Design for Chaos

How to embrace chaos and complexity
as a resilient organisation.

Authors

Edzo A. Botjes, ebotjes@xebia.com
Ton Eusterbrock, ton.eusterbrock@sogeti.com
Hans Nouwens, hans.nouwens@sogeti.com
Marlies van Steenbergen, marlies.van.steenbergen@sogeti.com

Enterprise Architecture, Sogeti Netherlands &
Xebia

Editor

Lisette Atsma

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– a DYA white paper by Sogeti –

Edzo A. Botjes, ebotjes@xebia.com
Ton Eusterbrock, ton.eusterbrock@sogeti.com,
Hans Nouwens, hans.nouwens@sogeti.com,
Marlies van Steenbergen, marlies.van.steenbergen@sogeti.com
from the departments of
Enterprise Architecture, Sogeti Netherlands & Xebia

Abstract—Our world is becoming more and more connected, driven by the need to make the production of goods and services more efficient. This results in the transport costs of capital, knowledge and goods becoming almost zero; New innovative technologies being created non-stop and never forgotten on the internet; People being constantly exposed to instantly available (new) services. The volatility of these three factors creates a never-ending uncertainty. Our current methods within Enterprise Architecture need to support this complex and volatile reality. This is only possible by embracing the constant chaos. The only type of organisation that gains value from the exposure to chaos, is the antifragile organisation. This is in contrast to a fragile, robust or less resilient organisation. This white paper investigates the concepts of unpredictability and chaos and provides design attributes to help in the evolution from a resilient organisation to an antifragile organisation. This is not easy matter to understand, nor to act upon, but it represents our current world. We hope this paper is a first step in comprehension. Which is a necessary step to progress towards sensible action.

I. How to embrace chaos and complexity as a resilient organisation

Home, finally. I am nursing a cup of fresh ginger tea after what has been a very chaotic day. After a few sips of tea in the quiet, some things have started to make sense.

I now recognise the chaos of the past few days as the result of a misalignment between the team and management. On one side is the team, building our new product under the pressure of a deadline. On the other side is management, deciding everyone in the company needs to dedicate time to a company wide personal development training. This has left half the team working on getting a product live against a deadline, where the other half is focused on the future of their organisation and their role within it. This creates a group dynamic that fascinates me.

What could I have done to create more focus and less chaos during this past few days? Why did I not take more of these quiet reflective moments in the past months? Slowly my thoughts drift off to the question of when to start cooking for the family. We are having my famous vegetable curry. I am looking forward to the creative chaos of improvising with the ingredients which will lead to the curry paste for the dish.

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II. Sensemaking Architecture

This white paper is part of a series of white papers dedicated to discover 'Sensemaking Architecture'. In our first white paper we stated that 'Sensemaking Architecture' is 'Human-centric', 'Flow-oriented', 'Value-sensitive' and 'Discretionary' (van Steenbergen et al., 2019). The premise of our vision is that the world is getting more connected and more complex, and therefore there is a need for ***sense***making. Sensemaking to us is understanding what is going on so that suitable actions can be identified, as well as knowing what is the right thing to do.

This white paper is about the limitations of predictability and why, because of the inherent unpredictability, organisations have to be prepared to deal with chaos. In answer to this need, we discuss the concepts of fragility, robustness and antifragility and how to design for the different types of resilience organisations may need.

III. Making sense of chaos

It all boils down to the following: Our grand-parents where right!

Our parents and our grand-parents have been saying that the world is moving faster, that it is difficult to predict what the next big thing is, and that it is almost impossible to keep up. No matter the time period in which you are reading this, you are probably experiencing the same thing. In business management we even introduced the term VUCA in 2014 to catch the Volatility, Uncertainty, Complexity and Ambiguity of the world (Bennett and Lemoine, 2014b,a).

The unpredictability is caused by the connections in our world. The connections together create a hyperconnected graph of our world (figure 1). These graphs, created by our global digital communication, transport of goods and transport of money, enable us to relocate production all over the world in an ever increasing speed.

The global digital communication via the internet makes it possible to exchange information, knowledge and technology real-time.

In addition to an ever increasing speed, the newly created knowledge and technology of today is here to stay and

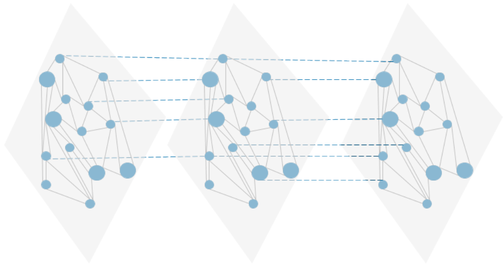

Figure 1: A hyperconnected multi-layered graph.

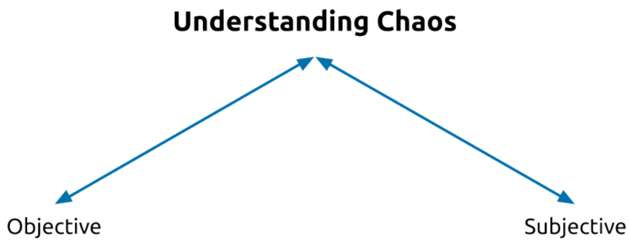

Figure 2: Making sense of chaos.

inspires the creation of new knowledge and technologies. The exchange of knowledge and technologies is not limited to what is initially created digitally. It also applies to old analogue knowledge (e.g. books). We are converting our old analogue knowledge into digital knowledge, and digital knowledge will find its way to the internet. The internet never forgets.

The interconnections in our world will grow ceaselessly, as there is no reason or force to remove them, and the connections are enforced by a need for more efficient and more effective products and production. This is causing the ever increasing frequency of the non-linear behaviour in our world.

Making sense of chaos.

On one side we have created a world that demands non-stop innovation to stay relevant as an (governmental/private) organisation. For most people, the added value achieved by this innovation is a good thing. On the other side we have created a world of which the behaviour is impossible to predict. Therefore this world also demands non-stop innovation to adapt to its chaotic reality. The concept of constant unpredictability makes most people unhappy. The aim of this white paper is to help in making sense of your context.

Context is very important. A railway track does not evolve and change with quite the same speed as the mobile app on your phone created by the latest startup. Different contexts require different tools. There are ways to design your organisation for dealing with chaos. DYA Sensemaking states that it is important to make sense of what is going on, and that you need to be sensitive to your context in how you design your organisation.

The first step of DYA Sensemaking in regards to chaos is to look at chaos via the (classical) lens of subjective and objective reality.

The second step provides concepts on how to reduce the subjective chaos and how to deal with the objective chaos.

Dealing with subjective chaos.

Reality looks different, when you have more knowledge and experience or when you change your perspective. To deal with subjective chaos, you should be embracing principles of the learning organisation in your own organisation. A healthy dose of humility and respect for other viewpoints should play an important role in the culture of your organisation.

Dealing with objective chaos.

To understand the concept of objective chaos, it helps to think of organisations as systems in itself consisting of interconnected subsystems.

These connections between sub-systems create a system with non-linear behaviour. Non-linear behaviour caused by interconnections between sub-systems lead to chaotic behaviour of the system.

When designing for dealing with such objective chaos, the question to ask yourself is: "Can I embrace the chaos or am I obliged to dampen the chaos before it enters my organisation." Let us return to the example of a railway track. A railway track does not reconfigure itself in response to the weather. Therefore the track needs to be designed to withstand a wide array of weather situations. This dampens the chaos of the outside world. The railway track can also embrace the chaos. You equip the railway track with a sub-system (e.g. a crew of mechanics) that can react to the weather with trains that can remove the snow from the tracks for example. When you provide the crew on the train with various tools to defrost and repair the railway track, you have created a sub-system trained to deal with the unexpected. This is an example of embracing chaos to a certain degree.

The challenge is: "how far are you willing to go in the embrace of chaos?"

In this white paper we elaborate on what we call subjective and objective chaos. By providing a more fundamental understanding of the two types of chaos, we aim to help you decide which tools may be used in your situation(s).

We introduce the Cynefin Framework by Dave Snowden as a tool to determine if you see the current context as chaotic or not (Turner and Baker, 2019). In the second part of the white paper we introduce the Extended Antifragile Attribute List (EAAL) as a framework (Botjes et al., 2021). The EAAL Framework distinguishes four behaviour-types to which you can design your organisation. These four are based on three types of resilience (Martin-Breen and Anderies, 2011) complimented with the ultimate form of resilient behaviour: antifragility (Taleb, 2012). For each of the four types the EAAL Framework provides certain attributes for you to incorporate in your design process of the organisation.

The main take-away of this white paper is: (1) unpredictability exists in both the subjective and objective world, and both worlds demand a different approach for dealing with it; and (2) neither type of chaos can be reduced to zero, and therefore the best coping strategy is to embrace it.

Figure 3: Embrace your subjective and our objective chaos.

IV. Limitations of predictability

In this section we will make the case that predictability (in the form of correlation or causality), in the occurrences of events and their outcomes, is fundamentally limited and challenged.

We elaborate on the classical distinction between objective and subjective views on reality. The four limitations we focus on are linked in the summary of this section, in order to make the (almost) philosophical view a bit more practical, and allowing us to use them in the design of our organisation(s).

The more we know, the more we know what we do not know

The parable at the beginning may have read to you as a familiar story. You probably observe the outcome of the chaotic and emergent process of cooking a curry, in a different way than the dynamics in a chaotic context of a project. The difference in observation plays a role in the difference between subjective and objective chaos.

Reflecting on what happened during the day, is in itself the basis of the scientific method to observe and try to make sense of what is going on. This implies that whatever is being observed will not make sense until the moment a hypothesis is formulated. The limitation of this method is our own reality, which is our reflection on the observations put into a hypothesis (Taleb, 2007; Hoogervorst, 2017; Jackson, 2019). More on this limitation in section IV-A. The creation of the hypothesis is part of what DYA calls sensemaking. The scientific method, which translates observations into patterns and then translates the patterns by controlled experiments into conclusions, brought us many beautiful inventions, the likes of paracetamol, antibiotics, air-travel and the internet.

The paradox of knowledge is that the more we know, the more we are confronted with things we do not know. This might be known to you as the Dunning-Kruger effect (figure 4, Dunning (2011)).

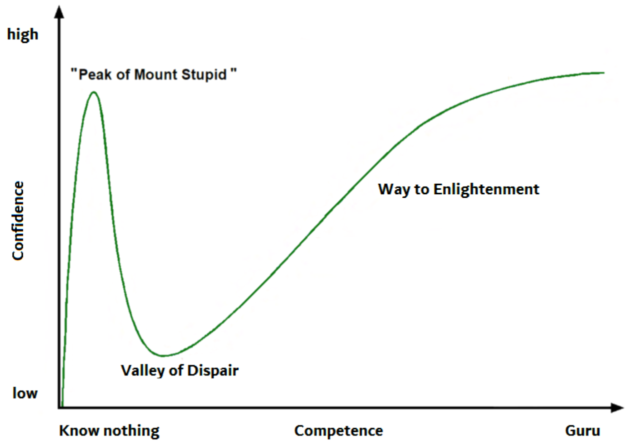

Figure 4: The Dunning Kruger effect (Commons, 2020).

Science is getting more aware that the scientific method of reductionism[1], repeatability and refutation has fundamental limitations (Jackson, 2019; Veronesi, 2014; Taleb, 2001, 2007). We highlight the following four limitations in this white paper (figure 5);

(A) The first limitation is that of perception in the observation. This limitation is known to us throughout the (modern) history and addressed by Plato, Nietzsche, Einstein, Popper and many more other scientist (Hoogervorst, 2017; Botjes et al., 2021).
(B) The second limitation is the interaction between the parts of the whole (Jackson, 2019).
(C) The third limitation is the limitation by the randomness of the observation (Taleb, 2001; Lorenz, 1963).
(D) The fourth limitation is the tendency of all things to transform into a state of a higher disorder.

These four limitations result in a world that is more unpredictable than we as humans are usually taught to accept. These limitations are the drivers behind rethinking our scientific method (Hodgson and Screpanti, 1991; Helbing, 2010; Hagger et al., 2016; Ioannidis, 2005; Veronesi, 2014).

[1]Reductionism is 'any of several related philosophical ideas regarding the associations between phenomena which can be described in terms of other simpler or more fundamental phenomena' (Wikipedia).

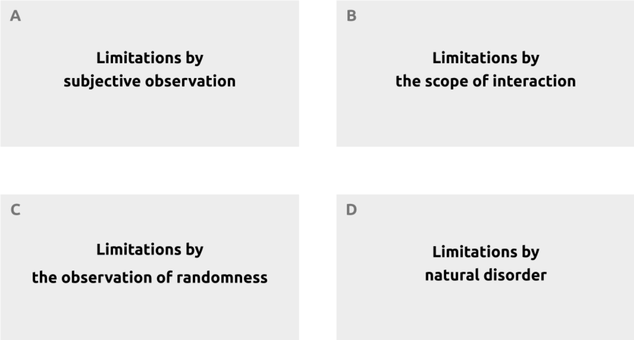

Figure 5: Each limitation requires a different design.

A. Limitations by subjective observation

The first limitation is that our observations are subjective on a personal level. This has impact on the conclusions we base on our observation, and on the observations by each of us individually.

It is very helpful and even essential in the communication between people to be aware of the subjective nature of our personal observations. It is possible to have a more human-centred dialogue with each other, when all parties recognise the concepts of correlation, causality and the role of perception in our observation. In the next six paragraphs we dig a bit deeper on these topics of correlation, causality and perception.

Experience determines pattern recognition

For some people a situation may feel chaotic, whereas for others, who recognise the patterns, it feels much less so. Pattern recognition is supported by knowledge, experience, and state of mind (Gladwell, 2013; Goleman and Davidson, 2018). Patterns are available in hindsight and sometimes they are considered predictive. For example, you can not predict *which* apple will fall from the tree, but when it does you can predict the speed of the apple when it hits the ground.

Causality is a pattern of cause and effect

When you can predict what is going to happen, you have insight in the relevant causal relations. For example, gravity and the acceleration of a falling apple have a causal relationship.

Correlation is a pattern of probability

When you can not predict what is going to happen, but if you can see the patterns in hindsight, then you have insight in the relevant correlations. For example, the wind and the act of the apple falling are not per say a causal relationship, since this will not be always the case. There might be a high probability that when the wind blows the apple falls from the three. This probability is called correlation.

Correlation becomes causality in a simplified controlled system

On the website "Spurious Correlations" of Tyler Vigen (Vigen, 2015a) there are many examples of things that have a very high degree of correlation but do not have a causal relationship (Vigen, 2015b).

If we know how high in the tree the apple is hanging from the tree-brach, we can calculate the acceleration of the apple and thus the time it takes the apple to hit the ground.

At least that is what is taught us in school. We might forget to include some external factors like, if there is somebody catching the apple, or at which altitude or on which planet the apple-tree is located. Or that the person that makes the calculation might make an calculation error. Causality can only be defined within a specific scope communicated in a simplified model of reality.

The scope is a limitation caused by perception. Perception is a result of our own experiences. Knowledge retrieved by education and study also influence our perception. Therefore our observation is formed by our experiences, which includes our knowledge. Observation is therefore subjective. See figure 6.

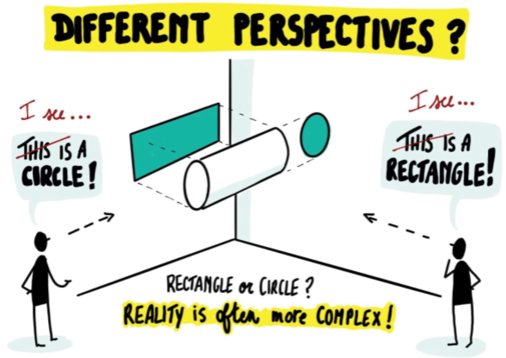

Figure 6: Personal Truth is bound by perspective by José Rafael Giraldo Tenorio.

Subjective observation is perception

The concept of perception is very old. The cave of Plato is a famous example on the influence of individual observation in the creation of ones own personal image of reality. Every observation is a personal observation and therefore different and difficult to communicate from one person to another. We need to simplify reality into reflections to be able to communicate with each other. Since reflection is a personal simplification it provides us with another challenge, that of perception (figure 7).

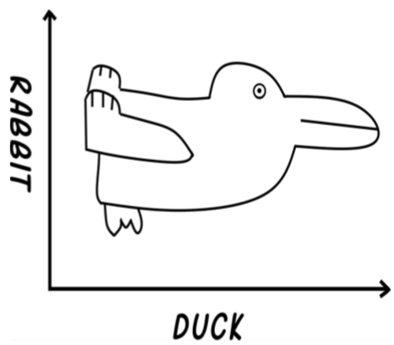

Figure 7: The Rabbit and the Duck.

> 'We do not see what we do not intend to see, we actually only see what we expect to see'
> - Dave Snowden 2018 - Domain Driven Design Europe Conference (Snowden, 2018; Ciborra, 2004).

The problem of the many

There is another reason that we use a simplified representation of reality in our communication. This is because reality, besides being personal, also in itself is very complicated and complex. Take for example the concept of a cloud in the sky which is an example of 'the problem of the many'. When we talk to each other, the concept of a cloud is very clear to us, but when we are trying to determine which part of the sky is part of the cloud and which part is not, it is not that clear anymore.

Summary It is important to be aware of the difference between correlation and causality, that causality is relative and to recognise that the difference between correlation and causality is at least limited by our personal knowledge and our personal observation.

Limitation A: Correlation and Causality are subjective and limit us in understanding our observations.

B. Limitations by the scope of interaction

In addition to our every observation being limited by our personal lens, a second limitation is the principle of causal relations only being understood when we make use of a simplified model of reality (section IV-A).

For example, when you suffer from a small pebble in your shoe. Since the pebble is very small and only touching your big toe, you can choose to ignore it. When you travel a few kilometres with this pebble in your shoe however, it starts to affect your whole being and not only the toe pressed against the sharp pebble. It might result in you suffering from the pain and not being able to walk for a few days. A nuance at your toe suddenly has now a big effect on your well-being as a human. The function of a simplified model is to limit the amount with which you take the the effect of the interaction between the sub-parts of a system into account.

To be able to apply causality in our reasoning, we need to simplify reality (section IV-A), but since most things in reality are connected to each other, this simplified model of reality excludes many influences, like second order effects or external influences. Someone catching the apple before it hits the ground is an example of an external influence. Your whole body hurting because you did not remove the small pebble from your shoe at the beginning of the long hike is an example of a second order effect.

The limitations caused by applying models as simplification of reality lead to observations of randomness.

Limitation B: Models are limited in describing and predicting reality.

C. Limitations by the observation of randomness

There is another aspect that limits our observation and analysis of a situation. This limitation can not be countered with knowledge or information, since it is not limited by subjectiveness or the scope of observation.

There are systems where the causality is known, where the relation between the input and the output can be defined via logical reasoning. For example the relation between the velocity of an apple and the duration of that apple falling. In the case of the apple; On earth, under normal atmospheric pressure, we define gravity, the linear relation between the speed of the apple and the period of the apple falling. A linear relation is deterministic when you can calculate a specific output with a known input.

That the combination of deterministic systems can create an non-deterministic system also applies to software. Examples of this non-linear behaviour are the flash-crashes on the stock exchange. These flash crashes are created by automated high-frequency trading platforms reacting on each other. The flash crash at the 6th of May 2010 has been investigated by the USA Securities and Exchange Commission (SEC) and delivered lessons learned on the non-deterministic behaviour of the systems.

> "One key lesson is that under stressed market conditions, the automated execution of a large sell order can trigger extreme price movements, especially if the automated execution algorithm does not take prices into account. Moreover, the interaction between automated execution programs and algorithmic trading strategies can quickly erode liquidity and result in disorderly markets. As the events of May 6 demonstrate, especially in times of significant volatility, high trading volume is not necessarily a reliable indicator of market liquidity. …May 6 was also an important reminder of the inter-connectedness of our derivatives and securities markets, particularly with respect to index products. …"
> - CFTC and SEC (2010)

Limitation C: When you combine two or more deterministic systems that interact with each other you create a non-deterministic system.

There are also systems that are non-linear. These are systems which behaviour (outcome) are non-deterministic. An example of a non-linear system is the Double Pendulum (figure 8). This is a construction of two beams connected to each other. The main structure is a beam with an axis to pivot around at the end of the beam. When you give the single blade a nice swing, the rotation speed and the positioning of the blade is pretty straightforward to predict and model in a formula (Shiffman, 2018). The interaction between the two blades creates a system in which the location of the blade tips can not be predicted. This because the smallest variation in the rotation creates an non-linear response, The non-linear behaviour of the double pendulum is an example of the smallest chaotic (non-deterministic) system you can build.

D. Limitations by natural disorder

There is a fourth way to look at a system and to state that chaos is inevitable. The second law of

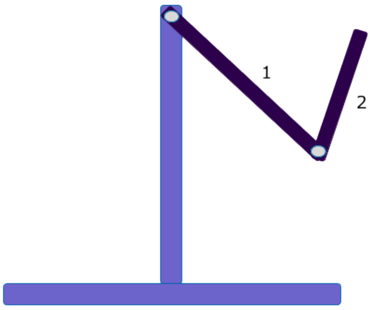

Figure 8: A double pendulum.

thermodynamics states that the disorder in the universe always increases (Lewis, 2000). It takes energy to keep structures intact when there is energy added to the system; this is the case for organisations as it is for materials. The concept behind this is entropy. The second law of thermodynamics is often projected on systems outside the domain of physics, for example organisations and IT Systems. There is no proof found by us that this projection holds to be true.

Having said so, below two examples of various concepts that predict the same outcome of natural disorder outside of nature.

1) IT Systems road to disorder. In the domain of IT systems there is the law of Lehman that states:

   > "As an evolving program is continually changed, its complexity, reflecting deteriorating structure, increases unless work is done to maintain or reduce it."
   > - Lehman (1996, 1980)

2) Human constructions and the road of nature to disorder. Where IT systems gain disorder when they change, it appears that mechanical constructions gain in disorder when left alone in contrast to nature which applies self-healing to deal with disorder.

   > "While the mechanical needs continuous repair and maintenance, dislikes randomness, and ages with use, the organic is self-healing, loves randomness (in the form of small variations), and ages with disuse."
   > - Dahlberg (2015), p. 17; Taleb (2012), p. 59

Systems appear to have the tendency to grow in disorder over time. Therefore hypotheses based on the observation in the now are limited by the tendency of systems to change over time. This is important to keep in mind when claiming that a hypothesis is proven by controlled experiments, since it might be the case that during the time between the original experiment and the moment of replication the system has changed and gained in disorder.

Limitation D: Systems have the tendency to change and gain in disorder over time.

E. Summary of limitations of predictability

The four limitations introduced in the beginning of this section, are elaborated up and provided with a single sentence reasoning. This combined provides us with the synopsis as depicted in figure 9.

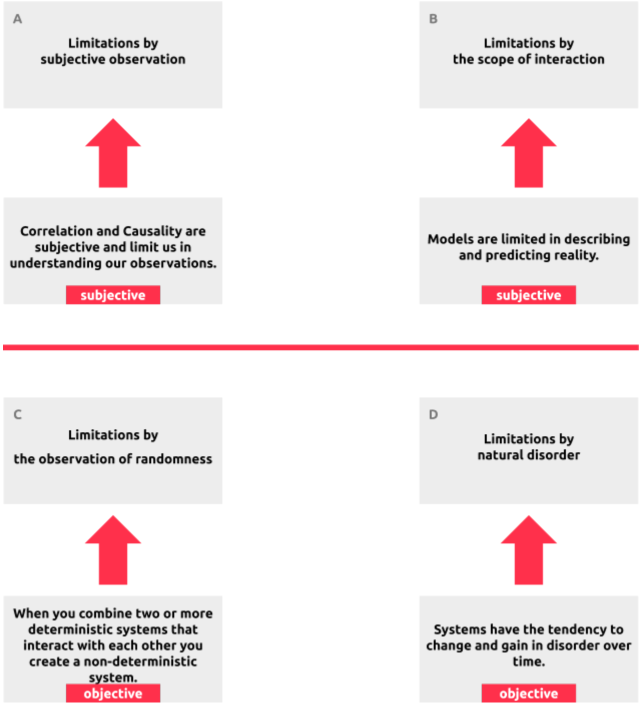

Figure 9: Limitations of predictability by objective and subjective reasons.

V. What is Chaos?

In this section we will go into (A) the relation between predictability and chaos, (B) Subjective and (C) Objective chaos and argue the relevance for organisations.

A. The relation between predictability and chaos

Chaos in the context of this white paper is defined by Edward Lorentz (Lorenz, 1963; Danforth, 2013) 'When the present determines the future, but the approximate present does not approximately determine the future.'.

Chaos is not something to be labelled good or bad. We argued in the previous section that predictability has at least four very fundamental limitations. Therefore unpredictability and thus chaos is inevitable and omnipresent. It makes sense that we accept the lack of knowledge and accept the limitations of our powers to predict. It is an effective way forward for us to understand what chaos is, what creates chaos and how to deal with chaos.

In line with the previous section we make make a distinction between two types of chaos: subjective chaos and objective chaos. Chaos is ***subjective*** since our observation and understanding of reality are limited. Therefore we are not aware of all causal relations that are relevant in regard to the design and operation of a system. Chaos is also ***objective***, since it is the result of the interaction of (deterministic) systems that create a non-deterministic system. In addition to the natural tendency of a system to transition into disorder. The importance of recognising the difference between these two types of chaos lies in the different ways how to deal with the chaos.

B. Subjective Chaos

Since chaos is also subjective, it is helpful to define when the situation seems chaotic and when it does not. In this white paper we adopt the following definition provided by Kurtz and Snowden (2003) also known as the Cynefin Framework (figure 10). The Cynefin Framework is a sensemaking framework.

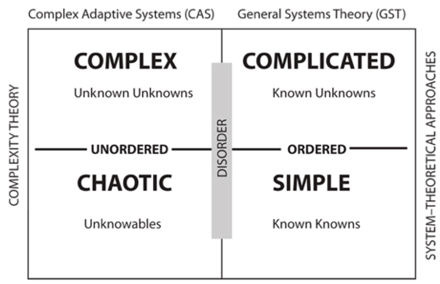

Figure 10: Cynefin Framework (Turner and Baker, 2019).

The Cynefin Framework provides context

We recognise the difference specified by the Cynefin Framework between: ***Chaotic***, ***Complex***, ***Complicated*** and ***Simple*** with ***Disorder*** as the context where it is not clear which of the previous four domains are most relevant.

When you do not see the patterns the situation is ***Chaotic*** to you.

When you see the patterns in hindsight but could not have predicated it would happen, the situation is ***Complex*** to you. In the ***Complex*** situation you can find correlation but no causality.

When you can predict the future after some careful and intensive study of what is going on, then your are in a ***Complicated*** situation. In the ***Complicated*** situation you can find correlation as well causality.

When it is clear what the result of an action is , and no study is needed, then you are in the ***Simple*** situation. In the various literature the synonyms ***Clear*** and ***Obvious*** are also used. In table I actions are defined for every of the contexts.

In which domain would you place a kids birthday party? Dave Snowden provides his view on this in the video "How to organise a Children's Party" (Snowden, 2009).

The value of the Cynefin framework is that it provides the possibility to see that chaos is a the contextual value. For example, when the understanding of a situation increases there is a possibility to move from the chaos domain to the complex domain.

Contextual design

When we design a system, it is important to acknowledge in which of the Cynefin domains a system will operate. For example: If we push down the throttle of a car, the car will most of the time accelerate (causality is known). On the other hand, if we do not know if the car is on ice, gravel or on a concrete slab, going full throttle can have various effects and might even cause death to the passengers and bystanders (causality is unknown). It is

Simple (Obvious / Clear)
Known Knowns This means that there are rules in place (or best practice). the situation is stable, and the relationship between cause and effect is clear. The advice is to: "sense–categorize–respond"
Complicated
Known Unknowns The relationship between cause and effect requires analysis or expertise. there are a range of right answers. Here it is possible to work rational. toward a decision but doing so requires refined judgement and expertise. The advise is to: "sense–analyze–respond"
Complex
Unknown Unknowns Cause and effect can only be deduced in retrospect, and there are no right answers. "impervious to a reductionist, take-it-apart-and-see-how-it-works approach. because your very actions change the situation in unpredictable ways.. - Thomas A. Stewar. The advise is to: "probe–sense–respond"
Chaotic
Unknownables Cause and Effect are unclear Events in this domain are "too confusing to wait for a knowledge-based response" - Patrick Lambe. The first and only way to respond appropriately is action. The advice is to: "act–sense–respond"
Disorder (Confusion)
There is no clarity about which of the other domains apply. "Here, multiple perspectives jostle for prominence, factional leaders argue with one another. and cacophony rules" - Snowden and Boone. The advice is to: break the situation down in to pieces that apply each to one of the other domains.

Table I: Cynefin domains (Wikipedia contributors - A, 2019).

clear that situational awareness is essential in the design and operation of a system. This applies to the design of a car and also to the design of an organisation.

C. Objective Chaos

We define objective chaos as: chaos that is caused by the non-linear behaviour of a system. Lorentz showed that connections between systems cause this non-linear behaviour.

Nature is a broad collection of these non-linear systems. We humans have used scientific methods to create systems which are linear. We also applied scientific management to the design and operation of organisations and IT systems. One of the ways to reduce the objective chaos was to control the context of a process. For example, when forging a kitchen knife, the scientific method is to analyse the optimal composition of the iron-ore and the optimal process and environmental situation during the forging processes. This method reduces the variation in the process. By making sure the ingredients are always of the same composition and making sure the atmospheric conditions are always the same, the system of forging is decoupled of as many of the factors that are to be identified. The standardisation and therefore decoupling of systems is the core of the scientific management method.

The intersection of exponential laws

The method of decoupling and standardisation, however, is losing its value due to the continuous growing inter-connectedness between systems. The inter-connectedness has been increasing since the invention of the combustion engine (trains, boats, cars, air-planes) and telecommunication (telegraph, phone, mass-media, internet). The inter-connectedness is growing at an exponential rate. This is caused by the 'laws' of "Moore¨, "Gilder" and "Metcalfe" (Kocovic, 2008). See figure 12 for the visualisation (Driscoll, 2011) of the effect of these three laws combined.

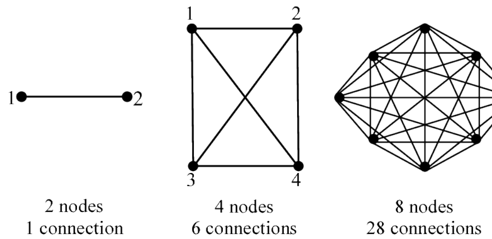

Figure 11: Metcalfes law (Yoo, 2015).

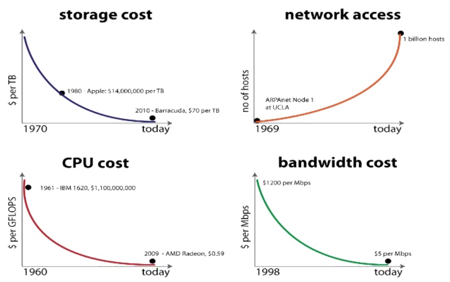

Figure 12: The attack of the Exponentials (Driscoll, 2011).

Moore's law 'is the observation that the number of transistors in a dense integrated circuit doubles about every two years' (Waldrop, 2016).

Gilder's and Nielsen's Law state that bandwidth doubles every 6 months (Gilder's Law) or every 24 months (Nielsen's Law) (Gilder, 1993, 2000; Nielsen, 1998).

Metcalfe's law 'states the effect of a telecommunications network is proportional to the square of the number of connected users of the system (N^2)' (figure 11) (Metcalfe, 2013, 1996).

It is therefore beneficial to increase the connection in a network topology. Metcalfe's law is often translated into a value proposition, since where costs increase linear with each new connection, the value increases exponentially (Jorgenson, 2015).

Exponential laws push the hockey-stick growth

Waldrop (2016) summarises the effect of the exponential laws as: The N^2 growth is often used as root cause for costs to decline sharply over the years. He continues with stating that the combination of the sharp decline in pricing and the sharp rise in network connections result in the sharp increase of the total value of the network. The sharp increase of the value of the network referred to was (or is) the driver behind platform solutions like Twitter, Facebook, Uber, AirBnB, etc (Waldrop, 2016). It was the value potential of companies, which made use of the technology to connect not only other computers but to connect people, that was the driving force behind the start-up hype in the early 2000. After the start-up hype the technology did not disappear and the value of networks did not evaporate. The phrase 'the network is the computer' coined in the 1980's by John Cage (Hubbard, 2014; Nikolaidis, 2016) has transcended to 'the network is the business model' (Parker et al., 2016).

Digitisation keeps on becoming more powerful, cheaper, faster and therefore keeps on having impact on product, services and organisations. The number of interconnections between IT, organisations and people are inevitably increasing. The increasing interconnections are not limited to the scope of the organisation. Digitisation enables the global society to become a global network (figure 13). Organisation structures are also changing into network-organisations (Aghina et al., 2017) by applying Holacracy (Robertson, 2015) and Sociocracy.

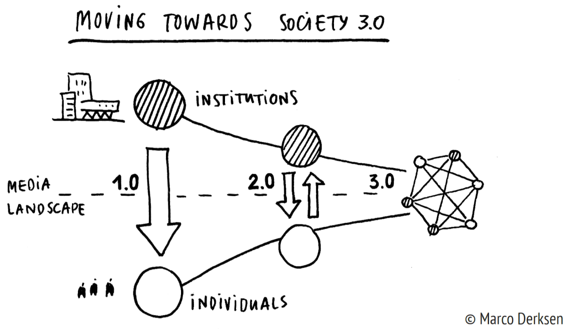

Figure 13: Moving to the network Society (Olma, 2013).

It is inevitable that platform solutions like Twitter and AirBnB will transcend from a platform to an ecosystem setup (figure 14), since an ecosystem has the potential to be a global network of interconnected platforms and networks. Therefore the evolution from a platform into an ecosystem will make it possible to diversify on a global level. Pagani describes this as the transition over three value networks: (1) a vertically integrated one, (2) a loosely coupled one, and (3) one based on a multi-sided platform (Pagani, 2013, 2014).

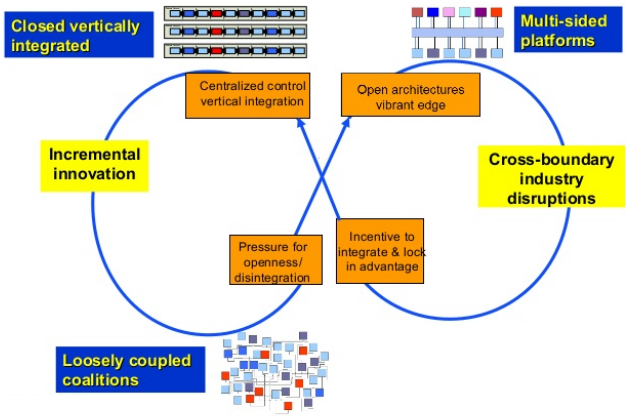

Figure 14: Mental Model of value networks (Pagani, 2013).

The global network

...made communication, information, knowledge and technology practically free, easy to acquire and easy to apply.

Communication and transportation of people and goods are friction-less and (almost) free. Communication happens every second through various channels and is available to us in multiple echo-chambers. Products are delivered quickly to our doorstep because of the network of the distributed logistics over air, sea, rail and road. In addition to free communication, knowledge and technology, product creation too, has fundamentally changed. Global logistics and assembly of goods, our economies of capital and labour and our knowledge sharing are the result of efficiency driven methods since knowledge, transport and communication used to be very costly.

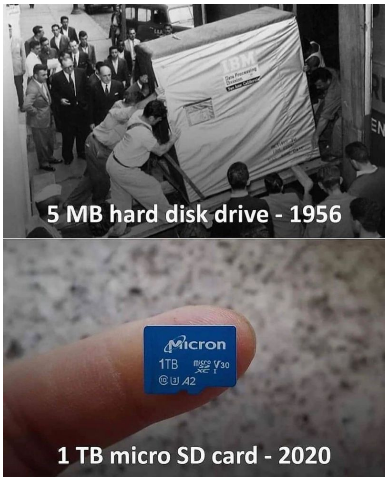

Figure 15: Technology Progress (nixcraft, 2020).

Scientific management founded by Taylor has enabled us to apply reductionism to decompose complicated situations into simple situations (Dietz et al., 2013). We have optimised these simple situations into the most lean and efficient situation. By applying the scientific management method we have created a global network for goods, people, capital, knowledge and services that is increasing in speed and diminishing in costs to the point that it is practically free and instant.

...enables consumers to switch within second to and away from your services.

Most products have become digital. The result of this is that the production processes have become shorter and iterative. The time from idea to real-life product at the fingertips of the end-user has never been this short and will become shorter in the future. The cost of switching between one digital product and the other is also minimised. A user can switch from energy providers with a swipe of the finger.

...enables us to achieve continuous innovation.

When the threshold to apply something is low because the prices are low (sometimes free) and the knowledge to be able to use it is also small, people are encouraged to create, re-use and co-create. It is the perfect breeding ground for innovation. The result is that new service offerings are popping up every second, and thanks to the internet, the potential market is global, providing every (new) service offering a global potential. Various digital companies, which started small and grew exponentially (hockey-stick growth curve), such as Google, Facebook, Instagram, Snapchat, Angrybird, Pokemon Go, Fortnite and AirBnB, are examples of the quick rise and disruption of the sectors they entered. The continuously increasing global innovation will cause non-stop disruption in every domain.

Objective chaos is the context of every organisation.

Due to free communication, information, knowledge and technology and the resulting distributed services, the current market is never complicated and straightforward. We have created a global non-linear non-deterministic system. An organisation operates in objective chaos by default. Thus every organisation operates in a complex or chaotic context. You cannot know everything that is of influence for your organisation because of the vast amounts of global interconnections. Every consumer and every co-worker is globally interconnected. Every IT, logistics and production system is globally interconnected. It is impossible to know everything in a situation. Complicated situations are almost all gone and have been replaced by complex situations.

D. Summary of what chaos is

Chaos is the inability to predict the future even if all the information is available. Whether this applies is a situational question that can be determined with the help of the Cynefin framework. The interconnected world is getting more connected, fuelled by an unstoppable force, causing the future to be unpredictable.

The question we need to answer is: What is needed for an organisation to stay relevant in the chaotic and complex context of reality.

VI. Organisations: complex systems in a complex context

Organisations are complex systems in a complex context.

A. What is an organisation?

The enterprise, in the scope of this white paper, is a synonym for organisation. The goal of an organisation is to remain significant for its stakeholders. Stakeholders are owners, employees and consumers (Op't Land et al., 2008).

An organisation is a system

Organisations are a certain type of system (Hoogervorst, 2017; Jackson, 2019; Beer, 1981; Morgan, 1986). This implies that some of the knowledge on systems can be applied to organisations.

An organisation is a complex system

An organisation is an intentionally created Complex Adaptive System (CAS) consisting of cooperating humans with a certain social purpose, whereby it is impossible to determine the ultimate (operational) reality of the enterprise down to the minute detail (Dietz et al., 2013). A Complex Adaptive System (CAS) is a type of a non-linear dynamical system. The scientific fields that study CAS are Complexity Science and Systems Engineering (Lansing, 2003). Chaos theory is part of both fields of study.

Engineering organisations

Organisations are designed with the skills available and most commonly accepted (popular). For long this has been (limited to) the school of scientific management which applies reductionistic methods and tools. In the current dynamic times the reductionistic way of reasoning and optimising is not sufficient to stay relevant as an organisation (Hoogervorst, 2017; Taleb, 2007, 2012; Botjes et al., 2021). As stated earlier, reductionism adds value in the 'Simple' and 'Complicated' domains, but when a topic is in the 'Complex' or 'Chaotic' domain reductionism adds little to no value.

An organisation is a collection of humans and a collection of open sub-systems. Human behaviour is not predictable, human communication is subject to subjective chaos, and open sub-systems have the tendency to show objective chaos. Therefore an organisation is in itself complex.

Organisations are part of a complex context that in itself is difficult to understand (subjective chaos) and often impossible to predict (objective chaos). Within Risk Management ISO 31.000 this is captured in the term VUCA (Hutchins, 2018).

B. Black Swans in the VUCA domain

Most, if not all, organisations operate in a complex or chaotic context that can be described as Volatile, Uncertain, Complex and Ambiguous (VUCA) (Hutchins, 2018; Mack et al., 2015; Bennett and Lemoine, 2014a,b). In table II you can find a definition per term.

Volatile and Uncertain are the result of objective chaos. Complex and Ambiguous are the result of subjective chaos. This makes it clear what the origin of the VUCA context is and why it is an essential part of Risk Management ISO 31000 and other ways that design the response to change of an organisation (Hutchins, 2018; Aven, 2011, 2012, 2015).

Volatile	
What it is	How to effectively address it
"The challenge is unexpected or unstable and may be of unknown duration, but it's not necessarily hard to understand; knowledge about it is often available.", "change is frequent and sometimes unpredictable."	"Agility is key to coping with volatility. Resources should be aggressively directed toward building slack and creating the potential for future flexibility."
Uncertain	
What it is	How to effectively address it
"Despite a lack of other information, the event's basic cause and effect are known. Change is possible but not a given.", "but it is unknown if an event will create significant change."	"Information is critical to reducing uncertainty. Firms should move beyond existing information sources to both gather new data and consider it from new perspectives.'.
Complex	
What it is	How to effectively address it
"The situation has many interconnected parts and variables. Some information is available or can be predicted, but the volume or nature of it can be overwhelming to process.", "not necessarily involving change."	"Restructuring internal company operations to match the external complexity is the most effective and efficient way to address it. Firms should attempt to 'match' their own operations and processes to mirror environmental complexities."
Ambiguous	
What it is	How to effectively address it
"Casual relationships are completely unclear. No precedents exist; you face "unknown unknowns."", "A lack of knowledge as to 'the basic rules of the game'; cause and effect are not understood and there is no precedent for making predictions as to what to expect."	"Experimentation is necessary for reducing ambiguity. Only through intelligent experimentation can firm leaders determine what strategies are and are not beneficial in situations where the former rules of business no longer apply."

Table II: VUCA abbreviation (Bennett and Lemoine, 2014b,a).

The ability to be prepared for what is going to happen, and designing an organisation accordingly, is limited. As not every potential unforeseen event can be foreseen. This is also known as the "Unknown Unknowns". These unforeseen events, which will disrupt the shared view of the reality, are called Black Swans (Taleb, 2007, 2012) or X-events (Casti, 2012; Hole, 2016).

The following statement is important to keep in mind, since this is the core premise of this white paper: **All models are simplified representations of reality and therefore vulnerable to black swans that come from the chaos of reality.**

VII. How to stay relevant

In a VUCA world in which organisations cannot fully prepare themselves for everything that might happen, the following questions become extremely important:

1) How do we stay relevant in order not to disappear?
2) How do we cope with the uncertainty of tomorrow with events that cannot be undone?

To address these questions we first of all turn to the different ways in which systems can react to stress from outside. We will see that there are various types of behaviour that systems can exhibit. When we want to design an organisation with the desired type of behaviour, we can apply a reductionist approach or a holistic approach.

A. Fragile, Robust and Antifragile

When systems are exposed to stress, their behaviour can be divided in one of the following three types: fragile, robust and the opposite of fragile, anti-fragile. The combination of these three behaviour types is illustrated as the triad in figure 16.

Fragile is the behaviour of a system (or you) that loses value when it is exposed to stress. An example of this is the behaviour of a fragile wine glass or delicate flower in response to a gush of water from a fire hose.

Robust is the behaviour of a system that is ignorant to stress in regard to value. An example of this is a block concrete that is exposed to a gush of water from a fire hose.

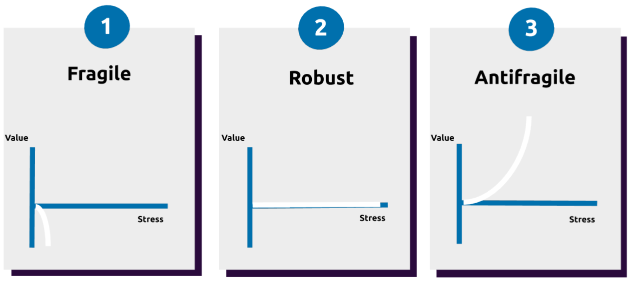

Figure 16: The triad (Taleb, 2012; Botjes et al., 2021).

The term antifragile is relatively new, and was introduced by Nicolas Nassim Taleb. Antifragile is the antithesis of fragile and therefore also written as anti-fragile (Taleb, 2012). A system displays antifragile behaviour when the value of the system increases when it is exposed to stress. An example of this is fertile ground exposed to a gush of water from a fire hose.

Organisations are complex adaptive systems. One of the properties of a complex adaptive system is that it is a system composed of various other systems, that can each be fragile, robust or antifragile. For instance, a fragile system can contain robust sub-systems: the delicate flower consists of pretty robust DNA and even more robust Atoms. Also, an antifragile systems can contain fragile sub-systems: an antifragile fertile patch of ground consists of fragile constructions of sand and fragile insects.

This implies that when we decide for ourselves which behaviour of the triad is the desired one, this behaviour is the result of a diversity of sub-systems.

An example of a robust system that contains fragile parts is the largest and one of the oldest living organism on our planet earth; a fungus with the name Armillaria ostoyae. '…the fungus is estimated to be 2,400 years old but could be as ancient as 8,650 years …' - (Casselman, 2007).

Figure 17: Armillaria ostoyae. This is image number 8037 at Mushroom Observer by Alan Rockefeller.

This fungus is very robust, it probably survived many extreme weather situations and even human interactions. This fungus is not a static system. Certain events have diminished the mushrooms (fragile behaviour) and after events like fire-storms or rain-storms the fungi experienced a growth spurt (antifragile behaviour). The behaviour of absorbing the change and returning to the (new) normal is resilient behaviour. Resilience is the path between robust and antifragility (Gorgeon, 2015; Kastner, 2017; Martin-Breen and Anderies, 2011; Passos et al., 2018; Aven, 2015).

B. Resilience

Resilience is all about dealing with change. There are many ways to define what resilience is. The most abstract definition is that resilience is the period in time from where a system absorbs the impact of a change until it recovers back to the original state of the system (figure 18).

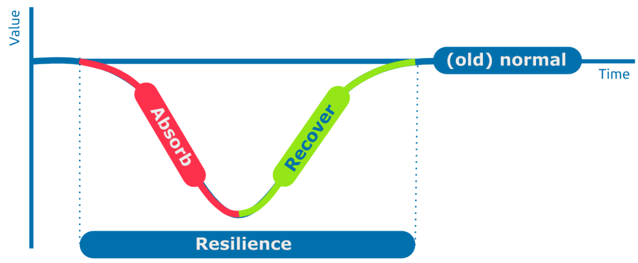

Figure 18: Generic Resilience.

A resilient fighter in a boxing match gets up after each hit and acts as if nothing happened. The boxer Rocky used this technique to outlast his opponent. A more resilient boxer would not only know how to take a punch but would also analyse the fighting style of their opponent, so that endurance and intelligence could be used to defeat them. There are many ways to find variations on the definition of resilience. For this white paper we use the definition provided by Martin-Breen and Anderies (2011).

Martin-Breen and Anderies (2011) identifies three types of resilience: Engineering resilience, Systems resilience and Complex Adaptive System resilience.

Engineering Resilience behaviour

This resilience is achieved by a detailed design and is the most efficient form of resilience. A system that is operated to achieve Engineering resilience can be recognised by a strict Command and Control operating model and micro-management style of leadership (Botjes et al., 2021).

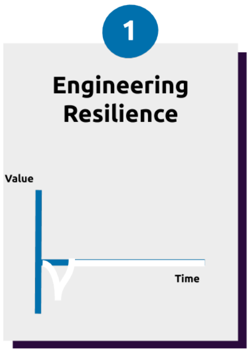

Figure 19: Engineering Resilience adopted from Martin-Breen and Anderies (2011) (Botjes et al., 2021).

A great example of this is a well designed monastery table. This is designed in a way that it can last for many centuries and generations. A monastery table only moves a little bit when you put it under great force, and quickly resumes it function of table. The construction of the table never changes. See figure 19.

Systems Resilience behaviour

Systems resilience achieves resilience by having backup systems in place. Key here is that certain functions are redundant; when one sub-system fails another one can fulfil the same function so the system as a whole can continue to work uninterrupted (Martin-Breen and Anderies, 2011). This demands a design that incorporates loosely coupled modules (Botjes et al., 2021; Mannaert et al., 2016).

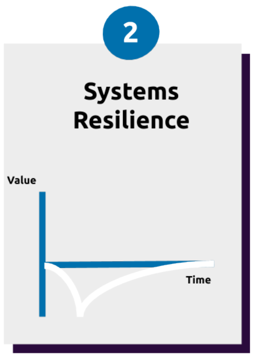

Figure 20: Systems Resilience (Martin-Breen and Anderies, 2011; Botjes et al., 2021).

An example of this is a laptop and the way power is provided to it. The battery in itself is redundant in respect to providing power when the power-adapter is plugged in. By applying the concept of loosely coupled modules it is possible for the laptop to keep on functioning when the power-adapter is removed from the wall socket. The construction that provides the power internally in the laptop automatically switches so you can keep using the laptop. See figure 20.

CAS Resilience behaviour

Complex Adaptive System Resilience is the third type of resilience identified by Martin-Breen and Anderies (2011). Here the sub-systems reconfigure to achieve a new optimum. To achieve a new optimum it could be necessary to not only change the construction of the system, the how, but also adapt the function of the system, the what. New circumstances might ask for a new proposition or services by the system. For example when the COVID-19 pandemic hit our global community, and lockdowns were issued as a countermeasure, many retailers around the world suddenly needed to digitise their business. This impacted their entire value chain; from receiving orders, delivering orders and the way customers could pay.

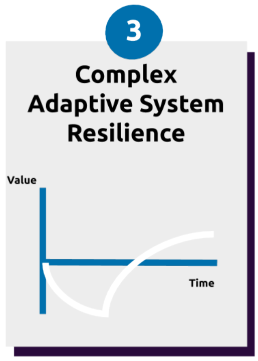

Figure 21: Systems Resilience (Martin-Breen and Anderies, 2011; Botjes et al., 2021).

Re-configuring the sub-systems of your organisation is not an easy task, the upside is that it enables you to achieve a new optimum. CAS resilience is therefore also the only resilience type that enables you to grow in value. This is important to understand when you design an organisation and the governance that comes with it. An organisational system that is designed for Engineering Resilience or Systems Resilience will not grow in value over time in response to stress.

In Section VIII we will discuss which attributes can be designed into a system to achieve a specific type of resilience, as well as which attributes are needed to optimise into antifragile behaviour.

Resilience in context with Robust and Antifragile

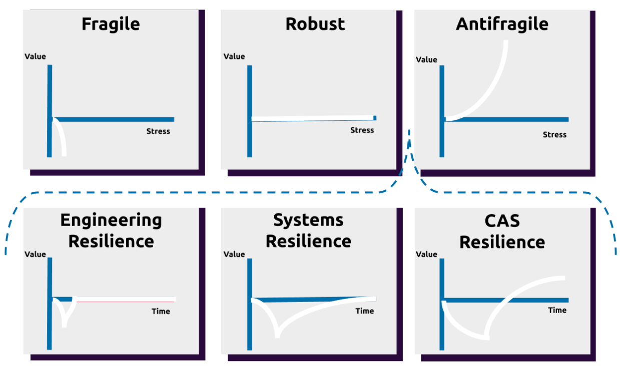

Figure 22: The triad of Taleb (2012) combined with the resilience of Martin-Breen and Anderies (2011) (Botjes et al., 2021).

The first two steps needed to design an organisation that can stay relevant are: 1) Choose between fragile, robust and antifragile as the target behaviour for your (sub-)system. 2) Choose which of the three resilience types you want as target behaviour for your (sub-)system. See figure 22 where the above are combined into one figure.

C. From Reductionistic to Holistic organisation design

Depending on the type of behaviour you want to design your organisation for, you can use a reductionist or holistic approach.

Reductionism

As stated in section IV, the scientific method of translating observations into an hypothesis and then via experimentation and data-analysis to reach a conclusion is a reductionistic way of describing reality. Reductionism has brought us much value and progress. When you choose to design an fragile or robust system, the reductionistic way provides many design tools and design methods.

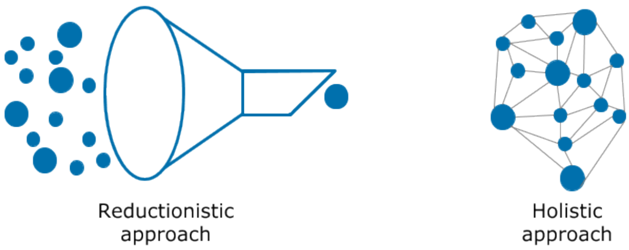

Figure 23: Reductionistic and Holistic approach (Botjes et al., 2021).

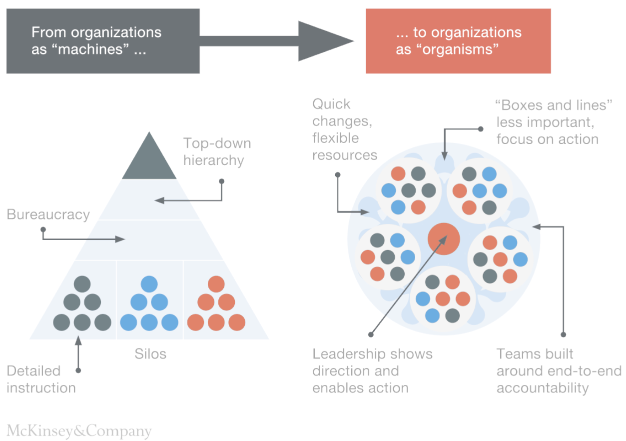

Figure 24: The Organisation as organism (Aghina et al., 2017).

Holistic

When the context is too unpredictable to apply reductionistic methods, the alternative approach is a holistic approach (figure 23). An holistic approach looks at the organisation as a whole, and applies principles and strategy (vision, purpose) as the glue between the autonomous sub-systems. Aghina et al. (2017) translates this into: "leadership shows direction and enables action" and "Teams built around end-to-end accountability." (figure 24). There are more tools and ways to use the holistic approach in organisation design.

D. Enterprise Architecture

It is important to understand however, that the field of Complexity Science intersects with the field of Enterprise Architecture, when we want to design an organisation in a holistic way, which is relevant when we want to design an organisation to deal with unpredictability. It is important to understand that the tools developed in the field of Enterprise Architecture originated in a time where the context around organisations could be identified as the domains Simple and Complicated. People where labelled as Human Resources. The labour that people did in an organisation was often compared to an assembly line. Dietz and Hoogervorst (2011) provides an critical view on reductionism in Enterprise Architecture.

In our view the more holistic view is fuelled by the global adoption of the agile way of working, which is less focused on blueprint architecture and more focused on value. The Enterprise Architect can not escape the need to deal with the complex domain. The EA methods and tools that focus on IT systems and apply a rigorous decoupling, can still be used, but as a compliment to a holistic approach.

What was a small group within the field of Enterprise Architecture in 2010, has grown, with more books and other publications focussing on how to design the coherence of an organisation in a complex environment by 2020. The challenge facing us is that the world is quickly moving into the chaotic domain, due to the open system property of (digital) organisations. With the chaotic domain being the context for more and more enterprises, Enterprise Architecture is facing an enormous challenge. The impact of an organisation changing to a chaos context is that models such as Porters supply-chain (Porter, 1985) and the Business Model Canvas (Osterwalder, 2004; Osterwalder et al., 2010) are less applicable, as they represent a two-dimensional relationship. The supply-chain and business model canvas work best in a predictable world. The challenge is to determine if they can be applied in the current Cynefin context for designing the desired resilient behaviour.

So, how do we design an organisation to stay relevant in time?

E. Enterprise & Systems Engineering

When the context inside and outside of the organisation is complex or chaotic, then how to design enterprises and organisations so that they can stay relevant for a longer time? To answer this question two fields within Systems theory merit special attention:

1) Enterprise Systems Engineering, as part of Systems engineering as part of System-of-Systems Theory.

"One type of enterprise architecture that supports agility is a non-hierarchical organisation without a single point of control. Individuals function autonomously, constantly interacting with each other to define the vision and aims, maintain a common understanding of requirements and monitor the work that needs to be done." – Systems-Engineering Body Of Knowledge.

2) Antifragility as part of Complex (Adaptive) Systems as

part of Systems-of-Systems theory.

The field of antifragility states that it is possible to create an organisation that is strengthened by a change in its context. Moreover, since the world is chaotic, there is non-stop change and thus non-stop input to enhance the organisation.

The design principles that come from antifragility are deeply intertwined with the main topics of Complexity Science.

For Enterprise Engineering, the key take aways are:

- Predicting is very hard. Stay away from complex (strategic) planning when possible.
- Reducing complexity is a must to stay agile as an organisation.
- Focus on the combination of the power of the network and the power of the individual to create maximum resilience.
- Create an eco-system that motivates learning and adapting in order to survive.
- Design principles should make use of game theory to strengthen and guide the enterprise since a principle that motivates people into action is stronger than a belief that guides decisions with a statement.

Communication, information, knowledge and technology are free, easy to acquire and easy to apply, so we should utilise these in a continuous process of adapting and strengthening the organisation. In the next section we discuss the attributes that need to be designed into various types of robust or antifragile organisations.

VIII. Extended Antifragile System Attributes

Resilience is the ability to deal with outside stressors. As we have seen, there are three ways to do this (Martin-Breen and Anderies, 2011).

1) Engineering Resilience, focus on resistance.
2) Systems Resilience, focus on risk vs efficiency.
3) Complex Adaptive Systems Resilience, focus on change.

Complex Adaptive Systems (CAS) Resilience does also include the ability for an organisation to change their function. When an organisation states that their business model is always changing (for example Amazon, BOL.com etc) then they state an attribute of a CAS resilient organisation.

An organisation is antifragile when it is not only focused on change but focused on gaining value from change on the in- and outside of the organisation. A CAS Resilient organisation learns by doing, and an antifragile organisation aims to increase the amount of outside stressors to gain value. For an organisation, being a system-of-systems, to be antifragile, it needs sub-systems that are robust and resilient (Taleb, 2012; Botjes et al., 2021).

The attributes that are needed for resilient behaviour of a system, are grouped in clusters in the EAAL (Extended Antifragile Attribute List) framework (Botjes et al., 2021).

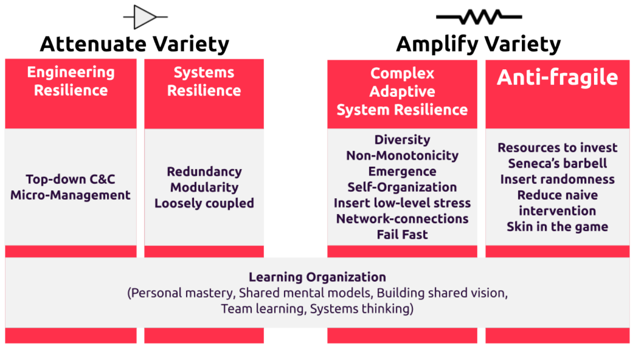

Figure 25: EAAL Framework (Botjes et al., 2021).

One cluster is the reduction or attenuation of the non-deterministic state of the chaotic world into a smaller and deterministic amount of states within the system. For example the translation of the gender of a person into male or female. Engineering resilience and systems resilience fall into this category.

The second cluster is focused on the the amplification of the amount of states within the system. For example by encouraging entrepreneurship and innovation within a team, and developing a service that supports every gender the user of the service identifies with. Complex Adaptive System resilience and anti-fragility fall into this category.

Besides these attributes related to the type of resilience, there is the universal need for all organisations to learn. An organisation can not be resilient without learning. This is the third cluster of attributes.

The next sections describe the system attributes which contribute to the resilience types and to learning organisations.

A. Attributes relevant to Engineering Resilience

To achieve Engineering Resilience we consider the following two attributes to be relevant:

1) Top-down C&C
2) Micro-Management

Top-down command & control As stated before, engineering resilience is achieved by a detailed design. Implementation follows design, therefore the design needs to be enforced by a clear top down command and control structure (Martin-Breen and Anderies, 2011; Kastner, 2017; Henriksson et al., 2016; O'Reilly, 2019; Johnson and Gheorghe, 2013).

In the organisational context, this implies that the employee is not free to decide which action is best to take in a specific situation. The freedom to act is provided by organisation hierarchy in contrast to an organisation where the freedom to act is linked to the purpose and autonomy of the employee.

Micro-management Next to a clear command-and-control (C&C) structure that enforces the following of the design, the detail of the design is relevant to achieving engineering resilience. The design needs to cover every minute detail to cover all possible events that might occur (Martin-Breen and Anderies, 2011).

Great examples of detailed design that result in a product that can absorb unforeseen events are the iPhone, a piece of Lego, and a German car (as for example a BMW). When an iPhone is dropped on the floor and/ or into the water, it will continue to function. An iPhone is designed to absorb the impact of the drop and continue functioning.

It can be stated that for a certain level of resilience these two attributes always need to be in place. If there is no clear hierarchy or no design then there is also never a way to absorb change and uphold the function and construction of the system.

B. Attributes relevant to Systems Resilience

The following three attributes are relevant to achieve Systems Resilience behaviour in an organisational system.

1) Redundancy
2) Modularity
3) Loosely coupled

Loosely coupled When resilience is achieved by the presence of backup systems, then it is clear that the sub-systems need to be loosely coupled. The loose coupling should have the effect that the failure of one sub-system has no effect on the other sub-systems. How to achieve the best segregation of components is a very challenging field of expertise (Mannaert et al., 2016).

Modularity To achieve loosely coupled sub-systems it is evident that the identifications of the sub-systems plays an important role. The design question at play here is how granular identified the various modules will be. The more granular the identification the more the ripple effects of a (un)foreseen change are contained (Hole, 2016; O'Reilly, 2019; Gorgeon, 2015; Martin-Breen and Anderies, 2011; Santos, 2012; Liu and Thompson, 2002).

Redundancy Containing the outage caused by an event is not enough to guarantee provision of the desired function. The system also needs to have alternative modules in play to provide the desired function. When the power-adapter in you laptop is removed, the power-connector in your laptop and the electrical wiring make certain that the screen and keyboard are not affected. This is loosely coupled in action. It is the presence of the Battery pack that enables the laptop to keep functioning The battery pack in itself is redundant but plays a crucial role when needed.

This is the design challenge with redundancy. It is not cost effective to have one or more sub-systems that provide the same function, but it is very effective when needed. Redundancy tends to stabilise systems and improve robustness (Kennon et al., 2015).

The paradox of redundancy and the decoupling of the various modules is that the addition of extra components and connections between the components adds to the complexity of the system and therefore increases the likelihood of failure (Perrow, 1984).

C. Attributes relevant to CAS Resilience

The Engineering and Systems resilience is achieved by dampening the effect on the system caused by an event. The design process aims to combine all the occurrences in reality into a predictable, reduced and known amount of states. For example: power-on and power-off.

A higher level of resilience than the engineering and systems resilience, is achieved by increasing the number of internal states in response to the outside world. This approach is the opposite of reducing the outside world into the few known states.

We identified the following seven attributes as relevant to achieving more resilient behaviour in an organisational system.

1) Diversity
2) Non-Monotonicity
3) Emergence
4) Self-Organisation
5) Insert low-level stress
6) Network-connections
7) Fail Fast

Diversity When the implementation of a certain system attribute is homogeneous, then this system is vulnerable at this attribute. Diversity is key to counter the impact of an unpredictable variety of events. This is why diversity is very important to be resilient

When the whole of the country is using public transport to commute between work and home, then the country is vulnerable to a strike in the public transport sector.

Other examples of homogeneous culture leading to vulnerabilities are the application of a limited amount of program languages in a company.

Forms of diversity are more heterogeneous mixes of implementation, as for example the application of multiple programming languages in the company, the usage of various forms of transportation in the commute from home to work and the multi-branding of the same product to appeal to various customers.

Another example of achieving diversity is the company Booking.com that runs in production various A/B tests with a wide variety of features (Kaufman et al., 2017).

Diversity is also present in the form of optionality. optionality is the ability to solve a problem in more than one way with different components (Taleb, 2012; Hole, 2016; Martin-Breen and Anderies, 2011; Gorgeon, 2015; Kastner, 2017; O'Reilly, 2019; Derbyshire and Wright, 2014; Martinetti et al., 2017). Optionality delivers flexibility to the system (Derbyshire and Wright, 2014; Martinetti et al., 2017; De Florio, 2014; Holling, 1996; Janssen, 2015).

An example of optionality is having multiple delivery companies that transport goods from your warehouse to your customers instead of contracting just one delivery company. This makes you less vulnerable to changes in service agreements, pricing etc.

Increased diversity provides you with more options, and this increases your resilience.

Non-Monotonicity Learning from mistakes can be an effective defence against stressors. When something bad happens you can make the most out of this situation by learning from it.

Learning from mistakes and failures will provide new information. Incorporating this new information in your way of working is called Non-Monotonicity.

As new information becomes available it defeats previous thinking, which can result in new practices and approaches. Explicitly learning from the failed situations and extending the tools, approaches and used languages is what non-monotonicity adds to the learning organisation.

Learning from the negative outcomes results in actually improving the system in response to stressors (Johnson and Gheorghe, 2013; Ghasemi and Alizadeh, 2017; Kennon et al., 2015; Ghasemi and Alizadeh, 2017).

Emergence Emergence describes the concept of each of the parts of a system not having a certain property while the system as a whole does. Phrased in a more complex way: when there is little or no traceable relation between the 'micro and macro level output', it is a case of emergence.

An example of this is a creative collaborative process in a team or a group of people achieving flow. Another example of emergent behaviour is birds flocking.

The law or Requisite Variety applied in this reasoning, leads to internal emergence countering external emergence, and this leads to antifragility (Kennon et al., 2015; Ghasemi and Alizadeh, 2017; Johnson and Gheorghe, 2013; Christen and Franklin, 2002; Goldstein, 1999; Menzies, 1988).

Self-Organisation Another key element for increasing the internal variety is the ability of self-organisation. Self-Organisation is the property of a system to achieve some form of overall order by interactions from within the system only (Kastner, 2017; Henriksson et al., 2016; Kennon et al., 2015).

For example, students sitting together in the school cafeteria grouping together and showing interactions between the groups and not only as individuals.

Insert low-level stress When a system is able to learn from failure (non-monotonicity), to self-organize and self-reorganize it makes sense to exploit these capabilities. By continuously inserting low-level stress into the system, stimulating it to learn, continuous improvement is achieved (Taleb, 2012; Kennon et al., 2015; Ghasemi and Alizadeh, 2017; Gorgeon, 2015).

Non-stop stress will keep the system sharp at al time.

Network-connections As discussed before, a system needs connections to grow in value, and also to increase the number of loosely coupled modules. Increased diversity in the system and the optionality needed, is also dependent on connections.

More connections increase the potential for new constructions and also new functionalities (Kastner, 2017; Johnson and Gheorghe, 2013; Ghasemi and Alizadeh, 2017; Markey-Towler, 2018; Henriksson et al., 2016; Gorgeon, 2015; Hole, 2016; O'Reilly, 2019).

This is why internal and external network-connections need to be designed into the system to support the CAS resilient behaviour.

Fail Fast When the system is able to learn and is continuously triggered by a low level-of-stress to keep learning, the next step is to increase the speed of learning (Kennon et al., 2015; Gorgeon, 2015; Hole, 2016; Ghasemi and Alizadeh, 2017).

We might know the credo of "Fail Fast and Fail often".

Exploiting the created feedback loop to learn faster than the competitors is the goal.

A CAS resilient system combining these seven attributes is a learning system able to adapt. The attributes described in the next section address what is needed to maximise the benefits of having a CAS resilient system and make it antifragile.

D. Antifragile attributes

The CAS resilience organisation over time recovers from a stressful event, where an antifragile organisation is optimised for stress. It is the antifragile organisation that loves chaos.

In other words, a CAS Resilient systems displays the following behaviour $value = f(time)$, and antifragile behaviour is described as $value = f(stress)$.

The following five attributes are provided by Nicolas Taleb. These attributes help a system to optimise the CAS resilient behaviour.

1) Resources to invest
2) Seneca's barbell
3) Insert randomness
4) Reduce naive intervention
5) Skin in the game

Resources to invest Opportunities can only be seized when there are resources available to invest. Acting with your hand tied behind your back is not ideal. Resources can mean money, but can also be time and labour. When you have no time in your team available to exploit an opportunity, then the opportunity will be missed. Having resources to invest is a clear example of choosing effective over efficient.

Bottom line: if you want to survive a Black Swan event, then you need to be able to make an investment in response (Taleb, 2012; Gorgeon, 2015; Kastner, 2017; Henriksson et al., 2016).

Seneca's barbell Taleb states that you should not limit investments to the moment a Black Swan occurs. You should also make nonstop investments to leverage opportunities. The Seneca's barbell investment strategy is what Taleb advises to achieve antifragility.

To be antifragile you need a robust sub-system in which 80-90% of predictable value is situated. The goal is to have a low risk, high predictable value stream, which is the base of your viability. Seneca's barbell investment strategy states that you invest the remaining 10% to 20% in high return and therefore high risk opportunities.

Using this strategy, it is OK when an opportunity does not pay-off since your viability is covered by the other side of the barbell. And when the high risk investment does pay off it will bring a very high return. This extra value can be used to add to the ***resources to invest*** or used to improve the organisation (Taleb, 2012; Johnson and Gheorghe, 2013; Kennon et al., 2015; Henriksson et al., 2016).

Insert randomness Antifragility is the optimisation of CAS resilience. The optimisation of ***insert low-level stress*** is the insertion of randomness.

Inserting randomness is not flipping a coin when a decision needs to be made. The challenge is to invite randomness into your system, where the driver is external.

A great example of inserting randomness is introducing a bug-bounty program. This will provide an incentive to people from outside your organisation to hunt for bugs in your software. You are not in control how and when they do this. The fact that you are not in control is an indication that you are inserting randomness into your organisation (Taleb, 2012; Kennon et al., 2015; Gorgeon, 2015; Ghasemi and Alizadeh, 2017).

Reduce naive intervention Naive intervention is an intervention based blindly on reductionistic logic and models. The fragility of this approach is the probability of ignoring the voice of experience. Taleb states that there is much value in experience. Experience that people have collected and experience of a system.

The example that Taleb often uses is that of the existence of books. These have been around for millennia and there is a high probability they will outlive you and me. Why this is the case might be open for discussion but the fact that they are still here can not be denied. There is value in respecting the balance that has been established in the (eco)system.

Respecting the experience should be applied to the experienced employee even when they are not as articulate as the less experienced but more eloquent coworker (Taleb, 2012; Gorgeon, 2015; Kastner, 2017).

Skin in the game To aim ***self-organisation*** towards a true north it is important to add the attribute of skin in the game to the organisation. Skin in the game boils down to the question: Do the decision-maker(s) have a pain and gain relation with the outcome of their decision?

An ancient story on the impact of having skin in the game is that of king Salome and the court case on who is the true child's' mother. Another example is the challenge who is going to fulfil the role of Product Owner. It is not uncommon that someone is selected who has connections with the user base of the product and who can communicate with the engineering team that is going to build the product. This is not a healthy setup. Even worse is the situation where the product owner is someone from the same part of the organisation as the engineers.

Best is to have someone as Product Owner who is a team-member of the people that are the end-users of the product. A product owner with skin in the game of the end-users will make decisions that will benefit the pain and gain of the end-user. A product owner then is able to defend features important for the users, and provide the needed context to the engineers.

Skin in the game goes beyond having a feedback system in place, and goes beyond having KPI's in place.

Taleb states that antifragility needs decisions to be made with skin in the game, otherwise decisions will be a technocratic evaluation of pro's and con's (Taleb, 2012; Kastner, 2017).

E. The learning organisation

The learning organisation is what makes it possible to design, implement and absorb change. That is why at the various levels of resilience, the learning organisation is mentioned, and should always be part of the organisation design.

There are many views on what defines a learning organisation. The attributes defined in literature as relevant to learning overlap with the concept defined by Senge (1990) as The fifth discipline. See figure 26.

Senge defined the following five elements, which together enable an organisation to learn.

1) Personal mastery
2) Shared mental models
3) Building shared vision
4) Team Learning
5) Systems thinking

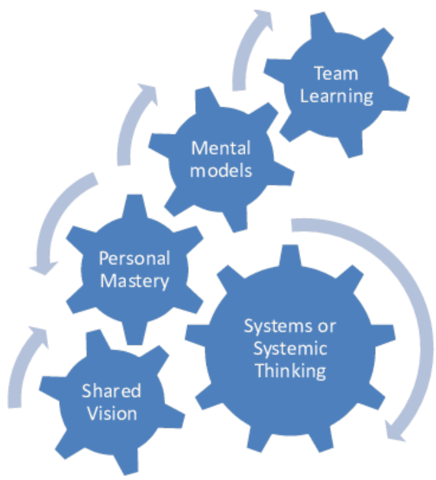

Figure 26: Fifth Discipline (Senge, 1990; Jain, 2020).

Personal mastery Most know the triad of Mastery, Autonomy and Purpose evangelist by Daniel Pink during the agile movement. The elements mastery and autonomy can be recognised in what Senge calls Personal Mastery. Senge states that for an organisation to learn it is important that every person is focused on excelling in their profession and understanding their own being.

> ”Personal mastery is a discipline of continually clarifying and deepening our personal vision, of focusing our energies, of developing patience, and of seeing reality objectively.” - Senge (1990)

When you know that your best way to learn is via visual stimulation and in co-creation, and you know you can not learn well from written instructions and constantly being challenged, and when you are able to communicate this to your surroundings, you can work together towards a learning environment suited for you.

Shared mental models Your reality and your observation of that reality is dependent on your perspective and experience. This is what we identified as one of the reasons that subjective chaos exists.

To align with other people it is good to have a shared view of the world. This can be through a story or a mindset. The role and impact of religion on the world is that it provided a clear shared mental model of reality. This is the case for many other things like politics, science and fiction.

> ”Mental models are deeply ingrained assumptions, generalisations, or even pictures of images that influence how we understand the world and how we take action.” - Senge (1990)

When an organisation wants to learn, it needs to share mental models of their reality. The earlier mentioned Purpose can only add value when people in the organisation share the mental model of this purpose.

The field of Enterprise Architecture and Change Management have in common that they revolve around the importance of shared mental models. To guide change and to see reality together through a similar lens.

Building shared vision When you know what works best for you to learn and you share views on the world with your peers, then you can collaborate on a shared vision. This again aligns with providing a purpose. The added value of building a shared vision in contrast to adopting a provided vision is that it becomes your vision when you are part of the building process.

> ”Building shared vision - a practice of unearthing shared pictures of the future that foster genuine commitment and enrolment rather than compliance.” - Senge (1990)

Co-creation of a vision has the benefit that the language and underlying models are part of the vocabulary of the participants. And that participants are evangelists of the vision from the start.

Team learning When you learn in solitude you can work on your own mastery. This has value. When a group of people develop themselves but not learn together the gap between the individuals of the group will grow.

> ”Team learning starts with ’dialogue’, the capacity of members of a team to suspend assumptions and enter into genuine ’thinking together’.” - Senge (1990)

Non-monotonicity as attribute of CAS resilience is a specific aspect of the development in Team learning, where the language of the group is expanded by learning from the failures. Team learning can also include refreshing the instructions or the team participating in a postmortem retrospective.

Systems thinking Systems thinking is also called systemic thinking. This is the fifth discipline that integrates the four other disciplines.

Systemic thinking is to understand that everything is connected in the now and by the past. The interconnections in the now have the effect that when you optimise one point in the now it affects many other elements in your system. Changing the now is never as easy as you think, since systems and persons are the result of their experience and history. Therefore an optimisation in the now is always a change on the underlying patterns.

According to Senge (1990) the four other disciplines play the following role in respect to systems thinking:

1) ”Building a shared vision fosters a commitment to the long term.”
2) ”Mental models focus on the openness needed to unearth shortcomings in our present ways of seeing the world.”
3) ”Team learning develops the skills of groups of people to look for the larger picture beyond individual perspectives.”
4) ”And personal mastery fosters the personal motivation to continually learn how our actions affect our world.”

Learning is the key foundation under the three types of resilience and under antifragile behaviour. When in doubt, start here.

IX. Design for Chaos

Chaos has a constant presence in our reality. The relevance of dealing with chaos will increase for our organisations and its stakeholders. Therefor it is of great importance to prepare your organisation by designing it for chaos.

To design your organisation for chaos, we propose the following steps:

1) *Embrace the chaos*,
since it is inevitable and omnipresent.
2) *Recognise objective and subjective chaos*,
since each demand different mitigations.
3) *Plot your problem scope on the Cynefin framework*,
since each domain within Cynefin contains a different challenge and asks for appropriate tooling.
4) *Determine the desired level of fragility*,
It matters if you aim to achieve fragile behaviour for your (sub-)system or antifragile behaviour. Resilience is relevant for robust and antifragile systems.
5) *Determine the level of resilience you desire*,
the more resilient a system, the less efficient and the more it can adapt. This is not desirable for every

situation. The more resilient a system, the more it can deal with objective chaos.

6) *Learn how to apply and improve*,
aspects of the learning organisation. Learning will increase your resilience and reduce subjective chaos.
7) *Use the EAAL Framework*,
to validate per sub-system if the appropriate attributes are in place. The EAAL Framework is a holistic view on how to reduce and deal with objective and subjective chaos.
8) **Loop over these seven steps for continuous improvement**

X. Next steps for DYA sensemaking

During our journey of discovering and designing DYA Sensemaking, we recognise that we apply methods, languages and processes that have a base in the school of reductionism.

Examples of our reductionistic behaviour is our usage of phrases as "an organisation is a system" and "determine if the systems should show a …behaviour".

We are asking ourselves: is this a good or a bad thing. For example: Dave Snowden is working in the field of Domain Driven Design, with a method that does not interview people on a certain topic to identify groups, but applies data analytics to create a view of which groups of people can be created that apply similar mental models. This approach is breaking with the classical interview and model methods we are applying in our day-to-day work.

The topic of human centric needs to be incorporated in our own way of working to discover less reductionistic ways to provide guidance on how to design an organisation. A more human centric approach would improve the impact of purpose and relevance to stakeholders of the organisation.

Our goal should be: how do we help stakeholders to collaborate to achieve their purpose and relevance. We welcome your help, inspiration and feedback and invite you to join our quest.

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About the Authors

Marlies van Steenbergen is an experienced enterprise architect. She works as an advisor and coach in the field of enterprise architecture and has guided many organisations from all industry sectors in the development of an effective enterprise architecture practice. In 2017 she became Professor Digital Smart Services at the university of Applied Sciences Utrecht. Marlies is co-founder of DYA (Dynamic Architecture), offering a pragmatic approach to architecture based on best practices. Nowadays, Marlies focuses on the link between architecture and innovation and on Digital Ethics.

LinkedIn | Sogeti Profile

Ton Eusterbrock is an experienced enterprise architect. He works as an advisor and coach in the field of enterprise architecture and has guided many organisations from all industry sectors in the development of an effective enterprise architecture practice. Ton is one of the promoters of DYA (Dynamic Architecture), offering a pragmatic approach to architecture based on best practices. He is also a speaker on seminars and lectures at universities and coaches students teams. Ton's focus is in architecture principles and how to organise architecture governance in modern ways of working.

LinkedIn | Sogeti Profile

Hans Nouwens is an experienced enterprise architect with 20+ years of practical experience in the field of ICT, infused with rigorous academic learning. He works as an architect and trusted advisor mainly for Higher Education institutes. Enterprise engineering, enterprise architecture and enterprise governance are his specialities that come with DEMO and CGEIT certifications. Hans has an academic interest in systems theory and cybernetics. Hans volunteers as board member for the interest group architecture of the KNVI and as board member of the Dutch society of systems thinkers (SCIO-NL). He regularly gives guest lectures on enterprise architecture and coaches students teams.

LinkedIn | Sogeti Profile

Edzo A. Botjes is an experienced all-round (IT) professional and architect with 25+ years' experience. He works as an enterprise, program and solution architect for companies from all industry sectors. He does this by combining various expertise's to identify and resolve root-cause issues in the Enterprise Governance domain and in the realisation domain of an organisation. Edzo is a creator and loves sharing his passion via blogs, workshops and presentations. His focus nowadays is on the evolution of organisations into antifragile organisations and the role of communication within the identity of organisations. He is Antifragility Architect at Xebia.

LinkedIn

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