

Managing Sudden Unexpected Disruptions in Complex Projects: The Antifragility Hierarchy

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Abstract: Projects are prone to a variety of sudden unexpected disruptions across their development cycle, requiring that effective organizations develop strategies for proactively recognizing disruption likelihood and swiftly responding to these events. This paper explores a hierarchy of responses to disruption, based on Taleb's (2012) theory of antifragile system behavior. Following this reasoning, we suggest that when faced with project disruptions, organizations need to investigate the means to trigger a 'convex' response that increases value through antifragile thinking. We propose an 'antifragility hierarchy' in which three key responses to project disruption are demonstrated, with a range of strategies available for addressing these disruptions. This hierarchy offers a novel conceptualization of responses to project disruption events, suggesting that the options available to organizations range from robust (the least effective) to antifragile (the most constructive). Finally, we offer a set of strategies for effectively responding to disruptions to promote antifragility in projects.

Keywords: Projects, Disruption, Resilience, Antifragility

1. Introduction

The regular underperformance of project investments is a well-known and significant societal challenge (Flyvbjerg et al., 2018; Flyvbjerg et al., 2022; Love et al., 2024). Traditionally, project success has been evaluated through the lens of efficiency, focusing on outputs such as time, cost and quality. However, a shift in recent research emphasizes the long-term effectiveness and the strategic outcomes of projects, particularly their abilities to deliver lasting value to stakeholders and wider society (Samset and Volden, 2016). There is a growing call for more of a strategic focus on the value generated by project outcomes because organizations increasingly recognize that long-term success is better measured by the lasting impact and benefits of a project rather than just its completion or the deliverables it creates. This shift in focus helps ensure that investments align more closely with organizational goals, deliver sustainable benefits, and enhance overall effectiveness and competitiveness in a rapidly changing environment (Laursen and Svejvig, 2016; Winter et al., 2006; Winter and Szczepanek, 2008). Project value is here defined as, “the sum of the economic and wider social benefits to be accrued minus the costs incurred” (Ika and Pinto, 2022, p.840).

One of the greatest challenges for project-based organizations lies in managing sudden unexpected disruptions. Disruptions are events or changes in the environment that can threaten the realization of project value (Oliveira et al., 2002, p.361). Sudden unexpected instances are particularly challenging to manage because they occur abruptly without warning and are especially impactful during the project implementation stages. These are the primary concerns of this paper.

To date, the main focus in handling these sudden and unexpected disruptions has been on building robustness and resilience. Robustness and resilience focus on withstanding (Hillson, 2023) or recovering from (Naderpajouh et al., 2020; Rahi, 2019) disruptions aiming to maintain or restore the project to its pre-disruption state. This paper instead argues that adopting an *antifragile* approach offers a more dynamic, opportunity-driven method to handle these events in complex projects. The concept of antifragility, introduced by Taleb (2012), provides a novel lens for understanding how projects behave when exposed to disruptions. One of the most important principles of Taleb’s (2012) antifragility is that such disruptions can actually help to create unexpected value. Antifragile systems, unlike robust and resilient ones, do not merely withstand shocks or recover from disruptions, they can also improve and become stronger from them. They are able to continuously adapt and respond to unpredictable

environments, they evolve under pressure and leverage disruptions as opportunities for improvement and long-term value creation (Blečić and Cecchini, 2019; Taleb, 2012). Thus antifragile projects, in contrast to non-antifragile ones, exploit unexpected challenges and enhance their performance over time. The concepts of robust, resilient, and antifragile projects are discussed in greater detail in Section 3.1 of this paper.

A practical example illustrates the benefits of adopting an antifragile approach. AIRCO, a UK-based company involved in developing safety-critical air traffic management software, faced numerous disruptions throughout the project, including technical challenges that affected the project's development process (Baxter and Turner, 2023). Initially, these disruptions seemed detrimental, but through a more adaptive, antifragile, approach, the project team was able to turn these disruptions into opportunities. By exploring innovative solutions and using disruptions to enhance collaboration and knowledge-sharing, the team significantly improved the final product beyond its original scope (Turner and Baxter, 2024). This case demonstrates how disruptions, if an antifragile system is in place, can serve as catalysts for growth, innovation, and long-term project success, rather than merely being obstacles to overcome.

This shift from robustness and resilience to antifragility unlocks significant benefits for projects operating in uncertain and unpredictable environments. However, there is limited focus within the project management literature on approaches such as antifragility that go beyond recovery and use disruptions to drive project value. While initial steps are being taken towards reversing our belief of seeing disruptions as negative and instead as opportunities that organizations can leverage (Wu et al., 2024), the concept of antifragile projects is underexplored. This paper seeks to fill that gap by exploring the concept of antifragility in project-based organizations.

The aim of this paper is to identify ways in which projects can become more antifragile in their response to disruptions. Three research questions are considered:

1. What are the responses of various project systems to disruptions and how do these responses affect the project value?
2. What are the characteristics of project systems that enable them to respond to disruptions?
3. What strategies can project-based organizations adopt to acquire additional characteristics and improve their ability to withstand, recover, and improve from disruptions?

To address these research questions, we develop an antifragility framework that consists of a hierarchy of the three project system types, with increasing capabilities to deal with disruptions, i.e., robust, resilient, and antifragile project systems. This framework reveals how project systems can become robust, resilient, or antifragile, by acquiring specific characteristics through the implementation of particular strategies. The range of strategies presented in this paper demonstrates how projects can not only preserve value during disruptions but also gain from these disruptions.

The remainder of the paper is structured as follows. Section 2 provides a theoretical overview of disruptions and fragility in project management. Section 3 introduces the three non-fragile project system types – robust, resilient, and antifragile – and examines their responses to sudden disruptions. Section 4 identifies specific strategies that project managers can adopt to foster antifragility and enhance their project's ability to thrive amidst disruptions. Section 5 discusses the implications of these findings for both theory and practice and Section 6 concludes with the main takeaways and suggestions for future research.

2. Theoretical Setting

Considering the myriad pressures, unforeseeable risks, and lingering uncertainty in which projects are delivered, disruptions should be considered inevitable (e.g. Dacre et al., 2024; Faruquee et al., 2024; Shishodia et al., 2022). Hence, we take, as our starting position, the premise that all projects are subject to a variety of disruptions that can impact their behavior and the ability to obtain the benefits anticipated (Williams et al., 2023). Disruptions are regularly headline news, and the negative impacts they have on organizational operations are increasingly important (e.g. Nikookar et al., 2024). Regardless of the source and nature of the disruption, we can better reflect on their impact on our projects by first uncovering the types of disruptions to which they may most be prone, as this process can help the firm develop effective scanning processes and subsequent solution strategies. However, the topic is challenging due to the lack of definitive language and the difficulty in identifying and understanding practical examples for learning. Disruptions can manifest in various forms, and understanding their impact is crucial for devising effective solutions.

2.1 Sudden or Creeping Disruptions

Kutsch et al. (2015) and Shen and Ying (2022) propose a distinction by categorizing disruptions as either *sudden* or *creeping*, based on their temporal characteristics. Sudden

disruptions are characterized by their abrupt and unexpected nature. These events unfold rapidly, often lacking prior indicators or warnings. Sudden disruptions (Naderpajouh et al., 2020) usually occur due to the existence of pre-conditions in the environment or as the result of a decision, or sequence of decisions, that result in a catastrophic system failure.

Reason's notion of project pathogens (Busby and Hughes, 2004) provides a metaphorical framework to understand the emergence and impact of disruptive elements within projects. The term 'project pathogens' compares disruptions in projects with biological pathogens suggesting that disruptive factors act as detrimental agents who affect the health and viability of a project. The discontinuous occurrence like the sudden onset of Coronavirus Disease 2019/20 (COVID-19) compares to the abrupt outbreak of a pathogen. It caught numerous firms unprepared thereby causing panic among businesses as they hastily tried to develop responses towards this emergency by securing supply chains and safeguarding employees' health or life, among other major issues. This situation mirrors the challenges posed by a sudden and unforeseen disruption.

Sudden disruptions can occur in projects through the deleterious effect of intervenor groups (Cleland, 1997), technical failures, economic or funding collapse, departures of key project champions, and so forth. Project champions are individuals (typically those of high visibility or status) who actively support and advocate the strategic value of a project (Zwikael and Meredith, 2018). In the context of sudden disruptions, with the departure of key project champions, the loss of the driving force behind the project may significantly impact a project's trajectory.

In contrast to sudden disruptions, creeping disruptions unfold gradually over an extended period. According to Shen and Ying (2022) creeping disruptions involve disruptions with long incubation phases that gradually emerge as ongoing risks and uncertainties accumulate. To illustrate, consider a project where initially minor changes in the design phase, which seemed reasonable at the outset, accumulate over time. Each change on its own may have a relatively small impact on the project cost or scheduled delivery date. Still, the accumulation of these seemingly minor disruptions can ultimately compromise the project's final success or value creation significantly. Mishra and Sinha (2016) highlight that the insidious nature of creeping disruptions lies in the cumulative effect of numerous seemingly mundane decisions, eroding the project's overall value. In this paper, the focus lies on sudden disruptions.

2.2 Classification of Project Disruptions

Disruptions can also be divided into internal and external disruptions, and expected and unexpected events. Internal and external disruptions refer to the locus of causality, i.e., the source of disruption and whether an outcome is caused by internal or external parties (Franke et al., 2022; Iao-Jørgensen, 2023). Internal disruptions arise from within the project or organization whereas external disruptions originate from factors outside of the project organization such as an economic crisis or sudden changes in regulations. Expected or unexpected disruptions refer to events that could reasonably be predicted or anticipated. Geraldi et al. (2010, p.547) describe unexpected events as “events that may have been predicted (or not) but are not expected to happen.” They are the result of a variety of different residual uncertainties. Table 1 shows the different classes of sudden disruptions and some examples.

Table 1. Classification and examples of sudden disruptions

	<i>Internal</i>		<i>External</i>	
	Expected	Unexpected	Expected	Unexpected
Disruption example	Staff turnover due to promotions or retirements Potential budget overruns based on past experiences or complexities in the project.	Resignation of a key team member for personal reasons. Change of senior leadership leading to a shift in priorities.	A change of government in line with the election cycle which brings with it new political and fiscal priorities. Regular new product introductions by competitors.	Rapid change in industry regulations or the funding environment such that the viability of the work is put in question. Bankruptcy of a key supplier.

Effective management entails identification, assessment, and development of strategies to counteract various disruptions regardless of their sources, to promote success even when faced by unforeseen challenges. Nonetheless, risk management generally aims at pre-emptively reducing the occurrences of predictable incidents and mitigating them if they do occur. This approach, however, may “produce an over-reliance upon strategies of anticipation and deflect attention from the need to build resilience into organizations to deal with the unexpected” (Loosemore, 1998, p.140). In this paper we will emphasize the disruptions that are unexpected. Here we are interested not necessarily in controlling the disruptions by reducing their probabilities, but in reducing the impact that unexpected and unpredictable disruptions can have on the work and improving projects’ ability to respond to disruptions.

Figure 1 shows the relationships between the concepts of project system and project life cycle system (for example, an IT system), internal and external disruptions, and the impact on project value for stakeholders.

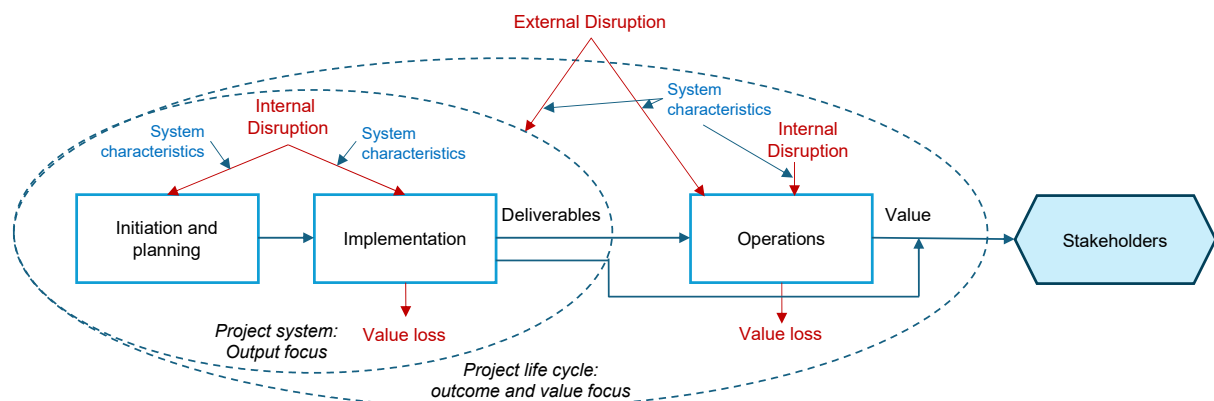


Figure 1. Impact of disruption on project value

2.3 Fragility

A fragile project system loses value when exposed to disruptions and never recovers. This will typically result in irreversible loss of functionality (Ansar et al., 2016). The disruption causes harm, and no benefits can outweigh the costs of the project to create project value. To be classified as fragile, two conditions must simultaneously hold: the potential for harm and the absence of any potential gain from perturbations (Blečić and Cecchini, 2019).

Every system has a unique ‘fragility threshold’, and when this threshold is crossed under the influence of stressors, the system breaks down. The size of the system and its interconnectedness play a role in fragility, with larger systems having proportionally lower fragility thresholds and interconnected systems sharing the fragility threshold of their weakest component. A famous example is the *Vasa* (Kessler et al., 2001). This Swedish warship was one of the most powerful ever developed when it was put to sea in 1628. Originally designed for 36 cannons, King Gustavus Adolphus decreed, mid-build, that the ship would be made longer than originally intended, with two-gun decks instead of one, and a total of 64 cannons. These amendments, together with 700 heavy sculptures and ornaments, appear to have made the *Vasa* unstable, and it heeled over in a gust of wind and sank to the bottom of Stockholm harbor on its maiden voyage, having travelled less than a mile, with the tragic loss of 50 sailors. Not only was this fundamentally not a robust product, but the inability to constrain the dangerous additions to the scope also shows an inherent weakness in the development process that could neither accommodate nor push back on the new demands.

Figure 2 presents a simple visualization of how a fragile project responds when encountering a sudden disruption.

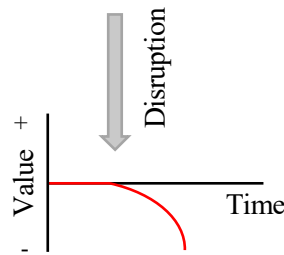


Figure 2. Fragile system response to disruption

There are four main sources for a system's fragility:

1. *Intrinsic fragility* relates to inherent aspects of fragility such as over-optimistic planning or inadequate risk assessments (Flyvbjerg et al., 2002).
2. *Inherited fragility* concerns interconnected elements (Taleb and Douady, 2013). An example of inherited fragility is supply chain dependencies. The reliance on a single supplier for critical materials or components in a project can result in disruption to project timelines and costs.
3. *Apparent fragility* occurs when a system's vulnerability may potentially be overestimated. There may be an external perception that a project is fragile or vulnerable based on visible challenges or setbacks, but this perception may not accurately represent the project and other skills and plans may be available to overcome these setbacks. For example, it has been argued that oil exploration or nuclear power projects can be considered apparently fragile due to negative public perceptions of them as energy sources (Jaradat and Keating, 2014).
4. *Hidden fragility* refers to vulnerabilities or weaknesses that are not readily apparent or visible from external observations or initial project assessments. These weaknesses may remain concealed until specific conditions or stressors are encountered during the project's execution. Hidden fragility could for example stem from underestimated complexity or unidentified dependencies. A good example of hidden fragility in projects can relate to the potential vulnerability of their funding streams, such as the case in 2008 where numerous financing organizations became over-extended during the lending credit upheaval and were forced to withdraw funding from multiple project organizations in mid-development (Crutchfield, 2020).

Understanding these concepts is essential when assessing a project's susceptibility to disruptions and stressors.

3. Non-fragile Project System Types

In this section, we explore the characteristics and behaviors of different project systems - robust, resilient, and antifragile - in response to sudden disruptions, highlighting how each system type impacts project value. Robust systems maintain value despite disruptions; resilient systems initially lose value but recover over time; and antifragile systems not only recover but also gain additional value from disruptions. This underscores the importance of understanding these system types to enhance project delivery and value creation.

3.1 Responses to Disruptions

Figure 3 shows a simplified graphical representation of the project behaviors in response to disruption. This offers insights into how different project system types—robust, resilient, and antifragile—navigate disruptions throughout the project lifecycle. By examining this visual depiction, we can gain a clearer understanding of how each system type interacts with disruptions and how these interactions impact project value over time. The figure shows how antifragile projects outperform non-antifragile projects by creating project value rather than restoring project value to its pre-disruption state.

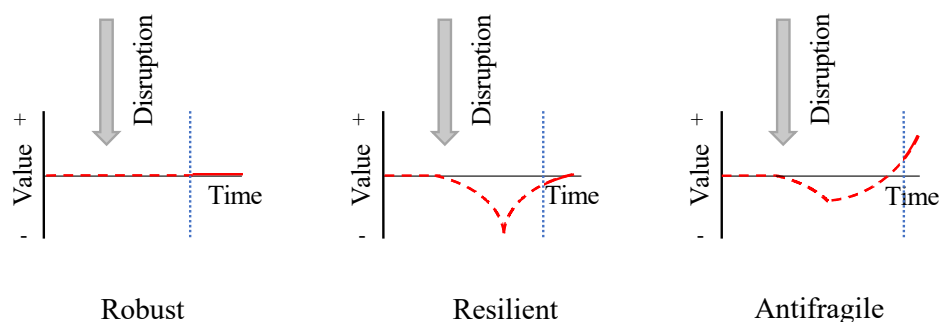


Figure 3. Project system responses to disruption

The emphasis on project value calls for adopting a project system lifecycle approach, which includes the front-end planning, the implementation as well as the back-end operations phase where opportunities for value creation lie (Artto et al., 2016). Disruptions can affect the project during any of its phases; however, the impact of disruptions will increase over the life cycle. Therefore, for the purpose of this paper we will consider the impact of disruptions from

the start of the implementation phase until a short time after project end, covering the operations phase to capture value creation. The dotted vertical line represents the end of the implementation period and start of operations. The dashed line represents the '*likely project value*' defined by Browning (2019, p.73) as "the estimated value of an incomplete project, given its resources and capabilities". The solid line following on from the dotted (after completion) represents the '*actual project value*' defined as "a project's final value at completion, based on how things turn out and where the project ends up" (Browning, 2019, p.73). The next sections describe the responses to disruptions and impact on value for each of the three project system types in more detail.

1. The robust system. A robust system is one that can withstand disruptions without losing value - the project value remains constant over time. All systems, including projects, are expected to be able to perform or deliver value under a range of different circumstances and challenges. Robustness as a pivotal characteristic of this project system type exemplifies projects' capacity to withstand various disruptions (Hillson, 2023) and external pressures while preserving their value, functionality, and objectives (Dubey et al., 2017; Durach et al., 2015) and resisting undesirable changes (Hillson, 2023; Munoz et al., 2022). Robustness involves the project's ability to absorb disruptions while still achieving its objectives within the set limits. Robust systems are critical in dealing with disruptions, however, they are focused on resistance and withstanding disruptions and are limited in their ability to adapt to changing environments.

2. The resilient system. A *resilient* system is a project system that loses value when encountering a disruption, but it can recapture the value at a later point. In this paper we adopt the definition of project resilience by Naderpajouh et al. (2020, p.5) as, "the capacity to organize under a variety of scenarios, including disruptions in the form of shocks or stressors." Resilience is a word offering multiple interpretations within specific contexts (Linnenluecke, 2017; Turner et al., 2020). For instance, in an organizational context, resilience is defined as "the ability to anticipate, avoid, and adjust to disruptions and changes" (Burnard et al., 2018, p.352). So far, the resilience literature has focused mainly on ecological, organizational, engineering, economic, or supply chain contexts (Rahi, 2019; Ramezani and Camarinha-Matos, 2020) while studies at the project level are far fewer. In line with Naderpajouh et al.'s (2020) idea of resilience as organizing under disruptions, we follow Rahi (2019, p.73) who considers resilience as an adaptive capacity and "the ability to return quickly to its equilibrium point once faced with a disruptive event." Resilient project systems, while capable of handling

disruption by returning projects to their original state, are limited because they primarily focus on recovery rather than growth. This does not fully embrace the complexity and unpredictability inherent in modern project environments. Consequently, the potential for innovation and value creation during disruptions remains underutilized.

3. The antifragile system. An antifragile system may be weakened by disruptions at first, but it grows stronger over time. Taleb (2012) coined the term ‘antifragility’ whereby something can “gain, get stronger, improve, evolve and adapt better” from perturbations (Blečić and Cecchini, 2019, p.174). While some authors like Hillson (2023) argue that with antifragility, an initial performance degradation (as is the case with resilience) is not observed and performance improves immediately, we follow Taleb’s (2012) original proposition that antifragility may face negative impacts initially but eventually delivers increased project value. Antifragility not only addresses disruptions but also uses them as a catalyst for growth and improved performance. Unlike resilience, which focuses on returning to equilibrium, antifragility embraces uncertainty, using disruptions to create value.

For example, when, in 2017, the NotPetya malware attack disrupted IT systems worldwide, global shipping giant Maersk, one of the most prominent victims, experienced significant operational disruptions. Yet, they managed to rebuild their entire network within 10 days, improve its cybersecurity and use the crisis as a competitive advantage (Greenberg, 2018). They transformed the disruption into an opportunity for substantial improvement in their systems and practices, illustrating how antifragile systems not only withstand shocks but also improve and become stronger from them.

The technical name for antifragility is positive convexity, which describes a nonlinear response to disruptions where benefits can increase exponentially over time. “For the antifragile, shocks bring more benefits (equivalently, less harm) as their intensity increases (up to a point)” (Taleb, 2012, p.271). There is a positive asymmetry where gains are larger than losses (Taleb, 2012), or “more gain than pain” (Russo and Ciancarini, 2017, p.3). An example of convexity is found in the use of real options (Copeland and Keenan, 1998; Leslie and Michaels, 1997) in project investments, where the investment includes the option to expand or scale up operations based on market conditions (Sunnevåg, 2009). With the option to expand, the project exhibits positive convexity. As market demand grows, the project can exercise the

option to scale up, leading to an accelerating increase in returns. Figure 4 illustrates this positive convexity and asymmetry in gain and pain.

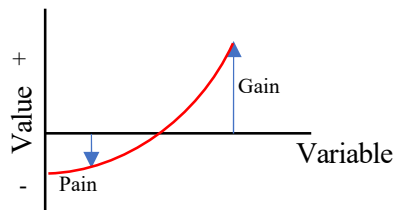


Figure 4. Positive convexity

Table 2 presents a summary of the different project system types, a description of how they behave when a sudden disruption occurs and the impact on the project value. The example context used is that of a hypothetical development project.

Table 2. Systems on the Antifragility Hierarchy and impact on project value when disruption occurs.

System type	Description	Resultant impact on value	Internal disruption example:	External disruption example:
Robust	A system that is able to <u>withstand</u> various disruptions while preserving its value, functionality, and objectives and resisting undesirable changes.	Nil: The disruption can be absorbed without significant adverse effects on the overall project. Long-term project value is unaffected.	Resignation of a key team member for personal reasons. The project team is able to draw in other people with the necessary expertise to take over critical tasks. The project can be delivered as planned not affecting financial or social project value.	Rapid change in government regulations. The organization can utilize contingency plans based on various scenarios and response strategies. The project can be delivered with its initial planned functionality and value.
Resilient	A system that is able to organize under a variety of scenarios, including disruptions in the form of shocks or stressors.	Nil: The project will initially experience a negative impact and loses project value when exposed to disruptions, but it can regain that value over time. At the time of disruption, projected value will be reduced, potentially very considerably. However, a resilient system will be able to recover that value over time.	Initially, project progress slows down and delay is anticipated, hence a loss in financial and social value. However, the project team is able to redistribute roles, tasks, and responsibilities, and capacity is increased to bounce back from the initial negative impact. The project can eventually be delivered as planned recovering initial planned value.	The change in regulations initially causes increased costs and delayed implementation due to changes in requirements affecting the financial and social value. However, the project is able to quickly assess the implications of the regulatory change, adapt processes though mobilizing resources and get back on schedule, or modify the intended design to meet the requirements. The project can be delivered with initial objectives and values.

Antifragile	A system that can also “gain, get stronger, improve, evolve and adapt better” from perturbations (Blečić and Cecchini, 2019, p.174).	<p>Positive:</p> <p>The project system will initially experience a setback and lose value when exposed to disruptions. However, the disruption is leveraged to its advantage to gain additional value over time. At the time of disruption, the long-term value recovery may not be apparent, and distinguishing between resilient and antifragile may only be possible when taking a longer-term perspective/life cycle approach.</p>	The disruption is used to build capability, bringing in new staff with new ideas and approaches. The organization has upskilling programs in place allowing for quick adaption. The project could be implemented more efficiently, adding project value.	The work will initially experience a negative impact on project value but the disruption is used as a catalyst to enhance capabilities and performance, seeking innovative solutions by reflecting on the situation, trialing and incorporating new ideas, processes or technologies, ultimately delivering additional value.
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It is important to recognize some of the key similarities and differences between these behaviors, particularly the differences between robust and resilient, and between resilient and antifragile. When ascribing the qualities of robustness or resilience to something, it is always in relation to a defined threshold of intensity: entities are robust or resilient only within the constraints of a specific perturbation intensity level (Blečić and Cecchini, 2019). In the case of robustness, these perturbations have no impact and do not alter its state. In contrast, resilience possesses the capacity to absorb, rebound, and recover from perturbations. Resilience is characterized by being able to recover performance levels that are acceptable after a degradation has occurred (Hillson, 2023; Munoz et al., 2022). There is also imprecision within the literature regarding the distinction between resilience and antifragility, with some considering ‘evolutionary resilience’ as antifragility (e.g., Blečić and Cecchini, 2019; Davoudi et al., 2013; Simmie and Martin, 2010).

Resilience and antifragility share some similarities, the most notable being that both could result in improvements. However, there are key differences that need to be recognized (Hillson, 2023). First, the source of improved performance differs. With resilience it is the response to stress that could lead to improved performance, also referred to as ‘bounce forward’, but with antifragility, it is the stress itself that directly causes benefits and enhanced performance. Second, the improvements gained from resilience are marginal and efficiency focused, while those from antifragility are more significant. Antifragile systems will thrive and grow when exposed to volatility, randomness, disorder, and uncertainty (Munoz et al., 2022).

3.2 Project System Characteristics

To improve project delivery and ensure value creation, policy makers, project managers and the like can assess how vulnerable their projects are to disruptions. To do so, we need to have a better understanding of how each of these system types are characterized. In this section we identify the key characteristics for each.

The robust system. A robust system is characterized by projects’ capacity to withstand various disruptions (Hillson, 2023) and external pressures while preserving their value, functionality, and objectives (Dubey et al., 2017; Durach et al., 2015) and resisting undesirable changes (Hillson, 2023; Munoz et al., 2022). Robustness involves a project’s ability to adapt and absorb disruptions while still achieving its objectives within the set limits. Developing robustness is essential to address uncertainty and pressures for the project to survive, but

robustness alone is insufficient. A robust system can only tolerate disruptions to a certain extent; once this threshold is exceeded, the system experiences the full negative impact of disruptions, highlighting that robustness has a limited capacity (Munoz et al., 2022). A closely related characteristic of a robust system is resistance, where the robustness of a system is equal to its resistance to disruptions (Dahlberg, 2015). It is the ability to withstand disruption “without changing its initial configuration” (Ramezani and Camarinha-Matos, 2020, p.16).

Besides robustness and resistance, the three main characteristics of a robust system are (1) redundancy, (2) diversity, and (3) fault tolerance. Both redundancy and diversity are based on the notion of having multiple assets or systems that perform the same function such that if one system fails another can take over without losing the project system functionality (Giezen et al., 2015; Ramezani and Camarinha-Matos, 2020). However, redundancy is more often associated with the physical components whereas diversity is related to having a diverse set of people, skills, and work styles to reduce the risk of a single point of failure and ensure continued functionality (Aven, 2015a). Lastly, fault tolerance is often associated with the capacity to maintain acceptable levels of service when affected by a disruption (Madni and Jackson, 2009).

The resilient system. A resilient system shares the characteristics of a robust system. However, in addition to these robust elements, resilient projects go further. Adaptability, recoverability, and flexibility are key characteristics that are similar but with some distinct differences. *Recovery* suggests that, although the system may initially lose value when impacted by a disruption, the recovery process ensures that this loss of value is not permanent and that the system will return to its original state and deliver the previous value (Nikookar et al., 2021). In a sense, *adaptability* addresses the project’s ability to adjust to unforeseen events while recovery focuses on mitigating the impact of disruptions and returning the project to its intended course. Some studies use adaptability and flexibility interchangeably (e.g., Blečić and Cecchini, 2019) or define adaptability as being flexible, but there are some key differences. Lengnick-Hall et al. (2011) consider the main differences deriving from the origin and outcomes. *Flexibility* emphasizes the ability to navigate effectively within an existing structure, while adaptability prioritizes adjusting to external conditions and potentially adopting a new balance or state. Schmitt and Singh (2012) argue that enhancing flexibility in the system reduces the likelihood of disruptions and makes it more able to face disruptions.

Several studies identify flexibility as a key attribute albeit in different context, such as in organizational resilience (Lengnick-Hall et al., 2011), supply chain resilience (Fiksel et al., 2015; Schmitt and Singh, 2012), or business ecosystems (Ramezani and Camarinha-Matos, 2020). Other characteristics of resilient systems include (emergent) *responsiveness* (Piperca and Floricel, 2013) or early responses (Aven, 2016), *preparedness* (Davoudi et al., 2013) or the capacity to prepare for incremental changes and unexpected disruption (Stachowiak and Pawlyszyn, 2021; Turner and Kutsch, 2015) or disasters (Dahlberg, 2015). Ramezani and Camarinha-Matos (2020) further identify *observability* as a resilience capability in collaborative business ecosystems, and this is relevant in a project system as well. Observability, or monitoring, is “the ability to observe and, optionally, signal an alarm on the external and internal states of the system and its components” (Tseitlin, 2013, p.4). The ‘art of noticing and interpreting’ as defined by Turner and Kutsch (2015) (see also Turner et al., 2020) is related to this idea, calling managers to notice more and interpret adversity more realistically. Lastly, *creativity and improvisation* are generally seen as key characteristics of resilient systems (Dahlberg, 2015; Lengnick-Hall et al., 2011; Turner and Kutsch, 2015).

The antifragile system. An antifragile system again shares the characteristics of the resilient system but has additional features. We now highlight and explain these, namely *positive convexity, optionality, hormesis, evolvability* and *transformability*. These concepts are not applicable to all projects, and thus antifragility is not achievable by all (or indeed most) projects. However, they provide a valuable way in which to understand how antifragility may be operationalized.

As mentioned before, antifragile systems are characterized by positive convexity, a nonlinear response to disruptions. Another core characteristic of antifragility is *optionality*. Taleb (2012, p.171) argues that “the option is an agent of antifragility.” Blečić and Cecchini (2019) consider optionality as a core property of antifragile systems which differentiates antifragility from resilience. Optionality refers to the capacity to have various choices or possibilities without being bound by obligations. In an antifragile system, optionality allows for the exploitation of unforeseen opportunities and limits potential harm from threats (linking to the positive convex nature of antifragility), emphasizing the system’s ability to evolve, improve, and gain benefits, even in terms of providing options, over time.

Hormesis is another characteristic of antifragility, suggesting that a certain level of stress or challenge, below the threshold of harm, can have a positive effect on the project system. As a response to disruption, overcompensation occurs and may result in a greater ability to resist the same disruption in the future (de Bruijn et al., 2018; Derbyshire and Wright, 2014). This overcompensation is a form of redundancy; for instance, as a reserve build up (Makridakis and Taleb, 2009) that is beneficial in the long-run and, in fact, a strategy that enhances the chances of survival. The antifragile system can only survive if it possesses sufficient redundancies, more than are required for a robust system. Hormesis “emphasizes that the removal or absence of stressors can be detrimental, even if it appears to be beneficial in the short term” (Derbyshire and Wright, 2014, p.220).

Lastly, *evolvability* and *transformability* are characteristics of antifragile systems. With evolvability, systems thrive in the face of disruptions (Ramezani and Camarinha-Matos, 2020). Transformability entails the ability of a system to adopt new strategies, challenge existing norms, and adapt to disruptions by reorganizing and restructuring (Iao-Jørgensen., 2023). We follow here Blečić and Cecchini’s (2019) classification of ‘evolutionary resilience’ (e.g., Davoudi et al., 2013; Simmie and Martin, 2010) and ‘transformative resilience’ (Dahlberg, 2015) as antifragility, as it goes beyond the traditional aims of resilience.

3.3 The Antifragility Hierarchy

Figure 5 illustrates the main characteristics at each level of the antifragility hierarchy, depicted as a nested structure. The outermost layer represents the antifragile system, encompassing all the characteristics of the inner layer systems. The structure suggests that project system types at the higher levels of the antifragility hierarchy possess the characteristics and capabilities of the lower levels, in addition to those specific to their level. For example, adaptability is a characteristic of both resilient and antifragile systems, with the antifragile system encompassing all lower-level characteristics while exhibiting increased adaptiveness at higher levels.

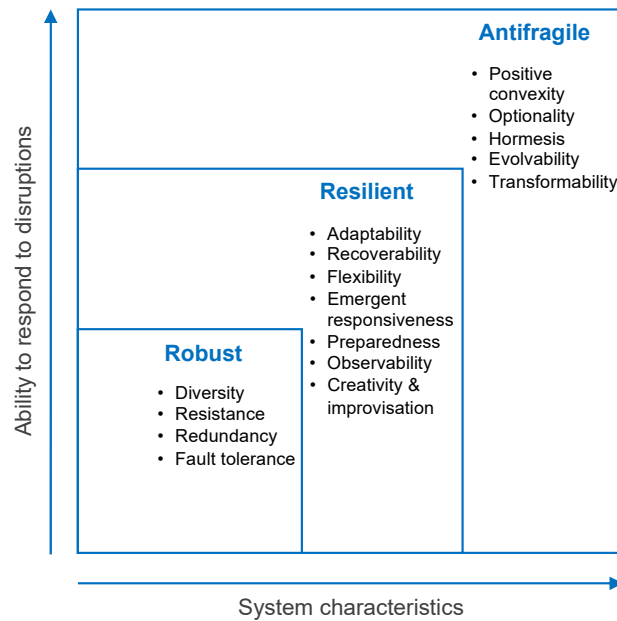


Figure 5. Antifragility Hierarchy

Studies so far have tended to focus on one of the project system types, either robust, resilient, or antifragile (see, for example, Munoz et al., 2022; Ramezani and Camarinha-Matos, 2020). Consequently, the characteristics that are identified are examined in isolation and do not consider whether those characteristics are relevant at other levels as well. For instance, some studies consider creativity and improvisation salient features of antifragile systems (Ramezani and Camarinha-Matos, 2020) while other studies consider them key for resilient systems. Considering our classification of project system types, we have included these characteristics at the lowest level, at the resilient level, implying that they are key for both resilient and antifragile project system types. The hierarchy can be used in project planning by building characteristics and capabilities into projects. For example, if the intention is robustness, a different set of actions is required as opposed to if the intention is resilience (Munoz et al., 2022). Given a better understanding of the characteristics of the project system types, in the next section we consider strategies that project managers and project-based organizations could deploy to gain these capabilities and move up the antifragility hierarchy and as such safeguard project value.

4. Strategies for Embracing Antifragility

To increase the likelihood of a project being antifragile, one can implement several preparatory strategies. It must be noted that there is an emphasis on preparatory rather than preventive strategies in VUCA (volatile, uncertain, complex, ambiguous) environments

because disruptions are unpredictable. Preventative strategies would require specific data about the causes, frequency, and duration of a disruption, which is often unavailable because the disruptive event has not occurred yet. Ergo, we cannot develop prevention strategies, we can only implement preparation strategies that strengthen our systems “so that the shocking effects of the shocking events are not that shocking” (Aven, 2015a, p.476).

4.1 Simplicity Strategies

We can consider some simplicity strategies to support the project in dealing with disruptions. *Subtraction* advocates removing unnecessary elements, streamlining project scope and minimizing disruption risks. The *less is more* rule emphasizes simplicity over intricate planning, fostering flexibility and resilience in project management.

4.1.1 Subtraction

The first simplicity strategy concerns *subtraction* which aims to remove unnecessary elements or reduce complexity from a system to make it more resistant to shocks and disruptions. By eliminating what is unnecessary, a system becomes less prone to unexpected failures and more adaptable to changing circumstances. Thus, the principle of subtraction is a strategy to enhance a system’s antifragility. In a project context, by practicing scope management and actively removing unnecessary elements or features that do not align with the project’s core objectives, project managers can simplify the project’s scope and reduce the risk of disruptions. At the organizational level, many organizations operate beyond their capacity and undertake too many projects (Hollister and Watkins, 2018) leading to overstrained resources. Effective portfolio management based on subtraction principles can help to select a subset of projects that maximize returns without overstraining resources. For instance, in their case study Ronen et al. (2012) showed how one company used the 25/25 approach for project portfolios. First, 25% of the overall project portfolio was eliminated to streamline focus. Then, in the remaining active projects, a further 25% reduction in workload was achieved by simplifying project features or relaxing specifications that did not compromise quality. Subtraction strategies are supported by Agile methodologies, which advocates minimizing waste and focusing on high-value tasks to improve adaptability and responsiveness. Additionally, Bhamra et al. (2011) emphasize that resilience in systems can be enhanced by simplifying and removing unnecessary components, allowing the system to respond better to change.

4.1.2 *Less is more*

The second simplicity strategy is the *less is more* rule (Taleb, 2012). This is a frequently used strategy by effective organizations who – instead of using rigid strategies – use flexible rules to guide key processes and decisions (Eisenhardt and Sull, 2001). When attempting to manage a complex system, such as a project, we need to move away from detailed planning, because they “do not require complicated systems and regulations... The simpler the better” (Taleb, 2012, p.9). Overly detailed planning is often undermined by unforeseen changes. Complex adaptive systems, like projects, operate based on a limited set of order-generating rules, or heuristics (Burnes, 2005; Love et al., 2024). Heuristics such as the ‘recognition heuristic’ rely on minimal information, to make quick and efficient decisions in uncertain conditions (Gigerenzer and Goldstein, 1996). By adopting simple heuristics, project teams can move fast and respond flexibly to new information or challenges. These are also referred to as ‘fast and frugal’ rules to simplify problems. Studies have shown how heuristics can support project decision making (Stingl and Geraldi, 2021) and improve the accuracy of cost contingencies in transport projects (Love et al., 2023). By employing heuristics, decision-makers can make quicker, more informed judgments under conditions of uncertainty. Love and Matthews (2022) advocate using simple, fit-for-purpose heuristics to navigate uncertainties, rather than relying on detailed and rigid protocols. For instance, in a major transportation infrastructure project, they observed that informally applied heuristics helped workers address rework issues by quickly adapting to on-site conditions and evolving project demands. This adaptive approach proved effective in reducing the cycle of errors and rework by applying straightforward, actionable guidelines suited to changing project contexts.

Managing projects effectively involves utilizing these broad rules at either a systems or local level, rather than relying on detailed plans prone to failure (Usher, 2021). By adopting simple rules, project teams can move fast and respond flexibly to new information or challenges.

4.1.3 *Impact of simplicity strategies on fragility*

Adopting simplicity strategies can result in a system that is better able to respond to disruptions, is more flexible, and can adapt more readily to changing circumstances. That is, they can lead to a less complex system, removing inherited fragility. Moreover, these strategies prevent overestimating system vulnerability and the unnecessary addition of elements to address the perceived vulnerabilities. This approach helps address apparent fragility by avoiding unnecessary complexity and ensuring effective system functioning.

4.2 Development Strategies

Here we explore development strategies, including building *optionality* and *modularity*, aimed at enhancing project adaptability.

4.2.1 Building optionality

Optionality emphasizes the importance of maintaining a diverse set of options to navigate unpredictable environments effectively. It enhances the system's ability to adapt and benefit from unpredictable opportunities while mitigating potential harm from unforeseen threats (Russo and Ciancarini, 2017). However, leaving a project with a full and diverse set of options (i.e., 'total options') is unlikely to be a suitable preparatory strategy. Instead, project managers engage in a process of optioneering (Usher, 2021), by presenting decision makers with a limited, but deliberately selected, range of options, as potential ways to progress a project towards its intended goal considering the information provided by the disruption.

In a similar vein, we have already noted that the real-options approach in decision-making provides options at each decision-making point to scale up investments (Derbyshire and Wright, 2014). For example, investment projects in the oil and gas industry often make use of a real-options approach, whereby a project may be deferred, expanded, or abandoned, depending on results and market conditions. The introduction of optionality in project planning is related to risk management, it can be considered a contingency approach to deal with this (Mardaras et al., 2021). However, in terms of antifragility it goes beyond traditional risk management and aims to provide a means to deal with the unknown risks in the future.

Optionality in combination with the less is more rule could mean less-detailed planning in projects. This result would then create the opportunity to "benefit from the positive side of uncertainty, without the corresponding serious harm from the negative side" (Taleb, 2012, p.171). In other words, by planning less, we provide room to shift courses of action, without losing the value of the original plan. Usher (2019) provides an example of how project value can be created by developing alternate options for sponsors and stakeholders to consider at key decision nodes in the schedule.

Small-scale experimentation (trial and error, or fail fast) is a closely related concept to optionality. Taleb (2012) consider them both key to antifragility while Derbyshire and Wright (2014) highlight the interconnection by arguing that small-scale experimentation facilitates

optionality. For example, in the aerospace industry, SpaceX uses iterative testing of its rocket systems. They launch rockets they know are not yet perfect, learn rapidly from any failures, and incorporate changes to build stronger, more reliable systems over time (Hughes, 2024). In this way, experimentation and optionality work hand in hand to create a system that can thrive in uncertainty. In so doing, the company has taken the lead in the hugely challenging space launch industry.

Similarly, Gorgeon (2015) argues that trial and error can create new knowledge and information which helps to improve the system overall. This strategy is frequently adopted in software development projects. For example, when a firm thinks about adding a new feature to its product, it takes little time and limited resources to make a rudimentary prototype of the feature so as to ascertain its feasibility and measure customer interest. Consequently, they can either proceed with the development of the feature or stop working on it based on what they find out in this process. However, it can be applied in a range of different project types, for example when project teams consider alternate methodologies and materials, rejecting some of them early if they do not meet the project requirements for cost or time.

4.2.2 Modularity

Modularity combines the simplicity and optionality strategies. It is a strategy to reduce complexity by breaking a complex system into sub-systems with varying degrees of interdependence (Ramezani and Camarinha-Matos, 2020). Modularity has long been recognized in the project management field as a way to reduce complexity (Ansar et al., 2014; Floricel et al., 2016; Hellström and Wikström, 2005; Loch and Payne, 2011; Patanakul et al., 2016; Tee et al., 2019). However, modularity is not only about simplification; it can also add optionality, positive convexity, evolvability and transformability to the project system. The modular approach allows for the option to expand if the benefits are proven. Flyvbjerg (2021) provides examples of modularity strategies in the energy and space industries where standard manufactured building blocks are used, positively impacting project delivery in terms of schedule and cost performance. Additionally, Boehme et al. (2024) show how a novel modular housing product was implemented to support socioeconomically disadvantaged communities in Australia. This involved developing a patented cyclone-proof system based on pre-engineered and pre-certified structural elements which could fit into a 20-ft container for easy transport to the installation site. Here it could be assembled by local communities and the flexible layout of the home could be (re)configured both on-site and over time as required as

the tenants' circumstances evolved. A key factor in the case was community buy-in, allowing technical and acceptance challenges to be addressed during the development period, resulting in greater acceptance of the product.

Another specific type of modularity is adopting Agile methodologies such as Scrum and Kanban. These approaches emphasize breaking down work into small, manageable iterations or increments. This iterative development, most prevalent in software development, allows teams to quickly respond to changes, gather feedback, and adapt their approach accordingly (Serrador and Pinto, 2015). Spotify has embraced Agile methodologies as well as antifragile principles in order to foster innovation, adjust to market changes and remain competitive. Spotify works through small teams called Squads who engage in continuous decision making and iterative work processes within autonomous boundaries. This structure and way of working allow them to respond quickly to customer feedback, adapt their product offerings, and deliver value incrementally. Furthermore, Spotify has adopted the concept of Tribes and Guilds, which foster collaboration and knowledge-sharing across the organization. Tribes are formed based on product areas, and Guilds are communities of practice where employees can exchange ideas, learn from each other, and contribute to collective learning and improvement (Almeida and Espinheira, 2021). This collaborative structure strengthens the organization's resilience and ability to navigate changes effectively.

4.2.3 Impact of development strategies on fragility

Development strategies help with the inherent uncertainty that projects face in a VUCA environment by providing flexibility in project plans, addressing the intrinsic fragility. For example, building in experimentation can provide a powerful means to uncover intrinsic weaknesses by testing quickly and on a small scale how disruptions affect the project system. For instance, infrastructure development in seismic zones benefits from modular design, as pre-fabricated sections of infrastructure can be quickly assembled or replaced in case of earthquake damage, reducing downtime and improving resilience (Fathieh and Mercan, 2016).

This approach can also help to remove perceived vulnerabilities that may not have a large impact after all. Building optionality is also valuable in managing apparent fragility, such as by allowing alternative plans to reduce perceived vulnerabilities. For instance, in the Agile software development approach, teams work in iterative cycles, which allow for continuous feedback and quick adaptations to customer needs or external changes. This flexible approach

reduces fragility by avoiding rigid, long-term plans that may fail under changing circumstances (Serrador and Pinto, 2015). Development strategies also indirectly contribute to managing hidden fragility. For instance, the structured nature of modularization allows for easier identification and isolation of hidden weaknesses within specific modules. Modularization also allows for the construction of systems with clearly defined components, making it easier to identify and address intrinsic weaknesses within specific modules.

4.3 Risk and Opportunity Strategies

We can also consider risk and opportunity strategies aimed at fortifying the project in the face of uncertainty. Organizations that actively manage opportunities can adapt more swiftly to changes, thereby increasing their resilience against unforeseen disruptions. For instance, Marsov et al. (2004) identified a range of activities and practices in construction projects that exploit opportunities. Here, we introduce the following strategies: (1) *Barbell Strategy*, (2) *Skin in the Game* and (3) *Considering Black Swans*.

4.3.1 Barbell strategy

A barbell strategy focuses on resource distribution, investing most of the assets to protect the core value of the project if confronted with disruption (Ramezani and Camarinha-Matos, 2020). A barbell strategy demonstrates an antifragile balance by investing most of the assets conservatively (staying robust to negative disruptions) while taking risks with the rest (open to positive disruptions). It is therefore a useful strategy to invest in advance of a disaster.

The purpose of a barbell strategy is not to eliminate uncertainty; rather it seeks to reduce the negative impacts of adverse disruptions, while simultaneously keeping the benefits of potential gains. The philosophy here is very much in keeping with the challenge that we embrace complexity to understand the roots of much project behavior (Ika and Saint-Macary, 2023). In a project setting, the barbell strategy can work as follows. Suppose, for example, that in consultation with the project sponsor, you have agreed on the priorities for a project to develop a new mobile phone application. The sponsor has advised that the performance of the application is the critical constraint, that speed to market is important and should be enhanced if possible, and thus, as a result of these decisions, the sponsor is willing to accept the overall cost of the project. In adopting a barbell strategy for this project, the project manager would allocate sufficient resources to ensure the minimum performance standard is achieved. They would then apportion the remaining resources to developing innovative options for speed-to-

market and then to cost control. Adopting this strategy safeguards the project from termination (i.e., the minimum performance outcomes are met) and provides the greatest opportunity for benefit by enhancing speed to market.

4.3.2 *Skin in the Game*

Taleb (2012, p.5) considers the *absence* of “skin in the game” as “the largest fragilizer of society, and greatest generator of crisis.” From an agency theory perspective, fragility comes down to a moral hazard problem (Gorgeon, 2015) where an agent may take excessive risks because they do not bear the full consequences of those risks. For instance, if a manager knows they will not personally bear the full cost of a risky decision, they might be more inclined to take that risk, creating fragility in the system. In a project context, decision-makers, planners, and forecasters, may benefit without facing the downsides of the risks, which often fall on others such as taxpayers. The antidote (Gorgeon, 2015) to the moral hazard problem is for agents “to have ‘skin in the game’ in the event of harm caused by reliance on his information or opinion” (Taleb, 2012, p.381). Decision makers, forecasters, or opinion makers need to be held accountable for the decisions that were made based on the information or opinion they provided; they need to have something to lose from it. Taleb (2012, p.430) also likens this view to “every captain goes down with every ship.”

There is a growing demand to incorporate this heuristic into project planning and execution. For instance, it has been suggested that the International Olympic Committee (IOC) should have skin in the game as regards costs (Flyvbjerg et al., 2021; Taleb and Sandis, 2014). The misaligned incentives are at the core of the extravagant cost overruns seen at the Olympic games and having skin in the game could give the IOC incentives to effectively manage cost. There is a trend to hold forecasters and investors accountable for deliberate manipulation of forecasts. In the extreme case this has led to litigation cases of forecasters facing criminal charges (Flyvbjerg, 2013). Flyvbjerg and Bester (2021) propose giving cost-benefit forecasters skin in the game to provide better incentives for accuracy in cost-benefit forecasts.

4.3.3 *Considering Black Swans*

Black swans are extreme events that are characterized by the triplet: rarity, extreme ‘impact,’ and retrospective (though not prospective) predictability (Taleb, 2007) (see also Aven, 2015b). They are outliers with an extreme impact that cannot be predicted. Managers often tend to ignore these low probability high impact events and most risk management tools

and techniques do not consider the risk of a black swan event. Instead of trying to predict the next black swan (which is not possible as per the definition of a black swan event), the focus should lie on building antifragility to manage the impact of negative issues and being able to exploit positive ones. Flyvbjerg and Budzier (2011) recommend stress tests to assess readiness (in terms of absorption and agility) against black swan type of events. Hajikazemi et al. (2016) take a different approach and propose early warning procedures and knowledge management as tools to proactively manage these types of events.

4.3.4 Impact of risk and opportunity strategies on fragility

Barbell strategies provide a balanced and adaptive framework for dealing with different forms of fragility in projects. By utilizing a dual approach that blends conservative and high-risk methods, it can provide both stability and innovation which are helpful in dealing with intrinsic, inherited, and apparent fragilities. ‘Skin in the game’ is a particularly suitable strategy to deal with apparent fragility as the high level of scrutiny can result in a more accurate assessment of the vulnerability of the project system. Black swan management recognizes the presence of hidden fragility by acknowledging the potential for unforeseen vulnerabilities in a project. It involves anticipating and preparing for unexpected events or conditions that may expose hidden weaknesses.

The different strategies have highlighted how they address different types of fragility and how they can provide project systems with additional resilient or antifragile characteristics. Table 3 provides a summary of the type of fragility addressed and the characteristics gained for each strategy.

Table 3. Strategy matrix: characteristics gained per strategy

Strategy		Type of fragility addressed	Robust system characteristics	Resilient system characteristics	Antifragile system characteristics
Simplicity	Subtraction	Intrinsic, apparent	Resistance	Flexibility, adaptability, responsiveness	Positive convexity
	Less is more				
Development	Building optionality	Intrinsic, inherited, apparent, hidden	Robustness, diversity, redundancy	Flexibility, adaptability, responsiveness, creativity and innovation	Positive convexity, optionality, evolvability, transformability

	Modularity	Intrinsic, inherited, apparent, hidden	Robustness, fault tolerance	Flexibility, adaptability, responsiveness	Positive convexity, optionality, evolvability, transformability
Risk and opportunities	Barbell strategy	Intrinsic, inherited, apparent	Robustness, redundancy	Preparedness	Positive convexity, transformability
	Skin in the game	Apparent	Robustness, redundancy	Preparedness	Positive convexity
	Considering Black swans	Hidden	-	Preparedness	Transformability

5. Implications

In this section, we address the theoretical implications, practical applications, and lines of inquiry for future research.

5.1 Theoretical Implications

This paper challenges and extends the current project management literature, particularly the focus on resilience as the primary response to disruptions. Existing literature tends to treat disruptions as events that must be mitigated and survived, which inherently limits the capacity for growth and innovation that can arise as a consequence. This paper introduces antifragility as a more dynamic and adaptive approach, one that not only mitigates disruption but also leverages it to create value and improve project outcomes. We identify three main theoretical implications:

First, while studies have started to explore project resilience as a possible response to disruptions (Kutsch et al., 2015; Markolf et al., 2018; Munoz et al., 2022; Naderpajouh et al., 2020), this is often studied at the individual or team/group level (Naderpajouh et al., 2020) or in a supply chain context (Rahi, 2019; Ramezani and Camarinha-Matos, 2020). Our work provides novel insight in how this can be applied at the project and organizational levels (including through value capture after project completion). While a resilient project may rely on contingency plans to manage risks, an antifragile project actively seeks opportunities within disruptions to, for example, introduce new methodologies, optimize resources, or reconfigure goals. This shift offers project managers a broader toolkit for responding to volatile and complex environments, extending the resilience concept to encompass growth rather than focusing primarily on survival.

Second, instead of focusing on a singular response to disruptions, we introduce an antifragility hierarchy framework, delineating three project system types—robust, resilient, and antifragile—with increasing capability to deal with disruptions and decreasing impact on project value. Each of these has different characteristics which result in different behaviors when encountering a disruption. The paper demonstrates the interconnectedness of these systems as they build upon one another to create a hierarchy. This implies that as one ascends to a higher level within the antifragility hierarchy, the project system possesses additional attributes that aid in managing disruptions. This is in line with some of the features identified by Naderpajouh et al. (2020) and the call to shift from strengthening, resistance and security (attributes of a robust system) to flexibility, adaptability, and recovery (attributes of a resilient system). Antifragile projects utilize disruptions as learning opportunities, refining processes and outcomes in response to challenges. Antifragile projects may maintain the widest range of options in decision-making, keeping multiple pathways for project development open, which enhances their adaptability during disruptions and their ability to capitalize on opportunities if and when they arise. This contributes to the growing stream of project behavior research by emphasizing the positive aspects of uncertainty and disruption and advocating for strategies that embrace complexity rather than merely mitigating it. By illustrating the specific behaviors that antifragile projects exhibit—such as evolvable, transformable, and opportunistic—this research deepens the understanding of how projects can succeed in uncertain environments. Ultimately, this paper not only extends the current understanding of project responses to disruptions but also highlights the novel behaviors that can arise with antifragile systems.

The third main contribution is the development of a set of preparatory strategies that target specific types of fragility in project systems (intrinsic, inherited, apparent, and hidden fragility). Moreover, it reveals how project systems can become robust, resilient, or antifragile, by acquiring specific characteristics through the implementation of particular strategies. A range of strategies is presented that ensures that projects at the very least do not lose value when facing disruptions, but also how projects can be set up to gain value from disruptions. Although the strategies themselves are not novel (proposed by earlier studies, e.g., Gorgeon (2015), Russo and Ciancarini (2017), Taleb (2012), and Usher (2021)) the focus on utilizing them to target particular levels within the antifragility hierarchy is innovative. This allows a link between the (sometimes rather intangible) ideas of antifragility and the underpinning actions that managers can take to support their organizations and projects.

5.2 Antifragility Strategies and Practical Implications

Sudden unexpected disruptions pose a difficult kind of challenge due to their inherent unpredictability. This paper offers alternative approaches that complement traditional risk management by focusing on strategies to enhance project resilience and antifragility. There is, however, no simple way to build in antifragility in projects. There is no ‘one-size-fits-all’ approach, but potential ideas can be discussed and evaluated by knowledgeable and experienced individuals within their particular projects and organizations. Managerial judgment is necessary to ascertain the most valuable way forward based on situated knowledge of the work, the context, and the team. By considering their project’s position on the antifragility hierarchy, they can determine which strategies may be most effective for their specific circumstances such that positive convexity may be obtained. For instance, if inherited fragility is a significant concern and the project is currently operating at the robust level, simplicity strategies can help reduce complexity and enhance flexibility, ultimately moving the project towards a resilient system level. This example illustrates our suggestion that these ideas are not intended to be prescriptive (i.e., creating a toolbox of various antifragility strategies to employ), but rather, offer useful alternative ways of thinking about projects, sources of disruptions, and framing a solution set for creative problem-solving.

The ideas can help drive key conversations amongst the team and stakeholders with regard to project approaches. For example, simplicity and development strategies are most beneficial during the early stages of the project development, in the planning and design phases. In this way, unnecessary complexity in project design can be prevented, different design choices can be explored, and flexibility can be created within the project plan, making the project overall less vulnerable and easier to manage. These conversations are important to have early, before firm commitments are made. The ideas we present are thus drivers for those critical conversations but cannot be a panacea.

Similarly, as the project progresses, the framework and strategies allow further discussions. Managers can use them, either at regular intervals such as gate reviews or as ongoing dialogue, to reflect on various aspects of the project like flexibility, recovery from disruptions, and responses to unexpected occurrences. Again, there is no prescriptive solution available, this requires reflection, dialogue, and the right conversations with the right people to explore the complexities they face, and identify realistic improvements and ways forward. Thus, the ideas of antifragility do not readily lend themselves to new processes or ‘simple’

improvements to the existing ways of working, but they can enable and support the critical thinking managers and teams may employ to improve their project performance.

5.3 Limitations and Future Research Avenues

In this paper we have explored three research question, looking at the responses of project systems to disruptions, the characteristics of various system types, and effective strategies that organizations can adopt. The concepts of antifragility can be difficult to observe in practice, and offering ‘simple’ ways forward is unrealistic given the inherent complexity of the topic. However, we believe that this subject is a valuable one to explore and progress, and it offers promising avenues of future research.

There is a shift towards considering project success from a value perspective (Laursen and Svejvig, 2016). In this light, antifragility is an important lens to study unexpected disruptions as it can provide an opportunity to create unexpected value. However, research on antifragility in projects is still in its infancy and there remain many unanswered questions. Here, we introduce several discussion topics and outline potential directions for future research.

This paper explores the impact of sudden disruptions on project systems from the start of implementation to shortly after completion. Early disruptions may have a lesser impact than mid-implementation ones, potentially leading to more project systems being classified as antifragile. Thus, antifragility’s meaning differs between planning and implementation phases. Moreover, evaluating a project system’s robustness, resilience, or antifragility often requires post-completion assessment, urging consideration of the appropriate evaluation timeframe. With an extended observation period, including a prolonged operational phase, all project systems might eventually demonstrate antifragility. Conversely, one could argue that some projects cannot reach antifragility level. Therefore, further research could investigate antifragility’s definition across project development stages.

This paper has considered unexpected sudden disruptions and differentiated between internal and external disruptions. External disruptions may have a more significant impact on project value and projects might be able to reach antifragility on internal disruptions more easily than on external disruptions. It illustrates that antifragility depends on the type of disruption and further research is recommended to differentiate this further, for example considering between physical, environmental, and legal disruptions and the size of the impact.

While the antifragility hierarchy is designed with broad application in mind, it may not be equally applicable to all complex projects. The framework is particularly relevant for projects operating in highly VUCA environments, where the likelihood of disruptions is high. However, its principles can be adapted and scaled according to the specific context and nature of different projects. For example, R&D and IT deployments can benefit from this hierarchy, but the specific strategies and implementations may vary. This represents a future area for research, to determine the application of antifragile thinking to the challenges presented by different types of complex projects.

One area that has emerged is the consideration of antifragility as an operational approach, yet also a socially-situated capability enabled by the working practices of the project team (such as in the AIRCO example earlier). The balance or tension between these ideas appears important to investigate further. The possibility that antifragility is (at least partially) an emergent property of a social system is intriguing. Is it a 'localized' property of the project team, enabled by culture, management support, and psychological safety? If so, what does this mean for scalability? These questions may offer tantalizing possibilities for future work.

Lastly, another area for future research lies in understanding the manner in which we can develop strategies that encompass antifragility as a project feature, as well as creating means for making the project management function itself more anti-fragile.

6. Conclusion

When Taleb (2012) first proposed his ideas of antifragility, his intention was to suggest that organizations need to modify their thinking regarding disruptions and begin viewing their goal as not to simply return the system to its original state (resilience), but to investigate the means to use the disruption to trigger a convex response that increases value or subsequent benefits through antifragile thinking. This paper proposed an antifragile hierarchy in which the three key responses to project disruption are shown as a hierarchy, with a range of strategies available for addressing these disruptions. This framework offers an alternative conceptualization of responses to project disruption events, suggesting that the range of options available to organizations facing disruptions range from robust (the least effective) to antifragile (the most constructive).

This paper extends the current project management literature by challenging the resilience approach and introducing antifragility as a more dynamic and opportunity-driven response to disruptions. By embracing complexity and uncertainty, project-based organizations can enhance their ability not just to survive, but to thrive in the face of unexpected events.

Moreover, there are a range of preparatory strategies available to project organizations and their key managers, from simplicity, development, to risk and opportunity management, all with specific actions the organization can take to focus on a goal of antifragility. We suggest that one of the reasons project-based organizations struggle with their responses to unexpected disruption events is due to a narrow framing of the challenge and, subsequently, an inability to view the widest possible range of behaviors and effective responses. In suggesting means of aligning our strategies with the most likely sources of fragility, we propose a more proactive and constructive framing of the disruption/response sequence so common to the management of projects, supported by a learning mindset to embrace the opportunities.

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