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Managing Disruptions in Complex Projects: The Antifragility Hierarchy

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Abstract

Projects are prone to a variety of 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 "antifragile hierarchy" in which four 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 facing disruptions range from fragile (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 strong potential for project disruptions remains a common feature of ongoing projects of all sizes and in all industrial settings (Flyvbjerg et al., 2002; Oliveira et al., 2022). As a result, the way project organizations and their actors identify and respond to these disruptions is critically important to their ultimate success. In this paper, we will explore how Taleb's (2012) concept of antifragility provides a novel lens for understanding how projects behave when exposed to disruptions. Of especial interest in our discussion is the idea of "…opportunities for special payoffs …" (Hirschman, 1967, p.4) contained in our conceptualization. One of the core principles of Taleb's (2012) antifragility is that unexpected events, such as disruptions, can provide an opportunity to create unexpected value. To explain how this circumstance is possible we examine four types of project systems that respond in distinct ways when faced with disruptions. These are: (i) Fragile; (ii) Robust; (iii) Resilient; and (iv) Antifragile. Each project system will produce different outcomes for a project, ranging from irretrievable value loss to unanticipated value gain.

Some studies in the project management field have addressed fragility and robustness. For instance, Killen and Hunt (2013) examined potential fragilities in portfolio management and Santolini et al. (2021) studied the fragility of activity networks in large-scale engineering projects. The phenomenon of resilience is often found in studies on risk management, as an alternative to probabilistic determinism. Resilience research recognizes the presence of unknown risks that may lie beyond proactive management (Naderpajouh et al., 2020), illustrating the importance of acknowledging the innate vulnerability of projects to external disruptions and the substantial levels of uncertainty (e.g., Rahi, 2019; Turner and Kutsch, 2015). While the project literature has begun to address resilience (e.g., Kutsch et al., 2015; Munoz et al., 2022; Naderpajouh et al., 2020), the broader context that examines the range of responses to disruption (up to and including antifragility) remains largely ignored.

The aim of this paper is to identify ways in which projects can move towards antifragility and hence improve their ability to respond to disruptions. First, we identify key characteristics that describe the four different project system types, and we explore how project value is affected when the project system is exposed to disruption (i.e., decrease, unchanged, increase). Second, we seek to classify strategies to handle disruptions for the different project systems. For this purpose, we will explore a range of preparatory strategies to ensure projects, at the very least, do not lose value when facing disruptions – but more importantly, how projects can be set up to gain value from disruptions.

By studying antifragility, we also address the need to emphasize "value creation" from projects rather than "product creation" or "project delivery" (Winter and Szczepanek, 2008). This effort aligns with the call towards "developing value creation and value capture as a broader concept in project management inferring short term, longer term and emergent value" (Laursen and Svejvig, 2016, p.743). The need for projects to focus on value creation demonstrates a direct link to the concept of antifragility, which Taleb (2012) defines in the subtitle of his book as "…things that gain from disorder…". Organizations can employ antifragile principles and strategies not only to protect the value generated by projects but also potentially to increase it by leveraging unexpected opportunities that arise during times of uncertainty and disruption.

The paper is organized as follows. Section two provides a classification on disruptions in projects. Section three describes the four project system types, how they respond to disruptions, and the impact on project value. Then, section four presents the antifragility hierarchy, with the four project system types and their characteristics. Finally, section five identifies various antifragility strategies and explores the effectiveness of these strategies in dealing with fragility.

2. Project Disruptions

The term VUCA is an acronym for volatility, uncertainty, complexity, and ambiguity. All modern projects are delivered in some form of VUCA environment. Considering the myriad pressures, unforeseeable risks, and lingering uncertainty in which projects are delivered, disruptions should be considered inevitable. Hence, we take, as our starting position, the premise that all projects are subject to a variety of disruptions that can impact their behavior. 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 we may most be prone, as this process can help the firm develop effective scanning processes and subsequent solution strategies. One helpful way to understand project disruptions is to view them as either sudden or creeping (Shen and Ying, 2022).

Sudden disruptions or shocks (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. The sudden onset of the COVID-19 pandemic caught numerous firms wholly unprepared and scrambling to develop responses, secure supply chains, and address significant human resource health emergencies. Likewise, 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. The effect of sudden disruptions is often critical because they are rarely anticipated or adequately prepared for through project risk analysis. Sudden disruptions can result in significant loss of value, or in the worst cases, project termination.

Creeping disruptions, per Shen and Ying (2022, p.672), are "… disruptions that have long incubation phases and emerge gradually as ongoing risks and uncertainties accumulate." In contrast to sudden disruptions, creeping disruptions are more insidious and often far harder to identify. Rather than being the result of one specific act of disruption, creeping disruptions occur because of an accumulation of decisions that appear to have been reasonable at the time but end up eroding the project's value. As Mishra and Sinha (2016) noted, while each disruption may have a relatively small effect on the cost of a project or scheduled delivery date, the accumulation of many mundane disruptions can severely compromise the project's final success or value creation.

Moreover, creeping disruptions share a common theme with the normalization of deviance behaviors, as suggested by Pinto (2014) and Davis and Pinto (2022), where the failure of governance and gradual accumulation of missteps, and post-hoc rationalizations ultimately lead to a catastrophic event or significant disruption to the organizational system. Creeping disruptions are particularly dangerous to projects because it may be impossible to fully identify the latent conditions under which these disruptions germinate, forcing a completely reactive response to quickly assess and, if possible, resolve or mitigate a disruption for which no warning was received.

Besides the categorization of sudden and creeping disruptions, one could differentiate, for instance, between internal and external disruptions (Iao-Jörgensen, 2023; Ramezani and Camarinha-Matos, 2020), known and unknown disruptions (Iao-Jörgensen, 2023), expected and unexpected events (Geraldi et al., 2010; Söderholm, 2008), and between controllable versus uncontrollable disruptions (Franke et al., 2022).

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 disruptions and some examples. While both sudden and creeping disruptions can be internal or external, generally external disruptions are more likely to be unexpected than expected.

Table 1. Classification of Disruptions with examples

	Internal		**External**	
	Expected	**Unexpected**	**Expected**	**Unexpected**
Sudden	Technical issues	Resignation of a key team member for personal reasons	Building in an area prone to seismic activities or political uprise	Natural disasters; change in government regulations (force majeure)
Creeping	Decline in team morale	Slow shift in project requirements	Working with suppliers in geographically distant locations	Long-term economic downturn

Effective project management involves identifying, assessing, and developing strategies to mitigate different types of disruptions, regardless of their origin, to ensure project success in the face of unexpected challenges. However, generally, the goal of risk management is to proactively mitigate the occurrence of predictable events and, if they do occur, provide strategies to minimize their impact. This approach, however, may "produce an over-reliance upon strategies of anticipation and deflect attention from the need to build resilience into organisations to deal with the unexpected" (Loosemore, 1998, p.140). In this paper we will emphasize the disruptions that are unexpected. Expected disruptions are easier to identify and can be dealt with by traditional risk management methods. 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 projects and improving projects' ability to respond to disruptions.

3. Responses to Project Disruptions

Disruptions can create different outcomes in a project, ranging from irreparable loss of value (i.e., project termination) to opportunistic value creation (e.g., new features, functions, cost savings, etc.). Whether a project loses/gains value because of a disruption depends on where the project sits in the antifragility hierarchy. This hierarchy covers four project system types and ranges from fragile at the lowest level, to robust, to resilient and then to antifragile at the highest level. Figure 1 visualizes the different project system types. The higher the project sits in the antifragility hierarchy, the better it is able to respond to disruptions and have a positive impact on the project overall value. This section describes how each of these project system types behaves when encountering a disruption and highlights key characteristics of each project system type.

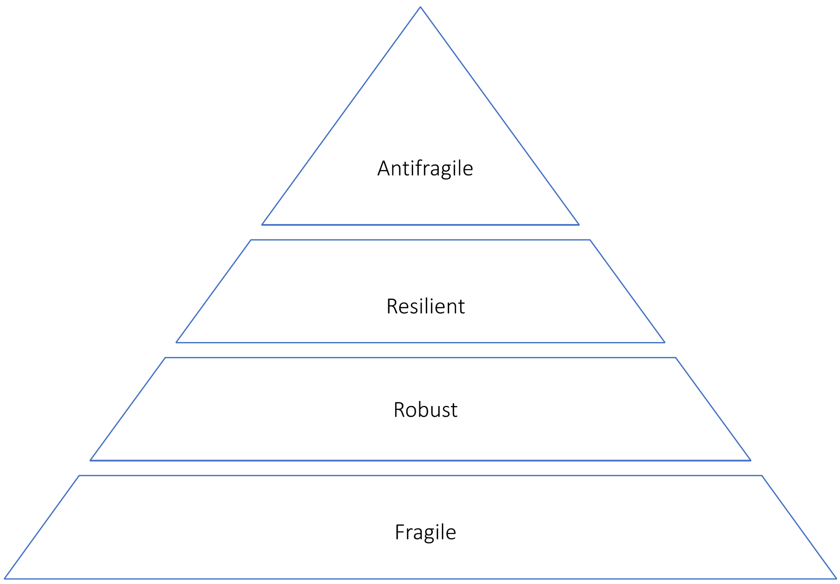

Figure 1. Antifragility Hierarchy showing different project system types

3.1 The Fragile System

A fragile system loses value when exposed to disturbances and never recovers. The core characteristic of fragility is related to the system's vulnerability to environmental variability beyond a predetermined threshold (Taleb and Douady, 2013). This will typically result in irreversible loss of functionality (Ansar et al., 2016). 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. Key characteristics of fragile systems include vulnerability, sensitivity to change, lack of redundancy, rigidity, and complexity. For example, 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. The literature identifies a range of sources for a system's fragility, these include:

- *Intrinsic fragility* relates to inherent aspects of fragility such as over-optimistic planning or inadequate risk assessments (Flyvbjerg et al., 2002).
- *Inherited fragility* concerns interconnected elements (Taleb and Douady, 2013). An example of inherited fragility is supply chain dependencies. If a project relies heavily on a single supplier for critical materials or components, disruptions in the supplier's operations can impact project timelines and costs.
- *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).
- *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. In a project setting, where fragility occurs, it is a failure of either the underlying project management systems, or of identifying solutions to address the newly disrupted state, or both.

3.2 The Robust System

A robust system is a project system that can withstand disturbances without losing value. Robustness exemplifies projects' capacity to withstand various disturbances (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). 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 (Munoz et al., 2022).

As highlighted by Johnson and Gheorghe (2013), the literature frequently conflates the notions of reliability and robustness, despite a significant distinction between them. A system can be considered reliable if it can remain unchanged within the bounds of the established system limits, whereas it is considered robust if it remains unchanged outside of the established system limits. In the context of a construction project, reliability means adhering to predefined limits and specifications, such as staying within the budget and completing the project on time. Robustness, on the other hand, involves the project's ability to adapt and absorb disruptions, like unexpected increases in material costs, while still achieving its objectives within the set limits.

From the literature, we were able to identify four other characteristics of a robust system. These are resistance, redundancy, diversity, and fault tolerance.

1. 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-Mators, 2020, p.16).
2. Redundancy refers to "everything that is not essential for the immediate functioning of a system" (Giezen et al., 2015, p.171). A project would have multiple systems that perform the same function such that if one system fails another can take over without losing its functionality (Giezen et al., 2015; Ramezani and Camarinha-Matos, 2020).
3. Diversity is also based on the notion of having extra components or systems in place to reduce the risk of a single point of failure and ensure continued functionality (Aven, 2015). However, diversity is more often related to the soft systems in projects, that is, the people and their skills and work styles (Ramezani and Camarinha-Matos, 2020).
4. Fault tolerance is often associated with the capacity of an infrastructure network and the ability to maintain acceptable levels of service when affected by a disruption (Madni and Jackson, 2009). It is often considered in software projects (e.g., Russo and Ciancarini, 2017).

3.3 The Resilient System

A resilient project system loses value when exposed to disturbance, but it can regain that value over time. According to Munoz et al. (2022, p.183) "resilient systems can recover to acceptable levels after experiencing performance degradation".

Naderpajouh et al. (2020, p.5) define “project resilience” as “the capacity to organize under a variety of scenarios, including disruptions in the form of shocks or stressors,” similar to Rahi (2019, p.73) who consider resilience as an adaptive capacity and “the ability to return quickly to its equilibrium point once faced with a disruptive event.” In contrast, “resilience of projects” is defined as “a form of temporary organizing to respond to disruptions and build long term resilience at the level of individuals, teams, projects, organizations, supply chains, or societies” (Naderpajouh et al., 2020, p. 5).

Piperca and Floricel (2023) propose three key viewpoints regarding project resilience. First, the strategic perspective focuses on risk in a VUCA project environment, designing flexible and generative structures termed “project governability.” Second, the *complex* system view sees project resilience as stemming from enduring structural characteristics that either facilitate or constrain the project’s ability to respond to shocks or stresses beyond expected boundaries. Third, the *organizing process* considers resilience as an ongoing organizational procedure in response to disruptions, portraying this process as a rebound life cycle.

A resilient system shares the characteristics of a robust system. However, in addition to these robust elements, resilient projects go further. The behavior of resilient systems described above highlights some of these additional key characteristics, i.e., adaptability, recoverability, and flexibility.

Adaptability is the capability of a system to adjust or modify in response to disruptions or external and internal change (Iao-Jörgensen, 2023; Ramezani and Camarinha-Matos, 2020). “Resilient systems don’t fail in the face of disturbances; rather, they adapt” (Fiksel et al., 2015, p.11). Adaption implies the system has emergent and potentially self-organizing capability (Anderson, 1999; Dahlberg, 2015). *Recovery* suggests that, although the system may initially lose value when impacted by a disturbance, the adaptation 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). *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 identified flexibility as a key attribute albeit in different context, e.g., in organizational resilience (Lengnick-Hall et al., 2011), supply chain resilience (Fiksel et al., 2015; Schmitt and Singh, 2012), or business ecosystem (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, 2011; 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 projects 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) are 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; Linnenluecke, 2017; Turner and Kutsch, 2015).

3.4 The Antifragile System

The antifragile system loses value when exposed to disturbances but can gain additional value over time. Taleb (2012) introduced the term "antifragility" to explain his idea that the opposite of fragile is neither robust nor resilient. Something is referred to as antifragile if it *can* also "gain, get stronger, improve, evolve and adapt better" from perturbations (Blečić and Cecchini, 2019, p.174). With antifragility, the potential for negative outcomes is limited, while the chances of positive outcomes are distributed exponentially (Derbyshire and Wright, 2014). It is important to highlight that the focus of this definition is the end-state of the project, not the measure of value at the time the disruption occurs. While antifragile systems may face negative impacts initially, their overall response to adversity is positive. Thus, an antifragile system improves through stress (Bendell, 2017).

Hirschman's (1967) theory of the Hiding Hand is popular in the project environment (Flyvbjerg, 2016) and, in practice, it has been considered a precondition for antifragility within projects. As Anheier (2016) notes, there are two dimensions to the Hiding Hand; the first is ignorance or underestimation of the complexity, challenges, and difficulties that the project is likely to encounter. The second dimension is ignorance or underestimation of the planner's problem-solving capabilities. That is, the enormity of many of these undertakings makes it impossible to see the challenges that lie ahead, and this ignorance makes us unduly optimistic. Hirschman also believed that in the face of such uncertainty, we routinely underestimate our capacity for generating creative solutions to problems. For antifragility to occur it requires a disruption (which may be the result of ignorance or underestimation of the complexity, difficulties, or challenges) plus a creative response in the face of this new uncertainty.

An antifragile system shares characteristics with robust and resilient systems, but in addition it has some key characteristics of its own. From the description of the antifragile system above we can derive *positive convexity* as a key characteristic. Positive convexity is a nonlinear response to disruptions and is the technical name for antifragility. A positive convex system becomes stronger, more resilient, or more valuable when exposed to challenges or shocks. "For the antifragile, shocks bring more benefits (equivalently, less harm) as their intensity increases (up to a point)" (Taleb, 2012, p.271). Thus, benefits increase exponentially over time. Positive convexity in a project context allows the project to benefit disproportionately from favourable changes or opportunities, leading to an accelerated increase in returns. 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 2 illustrates this positive convexity and asymmetry in gain and pain.

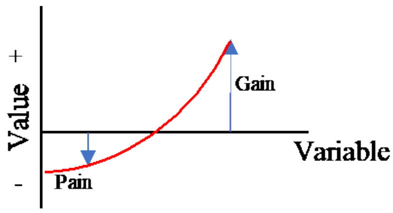

Figure 2. Positive convexity

This feature is closely related to another core characteristic of antifragility, i.e., *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 positive convex nature of antifragility), emphasizing the system's ability to evolve, improve, and gain benefits, even in terms of providing options, over time.

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-Jörgensen., 2023). We follow here Blečić and Cecchini's (2019) classification of "evolutionary resilience" (e.g., Davoudi et al., 2013) and "transformative resilience" (Dahlberg, 2015) as antifragility, as it goes beyond the traditional aims of resilience.

4. The Antifragility Hierarchy

4.1 Impact of disruption on project value

The previous section described how different project system types respond to disruptions. A summary of these behaviors and their result on the value of the project is presented in Table 2.

Table 2. Systems on the Antifragility Hierarchy

System type	Description	Resultant impact on value	References
Fragile	Lose value when exposed to disturbances and never recover	Negative	Ansar et al., 2016; Blečić and Cecchini, 2019; Jones, 2014; Taleb and Douady, 2013.
Robust	Able to withstand disturbances without losing value	Nil	Dahlberg, 2015; Dubey et al., 2017; Durach et al., 2015; Hillson, 2023; Munoz et al., 2022; Johnson and Gheorghe, 2013.
Resilient	Lose value when exposed to disturbances but can regain that value.	Nil	Anderson, 1999; Dahlberg, 2015; Hällgren et al., 2018; Kutsch et al., 2015; Turner and Kutsch, 2016; Munoz et al., 2022; Naderpajouh et al., 2020; Nikookar et al., 2021; Piperca and

			Floricel, 2023; Rahi, 2019; Shen and Ying, 2022; Sutcliffe and Vogus, 2003
Antifragile	Lose value when exposed to disturbances but can gain additional value over time.	Positive	Anheier, 2016; Bendell, 2017; Blečić and Cecchini, 2019; Derbyshire and Wright, 2014; Hillson, 2023; Taleb, 2012

This hierarchy provides a framework for understanding and predicting project successes, failures, and opportunities for special payoffs. The responses to disruptions of the different project system types can also be represented graphically as shown in Figure 3.

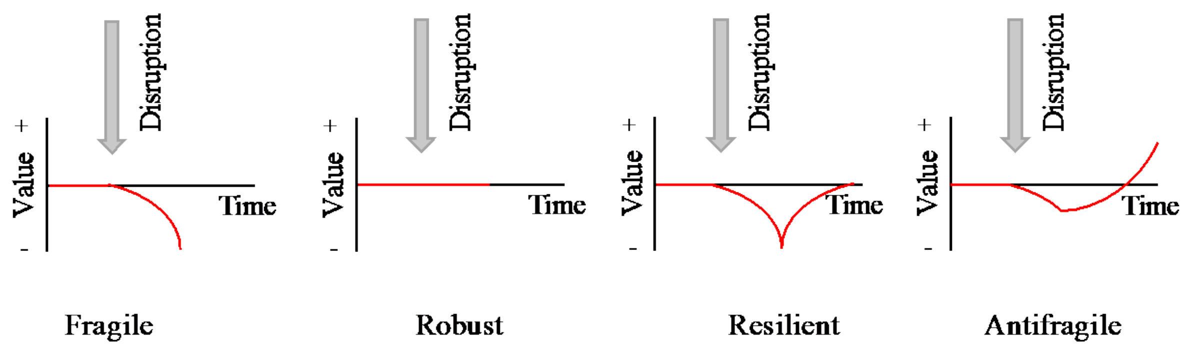

Figure 2. Project system responses to disruption

At the lowest level of the hierarchy, there is fragility, where systems permanently lose value, while at the highest level, we find antifragility, characterized by the potential for 'upside gain' as these systems gain additional value over time. Robustness is considered an intermediate state between the fragility and antifragility levels (Derbyshire and Wright, 2014). The same could be said for resilience. Robust systems are insensitive to uncertainty and remain unchanged, while resilient systems initially face performance degradation but recover lost value and, in some cases, improve performance.

It is important to recognize some of the key similarities and differences between these behaviors on the antifragility hierarchy, particularly the differences between robust and resilient, and between resilient and antifragile. Something is considered robust or resilient when it demonstrates significant indifference to perturbations. 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 and antifragility share some similarities, the most notable being that both could result in improvements. However, the source of improved performance differs (Hillson, 2023). 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. Moreover, the improvements gained from resilience are marginal and efficiency focused, while those from antifragility are more significant. Antifragile systems will really thrive and grow when exposed to volatility, randomness, disorder, and uncertainty (Munoz et al., 2022).

4.2 Characteristics of the Project System Types

To facilitate the classification of projects at the different levels of the antifragility hierarchy, and hence to assess a project's ability to manage disruptions, it is useful to consider the key characteristics of the different systems starting with the lowest level of fragility up to the highest level of antifragility. So far, the literature has focused mainly on resilience, and mostly in ecological, organizational, engineering, economic, or supply chain context (Rahi, 2019; Ramezani and Camarinha-Matos, 2020; Turner et al., 2020). Studies at the project level are far fewer.

Figure 4 illustrates the main characteristics at each level of the antifragility hierarchy. The pyramid structure implies that project system types at the higher levels of the antifragility hierarchy contain the characteristics and capabilities of the lower levels plus the characteristics for that specific level. This means that the higher the level on the antifragility hierarchy, the more characteristics the project system type has to have. For instance, adaptability is a characteristic of a resilient system, as well as of an antifragile system, but the level of adaptiveness increases if one moves to the level above. Similarly, robust, resilient as well as antifragile organizations possess redundancies.

Most studies so far have focused on one specific project system type. 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 as a pyramid model, 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).

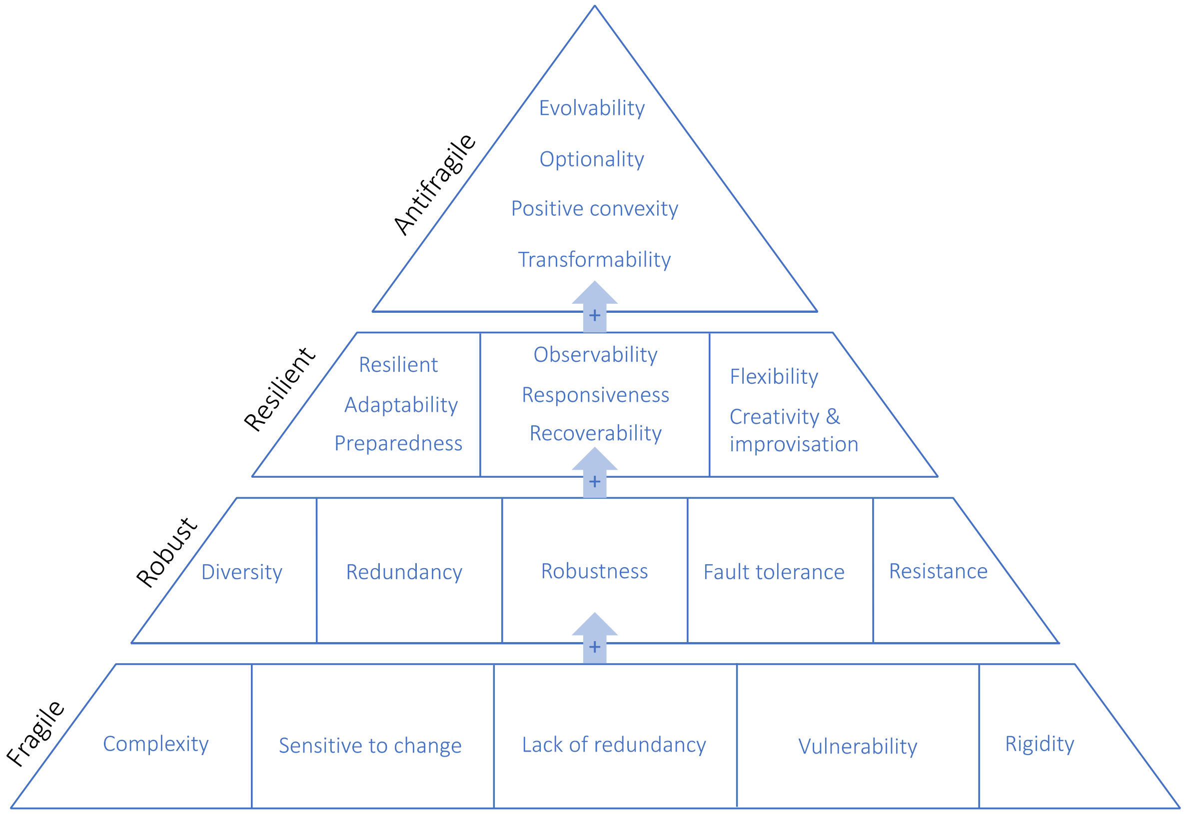

Figure 3. Antifragility hierarchy showing different characteristics for project system types

5. Strategies for Embracing Antifragility

The above set of characteristics in the antifragility hierarchy is a first step towards building antifragility into projects. This hierarchy can be used to select strategies to enhance their features and move towards the antifragility level of the hierarchy.

There are a range of preparatory strategies that can be adopted to increase the probability of a project achieving antifragility. Note that the focus is on preparatory strategies rather than preventative strategies due to the non-predictability nature of disruptions in a VUCA environment. 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.

5.1 Preparatory Strategies

5.1.1 Simplicity strategies

Given the fragility often observed in complex systems, it becomes imperative to prioritize the objective of simplification as a fundamental approach to build antifragile systems. Adopting simplicity strategies can result in a less complex system that is better able to respond to disruptions, is more flexible, and can better adapt to changing circumstances.

Subtraction. Taleb (2012) refers to "subtraction," which aims to remove unnecessary elements or reduce complexity from a system to make it more resistant to shocks and disruptions. This is related to his concept of "*Via Negativa,"* which is focused on removing the negative or harmful elements, rather than adding or optimizing positive ones. Taleb believes reducing exposure to harm or fragility can be a more effective strategy than trying to predict and control outcomes. By practicing scope management and actively removing unnecessary elements or features that don't align with the project's core objectives, project managers can simplify the project's scope and reduce the risk of disruptions.

Less is more. The "less is more" rule as introduced by Taleb (2012) is a key component of simplicity. This "less is more" rule has long been recognized in decision making where simpler methods of forecasting can work much better than complicated ones. 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). Complex adaptive systems, like projects, operate based on a limited set of order-generating rules, or heuristics (Burnes, 2005; Love, et al., 2022). 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). Based on a case study of the Beneluxlijn, a metro megaproject in the Netherlands, Giezen (2012) shows how simplification to reduce uncertainty can be very beneficial.

5.1.2 Development strategies

Building optionality. By incorporating optionality into a system or organization, you enhance its ability to adapt and benefit from unpredictable opportunities while mitigating potential harm from unforeseen threats (Russo and Ciancarini, 2017). 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. Stage-gate processes, additionally, offer development "break points" for reassessment, ensuring project objectives continue to align with stakeholder goals, and the opportunity to consider alternative options (Cooper, 1990).

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 means to reduce complexity (e.g., 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. For instance, constructing a new nuclear power plant like Hinckley Point C in the United Kingdom can be considered as being built with a modular design, where one unit is installed first, after which the second unit is installed. This approach allows the project system to adopt new processes and strategies, evolve and transform over the duration of the project.

Optioneering. Leaving a project with a full and diverse set of options (i.e., "total options"), although creating complete antifragility, is unlikely to be a suitable course preparatory strategy. Usher (2021) argues that project managers should filter options so that only those options that propel the project towards its end goal are considered by stakeholders, while simultaneously removing options that will detract from the final objective. He calls this process "optioneering" and explains that effective optioneering requires project managers to find a balance between a single course of action (a fragile state), irrelevant activities (that create no value), and too many potential actions (which creates confusion). Project managers apply the process of optioneering, 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 in particular projects (Derbyshire and Wright, 2014). 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.

5.1.3 Learning strategies

Learning strategies encompasses approaches that emphasize continuous learning, iterative experimentation, and the rapid identification and correction of failures.

Small-scale experimentation or trial and error. Small-scale experimentation or trial and error 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. Similarly, Gorgeon (2015) argues that trial and error can create new knowledge and information which helps to improve the system overall. This is particularly the case in an investment situation, where an initial small experimental investment can provide the opportunity (option) later to decide whether to proceed with or halt a specific project. This strategy is frequently adopted in software development projects.

Fail fast. The concept of fail fast involves a process of experimentation, in which ideas are developed and tested quickly to determine their viability. The fail-fast strategy is most easily recognized in the Agile methodology where multiple simultaneous project options, immediate feedback on interim technical results, and the cancellation of some project options to quickly divert resources to more promising ventures are commonplace (Khanna et al., 2016). Three key features of an effective fail-fast strategy are: (i) a focus on product-market fit ventures, or those for which a customer base was already established, along with a business plan; (ii) a focus on time-compressed scaling, or packing high growth into a shortened time period; and (iii) a focus on aggressive scalability testing, or the recognition that accelerated successes or fast failures are equally helpful learning devices provided data can be quickly mined from the venture (Shankar and Clausen, 2020). Assessing projects on these features allows firms to identify promising features in a set of new projects and not simply *absorb* but benefit from the inevitable disruptions of failed efforts by swiftly rechanneling energy and resources to more promising opportunities.

Adopting Agile. Agile methodologies, such as Scrum or Kanban, are rooted in principles that align with the concept of antifragility. These approaches emphasize breaking down work into small, manageable iterations or increments. This iterative development allows teams to quickly respond to changes, gather feedback, and adapt their approach accordingly (Serrador and Pinto, 2015). By embracing change and volatility, agile teams build resilience and create opportunities for antifragility. Agile also fosters a culture of continuous learning and improvement where teams regularly reflect on their work, identify areas for improvement, and experiment with new ideas. It views failures as learning opportunities. By permitting failure, agile teams develop the resilience to bounce back stronger and become more adaptable. Rather than trying to predict and control every aspect of the project upfront, agile teams embrace these uncertainties and focus on delivering value incrementally. Moreover, agile methodologies emphasize the importance of metrics and feedback loops. Teams define relevant metrics to measure progress, gather feedback from stakeholders and customers, and use that feedback to continuously improve their work. These feedback loops provide valuable insights that help teams become more antifragile by identifying areas for growth and adaptation.

Spotify, the music streaming platform, has embraced both agile methodologies and the principles of antifragility to drive innovation, adapt to market changes, and maintain a competitive edge. Spotify work in small, cross-functional teams called squads, which are empowered to make autonomous decisions and iterate on their work continuously. This structure and mindset 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. This collaborative structure strengthens the organization’s resilience and ability to navigate changes effectively.

5.1.4 Risk and opportunity strategies

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). For example, in consultation with the project sponsor, you have agreed on the priorities for a project to develop a new mobile cell 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, 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), provides the greatest opportunity for benefit by enhancing speed to market.

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 have 'skin in the game' and 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 regard 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 forecasters skin in the game to provide better incentives for accuracy in cost-benefit forecasts.

Considering Black Swans: Black swans are extreme events that are characterised by the triplet: rarity, extreme 'impact', and retrospective (though not prospective) predictability (Taleb, 2007). 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 ones 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.

The different strategies have highlighted how they can provide project systems with additional resilient or antifragile characteristics. Table 3 provides a summary of these characteristics for each strategy.

Table 3. Strategy matrix: characteristics gained per strategy

	Robust system characteristics	*Resilient system characteristics*	*Antifragile system characteristics*
Simplicity			
Subtraction	Resistance	Flexibility, adaptability, responsiveness	Positive convexity
Less is more	Resistance	Flexibility, adaptability, responsiveness	
Development			
Building optionality	Robustness	Flexibility, adaptability, responsiveness	Positive convexity, optionality, evolvability, transformability
Modularity	Robustness, fault tolerance	Flexibility, adaptability, responsiveness	Positive convexity, optionality, evolvability, transformability
Optioneering	Diversity, redundancy	Flexibility, adaptability, responsiveness	Optionality, evolvability
Learning			
Experimentation	Fault tolerance, redundancy	Creativity and innovation	Optionality, evolvability
Fail fast	Fault tolerance, redundancy	Creativity and innovation	Evolvability
Agile	Robustness, redundancy	Adaptability, responsiveness, creativity and innovation	Evolvability
Risk and opportunities			
Barbell strategy	Robustness, redundancy	Preparedness	Positive convexity, transformability

Skin in the game	Robustness, redundancy	Preparedness	Positive convexity
Black swan management		Preparedness	Transformability

5.2 Aligning Strategies with Fragility Sources

In the previous section we have described various preparatory strategies that can be adopted to acquire certain project characteristics, strengthening the project system against disruptions. In this section, we delve into the ways in which various strategies can be employed to mitigate different sources of fragility. Table 4 provides a summary overview of the strategies and the types of fragilities they can address.

Table 4. Strategies' ability to deal with fragility

	Intrinsic	*Inherited*	*Apparent*	*Hidden*
Simplicity				
Subtraction		✓	✓	
Less is more		✓	✓	
Development				
Building optionality	✓	✓		
Modularity	✓	✓	✓	✓
Optioneering	✓	✓	✓	✓
Learning				
Experimentation	✓			✓
Fail fast			✓	
Adopting Agile	✓		✓	✓
Risk and opportunity				
Barbell strategy	✓	✓	✓	
Skin in the game			✓	
Considering Black Swans				✓

Simplicity strategies are generally best able to deal with inherited fragility. They are focused on removing elements from the system, thus reducing complexity and the interconnectedness between elements that causes inherited fragility. Simplicity strategies can also be helpful to deal with apparent fragility. Simplicity 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.

Development strategies contribute to managing intrinsic fragility. They help with the inherent uncertainty that projects face in a VUCA environment by providing flexibility in project plans addressing the intrinsic fragility. For example, optioneering facilitates the exploration of alternative choices, helping enhance the adaptability of the project. Building optionality and optioneering are also valuable in managing apparent fragility, such as by allowing alternative plans to reduce perceived vulnerabilities. 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.

Learning strategies such as building in experimentation and agile working, provide powerful means to uncover intrinsic weaknesses by testing quickly and on a small scale how disruptions affect the project system. This approach can also help to remove perceived vulnerabilities that may not have a large impact after all. Through iterative feedback loops hidden fragilities can also be identified and mitigated.

Finally, barbell strategies provide a balanced and adaptive framework for dealing with different forms of fragility in projects. By utilising 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.

This section has shown that there are a multitude of different strategies that could be adopted to deal with various fragility types. Organizations should consider the source of fragility for their projects and assess their level on the antifragility hierarchy to decide which strategies would be most effective. For example, if inherited fragility is a major source of fragility and currently the project is at the robust project system level, simplicity strategies will be effective to reduce the complexity and make the project system more flexible, adaptable, and responsive to disruptions (moving on to the resilient system level).

Project managers could also consider these strategies during the different stages of the project life cycle. 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. On the other hand, learning strategies like experimentation, fail fast, and agile are most appropriate during the implementation and execution phases of a project. Lastly, risk and opportunity strategies can be applied iteratively throughout the project lifecycle. The barbell strategy involves continuously searching for a balance between the conservative and more high-risk strategy. Skin in the game can be adopted initially in the early stages of decision making, with key stakeholders actively participating and having a personal commitment to project success, but this remains a key strategy throughout the project life cycle.

6. Conclusions

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 four key responses to project disruption are shown as a pyramid, with a range of strategies available for addressing these disruptions. This hierarchy offers alternative conceptualization of responses to project disruption events, suggesting that the range of options available to organizations facing disruptions range from fragile (the least effective) to antifragile (the most constructive). Moreover, there are a range of preparatory strategies available to project organizations and their key managers, from simplicity, development, and learning strategies, 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 disruption events – either sudden or creeping – 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.

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