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An alternative view to assessing antifragility in an organisation: A case study in a manufacturing SME

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ABSTRACT

In complex adaptive systems, antifragility designates the positive sensitivity to volatility, caused by (exceptional or 'black swan') external stressors that intervene with the intended functionality of these systems. System Engineers can purposefully employ the concept antifragility to engender better systems. Prerequisite for this is the ability to adequately assess system changes and especially system improvements as the consequence of stressors. Albeit antifragility measurements do exist, their practicality is limited. This publication proposes a novel approach for antifragility measurement. A case study on a manufacturing SME depicts the antifragile spectrum rating of an SME to test the effects of system changes.

1. Introduction

Strategic leaders in an organisation have an important role in preparing their organisations for risk. Most organisations appeared to be ill-equipped to manage the risks of dramatically expanded leverage during the decade that led to the 2008 financial crisis [1]. Consequently, many of these organisations either failed, or were badly damaged by the crisis. Organisations that recognised these risks avoided them, or developed coping structures, systems, processes and cultures that allowed them to survive and even prosper [1].

In product development, addressing risks is inherent to the activities of the designer. In general, such risks are assumed to be argumentative consequences of cause–effect relationships. However, as is the case with, e.g. the mentioned financial crisis, some stressors on the environment have extreme outcomes that are irreducible through the cause–effect relationship. These stressors do not form part of the normal distribution as their severity and/or frequency do not predict the future [2]. They are also known as 'black swans' [2,3]. In terms of risks in organisations, black swans are characterised by the fact that:

(1) They are rare beyond what can be expected, thus having a high improbability;
(2) their impact is extreme in nature; and
(3) they are retrospectively predictable (as humans connect explanations after the fact).

Black swans are internal as well as external in nature. Black swans such as the financial crisis have mainly been negatively perceived, due to the reported negative consequences. But some organisations and individuals prospered due to the opportunities that arose because of these black swans.

As an inherent consequence of their rarity, black swan events seem to be incompatible with Systems Engineering, as it approaches problems that would typically conform to a set of reasonably collected assumptions. Such assumptions generally include requirements, an entity tasked with the development and configuration of the system/solution, the system/solution itself and the external environment's relationship with the system/solution. Black swan events endanger the stability of systems/solutions. Consequently, systems engineers increasingly aim to prepare systems better for extreme events, in other words, they aim to reduce the (so-called) fragility [4] through increased sustainability of the systems/solutions. In this, the main difficulty might well be to assess if the organisation's ability to cope with black swans has indeed improved (i.e. has become less fragile).

Initial steps to structure such assessments applied mathematical models, but appeared to be beyond the capabilities of the general organisation's management [5]. To allow for applicability in organisations, a more framework oriented approach was developed, aiming to measure an organisation's (anti)fragility [6]. This framework was based on a system of systems criteria (by sourcing quantitative values from stakeholders). It reduced a multi-dimensional concept of fragility into a two-dimensional continuous interval scale (ascribed to by this research, Fig. 1) on which the quantitative average was plotted.

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Fig. 1. A continuum of system responses, adapted from Refs. [6,7].

The reason for elaborating on such a framework is that the ability to be able to adequately measure (anti)fragility is an imperative precondition for purposefully improving the organisation's strategic position to be less fragile or more antifragile.

2. Antifragility, the opposite of fragility on a system response continuum

Systems often do not function as predicted. These systems are seen to be in their unintended state, which can be known or previously unknown.

2.1. Fragile

The unintended and previously unknown states are known as failure states. Systems move from an intended to an unintended state through the application of stressors outside the constraints for operation [6]. A fragile system is limited in its upside, thus its functionality, but unlimited in its downside. As the event increases, the system approaches a failure state, large negative consequence in Fig. 2A. Fragility can be placed on a two-dimensional continuum in relation to other system states (Fig. 1).

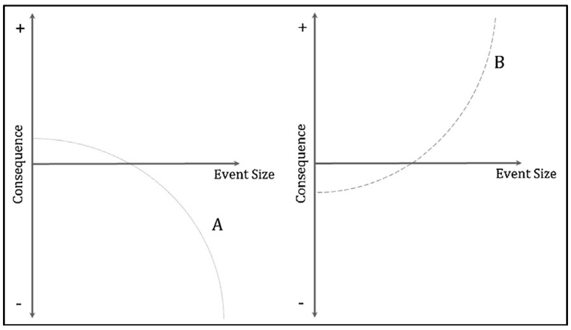

Fig. 2. (A) 'Unbound' downside risk and limited upside, and (B) 'unbound' upside risk with limited downside (adapted from Ref. [2]).

2.2. Resilient/robust

Resilient/robust is the ability of the system to remain in a desired state while impacted by a range of stressors [6]. It is displayed on the two-dimensional continuum (Fig. 1). A robust system will show no significant effect as a result of stressors and continue to function and deliver on its designed capabilities. The broader the range and size of stressors that can be practiced on the system without losing its designed functionality, the more robust it is considered.

2.3. Antifragile

With 'fragility' being a non-desired quality, it makes sense to define its opposite. Often, this opposite is thought to be something that is resilient or robust. However, by logical deduction, the opposite of that which is negatively sensitive to volatility would be that which is positively sensitive to volatility [7]. Consequently, the notion 'antifragile' is used [7] to depict something that is positively sensitive to volatility; antifragile systems thus thrive during or on volatility.

This notion of antifragility gives the systems engineer a wider spectrum than 'just' addressing fragility: beyond realising resilient or robust systems also lies the possibility to aim for antifragile systems. In relation to black swan events, this plots antifragility to the right of the system state continuum somewhere on a continuum between fragile to robust or resilient and additionally to antifragile [6,7] (see Fig. 1).

Antifragility requires system strategies that, when faced with a stressor, limit the downside, but have increased exposure to upside, Fig. 2B with Fig. 3 as an example. Strategies that limit downside include the use of failure components (e.g. shear bolts), insurance (e.g. production line failure due to power failures), financial options on key elements that affect the system (e.g. metal prices for raw material), etc. In designing the limiting downsides, antifragility supports a system that will fail early and cheaply. Through failing, a system should learn and adapt. A sustainable competitive advantage is supported by its ability to learn and adapt faster than the competition [8]. Through this learning, a system should be able to action the repair of the system [8] and/or future design improvements [7].

> Apple positioned itself to prosper from the upside, Fig. 2(b), of volatility through the launch of the iPhone software development kit in 2007. A free download was available to independent developers, which included documentation, bug-testing software, graphical layout design software, and programming application. Applications were designed and tested by the developers and submitted to the AppStore for approval to sell. The income generated from the sale of the application is split between Apple and the developer, increasing both the turnover through application sales and the value that Apple consumers get from their devices [9].

Fig. 3. An example of 'unbound' upside risk, Apple (Fig. 2a) [9].

Dynamic environments have a host of stressors continually changing; constraints, opportunities, knowledge, technology, etc. Agility/adaptability is being able to make internal adjustments in response to, or in anticipation of, external changes. In this context, being adaptive has two levels: (1) the ability to (autonomously) respond to or anticipate consequences of particular actions in a deterministic and structured manner; and (2) by not just being responsive to environment dynamics, but self-organising, evolutionary or natural selection type behaviours like those of biological systems [6].

3. Antifragility measurement framework for a system of systems

The absence of a measurement approach for system (anti)-fragility limits the effectiveness of governance in making systems less fragile and more robust if not antifragile [6]. Johnson and Gheorghe [6] (J&G) provided a framework oriented approach which aims to measure and organisation's (anti)fragility. It is based on reducing the concept of fragility on a two-dimensional interval scale.

3.1. The structure, logic and use of J&G

The evaluation system was built on the attributes that are of interest to system stakeholders: strategies, policies, governance, structure, components, sub-systems and processes. The questions are then contextualised for a system in terms of how it would respond to the stressor based on system criteria (Table 1). The final result is an aggregate value over all criteria which is plotted on a curve in order to highlight its position on the fragile-antifragile continuum. The plot would allow for the system to assess its position on the continuum as well as create a reference to what future measurements can be compared.

J&G measured the system according to system criteria (Table 2), that assesses the system as a whole. They required quantitative responses to their question on an interval scale. The main endogenous question in relation to this system criteria is [6]:

- How will a system respond to a Black Swan stressor?

Table 1
Analytical criteria of a system of systems adapted from Refs. [6,10].

Key	Criteria	Definition
F1	Emergence	Emergent outputs, there is little/no traceability between micro- and macro-level results of a system, has greater black swan event exposure compared to resultant due to an increase in the amount of unintended system states.
F2	Efficiency and risk	Efficiencies are often gained at the expense of increased potential for harm due to stress. Less redundant systems designs are more efficient, but more fragile.
F3	Requisite variety	Regulators in a system of systems attempt to control the outcome and behaviours in the system. Black swan events increase as a result of the number of regulators being insufficient relative to the number of agents (unpredictable behaviour).
F4	Stress starvation	Protecting a system from stress or attempting to reduce uncertainty can cause weakness, fragility and expose them to hazardous Black Swan events.
F5	Redundancy	Duplication of components to meet the same objective create excess capacity in a system and are effective tools for extreme stressor defences. Redundancy tends to stabilise systems and improve robustness.
F6	Absorption	Absorption in systems can be used to improve robustness. Design margins that increase the magnitude and duration it can take during potential stresses to ensure it continues functioning as it should increases the absorption ability of the system.
AF1	Induced small stressors	Some systems are found to improve with greater exposure to stress. Controlled stress to a system can increase its robustness and potentially lead to antifragility where the system 'learns' from these controlled responses.
AF2	Non-monotonicity	Learning from negative consequences induced by stressors can lead to new information. New information can result in improved practices and approaches. Stressors, when learned from, can thus cause a system to improve.

The system assessment criteria were mapped to a key (shown in 1st column) to allow for ease of representation in tables, graphs and discussions.

Table 2
Criteria raw metric values per individual.

		Criteria							
		F1	F2	F3	F4	F5	F6	AF1	AF2
Indiv-idual	Ind1	−10	−8	−7	−8	−9	−8	0	0
	Ind2	−7	−8	−8	−2	−8	−2	4	3
	Ind3	−6	−7	−5	−4	−7	−5	1	6
	Ind4	−7	−7	−7	−6	−6	−8	0	2

In application, they used the Delphi method to converge the stakeholder's interval responses per criterion. This allows for order, distance and the application of statistics and applied inferences [6].

These criteria are not mutually exclusive, but exclusion of one or another would reduce the probability of adequately assessing the system. It is important to note that these criteria are more focused on the fragile-robust section of the continuum than to the robust–antifragile section. Possible reasons for this could be that the fragile- robust part of the continuum has received more focus or just that there are not as many robust–antifragile criteria.

3.2. Disadvantages of the J&G framework

An inaccurate ruler will not measure the correct length of a child, but when used continuously, it will prove whether the child has grown [5]. The J&G framework is one which gives a specific value on a measured ruler, and is thus useful to assess antifragility changes if the criteria remains the same.

However, if future research proves that criteria need to change, the ruler's previous values would have no comparable value. As noted, the current model can be improved by formally defining the standards for selection of the criteria and methods for aggregating evaluation results [6]. Another shortcoming of the framework for measurement is that it, in itself, is not adaptive. It does not depend on the type of criteria, but rather how criteria can be added and still be comparative to previous measurements. Given that the field of antifragility is still in its infancy, other criteria could be identified to form part of an antifragility assessment (e.g. leadership [1]).

4. Adapted approach to (anti)fragility analysis and assessment

The purpose of this research does not question the comprehensiveness of the criteria as given in Table 2, but aims to utilise the appropriate criteria in a more purposeful manner.

4.1. Requirements specification of the adaptive assessment approach

A shortcoming that needs to be addressed is the fragility/rigidity of current tools to be aligned with previous criteria to ensure that the same ruler is consistently applied when measuring. The first requirement is that:

- It should be flexible to changing assessment criteria.

The second disadvantage of the measurement tool is that it is biased to 'fragility' criteria on the continuum. This results in an assessment of fragile when it could be antifragile. The second requirement is:

- The criteria that are used in the model should allow for comparisons between measurements once a change has been made to the assessment criteria.

4.2. The structure, logic and use of the adapted assessment approach, an explanation through a case study

To make the adapted approach as purposeful and effective as possible, it was developed and simultaneously applied in a case study that was done on an electro-vehicle assembly company based in the Western Cape, South Africa. The system evaluated was the organisation with all the supporting functions around the assembly line. The organisation was chosen as it is in final stages of receiving funding for expansion and strategic change. The stakeholders that formed part of the group have been through a organisational due diligence exercise.

The adapted assessment approach focuses on the ability of each criterion to have a quantitative value of −10 to 0 (fragile criteria) and 0–10 (antifragile criteria). These values are quantitative responses to questions. Note that these set of questions were not the only interaction with the stakeholders, but rather a starting point to move towards specific 'what-if' type of questions around extreme stressors. As an example, non-monotonicity's initial questions are presented:

- What is the system's ability to gather information on the consequence of a stressor?
- Are processes in place to assess the information gathered?
- Are processes in place to act and are they validated?

These questions provided a platform for 'what if' type of discussions, after which, the stakeholders' quantitative responses were submitted anonymously, to prevent anchoring. Anchoring follows that when estimates are made starting from an initial value that is adjusted (as with the Dephi method) the adjustments are typically insufficient as different starting points yield different estimates, which are biased towards the initial values [11].

The raw results, Table 2, were used to calculate each criterion's average and standard deviation. The average is not intended to determine the system response, but to assess whether the organisation's (anti)fragility improved in one of two ways:

- *Assessment 1*: Did consensus improve on the impact of the criterion (indicated by a reduced standard deviation)?
- *Assessment 2*: Did changes in the average assessed criteria improve the organisation's (anti)fragility (strives to 0 for fragile criteria and 10 for the antifragile criteria)?

4.2.1. Assessment 1, assessing standard deviation

A standard deviation that is larger than the other criteria's shows that the consensus on all the criteria is not the same. If a consensus does not exist between the stakeholders, a question arises as to the known states of the system. In this way a criterion's spread can be assessed and compared to its previous measurements.

The adaptive approach does not aggregate values over different criteria as subsequent measurements are not comparable. If the values of all the criteria are aggregated without investigation, a learning opportunity is lost. Under the assumption that a new criterion might be added, an aggregate value as well as a standard deviation for the new criteria is calculated.

F1, F2 and F5 have the worst average, but F6 and F4 have the largest standard deviations (Fig. 4). These criteria might not be mutually exclusive which increases the unknown probable system states if a large spread is encountered (stakeholder views do not converge). Senior management stated that they viewed stressors (F4) as something to avoid at all costs as they were in the process of continually 'fixing' consequences of unwanted stressors. The result of this was their time away from their operational roles, thus reducing active regulators in the system (F3) which they believe resulted in more failures.

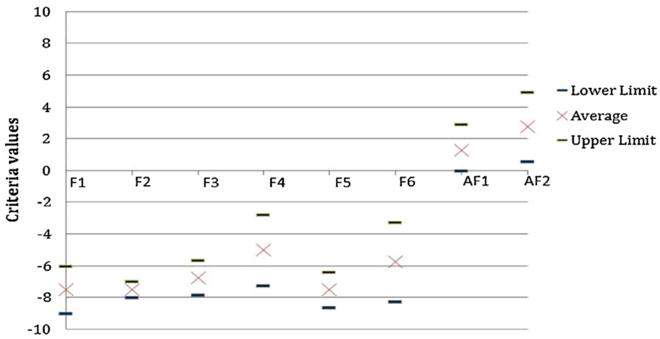

Fig. 4. Assessment 1 displays the spread of metric values.

4.2.2. Assessment 2, complete system improvement

To provide an overall view of the system improvement, the adaptive approach does not use a singular value to categorise a system response, but intends to show whether the system is moving in the right direction. This can be achieved with linear regression. The absolutes of the fragile criteria are ordered from the highest to lowest values and are then followed by the average antifragile criteria (sorted from lowest to highest) (Fig. 5).

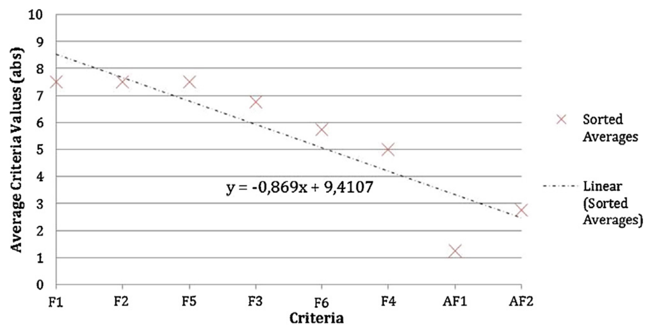

Fig. 5. Applied linear regression for assessment 2.

The slope (−0.869) in this case provides a starting point for future assessments. This value is only significant in relation to other assessments on the system and should not be seen to categorise a system as fragile or antifragile. The improvement of a system would then be presented by slope improvement (as the slope increases or flattens).

4.3. Evaluation of the adaptive approach

The stakeholders agreed that it was difficult to understand the criteria at first, but allowed for clear constructive thinking to present quantitative values when supplemented by 'what if' questions and further discussions. The spreads on assessment 1 surprised them as they believed they had consensus views after the recent due diligence procedures.

With the platform, the company envisages to provide feedback to investors on the improvement to the organisation (before feedback on financial metrics). It would thus be beneficial to reassess the organisation once preliminary funding has been applied in support of the assessment of their strategy.

In answering the requirements as provided in Section 4.1, two assessment phases allow for changing assessment criteria. As criteria are changed, assessment 1 allows for the evaluation of the criterion and how the spread relates to other criteria. It highlights the criteria that need attention as well as provides an introduction into a new way of thinking about systems.

Linear regression was used on the averages of the criteria for assessment 2. The objective is to provide feedback to stakeholders as to whether the system has improved, but not to place it on a specific point on the continuum.

The greatest perceived difficulty proved to be the initial understanding of the criteria, but this was overcome with 'what if' discussions. It was thus not a specific question that supported their understanding of the criteria, but the context in which it was asked.

5. Conclusions and recommendations

A framework for the measurement of antifragility provided a starting point that enhances the understanding of how systems can be measured for antifragility. An increased understanding of criteria will allow for more accurate measurements/comparisons as well as increased understanding of the stakeholders' system.

The adapted assessment tool is antifragile in itself as it will improve with further stressors (e.g. additional research). As more criteria are added, the measurements provide more information on the system as well as the stakeholder's understanding of the system.

Future work is envisaged on the specific criteria (and their appropriateness) and the role that they play in specific industries. The tool will also be applied in multiple iterations that enables assessment of the stakeholder's improvement in understanding of the criteria that tests the system and how that relates to innovative thinking to improve the system.

The fragile–antifragile continuum was used, but the argument could be made for it being a fragile–robust/resilient–antifragile triangle in which a system could possess all criteria in the system.

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