp. 14–35, 2009.
[34] E. Kutsch, T. R. Browning, and M. Hall, "Bridging the Risk Gap: The Failure of Risk Management in Information Systems Projects," *Research-Technology Management*, vol. 57, no. 2, pp. 26–32, 2014.
[35] H. Taylor, "Risk management and problem resolution strategies for IT projects: prescription and practice," *Project Management Quarterly*, vol. 37, no. 5, p. 49, 2006.
[36] C. Besner and B. Hobbs, "An Empirical Identification of Project Management Toolsets and a Comparison among Project Types," *Project Management Journal*, vol. 43, no. 5, pp. 24–46, 2012.
[37] H.-M. Füssel and R. J. T. Klein, "Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking," *Climatic Change*, vol. 75, no. 3, pp. 301–329, 2006.
[38] S. McManus, "Organisational resilience in New Zealand," Ph.D., University of Canterbury, New Zealand, Christchurch, 2008.
[39] A. Aleksic, H. Puskaric, D. Tadic, and M. Stefanovic, "Project management issues: Vulnerability management assessment," *Kybernetes*, vol. 46, no. 7, pp. 1171–1188, 2017.

[40] J. Lehnen, T. S. Schmidt, and C. Herstatt, "Bringing agile project management into lead user projects," *International Journal of Product Development*, vol. 21, no. 2/3, p. 212-232, 2016.
[41] A. Cockburn and J. Highsmith, "Agile software development, the people factor," *Computer*, vol. 34, no. 11, pp. 131–133, 2001.
[42] M. Coram and S. Bohner, "The impact of agile methods on software project management," in *12th IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'05)*, 2005, pp. 363–370.
[43] S. Lee and H.-S. Yong, "Distributed agile: project management in a global environment," *Empirical Software Engineering*, vol. 15, no. 2, pp. 204–217, 2010.
[44] B. Hobbs and Y. Petit, "Agile Methods on Large Projects in Large Organizations," *Project Management Journal*, vol. 48, no. 3, pp. 3–19, 2017.
[45] K. Werder and A. Maedche, "Explaining the emergence of team agility: a complex adaptive systems perspective," *Information Technology & People*, vol. 31, no. 3, pp. 819–844, 2018.
[46] M. Bianchi, G. Marzi, and M. Guerini, "Agile, Stage-Gate and their combination: Exploring how they relate to performance in software development," *Journal of Business Research*, vol. 110, pp. 538–553, 2020.
[47] L. Morgan and K. Conboy, "Combining open innovation and agile approaches: implications for IS project managers," ECIS 2010: 18th European Conference on Information Systems, 7 - 9 June, Pretoria, South Africa, 2010.
[48] S. Baweja and N. Venugopalan, "Agility in Project Management," *PM World Journal*, vol. IV, no. X, pp. 1–14, 2015.
[49] A. Wieland and C. M. Wallenburg, "The influence of relational competencies on supply chain resilience: a relational view," *Supply Chain*, vol. 43, no. 4, pp. 300–320, 2013.
[50] C. R. Nelson, G. Taran, and L. de Lascurain Hinojosa, "Explicit Risk Management in Agile Processes," in Agile Processes in *Software Engineering and Extreme Programming*, vol. 9, P. Abrahamsson, R. Baskerville, K. Conboy, B. Fitzgerald, L. Morgan, and X. Wang, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 190–201, 2008.
[51] C. Tam, E. J. da C. Moura, T. Oliveira, and J. Varajão, "The factors influencing the success of on-going agile software development projects," *International Journal of Project Management*, vol. 38, no. 3, pp. 165–176, 2020.
[52] S. Berglund, "Agility in Military Processes," Master in Cognitive Science, Linköpings University, Linköping, 2012.
[53] J. L. Carlson et al., "Resilience: Theory and Application," *Argonne National Laboratory* (ANL), ANL/DIS-12-1, 2012.
[54] R. Bhamra, S. Dani, and K. Burnard, "Resilience: the concept, a literature review and future directions," *International Journal of Production Research*, vol. 49, no. 18, pp. 5375–5393, 2011.
[55] S. Y. Ponomarov and M. C. Holcomb, "Understanding the concept of supply chain resilience," *The International Journal of Logistics Management*, vol. 20, no. 1, pp. 124–143, 2009.
[56] C. S. Holling, "Engineering Resilience versus Ecological Resilience," *Engineering Within Ecological Constraints*. National Academy Press. Washington DC, pp. 31–43, 1996.
[57] A. V. Stephenson, "Benchmarking the Resilience of Organisations," Ph.D., University of Canterbury, New Zealand, Christchurch, 2010.
[58] C. A. Gibson and M. Tarrant, "A 'Conceptual Models' Approach to Organisational Resilience," *The Australian Journal of Emergency Management*, vol. 25, no. 2, p. 6–12, 2010.
[59] N. Naderpajouh, J. Matinheikki, L. A. Keeys, D. P. Aldrich, and I. Linkov, "Resilience and projects: An interdisciplinary crossroad," *Project Leadership and Society*, vol. 1, p. 100001, 2020
[60] J. Varajão, G. Fernandes, A. Amaral, and A. M. Gonçalves, "Team Resilience Model: An Empirical Examination of Information Systems Projects," *Reliability Engineering & System Safety*, vol. 206, p. 107303, 2021.
[61] J. Mochizuki, A. Keating, W. Liu, S. Hochrainer-Stigler, and R. Mechler, "An overdue alignment of risk and resilience? A conceptual contribution to community resilience," *Disasters*, vol. 42, no. 2, pp. 361–391, 2018.
[62] R. Anholt, F. K. Boersma, I. Linkov, M.-V. Florin, and B. D. Trump, "IRGC resource guide on resilience (vol. 2): Domains of resilience for complex interconnected systems.," *CH: EPFL International Risk Governance Center*, Lausanne, 2018.

[63] K. Schroeder and M. Hatton, "Rethinking risk in development projects: from management to resilience," *Development in Practice*, vol. 22, no. 3, pp. 409–416, 2012.
[64] S. W. Ambler, "The Agile Scaling Model (ASM): Adapting Agile Methods for Complex Environments," *IBM*, 2009.
[65] D. Leffingwell, *Scaling software agility: best practices for large enterprises*. Upper Saddle River, NJ: Addison-Wesley, 2007.
[66] M.-V. Florin and I. Linkov, "IRGC Resource guide on resilience," *Lausanne: EPFL International Risk Governance Center (IRGC)*, 2016.
[67] L. Klein, C. Biesenthal, and E. Dehlin, "Improvisation in project management: A praxeology," *International Journal of Project Management*, vol. 33, no. 2, pp. 267–277, 2015.
[68] D. Hillson, "How to Manage the Risks You Didn't Know You Were Taking," presented at the PMI® Global Congress 2014, United States, Phoenix, AZ. Newtown Square, 2014.
[69] L. Crawford, C. Langston, and B. Bajracharya, "Participatory project management for improved disaster resilience," *International Journal of Disaster Resilience in the Built Environment*, vol. 4, no. 3, pp. 317–333, 2013.
[70] J. Zhu, "A System-of-Systems Framework for Assessment of Resilience in Complex Construction Projects," Ph.D., Florida International University, United States, Florida, 2016.
[71] N. Turner and E. Kutsch, "Project Resilience: Moving beyond traditional risk management," *PM World Journal*, vol. 4, no. 11, 2015.

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