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ARTICLE

Storytelling as a strategy in managing complex systems: using antifragility for handling an uncertain future in reliability

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ABSTRACT

The changes currently being experienced by industry demand more flexibility and more interconnections. More interconnections mean more extended domino effects within a network in case of failure. Using the powerful tool of storytelling, this paper aims to highlight the need for a mind-set change in approaching reliability. Firstly, the paper will briefly explain why professionals need new tools and techniques for facing an uncertain future from a reliability perspective. Secondly, an explanation of the increasing importance for embracing disorder will be given, pinpointing the limitations of a deterministic approach and the benefit of a more antifragile method for reliability. Afterwards, the paper introduces the storytelling technique as a tool for breaking the common mind-set on reliability approaches, using a story based on the Dutch railways for underlining the value of antifragility in preparing for unexpected events. Finally, the paper discusses the findings and reflects on future research that would substantiate the benefits in several industrial sectors.

Abbreviations: NS: Netherlands Railways; Flirt: Fast Light Innovative Regional Trains

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KEYWORDS Antifragility; reliability; storytelling

1. Introduction: why tools and techniques for managing the uncertain future?

As highlighted by Heylighen (2002), there is a common 'overwhelming' feeling that the world and global society are changing very fast. Hyper-

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connectivity (a networked world where every event, agent and process are interconnected) and accelerating change foster technical and social complexity (Veitas & Weinbaum, 2017). Next to that, Martinetti, Braaksma, and van Dongen (2017) have underlined how technical complexity of products is dramatically increasing and Kececioglu (2002) shows how this complexity directly affects reliability reducing the performance of the entire system. Even if the definition of system complexity is not always clear (Efatmaneshnik & Ryan, 2016), most of the studies converge in thinking that the more components there are, the higher the likelihood there is to encounter failures. Failures typically do not only affect reliability. Unexpected drifts from normal working conditions pose several concerns about the decrease of safety levels as well. Despite the enormous changes and developments in industry in the last decades, defined by Maynard (2015, p. 1005) as 'an unprecedented fusion between and across digital, physical and biological technologies', approaches for guaranteeing comparable safety and reliability improvement do not evolve quickly enough to offer adequate solutions in managing the mentioned complexity (Leveson, 2011).

This lack of innovative approaches, able to support decision-making processes, increases the inability to manage unexpected future events, physiologically embedded in a complex system. Moreover, the actual state of the art of static analysis and testing in industry have not yet proved to be able to provide those capabilities (Chandra, Griesemer, & Redstone, 2007). As described by Johnson and Gheorghe (2013, p. 160), a not negligible amount of hazards, defined as Black Swans (Taleb, 2007) or X-Events (Casti, 2012), is 'generally not reducible to cause-effect relationships'. Therefore, those hazards cannot be included in a normal distribution, leaving them 'surviving' in a grey unpredictable zone where the common analysis cannot create adequate measures to manage their disturbances on the system.

Modern infrastructures, such as the railway network, air-traffic management, smart electrical grid and digital cloud-based network, are normally classified as a System-of-Systems due to some distinctive features (Filippini & Silva, 2014; Sousa-Poza, Kovacic, & Keating, 2008). These assets require a different approach in dealing with unpredictable events and disorder. Consequently, it appears necessary, during the design phase of a complex system, to use tools and techniques for both withstanding stress (Kriete, 2013) and becoming stronger but without the necessity of predicting every circumstance. Referring to the work of Taleb (2012), reliability professionals are in need for 'antifragile' methods for embracing disruptive situations and unknowns.

The aim of this paper is to show how the storytelling technique may support reliability professionals in a better understanding for handling an uncertain future using the philosophy and underlying heuristics of antifragility. The paper proposes an application of the story-telling technique within Netherlands Railways (NS), at a strategic level to face complexity and ambiguity in new train introductions with a new perspective, to induce a different way of thinking to decision-makers, designers, reliability engineers and project managers. It shows how the storytelling technique may support NS in a better understanding for handling an uncertain future through the lens of antifragility. Finally, it briefly evaluates, using a small survey, how storytelling was able to transfer the correct information to project managers of the NS.

2. Reliability and uncertainty

There are two major interpretations of the origin of uncertainty as described by Derbyshire and Wright (2014), one which emphasises determinism and one which rejects it. The deterministic view suggests that if we are able to identify relevant causes at an early stage in their development we can alter the expected outcome by changing the causes. This view originated from the work of Pierre-Simon Laplace in the 19th century (Laplace, 1825, 2012). The other view, that rejects the notion of cause, believes that a particular combination of factors may result in one outcome on one occasion, and a completely different outcome on another, comparable to Brownian motion in physics (Einstein, 1956). This view of indeterminism considers accurate predictions as impossible.

Most of the current methods and approaches for reliability are based on the deterministic view. However, in a System of Systems context, like the railway network, deterministic approaches are becoming less and less valuable due to higher levels of unpredictability. Therefore, it is essential to adopt approaches that accept indeterminism as a complement to the prevailing deterministic perspective, in order to handle an uncertain future.

2.1 Between deterministic and non-deterministic approaches: a third way

The dilemma between deterministic and non-deterministic approaches is extremely current and is central to many publications. Moreover, it is debated in a variety of research domains and industrial sectors. Generally speaking, as mentioned by Sawik (2017), the deterministic model aims at optimising the performance of a system in a countable group of possible scenarios offering dedicated solutions. On the contrary, usually a non-deterministic model takes into account wider scenarios and non-dedicated solutions characterised by uncertainty (Klir, 2005).

Choi and Allen (2009) clarified how nature, new materials and socio-technical systems due to their variability and complexity cannot be forecasted with models based on rigid assumptions. Rather, they suggest adopting approaches based on non-deterministic models to quantify parameters that cannot be assessed.

In summary, reducing the discussion to its simplest expression, the problem can be approached as follows such:

- Deterministic models: stochastic-based (or based on a non-probabilistic method such as Fuzzy Logic) input information is requested for predicting specific future states of the system using a pre-defined approach.
- Non-deterministic models: stochastic information is requested for predicting future states with a specific degree of uncertainty due to unparametrizable variability.

Nevertheless, in essence, the final aim of both approaches is similar: trying to predict the future state of the system in one way or another. But, despite the chosen method, despite the use of relevant information, unexpected events drift the system from the initial planned conditions to unforeseen states greatly surprising analysts time after time. According to that, the question to analyse is why to try desperately to predict the future, rather than how to predict it. This leads to a third option based on not trying randomly to guess the future state of the system. It can be summarised as:

- Information is poor and it is not required. Some kind of stress will force the system to deviate from normal working conditions. The final goal is not predicting the future state of the system but designing it to be ready to improve under external stresses.

The principles of this option are further explained in section 2.2.

2.2 Embrace disorder instead of trying to control: thinking antifragile

Accepting that no accurate predictions are possible for every state of the system is psychologically disturbing, as it shows lack of control over future outcomes, and its consequences of high levels of uncertainty. 'This is called the paradox of control, which results in improved benefits if we avoid the illusion of control and instead accept that accurate predictions are not possible' (Makridakis & Taleb, 2009, p. 842). Nevertheless, most organisations today do not like volatility, randomness, uncertainty, disorder, errors, stressors and chaos. Yet, we live in a world where disruption and randomness are increasing, especially in the case of a System of Systems. Organisations that gain from randomness and disorder will dominate, and organisations that are hurt by it will not survive (Power, 2013).

Disorder is not only integral to the fabric of nature, but adding more of it can sometimes improve things (Abrahamson & Freedman, 2013). In Drachten, a small town in the Netherlands, an experiment was conducted at a traffic junction to increase disorder by removing all traffic controls (traffic lights, lines and road markings). This changed people's perspective of risk, encouraging them to use junctions with more care and resulted in fewer accidents. (Monderman, Clarke, & Baillie, 2006). Furthermore, research in the field of critical infrastructures showed that there are indeed conditions under which disorder can be managed so as to increase the options for reliability, even if it leaves things messy but more manageable (Roe, 2013).

The concept of antifragility (Taleb, 2012) offers new insights in to preparing for an uncertain future by embracing disorder. Taleb refers to fragility as how a system suffers from the variability of its environment beyond a certain pre-set threshold, while antifragility refers to when it benefits from this variability (Taleb & Douady, 2013). Additionally, Taleb argues that we have been 'fragilizing' our systems by denying them stressors and disorder, making them vulnerable to unexpected events. Jones states (2014, p. 872) 'current systems are designed to be fragile to some degree: requirements for performance are specified, and the system is designed to meet those requirements. If the system is stressed beyond the design requirements, it will fail'. In summary, the fragile wants tranquillity while the antifragile grows from disorder and becomes stronger when stressed.

This section introduces three key heuristics for reliability, adopted from the antifragility concept: Optionality, redundancy and hormesis. Optionality is seen as both building flexibility to increase the range of strategic options as well as an enabler for convexity to respond to unpredictable events (Taleb, 2012). Systems that are convex, benefit from uncertainty, while things that are concave are hurt by it. The implication of convexity is that you are harmed much less by an error (or a variation) than you can benefit from it and you would welcome uncertainty in the long run. The concept of optionality is of critical importance because it is one of the factors that makes the antifragility approach truly non-deterministic in facing an uncertain future (Derbyshire & Wright, 2014). The second key heuristic is redundancy. The potential benefits of redundancy are well known and documented (Clarke & Hollister, 2010; Contte & Jacobs, 1997). The heuristic of redundancy in antifragility adds to this and places additional emphasis on the possibility of gaining from, not just defending against, uncertainty. Redundancy is seen as a form of investment rather than a defensive strategy. It may seem like a waste if nothing unusual is happening, but as Taleb

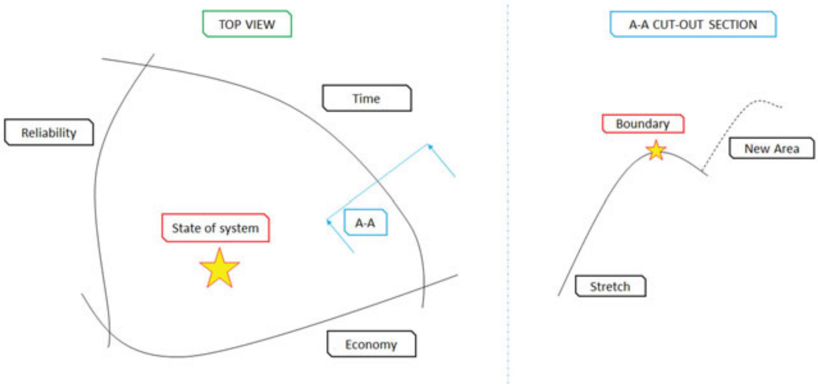

Figure 1. Resilience and antifragility in top and cut-out view, left and right respectively.

explains, layers of redundancy are the central risk management property of natural systems (Taleb, 2012). The third heuristic is hormesis (Taleb, 2012). Hormesis is a phenomenon whereby a positive effect (for example improved health) results from exposure to low doses of a substance that is otherwise toxic or lethal when given at higher doses. The heuristic of hormesis in the concept of antifragility uses this phenomenon in a deliberate way in order to increase strength and resilience in a system. A typical example of hormesis in an organisational context is security stress tests on critical IT infrastructures to strengthen the capability to withstand future cyber-attacks.

2.3 Antifragility for reliability

As described, the concept of antifragility offers a new approach for dealing with indeterminism. One of the major advantages in applying this philosophy lies in the opportunity to increase system reliability, defined as probability to perform a required function under given conditions for a given time interval (Todinov, 2015).

The Netflix Company has already experienced and proved how valuable it is for reliability using Chaos Engineering (Basiri et al., 2016) for testing the resilience of the system. The results obtained after the deployment in the system of Chaos Monkey, Chaos Gorilla and Chaos Kong (Izrailevsky & Tseitlin, 2011), so called ‘the Simian Army’, have revealed the benefit of inducing failures regularly at different level of the network (Tseitlin, 2013).

Figure 1 offers a conceptualisation of the common resilience mechanism. Resilience is based on being robust against stress. In the top view, it is possible to look at the position of the system in relation of some boundary constraints (reliability, time, economy). In the cut-out section, it is possible to recognise position of the systems in regards of the level of stress received and its ability to stretch up to the limit of one of the boundaries due to disturbances.

Achieving resilience cannot be considered the final destination. The concept of resilience engineering remains focussed on design for expected disturbances and prevention of the unexpected. Learning and acquiring knowledge is always part of engineering, but never part of the system itself during normal operating conditions. Improvements can be reached by coupling resilience features with the ability to learn and become stronger (Jones, 2014; Verhulsta, 2014) with each failure, moving forward to a 'New Area' of Figure 1. This area represents a real challenge facing modern complex systems, the ability to overcome simple robustness.

The heuristic of optionality offers special potential for the systems to improve their reliability. Optionality can be seen as an extension of flexibility (Derbyshire & Wright, 2014). Aiming for optionality, the system will not only provide robustness in facing or solving unexpected failures (i.e. a power outage in one of the hosting racks causing inaccessibility to a digital network or an obstruction in a track switch causing unavailability of a railway portion) but it will also achieve benefits in terms of reliability, offering an 'option' and not an 'obligation' to the system for evolving to a specific state or configuration. In nature, successful evolution of the biological species lies in the foundations on their opportunistic approach of exploiting solutions. In industry, the paradigm of optionality, intended as a starting point in the design phase, is becoming predominant (as already mentioned in the section 2) for ruling autonomous traffic lights, increasing reliability and ensuring smooth traffic flows.

3. The storytelling technique for embracing disorder

The challenge that organisations face in adopting the concept of antifragility in reliability, is changing the prevailing mind-set of determinism when facing uncertainty. A mind-set used to scan and interpret the world, but which is rarely examined by itself (Delgado, 1989). Stories are powerful means for altering this mind-set.

Stories help organisations to make sense of the past and understand possible futures (Bruner, 1991; Weick, 1995). In organisations, storytelling has been identified as a means to share norms and values, building trust and commitment, sharing tacit knowledge, facilitating unlearning and change, generating emotional connection and communicating rules, laws and policies (Sole & Wilson, 2002). Storytelling has already been recognised as a useful technique in many organisational areas. It has been used, among others, for introducing change (Boje, 1991; Boyce, 1996), design management (DeLarge, 2004), leadership (Denning, 2006) and organisational learning (Lämsä & Sintonen, 2006). The next section proposes an application of the story-telling technique at a strategic level to face complexity and ambiguity in new train introductions. It shows how the storytelling technique may support reliability professionals in a better understanding for handling an uncertain future using the philosophy and underlying heuristics of antifragility.

3.1 The antifragile story: introduction of new trains

Many countries need a strong public transport system to deal effectively with the economic, social and sustainability challenges over the next few decades. Safe and reliable passenger railway transport is essential to achieve such a system. Nevertheless, passenger railway organisations, such as the NS, deal with an increasingly complex and uncertain environment, due to new complex technologies, higher utilisation of the railway network and strong political influences. The NS is the main railway operator in The Netherlands, having the exclusive right to operate passenger trains on the Dutch Main Railway Network until 2025. The story in the next section is based on a case study of the introduction of the Flirt Fast Forward (Flirt) train (Moerman, Braaksma, & Van Dongen, 2018). The Flirt train was formally introduced on 11 December 2017 by the NS in the Netherlands. Introducing new trains without major disruption is a big challenge for railway operators.

Back in 2014, the House of Representatives in the Netherlands decided unexpectedly that the railway student card had to be extended to vocational education, instead of abandoning it completely as had been expected. This was a big surprise to the NS, who were preparing for a decrease in railway passengers due to the loss of the railway student card. If the NS had done nothing at that time, it would have resulted in a lack of capacity of Sprinter trains in the year 2017. However, the NS acted swiftly and signed a contract to buy 58 Fast Light Innovative Regional Trains (Flirt).

The following story was produced about the introduction of the Flirt train to explain the ideal situation in the event of a system failure.

> It is Wednesday, eight o'clock in the morning. Usually, Hans needs to rush to the nursery school to drop off his daughter in order to run after the next scheduled train to Amsterdam to arrive in time for his meeting at the office. But even then, he still has a good chance that due to the complexity of underlying planning and logistics of the timetables the train deviates from its original departure time. Moreover, today is a special day: the NS introduces the latest brand new train, the Flirt. In the last couple of years, the introduction of new trains has caused several delays to Hans due to unexpected failures related to the infant mortality phenomena.

Consequently, Hans wonders whether this last event will again affect his daily commuting …

However, today, things are different at NS. Today, after months of preparations and simulations, a fall-back option has been prepared in case of sudden train unavailability. Hans drives his daughter safely to school. He waves his daughter goodbye and heads towards the railway station. Due to a problem to the sliding step of the door of the first couch, the train is not able to leave the station. Normally, it would have cost him a delay of between 60-70 minutes and some angry colleagues. But today, he does not have to be scared of the Flirt introduction anymore. A Flirt introduction team is on stand-by to tackle these problems and to respond adequately to these unexpected failures; as a result, Hans still has the option to catch the same train. This gives him the opportunity to grab a nice cup of coffee before his meeting starts in Amsterdam. Even after an unexpected failure, he was able to catch his train because the replacement for the defective Flirt was already there!

3.2 Reflections and inspirations

The story of the Flirt introduction illustrates one of the key heuristics of antifragility, as introduced in paragraph 2, to emphasise and support the need for adopting a new perspective in preparing for an uncertain future. This section elaborates on how the three key heuristics enhanced the reliability of the Flirt implementation.

One of the key lessons learned from the V250 introduction was the need to have a fall-back option in case the new trains were unavailable. Therefore, the NS decided not to focus on a single implementation scenario, but to develop alternative options to ensure reliable train services. Considering more options at an early stage, enlarged optionality and enabled NS to anticipate and cope with possible unexpected events activating the fall-back option. Future train introductions need to prepare alternative options to ensure reliable performance.

A second important lesson from the V250 introduction was the experience that train drivers were not fully prepared to operate the new train. This was partly because they were not used in dealing with unexpected failures of this new train. Consequently, the NS decided to introduce random failures during the pilot operations phase of the Flirt to increase the capability of train drivers and train managers to respond adequately to unexpected failures in commercial train operations. This contributed to the reliability of train services and made the railway system a bit more antifragile.

An accurate understanding of future operations with new trains is difficult to achieve, especially considering the fact that the new Flirt trains were also referred to as ‘driving iPads’ or ‘Windows on wheels’ with unknown

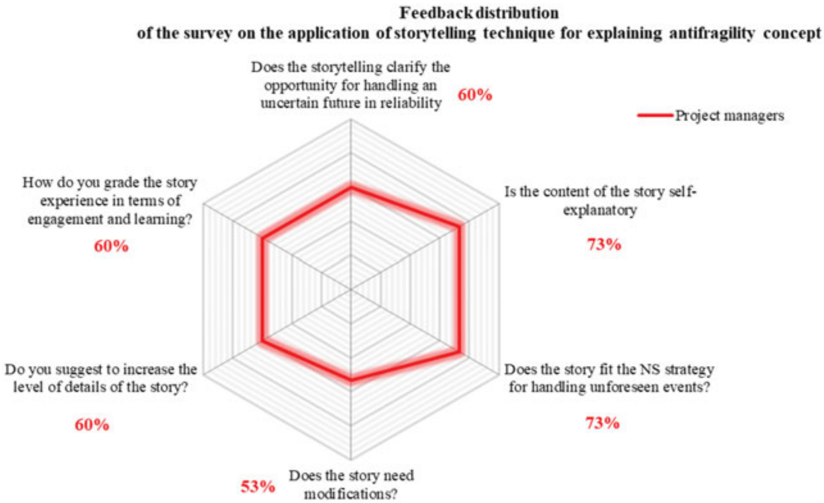

Figure 2. Feedback distribution of survey of the project managers involved in the Flirt introduction.

probability of failures. This forced the NS to adopt a less predictive strategy. By injecting the Flirt introduction with more redundancy and buffers (as described in the story) increased inefficiencies in the short term, provided extra layers of protection against unexpected events. When the Flirt trains were taken into operation, extra capacity was reserved for assisting train drivers and train managers to ensure a smooth start-up of train operations in the morning. Furthermore, maintenance experts from the train supplier were on hot standby to assist immediately when required. Avoiding optimisation and building a margin of safety and reliability mitigates the risk of not being able to deal with uncertainty in the future.

Telling the story of the Flirt increased the awareness of project managers of new train introductions to consider a more antifragile approach to ensure and maintain reliable performance when introducing a new train. However, to also gain indications about whether the concept of antifragility has been properly explained using the storytelling technique a small survey was carried out among some of the project managers of the NS involved in the 'smooth introduction' of the Flirt. Despite the data set not being statistically robust so that it cannot be used for structured analyses, it provides some useful insight to set the direction of the perceived engagement of the users, and about the performance of the storytelling in terms of provided information on the asset management study topic. The questionnaire had six closed questions based on a Likert scale version (range of value from 1-very negative to 5-very positive) as a psychometric tool to grade the responses. The feedback results are summarised in the spider graph of Figure 2. The values represent the percentage of the possible score reachable for every posed question. As shown, the distribution of the results obtained suggests an overall positive reaction by the managers.

The element that requires improvements at its most general is the level of details in the story ('Does the story need modifications?'). The project managers agreed on the need for a more extended and detailed story to not only get the strategic message embedded in the antifragility (well outlined by the story), but also to be able to appreciate the advantages of the concept from a more operational perspective.

4. Discussion

Based on the concepts outlined above, some interesting recommendations for the adoption of a non-deterministic approach and on the power of the story-telling technique can be given. The old-fashioned analysis based on deterministic principles needs to be revised due to the complexity of modern systems. Future systems design, or System of Systems design, should avoid one-on-one solutions using chaotic and antifragility approaches. Existing systems characterised by a high number of nodes and state configurations should evaluate the gradual introduction of regular failures to assess the level of resilience and the opportunity to increase antifragility. Acknowledging that the changes mentioned might be time and cost consuming, the concepts and examples show the long turn benefit produced by a 'quantum' leap in mind-set.

With regards to inducing the change in the mind-set of the organisation, the storytelling offers a powerful tool for showing the opportunities of the antifragility approach. The antifragile story highlights how the users and the organisations are more likely to accept an unexpected event if the system matches the planned reliability with comparable (or even better) service solutions. Antifragility allows the organisation to place itself in a position to benefit from the unknown. Organisations that mainly rely on a deterministic approach/analyses are, therefore, less likely to be able to improve their performances to ensure the same reliability. Preparing for the future is not always possible using deterministic reliability approaches. To allow for a proper preparation to a more antifragile system and facilitate the transition from the current to a non-deterministic approach, all the stakeholders involved need to share this vision and its goals.

Even if it will not be possible to change philosophy without encountering difficulties during the migration, organisations that aim to increase their reliability and to reduce the impact on the unknowns to their users' experience should gradually invest and test the introduction of both higher optionality and regular failures to assess improvements on the system.

Conclusions

The paper acts as 'position' paper in the application of a powerful tool (storytelling) in spreading a new and breakthrough concept (the antifragility) in a complex context (railway sector). Due to the intrinsic properties of the position paper, further and more extensive research is required to validate both the storytelling technique and the benefits of non-deterministic approaches.

Moreover, given the potential of antifragility solutions for designing new systems that achieve better reliability performances, there is still a surprising lack of application of this philosophy in current industries, especially in managing complex assets. However, taking into account the power of storytelling in helping people to understand the potential of a certain approach, this paper proposes an 'antifragile story' to make evident the benefits of using a non-deterministic approach to the management of organisations.

This has resulted in a simple and direct way to pinpoint the expected results of antifragility: (i) same level of reliability and performance with unexpected events and failures and (ii) higher acceptance of changes from the users due to limited-to-zero negative impacts on their lives.

Although the story has been written to inspire reliability professionals in the railway industry and is based on a case study, the combination of storytelling and antifragility approaches should be more extensively used in different industrial sectors and assets for fostering the real potential of this combination. The authors are deeply committed to the proposed approach for inducing organisations to change their policy. Further research will focus on the sensitising of organisations in smoothly introducing antifragility in their programmes for ensuring higher reliability standards.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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