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THE CASE FOR ANTIFRAGILITY IN SAFETY

McKell W Sanderson
Capitol Technology University

Justin Thygerson
Capitol Technology University

Abstract

Nassim Taleb's "Antifragility" has caused a large stir in the world of finance and economics. It has gained popularity across many other disciplines as well, ranging from computer coding, to systems engineering, and even to online video streaming. One area to which it has not been applied is the safety profession. The safety profession operates on many "fragile" concepts, and antifragility provides a promising, and practicable solution. This article explores some of the sources of fragility that are found in the safety profession. The concepts of antifragility are developed, and the application of antifragility concepts are presented as possible solutions to the fragility challenges found in the safety profession.

Introduction

Risk Management has been a challenge in the safety profession for many years(Sanderson & Martin, 2022). From the beginning of the modern safety efforts, risk management has been a neglected topic in the safety profession. Unfortunately, when it has been incorporated, it has often been done incorrectly (Sanderson & Martin, 2022). Overcoming this risk management problem is a key to improving the safety profession. Many of the current challenges in safety, could be improved by a more complete utilization of risk management concepts and practices. These include incorporating the social psychology of risk, and the tools and methods associated with the social and psychological aspects of risk.

The risk management challenge, gives notion to the Black Swan problem in safety (Sanderson et al., 2022). Current methodologies, practices and approaches, can potentially increase this problem. A new paradigm is needed in the safety profession, one that focuses on the improvement possibilities, rather than the absence of negative occurrences. Negative occurrences are going to happen.

Taleb, the mathematician and author of The Black Swan, introduced the concept of antifragility as a means of dealing with the Black Swan phenomenon (Taleb, 2016). What is antifragility? Taleb explains the concept utilizing a package:

> Logically, the exact opposite of a "fragile" parcel would be a package on which one has written "please mishandle" or "please handle carelessly." Its contents would not just be unbreakable, but would benefit from shocks and a wide array of trauma. The fragile is the package that would be at best unharmed, the robust would be at best and at worst unharmed. And the opposite of fragile is therefore what is at worst unharmed (Taleb, 2016).

Taleb gives this phenomenon the name "antifragile." He explains that humans often confuse the opposite of fragile for robust, but concludes that the opposite of negative is not neutral, but positive (Taleb, 2016). Antifragile comes to mean that when things go awry, there is more upside than downside, especially in relation to Black Swan events.

There are many applications of antifragility, across a multitude of domains, that can all be traced back to Taleb. Antifragility is now common practice in system design, computer coding, and even in streaming video services (Basiri et al., 2016). The purpose of this article is to identify the concepts of antifragility, how to increase antifragility, and how to apply those principles to the safety profession.

Becoming antifragile

Antifragility principles can improve safety and risk performance. Following some simple rules can help create antifragility in an organization. Buster Benson offers 10 guidelines to becoming antifragile:

1. Stick to simple rules
2. Build in redundancy
3. Resist the urge to suppress randomness
4. Be wholly committed (have "soul in the game")
5. Take lots of small risks
6. Avoid risks that could not be recovered from
7. Do not get consumed by data
8. Keep options open
9. Focus on avoiding what does not work, more than finding what does work
10. Look for established and lasting ideas/methods (Benson, 2013)

Each of these rules can help to create antifragility. Simple rules are easier to follow, and eliminate more of the gray area than complex rules. Redundancy avoids single point failures in systems. Small risks foster innovation and new ideas, allowing for growth. Identify reversible decisions, and take risks with reversible decisions. The constant application of these rules will build a system that improves with uncertainty.

Netflix has been building antifragility in their operations. Netflix has an established program called "Chaos Monkey." Chaos Monkey is a program that randomly shuts down servers,

simulates power outages, cyber-attacks, and sends "terminate" commands to specific operations. The purpose of Chaos Monkey is to ensure that common failures do not affect the customer experience. Netflix purposefully tests their own systems by adding chaos. Netflix engineers are constantly monitoring the state of the system, because Chaos Monkey can strike at any time. It has allowed Netflix to build a streaming services that rarely sees interruptions for the customers due to technical difficulties on Netflix side of the operation (Basiri et al., 2016; Dumiak, 2021; Tseitlin, 2013).

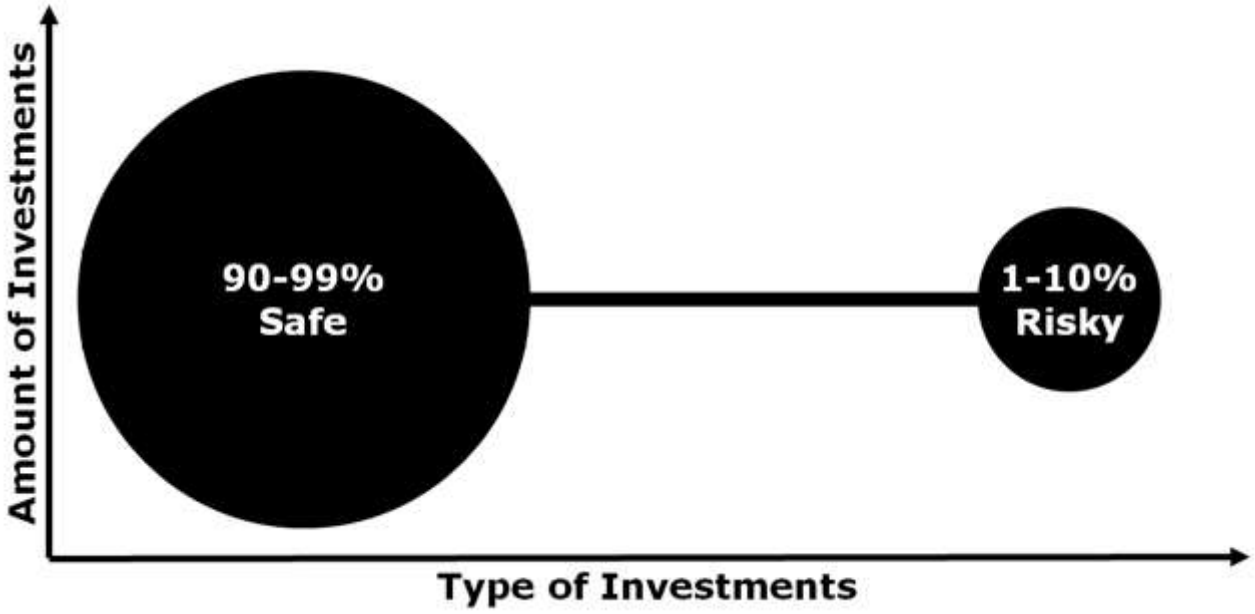
In addition to these general rules, some specific tools, methods, and approaches, will be discussed. The focus will be on how these methods could benefit the safety profession.

Barbell approach

Antifragility utilizes a simple tool, a "barbell," to approach situations of uncertainty (Taleb, 2016). The barbell is used to illustrate a bimodal strategy. Imagine a barbell (used in weightlifting), it consists of a bar in the middle, and weights on either end. The purpose of the strategy is to separate the extremes, and avoid the middle (Taleb, 2016). The barbell need not be symmetric, especially if the risks presented are not symmetric. In a simple sense, one side of the barbell should represent extreme risk adversity (avoidance/prevention of negative Black Swans) and the other side should represent extreme risk loving (open to growth from positive Black Swans). Remember, positive consequences can come from rare events as well, but organizations need to be prepared to act quickly. This approach is often seen in financial investments (see

Figure 1). The purpose of the bimodal strategy is to minimize exposure to ruinous events, while providing sufficient exposure to positive events.

Figure 1: Example of barbell, or bimodal, strategy in investments



Source: [Image from Seeking Alpha – http://seekingalpha.com/article/2843836-profiting-from-market-randomness]

In safety, it is difficult to imagine events with upside, because most events in the safety profession involve a loss. However, if the view changes from "who is to blame for this?" to "what can we learn from this?" then a potential for upside exists. This will require a fundamental paradigm shift, from 'assigning blame' to 'learning' (Conklin, 2019; Dekker, 2014). In the proverbial sense, this is making lemonade when handed lemons. This approach will not make the immediate situation better, but it can lead to improvement overall for the organization. As an example, a barbell style approach to incidents would involve a "Safety I" and "Safety II" style approach. The Safety I approach would involve traditional incident investigations, root cause analysis, and human factors approach (such as Behavioral Safety concepts), it would ask "why" did this occur? It would remain focused on the actual event that occurred. The Safety II approach would look at the system holistically, the culture, it would ask "how" did this occur? It would focus on the system, and how it failed to prevent the event from occurring. There is something to learn from both approaches, and while neither approach will prevent 100% of incidents from occurring, the combination of both approaches provides the greatest chance for the organization to improve past the neutral state.

One point that a barbell strategy will not address is a principle pointed out by Todd Conklin. He states:

> "Anytime something occurs in your organization you have two choices: You can blame and punish or learn and improve. The problem is you can't do both. Many leaders struggle with this idea." (Conklin, 2019)

Dr. Conklin is correct. This principle is nearly Newtonian in nature (for every action there is an equal and opposite reaction). If the organization observes that blame and punish is the objective, it will hinder all future efforts to learn and improve. There is a current focus in the safety

profession on "psychological safety" in the workplace, blaming and punishing destroys any sense of psychological safety (Carillo, 2020; Lloyd, 2020).

Barbell strategies can be applied to many scenarios. When they cannot be applied, a different approach must be considered. A direct application of the barbell strategy is in the acceptance or rejection of risk.

Eliminating or embracing risk

A fundamental idea across Taleb's essay is the complications caused by randomness (Taleb, 2004, 2010, 2016). Randomness, when it is distilled down, is just "fundamentally incomplete information" (Taleb, 2010). The inability to accurately forecast, specifically with large events (Black Swans) continually causes problems for "tidy minded organizations" and professions (Harford, 2016). How then, does one cope with randomness?

> "This is the central illusion in life: that randomness is risky, that it is a bad thing – and that eliminating randomness is done by eliminating randomness." (Taleb, 2016)

By definition, randomness is not completely known, but that does not make it a bad thing. Many discoveries and innovations have resulted from unknown occurrences (Viagra®, for example, was being tested for hypertension when the side effects were discovered and the drug was later remarketed) (Harford, 2022).

When it comes to safety, we often assume that the elimination of chance, is the end goal. Afterall, if the randomness is removed, probabilities can be calculated/identified with much better accuracy. In theory this concept reads well, but is impracticable, there is always an element of unknown. These ideas lead to the erroneous concept:

> "We commonly assume that safety is achieved by imposing rules and restricting the autonomy of management and workers" (Vincent & Amalberti, 2016).

This approach is still widely used in industries that Amalberti refers to as "ultra-safe" sector of industries (Vincent & Amalberti, 2016). These industries avoid risks, including the 'upside' risks that exist, by empowering regulators and supervisors to control all actions of the workers (Vincent & Amalberti, 2016). The "ultra-safe" industries have no need of innovation, because employees are treated as living robots. Employees simply repeat the same procedures throughout the shift. Many of the case studies that support the "old view" of safety come from the ultra-safe industries.

At the other end of the spectrum, Amalberti identifies "ultra-adaptive" industries. These industries focus on embracing risk, as well as potential rewards of innovation, by empowering the experts. The workers are viewed as the experts (Vincent & Amalberti, 2016), or sometimes reduced to the slogan of "people are the solution" (Conklin, 2019). Traditional safety interventions, such as policies, procedures, and others are not effective in this sector. Amalberti explains:

"The problem is that the constantly changing environment in which they work does not lend itself to managing risks by using rules and procedures" (Vincent & Amalberti, 2016).

The focus is placed on adaptation and recovery (Vincent & Amalberti, 2016). Many of the "new view" case studies come from this sector of industries.

A third part of the spectrum was described by Amalberti, the "high reliability" industry sector (Vincent & Amalberti, 2016). This sector is characterized by managing risks, which are not sought out, but are intrinsic to the operations. A focus on procedures and adaptability strategies is necessary for success in the is sector (Vincent & Amalberti, 2016). Operating at acceptable levels of risk, is the core focus of the high-reliability sector.

Amalberti's work suggests that portions of all three approaches should be utilized. This can best be done by breaking up tasks, rather than industries, and placing the tasks into the appropriate classifications. Tasks should be divided by their required risk tolerance. Does the task require embracing risk? Does the task require managing risk? Or does the task require avoiding risk? Risk tolerance, should be determined by the organization's risk appetite, and available mitigation techniques. Task based risk assessments, commonly utilized as "pre-task assessments" or "task hazard analysis" are not new. However, through the paradigm of Amablerti's "Three approaches to safety" (Vincent & Amalberti, 2016), task hazard analysis can present a new opportunity for growth and success.

Unfortunately, this particular strategy will require a lot of work. No generic template will be adequate. Tasks must be evaluated, and approaches must be created for each task. Policies will have to be specifically developed . Specific tasks will require the empowerment of employees, other tasks will require the empowerment of supervisors, while others still will require the empowerment of a group (Vincent & Amalberti, 2016). This is an immense amount of effort, but it allows the reaping of benefits, including the strategic risk-based benefits, hidden in many of the tasks. After all, "the road to robustness starts with a modicum of harm" (Taleb, 2016). Becoming antifragile requires embracing an element of risk.

Sources of fragility

Interventionism

Trying to prevent all harm, including the beneficial harm springs from naivety. People who try to intervene to stop all harm are referred to as "Naïve interventionists" by Taleb. An interventionist, is a person who does not "accept that things can improve without their intervention" (Taleb, 2016). A naïve interventionist may actually cause harm to the system by over intervening. Interventionists (including the naïve interventionists) are present in many fields, including safety.

Interventionists, tend to over intervene with minimal benefits (Taleb, 2016). In safety there is often a "checklist" mentality that reinforces this over intervention. Arguments can be made about the "improvements" of following this course of actions, but they are reactive. The organization may save money, but overall improvement is unlikely. This increases the fragility in the organization.

Other examples of over intervention include 'company wide policies.' Many large companies, often in the name of simplicity, create policies that cover all employees, regardless of tasks. To illustrate how this over intervention can be counterproductive, imagine a large complex workplace (University, Municipality, etc.). The workplace may have construction crews,

loading docks, ground/landscaping crews, and more. A single statement such as "fall protection is to be warn whenever a fall danger exists over 48 inches" will often be included into the fall protection policy/program. Perhaps a construction crew is working 60 inches off the ground, the Federal requirements do not require fall protection until 72 inches (in the construction industry), and it is not likely that fall protection will be worn. Efforts to be efficient introduce fragility, as OSHA can cite employers for not following their own procedures.

Counterintuitively, interventionists tend to under intervene when intervention is needed or beneficial (Taleb, 2016). Primary examples of this can be found in safety by simply looking at the second order effects (Li & Thimbleby, 2014). The primary intervention with minimal benefits is often enacted, and the second order effects, (where intervention would be useful or needful) is ignored. The safety profession is constantly striving for more and more interventions. This hyper-interventionism is partially driven by the safety profession's well-known need to "self-justify" its own existence.

> "There is an element of deceit associated with interventionism, accelerated in a professionalized society. It's much easier to sell 'Look what I did for you' than 'Look what I avoided for you.' Of course a bonus system based on 'performance' exacerbates the problem." (Taleb, 2016)

Interventions at a system level, such as those promoted by HOP or Safety Differently, often lead to a decrease in worker awareness (Harford, 2016; Sanderson et al., 2022; Taleb, 2016). As more and more control is removed from the worker, they become more placid, and this results in higher error rates, as observed with traffic signs (Vanderbilt, 2008). The question becomes one of "how does one know when to intervene?" One should establish a systematic protocol to make those determinations.

> "It is mostly about having a systematic protocol to determine when to intervene and when to leave systems alone" (Taleb, 2016).

Systems often improve on their own, and often are made worse by interventions. To decide when one should and should not intervene, create a protocol, and be consistent. Allow that protocol to force, or stay, the hand of intervention. Review that protocol, and its track record periodically. Interventions that do not produce desired results should be discarded, or modified. Antifragility implies that adding interventions should be reversible operations. Non-reversible interventions lead to problems with a concept known as "path dependence."

Path dependence

Many things in life are antifragile, in the sense that a little stress can make the system better. This is evident in many naturally occurring phenomena, such as exercising, recovering from a viral infection, businesses surviving when their competitors do not, etc. Stressors are needed to challenge the system, and help it improve. Over intervention, as mentioned previously, can rob a system of the stressors that are needed (Harford, 2016; Taleb, 2016). This tendency to over-intervene is further complicated by path dependence. Path dependent challenges arise when order of occurrence matters. For example, if one milks a cow, then butchers the cow, one ends up with both milk and meat. If one butchers the cow, before milking it, one ends up with only meat. The order of operation matters.

Path dependence cannot be separated from the concept of "ruin" (Taleb, 2020). Ensemble probabilities are useful when discussing the concept of path dependence and ruin. Ensemble probabilities are when a group of probabilities cannot be compared to a single participant sample. For example 1,000 people gambling for an hour is not the same probability as one person gambling for 1,000 hours. In the ensemble, any of the 1,000 participants can go bankrupt, while the rest will continue to gamble. In the single participant example, if they go bankrupt any hour, there will not be any additional games (Taleb, 2020).

Path dependency, and ruin, cause significant challenges for safety. One cannot simply wait for serious injuries to occur, that is not ethical. This path dependency is rooted in the very core of the "target zero" initiatives. Target zero initiatives have been widely studied and show many negative effects (Long, 2012; Sanderson et al., 2022; Sherratt & Dainty, 2017).

The concepts of antifragility remind one to be aware of the dynamic nature of the systems. Path dependency, can also shift in a dynamic system. Second order thinking, understanding the dynamics of the system is crucial for managing the system (Aven, 2015). This includes path dependent interventions and outcomes.

If misapplied, both interventionism, and path dependency can lead to fragility.

Theories and interconnectedness

Fragility tends to increase as systems grow larger (Taleb, 2016). This concept is familiar to any toddler who has built a tower of building blocks, the taller it grows the easier it falls. In a non-physical sense as systems grow larger, they have a tendency to become more and more complex. This complexity, can lead to increased fragility as well.

Safety is complex. Safety as a profession has grown from an ad hoc style approach. Each piece of the safety puzzle has been identified, developed and customized, in a million different laboratories. Safety continues to experience this ad hoc nature, but with the internet, professional networking sites, and professional practice societies, the different ideas are becoming inseparably entwined.

Each idea is tested and proved in a workplace. The success stories are written as case studies, and shared via academic journals and business books. As these ideas grow, and move from case studies to theories, fragility is introduced (Taleb, 2016). Theories as fragile, phenomenology is robust. Theories are fragile because they come and go, and they are constantly changing. Theories can never be proven true, and this makes them inherently fragile. The rule to "focus on things that don't work rather than trying to find what does work" (Benson, 2013) is the practical application of the fragility of theories.

It is the generalizing, the 'guessing at why' that introduces fragility. Those observed phenomena, tend to be antifragile. Somewhere along the development, the scientific method of hypothesizing and testing that hypothesis has given way to hypothesizing and theorizing about why the hypothesis holds up or does not. As systems and interventions are built upon fragile theories, fragility in the systems or interventions will result.

Confusing catalysts for causes

Another source of fragility is the confusing of catalysts for causes. In chemistry, a catalyst is a compound that increases the rate of a chemical reaction without being consumed itself (Define Catalyst - Google Search, n.d.). Catalysts often function by lowering the activation energy for a given reaction. The catalyst-for-cause confusion is a direct obstacle to Heinrich's "Domino Theory" or, more generally, root cause analysis.

Anyone who has been involved in the debate between Safety I and Safety II has confused catalysts for causes. That is largely why there is a debate as to which approach works better! Both approaches focus on a catalyst in the scenario, but equate it to a larger cause. The lack of repeatability in social science experiments is a direct effect of confusing catalysts for causes.

This concept is widely evident during root cause analysis. Oftentimes, contributory events (catalysts) are misidentified as root causes. Without the catalyst, the final outcome perhaps would not occur, but the catalyst is not an actual cause of the event. The catalyst acts as a multiplier on the probability that an incident will occur, without actually causing the event to occur. Colloquially this is argued as "correlation alone is not causation." Root cause analysis frequently results in a catalyst-for-cause confusion.

Root cause analysis, especially regarding human behavior is also the victim of yet another source of fragility. The over-simplifying of human behavior.

Overly simplifying human behavior

In order to create theories, social scientists need to define a default behavior. The introduction of "rational" behavior has become commonplace in the social sciences because it defines a default behavior. Economists, business professionals, safety professionals, and others, have all accepted the idea of rational behaviors. In spite of acceptance across the social sciences, many articles highlight the shortcomings of rational behavior theory in specific disciplines (Vriend, 1996). Rational behavior is defined differently in different disciplines, but in all disciplines the simplification of behavior down to a construct of "rational" is at best, a poorly defined concept, or at worst, an outright fallacy. This simplification takes something abstract, interconnected, and nonpredictable, and reduces it to an algorithm. It has a terrible track record, even in disciplines where it tends to be more rigorously defined, such as economics (Taleb, 2016). It is a difficult exercise for a safety professional, but one should ask oneself "what is rational behavior in safety?"

This challenge is particularly unique in safety, because safety itself is poorly defined. How can one act rationally regarding safety, when many cannot even define safety? In economics, which is much easier to define, rational behavior is often defined as "acting in the manner that optimizes one's gains" (Taleb, 2010). The challenge for economics is simply that not all humans view optimization as the same goal! Some are interested in maximizing profits, while others are interested in reputation, and others still interested in time. This simplification of behavior to something termed 'rational' is necessary to allow for predictions. However, the old adage "garbage in, garbage out" still applies. If the assumptions that people will behave in a rational manner are necessary for the model, that model is useless in the real world. Furthermore, in safety, the concepts of rational behavior have to be based on a proxy. Arguably, no one ever intends to be injured. Yet workers trying to act rationally are injured every day.

Safety organizations across the world have begun to realize this. Originally, many of these organizations were aimed at helping the worker remember to stay safe at work. Slogans such

as “Be alert, don’t get hurt” were commonplace. Over the previous years, campaigns such as “why do you work safe?” or “Be safe, your family is expecting you” campaigns have tried to help workers recognize that their safety matters to others. None of this points to “rational behavior” in safety. The very concept of rational behavior in safety has a tendency to “blame the worker.”

In the context of “optimizing” for rational behavior in behavior in safety, that has led to many of the “safety culture” or “safety climate” discussions. Behavioral safety practitioners focus on the concepts of consequences (Geller, 2005), and utilize those as a venue for optimization. It seems simple to understand rational behavior if workers are simply optimizing their consequences, but that turns out to be untrue. It is not simple, as consequences that motivate many, do not motivate all.

Behavior is an event that is “produced by interdependent systems and… therefore not statistically understandable at the individual level” (Aven, 2015; Taleb, 2016). Behavior in safety is heavily influenced by, or perhaps results from, the social psychology of risk (Long, 2019). It is not simply a linear cause-and-effect phenomenon. The social psychology of risk is a view, championed by Dr. Robert Long, that focuses on the impact that the social psychology, the study of how socially arranged conditions impact behavior, has on risk. Social psychology is observable all around, think of how one acts when their boss is present, versus how they act around an old high school friend. Who is around, or even who is perceived to be around, will have an impact on the behavior of the individual (Long, 2019).

Fragility can come from many sources, a few are mentioned above, many more have not been included. Antifragility, as the opposite of fragility, requires organizations to avoid fragility introducing concepts where possible.

What antifragile safety is not

It is important to highlight that organizations cannot be antifragile in all things. The tradeoff to becoming antifragile in one area will often cause fragility in another (Taleb, 2016). Companies that focus on the elimination and control of human error become fragile to changes in the system (Sanderson et al., 2022). If pursued to aggressively, antifragility will become a hindrance to your safety culture.

Any virtue, even a perceived virtue, becomes a vice if taken too far or too seriously. For example, measuring performance (gathering data) can be important. However, if goals are set on those gathered data and they become a metric (or a goal) those can become detrimental to organizations (Harford, 2016, 2022). Examples of metrics becoming goals, with unintended consequences abound in safety, as well as other areas. In safety, metrics often are used in performance incentives. OSHA recognizes that “safety incentives” have repeatedly led to underreporting of injuries (Clarification of OSHA’s Position on Workplace Safety Incentive Programs and Post-Incident Drug Testing Under 29 C.F.R. §1904.35(b)(1)(Iv) | Occupational Safety and Health Administration, n.d.). Once a useful measure is set as a goal, it ceases to be a useful, or valid measure (Harford, 2016). Safety has a history of over pursuing good ideas, and creating vices. Some specific examples of metrics becoming detrimental to organizations:

Effort is spent on counting the number of people trained, rather than verifying that learning occurred.

Days away restricted or transfer (DART) rates. In an effort to keep this number low, some employer's force employees to schedule surgeries on weekends, after work, and then recover over the weekend when work days are not missed. These are followed by an employer provided shuttle to the jobsite where they work for a couple of hours, before being shuttled home. While these interventions are often done legally, they give an artificially low number to the DART rate. Other rates can suffer from similar manipulations. Perhaps an additional reason that TRIR was deemed to be "statistically invalid predictor" of company performance (Hallowell et al., 2021)

If antifragility is over pursued, it too can lead to detriment. Antifragility is not meant to be a silver bullet for the safety profession. It is not meant to replace behavior-based safety or human and organizational performance, or any other safety theory. Antifragility is simply meant to add to these.

The concepts of antifragility are to look at what is currently being done, identifying weaknesses, and hedging the bet that a system can handle everything. Engineering chaos into your system and seeing how it performs. Antifragile concepts require implementing an "improvement over time" paradigm (Aven, 2015). Accomplishing these goals will require good data, attention to feedback loops, and an unlearning of much of what you currently believe.

Antifragility is unable to completely eliminate risk, and it is not attempting to do so. Amalberti stated:

> "Errors will inevitably occur, [people] will sometimes be harmed and the best we can hope for is to respond quickly and minimize the damage" (Vincent & Amalberti, 2016).

Antifragility, is focused on continual improvement, especially after a loss, to become better in the future. "The idea of a single model of safety that applies to everything and aims to have zero accidents is too simple" (Vincent & Amalberti, 2016). Single models are overly simplistic. Single models are also irresponsible (Sanderson et al., 2022; Sherratt & Dainty, 2017). Even antifragility, in all of its complexity and adaptability is not a single model sufficient to solve all safety challenges.

Conclusion

Antifragility helps create a framework for continual learning, improvement, and risk control that safety needs. It is not a magic bullet meant to solve all problems, but rather another tool for the safety professional to utilize. Antifragility should help drive continual improvement. Further research is needed to quantify the proposed gains. Second order reviews are needed to ensure that the proposed framework does not create further unintended consequences. In spite of the necessary follow-up, antifragility concepts do add to the practice of risk management (Aven, 2015). The barbell strategy, can be of particular use, and is easy to implement into operations quickly.

Antifragility concepts have spread rapidly across many fields. They are not perfect for every application, but they add value. They can help to recognize, and address, the dynamic nature of

systems. They can help to promote continual improvement and learning following a stressor event. They can lead to overall improvement, and most importantly, can lead to an increase in safety performance.

References

1. Aven, T. (2015). The concept of antifragility and its implications for the practice of risk analysis. Risk Analysis, 35(3), 476–483. https://doi.org/10.1111/risa.12279
2. Basiri, A., Behnam, N., De Rooij, R., Hochstein, L., Kosewski, L., Reynolds, J., & Rosenthal, C. (2016). Chaos Engineering. IEEE Software, 33(3), 35–41. https://doi.org/10.1109/MS.2016.60
3. Benson, B. (2013, August 24). How to Be Antifragile: Live Like a Hydra. Better Humans. https://betterhumans.pub/live-like-a-hydra-c02337782a89
4. Carillo, R. A. (2020). The relationship factor in safety leadership: achieving success through employee engagement (First edit). Routledge.
5. Clarification of OSHA's Position on Workplace Safety Incentive Programs and Post-Incident Drug Testing Under 29 C.F.R. §1904.35(b)(1)(iv) | Occupational Safety and Health Administration. (n.d.). Retrieved February 27, 2022, from https://www.osha.gov/laws-regs/standardinterpretations/2018-10-11
6. Conklin, T. (2019). The 5 Principles of Human Performance: A contemporary update of the building blocks of Human Performance for the new view of safety. Pre-Accident Investigation Media.
7. define catalyst - Google Search. (n.d.). Retrieved February 25, 2022, from https://www.google.com/search?q=define+catalyst&rlz=1C1CHBF_enUS849US849&oq=define+catalyst&aqs=chrome.0.0i433i512j0i512l9.2255j1j7&sourceid=chrome&ie=UTF-8
8. Dekker, S. (2014). Safety differently. CRC Press London.
9. Dumiak, M. (2021). CHAOS ENGINEERING SAVED YOUR NETFLIX. Spectrum.Ieee.Org, March, 4–5. https://ieeexplore.ieee.org/abstract/document/9370069/
10. Geller, E. S. (2005). Behavior-based safety and occupational risk management. Behavior Modification, 29(3), 539–561. https://doi.org/10.1177/0145445504273287
11. Hallowell, M., Quashne, M., Salas, R., & Jones, M. (2021). The Statistical Invalidity of TRIR as a Measure of Safety Performance. Professional Safety Journal, November, 28–34.
12. Harford, T. (2016). Messy: The Power of Disorder to Transform Our Lives. https://books.google.com/books?hl=en&lr=&id=P9gzDwAAQBAJ&oi=fnd&pg=PA1&dq=Tim+Harford+Messy&ots=HtBX68OBTH&sig=eAZRkEKCKTt2GDqzZqsF4mu5rOQ

13. Harford, T. (2022). The data detective: ten easy rules to make sense of statistics. Penguin.
14. Li, Y., & Thimbleby, H. (2014). Hot cheese: A processed Swiss cheese model. Journal of the Royal College of Physicians of Edinburgh, 44(2), 116–121. https://doi.org/10.4997/JRCPE.2014.205
15. Lloyd, C. F. (2020). Next generation safety leadership: from compliance to care (First edit). CRC Press.
16. Long, R. (2012). For the Love of Zero : Human Fallibility and Risk. Scotoma Press.
17. Long, R. (2019). The Social Psychology of Risk Handbook. Scotoma Press.
18. Sanderson, M. (Capitol T. U., & Martin, L. F. (2022). Challenges of risk management in safety [Submitted for publication].
19. Sanderson, M. (Capitol T. U., Thygerson, J. (Capitol T. U., & Martin, L. F. (2022). Black Swans, SIFs, and safety [Submitted for publication].
20. Sherratt, F., & Dainty, A. R. J. (2017). UK construction safety: A zero paradox? Policy and Practice in Health and Safety, 15(2), 108–116. https://doi.org/10.1080/14773996.2017.1305040
21. Taleb, N. N. (2004). Fooled by Randomness. Random House Trade Paperbacks.
22. Taleb, N. N. (2010). The black swan: The impact of the highly improbable. Random House Trade Paperbacks.
23. Taleb, N. N. (2016). Antifragile: Things that Gain from Disorder. Random House Trade Paperbacks. https://doi.org/10.1177/1755738019885153
24. Taleb, N. N. (2020). Statistical Consequences of Fat Tails: Real World Preasymptotics, Epistemology, and Applications. http://arxiv.org/abs/2001.10488
25. Tseitlin, A. (2013). The Antifragile Organization. Queue, 11(6), 20–26. https://doi.org/10.1145/2493944.2499552
26. Vanderbilt, T. (2008). The Traffic Guru. The Wilson Quarterly, 32(3), 26–32. https://www.jstor.org/stable/40262136
27. Vincent, C., & Amalberti, R. (2016). Safer healthcare: Strategies for the real world. In Safer Healthcare: Strategies for the Real World. https://doi.org/10.1007/978-3-319-25559-0
28. Vriend, N. J. (1996). Rational behavior and economic theory. Journal of Economic Behavior & Organization, 29(2), 263–285.

