ANTWERP MANAGEMENT SCHOOL

MASTER THESIS

Defining Antifragility and the application on Organisation Design

a literature study in the field of antifragility, applied in the context of organisation design

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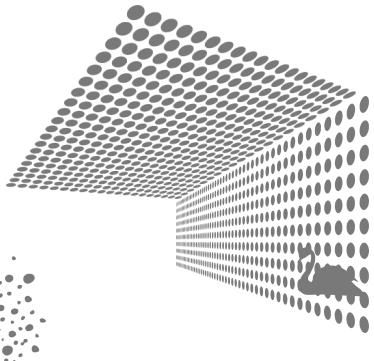

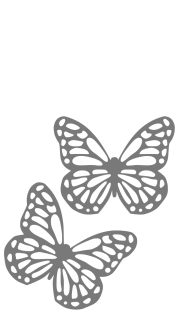

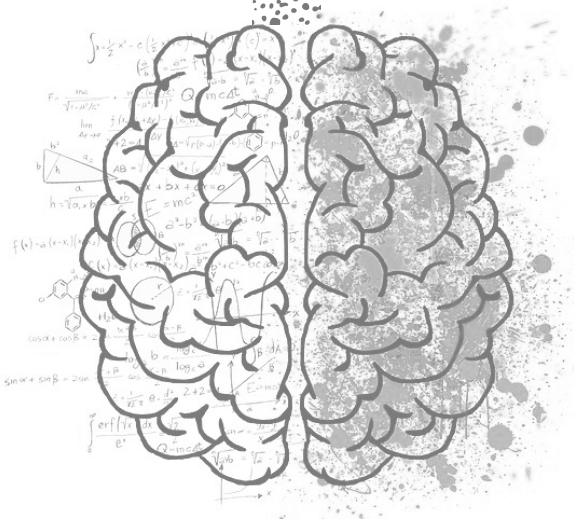

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \sigma(y - x),$$

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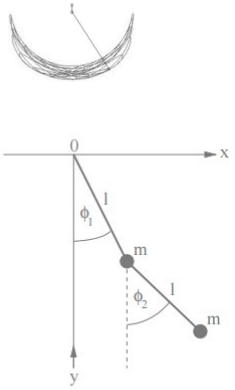

A thesis submitted in fulfilment of the requirements
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May 14th 2020

Executive Summary

Turbulent times ask for resilient organisations

The .com crisis of 2000, the financial crisis of 2008 and the COVID-19 crisis of 2020 show us the importance for organisations to become resilient or even antifragile to survive (unexpected) external stressors. Research states that the current VUCA world will expose enterprises to more and more stressors. Resilience is the way how a system bounces back from impact by a stressor. Antifragile is the way a system improves by impact by a stressor. This thesis combines (1) literature research on resilience with (2) the antifragile attributes found in the literature and (3) variety engineering into one model. This model is an Extended Antifragile Attribute List (EAAL). The research provided in this thesis enables the leadership of an organisation to determine if the organisation should aim to be antifragile or to be a specific type of resilience. After this determination, the EAAL model enables leadership to determine which attributes to include into their enterprise design. The EAAL is validated with various experts and with the leadership of various organisations. The EAAL model might also be applied to generic system design including technology infrastructure, software systems etc. The validation of the application in these domains is outside the scope of this research.

The challenge

The goal of an enterprise (e.g. organisations) is to remain significant for its stakeholders. Stakeholders are owners, employees and consumers (Op't Land et al., 2008, p. 10, 13).

The challenge for organisations is to stay relevant in the current **V**olatile, **U**ncertain, **C**omplex and **A**mbiguous (VUCA) world and regain their 'value' after being disrupted by a black swan stressor event (Hutchins, 2018; Mack et al., 2015; Bennett and Lemoine, 2014b,a; Anthony et al., 2016; Taleb, 2007; Casti, 2012).

The context of the challenge

A black swan is a stressor event in the VUCA domain that has a disruptive impact on a fragile and robust system and is non-predictable (Taleb, 2007; Casti, 2012; Hole, 2016, p. 14). The non-predictability is dependent on the model applied (Taleb, 2007) and the random behaviour of the world (Taleb, 2001).
Summarised: In the perspective of an enterprise, unpredictable events will occur.

An enterprise is an intentionally created Complex Adaptive System (CAS) consisting of cooperating human beings with a certain social purpose, whereby it is impossible to determine the ultimate (operational) reality of the enterprise down to the minute details (Dietz et al., 2013, p. 93-94).
Summarised: An organisation is a system (of humans) which state is non-deterministic.

A Complex Adaptive System is a type of a non-linear dynamical system in the field of Complexity Science and Systems Engineering (Lansing, 2003).
Summarised: An organisation is a system which behaviour is non-deterministic.

Defining antifragility and the application on organisation design

To deal with the VUCA world enterprises need to be resilient (Martin-Breen and Anderies, 2011; Kastner, 2017; Henriksson et al., 2016; Aghina et al., 2017). Agility is one of the tools to be resilient. To survive a black swan event just resilience is not enough, for this, an enterprise needs to be antifragile (Hoogervorst, 2017; Taleb, 2012).

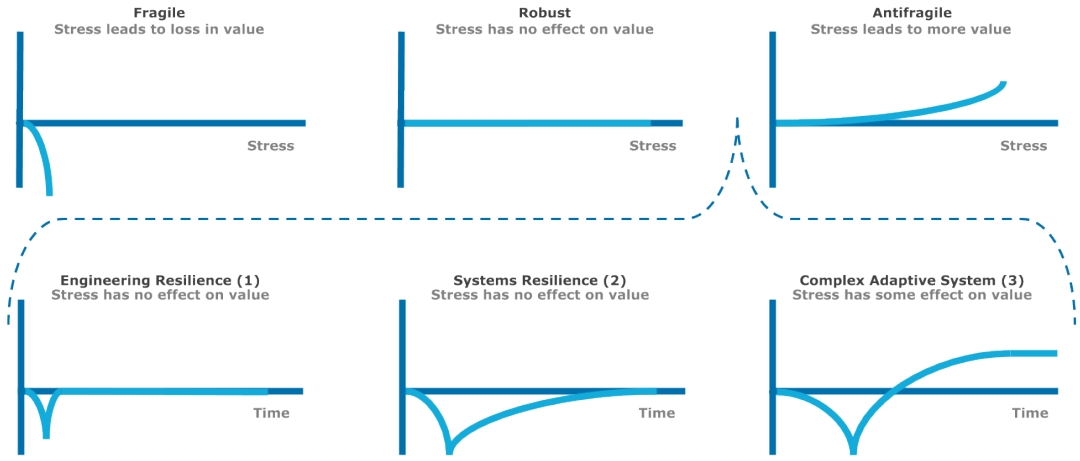

FIGURE 1: Fragile, antifragile and robust system behaviour to stress. Resilient behaviour to time.

The Extended Antifragile Attribute List (EAAL) is a summary of the available literature validated by experts and C-level management. This model is the first step in the design process of a resilient or antifragile organisation. The model proofed to enable C-level managers to determine the level of resilience (figure 1) that (parts of) the enterprise needs to have. It enabled leaders to determine what attributes (figure 2) are needed to be able to develop the selected behaviour.

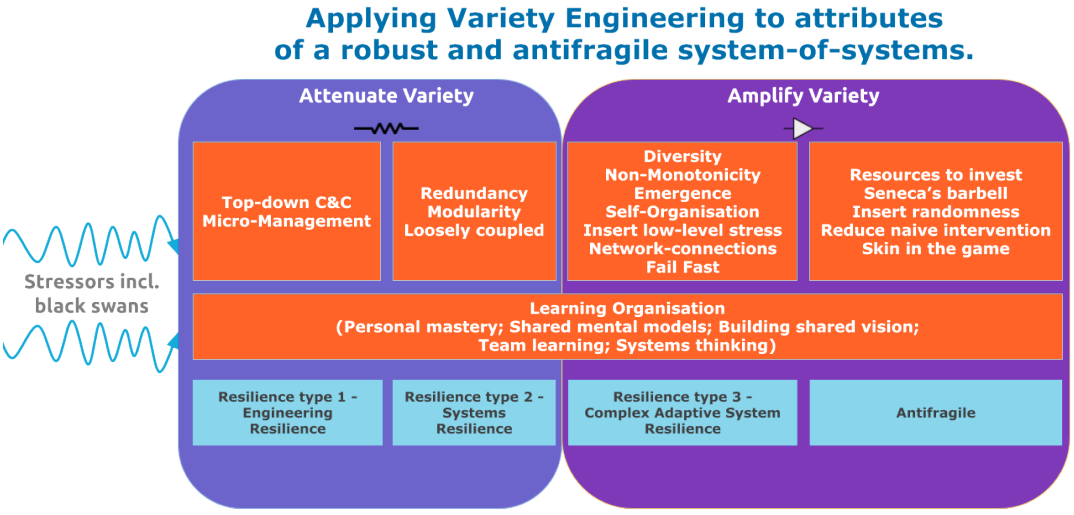

FIGURE 2: The EAAL model.

This study can be extended with respect to the practitioner's review by design authorities outside of the organisational domain. Follow up study is needed on the causal relationship between the attributes and the behaviour of the system.

ANTWERP MANAGEMENT SCHOOL

MASTER THESIS

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About

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Story

See Appendix G.

Declaration of Authorship

I, Edzo A. BOTJES, declare that this thesis titled, 'Defining Antifragility and the application on Organisation Design' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

'. . . each giant calling to his brother through the desolate intervals of time. . . '

Friedrich Nietzsche (1873)

'If I have seen further it is by standing on the shoulders of Giants.'

Sir Isaac Newton (1675)

'Each generation stands on the shoulders of those who have gone before them'

Stephen Hawking (2017)

'Whether you can observe a thing or not depends on the theory which you use. It is the theory that decides what can be observed'

Albert Einstein (1926)

ANTWERP MANAGEMENT SCHOOL

Abstract

Faculty Enterprise Engineering
Executive Master Enterprise IT Architecture

Master of Enterprise IT Architecture (MSc)

Defining Antifragility and the application on Organisation Design

by Edzo A. BOTJES

The .com crisis of 2000, the financial crisis of 2008 and the COVID-19 crisis of 2020 show us the importance for organisations to become resilient or even antifragile to survive (unexpected) external stressors. Research states that the current VUCA world will expose enterprises to more and more stressors.

Resilience is the way how a system bounces back from impact by a stressor. Antifragile is the way a system improves by impact by a stressor.

This thesis combines (1) literature research on resilience with (2) the antifragile attributes found in the literature and (3) variety engineering into one model. This model is an Extended Antifragile Attribute List (EAAL).

The research provided in this thesis enables the leadership of an organisation to determine if the organisation should aim to be antifragile or to be a specific type of resilience. After this determination, the EAAL model enables leadership to determine which attributes to include into their enterprise design. The EAAL is validated with various experts and with the leadership of various organisations.

The EAAL model might also be applied to generic system design including technology infrastructure, software systems etc. The validation of the application in these domains is outside the scope of this research.

Dedicated to my wife and love of my life, Annelies

Acknowledgements

I would like to thank my wife Annelies Botjes for supporting me in this period of almost two years at the Antwerp Management School (AMS). The time and effort this period would ask of us was underestimated without measure by me. She supported me non-stop and gave me trust that the journey would be successful.

Furthermore, I would like to thank the following people.

Antwerp Management School

I have great respect and thanks to AMS for providing me with this great selection of content and learning experience. Great thanks and respect to my supervisor's prof. dr. ing. Hans Mulder and Hans Nouwens MSc. for supporting me with their trust, patients and guidance.

Sogeti Netherlands

At Sogeti, I am surrounded by great colleagues. We have had many inspiring talks about Enterprise Architecture, DYA, Systems Thinking, DEMO, Pronto, and the role of language in the perception of reality. Thank you Marlies van Steenbergen, Ton Eusterbrock, Hans Nouwens, Adosh van der Heijden, Maarten van der Werff, Bert Noorman, Menno van Doorn and Wijtse de Boer. I am looking forward to many years of inspiration.

Special thanks to Pety Warringa and André Veelders for providing the support by the Sogeti organisation that made it possible for me to join AMS. And to Deirdre van Baar, Marriet Rosier, Arjan Meijer and Menno van Doorn for guidance in my personal and professional development from a young professional in 2006 to my current role of architect.

Without the inspirational lectures of Hans Mulder and Jan Hoogervorst at Sogeti, and the adoption of Pronto within Sogeti I would not have known of Enterprise Engineering, and would not have been set on the road to AMS.

Experts on antifragility

Antifragility was a new topic for me. I would like to thank Barry O'Reilly, Dennis Kastner and Chris van Houten for their time to talk to me, and for their work on the topic of antifragility. It helped me more than you probably know.

Love, nice food and fun

Sietske. We had the luck that our time in Antwerp aligned, as it often happens the past (almost) 20 years. It was amazing to be able to cool down after the lectures with you and Annelies and enjoy a meal and good talks together.

Hans, Roel and Olga for helping me with my spelling and grammar.

Team Korsakov! Great thanks for the joy and inspiring conversations on how to party and aim for the moon, Dave, Joshua, Nick, Jan-Willem, Theo, Roos, Dorian and Kevin.

Bar Korsakov in Antwerp for being the focal point of bringing people together and focus on the most important part of Management, Enterprise Architecture, Enterprise Engineering etc.. The people!

Bar Bazs in Hilversum for being a place of love, nice food and concentration. So many more friends have helped with feedback and support. Thank you all so much!

To my godchildren Eline, Keeto, Chloë, Mattéo and Lasse: See you soon!

Contents

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List of Abbreviations

CAS	**C**omplex **A**daptive **S**ystem
CC	**C**reative **C**ommons
CIAO	**C**ommunication **I**nformation **A**ction **O**rganisation
EE	**E**nterprise **E**ngineering
EAAL	**E**xtended (or **E**dzo's) **A**ntifragile **A**ttribute **L**ist
ISO	**I**nternational **S**tandards **O**rganisation
IT	**I**nformation **T**echnology
RBN	**R**andom **B**oolean **N**etwork
SoS	**S**ystem **o**f **S**ystems
VUCA	**V**olatile **U**ncertain **C**omplex **A**mbiguous

EE Theories

ALPHA	**A**bstraction **L**ayers in **P**roduction for **H**olistic **A**nalysis
BETA	**B**uilding from **E**ssence with **T**echnology and **A**rchitecture
DELTA	**D**iscrete **E**vent in **L**inear **T**ime **A**utomaton
FI	**F**actual **I**nformation
IOTA	**I**mplementing **O**rganisations with **T**echnological **A**lternatives
MU	**M**odelling **U**niverse
NU	**N**ormalised **U**nits
OMEGA	**O**rganisational **M**odules **E**merging from **G**eneral **A**rrangements
PSI	**P**erformance in **S**ocial **I**nteraction
SIGMA	**S**ocially **I**nspired **G**overnance and **M**anagement **A**pproach
TAO	**T**eleology **A**ffordance **O**ntology

List of Symbols

The following symbols are part of the Enterprise Engineering (EE) framework of theories (2.11, 6.3.4).

		Ideological EE Theories	
Σ	Sigma	EE governance & management theory *How enterprises should be managed and governed*	[TEE-07]
		Technological EE Theories	
B	Beta	EE organisation design theory *Binding Essence, Technology, and Architecture*	[TEE-06]
I	Iota	EE organisation implementation theory *Determining implementation (alternatives)*	[TEE-10]
N	Nu	EE normalisation theory *Concerned with the evolution of systems*	[TEE-11]
		Ontological EE Theories	
A	Alpha	EE organisational essence theory *Understanding the essence of organisation*	[TEE-08]
Δ	Delta	EE system theory *Understanding discrete event*	[TEE-04]
Ψ	Psi	EE organisational operation theory *Understanding human collaboration*	[TEE-03]
Ω	Omega	EE organisational construction theory *Understanding the construction of organisations*	[TEE-09]
		Philosophical EE Theories	
Φ	Fi	EE information theory *Clarifying how people acquire factual knowledge*	[]TEE-01]
M	Mu	EE model theory *Understanding models and modelling*	[TEE-05]
T	Tao	EE function-construction theory *A theory about subjects (with purposes) and objects (with properties)*	[TEE-02]

The following symbols are part of section on Requisite Variety (2.7).

S	Entropy
ln	Natural Logarithm
Ω	Number of Microstates
k_B	Boltzmann constant
$S = k_B \ln \Omega$	Ludwig Boltzmann equation

1 Introduction

We are living in complex and uncertain times (Hutchins, 2018). Our organisations are adopting Digital Transformation and adopt the agile way of working to increase their speed of adoption to the changing world (Aghina et al., 2017). The origin of the agile way is in Software Engineering (Beck et al., 2001). Adopting the way of working from Software Engineering is not enough for an organisation to stay relevant in the current dynamic times (Hoogervorst, 2017; Taleb, 2007, 2012).

In this thesis, I define antifragility and resilience, based on the available literature on antifragility, by applying Variety Engineering to attributes of a resilient and antifragile System-of-Systems and combine this into one model. This model is an Extended Antifragile Attribute List (EAAL). I do this with the aim that business leaders are able to determine which factors are relevant for them when designing their organisation, so that they can stay relevant as an organisation.

Resilience is the ability to recover from or adjust easily to misfortune or change (Merriam Webster, 2020i; Martin-Breen and Anderies, 2011). Antifragility is the ability to gain from disorder (Taleb, 2012). I recognise that the creation of this EAAL model is a first step in creating a holistic view on the concept of antifragility and resilience. My research in this thesis limits itself to the validation of the model as a summary of the current Body of Knowledge. It does not prove if the model is complete, or if the implementation of the model delivers the described results.

1.1 Structure of this document

The structure of this document is as follows: Chapter 1 sets the stage. I will address in chapter 2 the theoretical background and chapter 3 the used methodology for the research. In chapter 4 I describe the conceptual model used in my research. The results and analysis of the gathered data will be presented in chapter 5. Chapter 6 contains the conclusion, discussion and recommendations for future research.

1.2 Structure of chapter 1

The content of this chapter is:

1.2.1 Part 1 - A shared mental model of the storyline

First, I will provide a summary of this thesis as a whole in section 1.3 within section 1.3.5 some introduction into the "why" of this thesis. In section 1.4 I provide insight into my decision to include more context and background than is common for a master thesis. My aim of this part of chapter 1 is to share my mental model of the topic of antifragility.

I have looked at it in many ways and the topics and the order of the books written by Nassim Taleb keeps coming back as the most logical way to grasp the underlying reasoning for what antifragility is. The view that Taleb conveys is that the world is not a collection of predictable causally linked events but is (mostly) random. I share this view, even before I read the books of Taleb. It can be argued that our notion of reality is fragile to reality. Considering that we all have a mental model of reality in our mind, and a model is a simplifies representation of reality. Combined with the idea that every model is fragile for events outside of the observations. Antifragility is the behaviour that does not behave fragile to reality.

1.2.2 Part 2 - Introduction of the terms antifragile and resilience

After sharing my mental model, I will start to introduce the concepts of antifragility and resilience. See sections 1.5 (Introduction into Antifragility) and 1.6 (Introduction into Resilience). I aim to provide a basis to put the rest of the content of this thesis in perspective.

1.2.3 Part 3 - Introduction into the role of antifragility and resilience in risk management

Risk management is a discipline that has strong relations with antifragility and resilience. See also section 1.7 (Introduction into Risk Management).

Antifragility and resilience describe how a system behaves. Risk management is the discipline of which goal is to design systems to have a specific behaviour. The behaviour of a system is usually expressed in relation to the influence (input) on the system.

In section 2.6 (Randomness) I provide an introduction to chaos and complexity. There it will be explained why the influences on a system are getting more and more differs and unpredictable. This increase in diversity and unpredictability of the influences is the reason to design resilient and antifragile organisations.

1.2.4 Part 4 - Application of Antifragility

In section 1.8 I provide some examples of the application of antifragility.

1.2.5 Part 5 - Problem statement & research question

I end with the problem statement and research question in section 1.9. This also includes the reason why I focus this thesis mainly on the application of antifragility and resilience in the context of an organisation. See section 1.9.1 (Why the focus on organisation systems?).

1.3 Why a thesis about antifragility?

Taleb introduced the term antifragile as the concept of gaining from disorder (Taleb, 2012). His publication of the concept of antifragile sparked the creation of many blog articles and books on this topic[1].

I present in this thesis a model of system attributes that are relevant for being resilient or to become antifragile. The list of attributes is limited to what is available in the existing Body of Knowledge. This model is an Extended Antifragile Attribute List (EAAL). The EEAL model is a synthesis (summary) of the available Body of Knowledge to date (2019). I do not prove nor do I claim that these attributes will lead to the specified type of resilience. The EAAL model is just a little step in bringing people together towards a shared mental model in this very interesting a new field of science.

Nassim Nicholas Taleb wrote down his journey towards antifragility in three books in the period 2001-2012. These books are titled: "Fooled by Randomness", "The Black Swan" and "Antifragile" (fig. 1.1) (Taleb, 2001, 2007, 2012).

By coincidence I read these books each in the year they were published and they have had a big impact on my personal journey into science and into the topic of a shared model of reality (Appendix A, Appendix - Why Antifragile - My personal why). This also motivates me highly to write my thesis on the topic of antifragility.

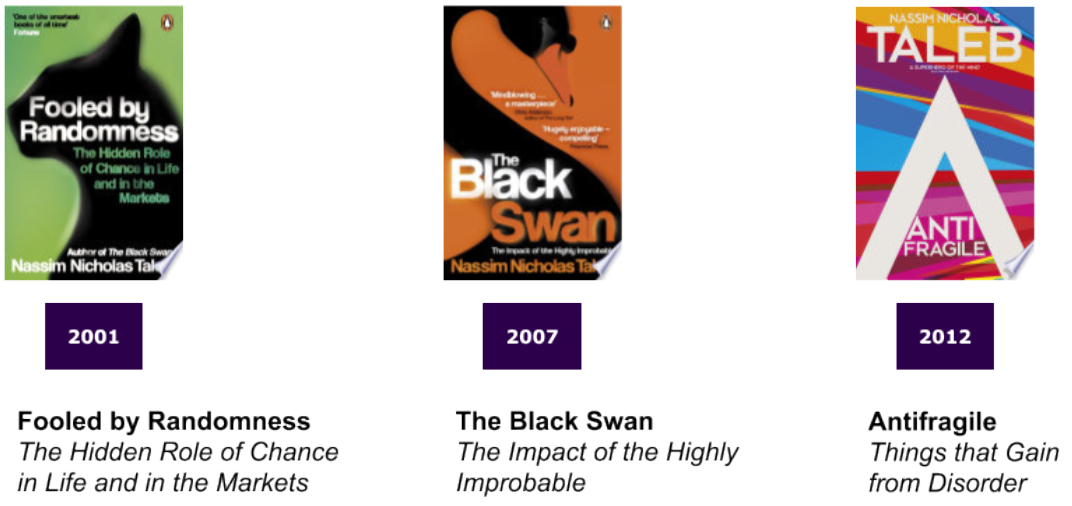

FIGURE 1.1: Fooled by Randomness, Black Swan and Antifragile by Nassim Nicholas Taleb. Images retrieved from Goodreads.com.

1.3.1 Fooled by Randomness, Taleb 2001

In "Fooled by Randomness" Taleb tells us that reality is more a collection of random events then the logical outcome of a predictable chain of events (Taleb, 2001).

That it is difficult to predict the future and that most things just happen is something that has been stated by many other writers (Tversky and Kahneman, 1974; Mintzberg, 1994b; Augusto Wrede and Simari, 2001; Governatori and Terenziani, 2007; Makridakis et al., 2009; Makridakis and Taleb, 2009b; Makridakis and Taleb, 2009a; Dietz et al., 2013; O'Neil, 2016; Dietz, 2017; Hoogervorst, 2017).

See also sections 1.7 (Introduction into Risk Management), 2.6 (Randomness), 2.6.2 (What is chaos?), 2.9 (VUCA). and 3.1.2 (Taleb and Enterprise Engineering).

The conclusion of Taleb is: if we capture reality in a simplified representation (a model), we cannot use this model to predict what is going to happen; We tend to overestimate causality and view the world as more explainable than it really is.

[1] https://gitlab.com/edzob/antifragile-research/wikis/Antifragility-Literature-Research

1.3.2 The Black Swan, Taleb 2007

The story continues with his book "The Black Swan" (Taleb, 2007). Here Taleb states that every model that we create is limited by our observations. Based on these (limited) observations we tend to translate the outcome of correlation analyses into a model that we use as a model that states causality (Taleb, 2007). The limitations of the usage of models are not new and argued by many other experts (Hoogervorst, 2017; Ciborra, 2004). See also section 2.6.6 (We are limited by observation).

Models are fragile

Taleb combines in his book "The Black Swan" the content of his previous book "Fooled by Randomness" in concluding that it is (almost) impossible to create a model that contains causal relations. It is impossible to predict what is going to happen not only on the fact that the information obtained through observation is never complete (1), but also since the behaviour in itself cannot be predicted (2).

An example of this unpredictability is that the combination of two deterministic systems can lead to a non-deterministic system. See also section 2.6.5 (Example of a simple chaotic system).

The result of these two factors is that the model of reality, for example, a financial model, will only function in the context of very strict (theoretical) conditions. Since reality will create events that were not taken into account during the creation and testing of the model, the model is fragile to reality.

Something that is not foreseen in the design of a model and that will have a disruptive effect is called a 'black swan' (Taleb, 2007).

1.3.3 Antifragile, Taleb 2012

Taleb did not provide a solution to the black swan problem in his book "The Black Swan" (2007). In 2012 Taleb states that the only way for a System-of-Systems to survive a black swan event is by being antifragile (Taleb, 2012).

Antifragile is the word he introduced as the opposite of fragile and is in therefore in the literature also written as anti-fragile. See also section 1.5 (Introduction into Antifragility).

Taleb's definition of antifragile is difficult to implement

In the book "Antifragile" Taleb provides a few principles (or attributes) that are mandatory for a system to be antifragile. Taleb provides per principle many examples, but to change a system a comprehensive set of principles that have a clear relation to each other is needed. This is not provided.

These principles have proven to be difficult to translate into action within in a specific domain. An example is the principle of "no naive intervention". This is a statement that inspires many but is not easily translated into the design of a business or IT solution.

1.3.4 The relevance of antifragility to the Master of Enterprise Architecture and Engineering

When I was introduced into Enterprise Engineering (EE) I immediately noticed the overlap with the way-of-thought of Taleb. The first overlap is the idea that models based on observations do not provide insight in the reason why things happen.

Second, both EE and Antifragility state that providing employees with more freedom makes an organisation more resilient against the stress events (Hoogervorst, 2015).

See also section 2.3 (Organisation Design), 2.7 (Requisite Variety), 2.8 (What is a stressor?) and 3.1 (The replication challenge).

Third, there is an overlap with the discipline of Enterprise Architecture (EA, section 2.12) & Enterprise Engineering (section 2.11) on design. EA and EA concern the design of organisations and define organisations as a System-of-Systems. Antifragility covers the design of System-of-Systems. Therefore, Antifragility is relevant to the discipline of Enterprise Architecture and Enterprise Engineering.

1.3.5 The goal(s) of this thesis

I have the following three goals with this thesis.

1. Provide, in the form of a model, a summary of the attributes that a system should have, when it wants to evolve from a robust to an antifragile system.

   The limitation here is that this model is purely based on the available literature on antifragility.

2. Provide validation of the model by experts to prove that there are no inconsistencies or red-flags in the model.

   The limitation here is that this model does not intend to be complete since this is impossible. My aim is that this model can function as a shared mental model for antifragile experts. Therefore, the experts consulted include various experts.

   One of the experts provided a lecture on Normalised Organisations at the Antwerp Management School and is daily involved in implementing Holacracy at various clients.

   Another one of the experts is someone who daily works with and educates in designing antifragile IT systems. He started in January 2020 his PhD in Software Engineering and complex systems at the Open University (UK). He has also written papers on antifragile software design (O'Reilly, 2019, 2020).

3. Provide validation of the possibility to apply this model to an organisation.

   The limitation of this validation is that experiments with antifragile organisations that need to be set up from scratch are too complex and time-consuming to be part of this thesis. This validation of application is done with various business leaders. The goal is not to prove that these attributes will lead to a more resilient and antifragile organisation. The goal is a bit humbler. The validation by the business leadership only states that the language and way-of-thought of the model make sense to them and that they think that they can translate the model into actions.

1.4 There are no clear definitions on which there is consensus

The field of antifragility is young since it started with the book Antifragile by Taleb in 2012. Furthermore, antifragile overlaps with concepts from the domain of Complexity Science. The domain of Complexity Science is a field where it is more common to describe concepts than it is to provide crystal clear definitions on which is consensus achieved. I noticed that definitions of concepts used in the field of antifragility are not discrete and that writers mostly are describing concepts.

1.4.1 Consequences of having no clear definitions

The consequence of this is that I am not able to define every attribute precisely. I am also not able to logically prove that the same words in different papers have the same meaning, or that different words have the same meaning. This has an impact on the rigour and replication of my research. When reading into the topic of rigour I also found various definitions.

The shortcoming I mentioned has an effect on the rigour of the logic component. Since the lack of the (complete) definition of words limits formulating reasoning in a way that resembles discrete logic.

1.4.2 Mitigation to having no clear definitions

I mitigate this shortcoming in determinism in three ways with the aim to maintain rigour in the research. These three ways are inspired by open science[2], open science framework (OSF[3]) and reproducible research[4].

Firstly, by providing extra literature and context information around the various terminology and concepts used in the antifragile literature. When using literature, I try to include the specific page I am referring to.

Secondly, by thoroughly documenting my steps. This is done in two ways. On a data level using versioning in GitLab for my thesis and versioning in Google Documents for my presentations. See also section 3.6 (Applied research tooling and infrastructure). On a functional level, this is done by including the steps of reasoning in this thesis. An example of this documenting is including the binary decision tree, which is used to sort the antifragile attributes collected from the literature. See section 4.3.6 (The Decision tree). This decision tree limits the creative process that leads to the EAAL model. This does not remove the creative process completely but provides clear discussion points in the reasoning on the sorting of attributes.

Thirdly, by limiting the scope of the expert validation step. I ask various experts if the usage of the attributes in the context of the model did not lead to something that is fundamentally wrong. I do not ask them if the EAAL model is correct. I do not ask them if the EAAL model is complete. I can only ask them if the EAAL model does not have an inconsistency or has a fundamental flaw.

[2] https://en.wikipedia.org/wiki/Open_science (Wikipedia contributors - B, 2020c)
[3] https://vickysteeves.gitlab.io/repro-papers/open-science-reproducible-research.html
[4] https://ropensci.github.io/reproducibility-guide/sections/introduction/

1.5 Introduction into Antifragility

1.5.1 Definition of fragile, robust and antifragile

A stressor is defined as a stimulus that causes stress (Merriam Webster, 2020j). Fragile is the concept of losing value from exposure to stressors. Antifragile is the antithesis of fragile. Antifragile is the concept of gaining value from exposure to stressors. The concept of stressors having no effect on the value is called robust (Taleb, 2012, p. 18). Fragile, robust and antifragile form together a triad (Taleb, 2012, p. 34; Gorgeon, 2015, p. 3; Hole, 2016, p. 7; Ghasemi and Alizadeh, 2017, p. 22; Kennon et al., 2015).

See figure 1.2 and 1.3 for a visualisation of the triad.

1.5.2 Behaviour of fragile, robust and antifragile

Concave is having an outline or surface that curves inwards like the interior of a circle or sphere (Merriam Webster, 2020a). Convex is having an outline or surface curved like the exterior of a circle or sphere (Merriam Webster, 2020c).

Fragile systems behave concave to stress (see figure 1.2). Antifragile systems behave convex to stress (see figure 1.2). Robust systems are ignorant in value as response to volatility and stressors (see figure 1.2) (Taleb, 2007, p. 317; Taleb, 2012, p. 288; Ghasemi and Alizadeh, 2017, p. 24; Derbyshire and Wright, 2014, p. 219; Johnson and Gheorghe, 2013, p. 163).

System-of-Systems (SoS) is defined by ISO 21839:2019 as a 'set of systems or system elements that interact to provide a unique capability that none of the constituent systems can accomplish on its own' (SEBoK et al., 2019; IEEE, 2019). For a system to be antifragile it needs a fragile and robust part (Taleb, 2012). This implies that an antifragile system is a System-of-Systems.

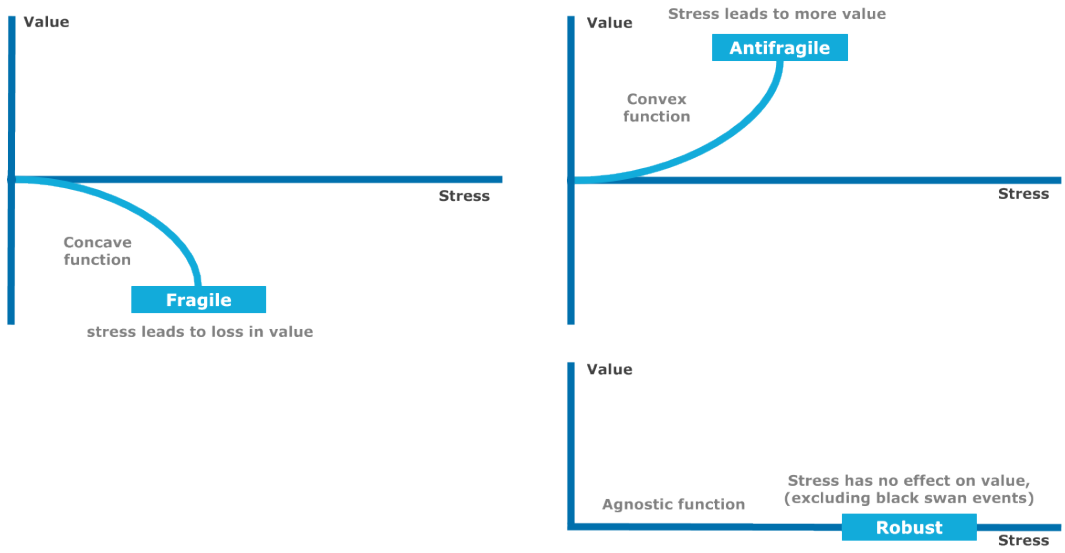

FIGURE 1.2: Fragile, antifragile and robust system behaviour to stress.

1.6 Introduction into Resilience

1.6.1 Resilience has no clear definition

Resilience can be defined as 'the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress' (Merriam Webster, 2020i).

There are various (literature) studies stating that there is no clear definition of resilience available (Müller et al., 2013; Martin-Breen and Anderies, 2011; Passos et al., 2018; Henriksson et al., 2016, p. 31; Kastner, 2017, section I.2.1).

The definitions of resilience and robust are varied and overlap (Johnson and Gheorghe, 2013, p. 161; Kennon et al., 2015, p. 178; Gorgeon, 2015, p. 4).

The definitions of resilient and antifragile are various and overlap (Henriksson et al., 2016; Kastner, 2017).

Sources state that resilience is the evolution of a system from a robust system into an antifragile system (Taleb, 2012, p. 17; De Florio, 2014, p. 838; Aven, 2015, p. 477; Ghasemi and Alizadeh, 2017, p. 23; Passos et al., 2018, p. 7).

1.6.2 A definition of resilience is needed to define antifragile

I found that the definitions of antifragile itself are also varied. This is the reason that a replication study of antifragility did not seem possible to me. With this thesis I want to help organisations to become more antifragile, therefore I have to define what antifragility is.

Since the literature is inter-mixing (overlapping) definitions of resilience and antifragility, I need to select a definition of resilience. The selection of one definition will make it possible to determine which elements in the current Body of Knowledge addresses resilience and which elements address antifragility.

1.6.3 Resilience definition

I follow Kastner (2017) in adopting the definition of resilience by Martin-Breen and Anderies (2011).

Resilience is between robust and antifragile

Martin-Breen and Anderies (2011) place resilience in between robust and antifragile (see figure 1.3).

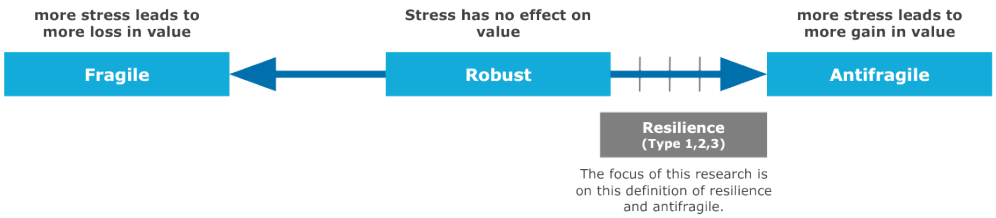

FIGURE 1.3: Triad of fragile, robust and antifragile.

Resilience goes beyond robust but stops before being antifragile

Resilience is about recovering from stressors and returning to the normal (robust) state (see figure 1.4).

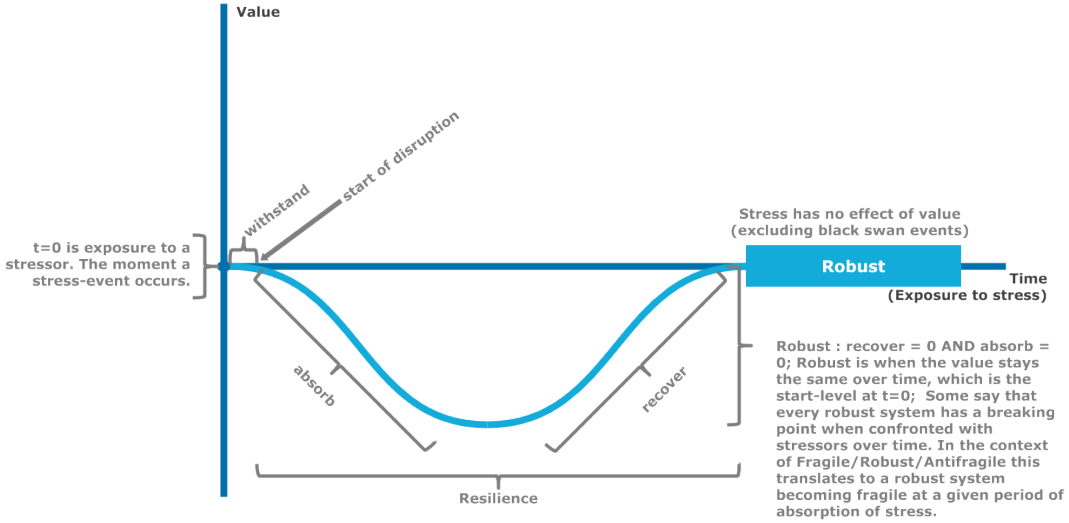

FIGURE 1.4: Resilience is about absorbing and recovering.

There are three (sub-)types of resilience (Kastner, 2017, sec. I.2.2; Martin-Breen and Anderies, 2011, p. 5).

1. **Engineering Resilience** or 'Common Sense' resilience.
   The goal is to prevent disruption and changes. The goal is to bounce back to the fixed function/basis (Kastner, 2017; Martin-Breen and Anderies, 2011; Holling, 1996). Measurable by the following three characteristics: resistance, elasticity and stability (Martin-Breen and Anderies, 2011, p. 43).

   The function and construction of the system stay the same over time.

2. **Systems Resilience** (or Robustness in economics).
   The system has the capacity to absorb disturbance and reorganise while undergoing changes. While doing this still retain essentially the same function, structure, identity, and feedback, where 'essential' is defined as 'something functional and not identical' (Walker et al., 2004, p. 5; Martin-Breen and Anderies, 2011, p. 6-7). The system is able to withstand the impact of any interruption and recuperate while resuming its operations / fixed functions (Santos, 2012, p. 2).

   The function of the systems stays the same over time. The construction of the system may change.

3. **Resilience of Complex Adaptive Systems** (CAS).
   The system is able to become more resilient and to generate new system relationships by reorganisation (Martin-Breen and Anderies, 2011; Kastner, 2017). Function is maintained, but system structure may change (Martin-Breen and Anderies, 2011). This results in the system to being as dynamic as the world around them, resulting in a system that is constantly evolving (Kastner, 2017).

   The function of the system may change over time, and the construction of the system may change over time.

1.6.4 Engineering and Systems Resilience are about absorbing stressors

Kastner (2017) argues that the first two types of resilience are applicable to centralised organisations and that resilience is about **absorbing the stressors**.

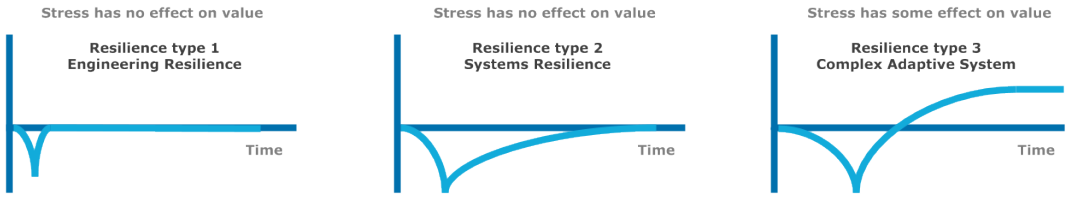

FIGURE 1.5: Resilience type 1, 2 and 3.

Engineering Resilience mainly absorbs the stressors by applying a fine-grained design and/or a strict command & control structure.

Systems Resilience applies layers of systems to absorb the stressors. An example of this is backup systems or decentralised systems like applied in the design of the internet (Passos et al., 2018, p. 8).

1.6.5 CAS Resilience is about the amplification of emergence

The dynamical changing of the structure and the function of the system is emergent behaviour which is an essential part of CAS resilience (type 3) (Martin-Breen and Anderies, 2011; Kastner, 2017). CAS resilience is about creating more diversity in the organisation. A question that Kastner (2017) and Taleb (2012) ask themselves is: How far can an organisation change its function and construction and still be the same organisation as before the change (Kastner, 2017, p. I.2.5)?

1.6.6 Resilience definition summarised

Resilience can be summarised as: Resilience is the behaviour of a system expressed in the value over time after a stressor event. The three types of resilience are represented in figure 1.6.

1. **Engineering Resilience** is the behaviour of a system where the function and the construction of the system stays the same over time.
2. **Systems Resilience** is the behaviour of the system where the function of the systems stays the same over time, the construction of the system may change.
3. **Complex Adaptive Systems Resilience** is the behaviour of the system where the function of the system may change and the construction of the system may change over time.

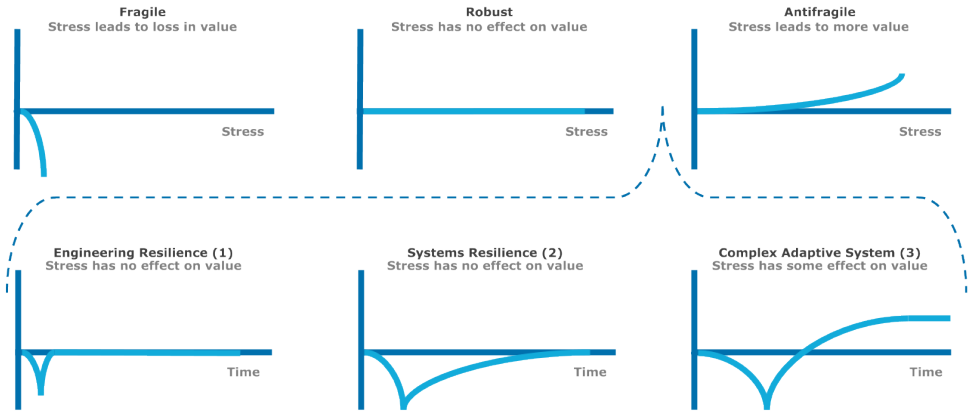

FIGURE 1.6: Fragile, antifragile and robust system behaviour to stress. Resilience behaviour to time.

1.7 Introduction into Risk Management

The survival of a system is dependent on the predictability of the course of the system inside its environment and the predictability of the environment so that risk can be managed (Gorgeon, 2015). Stressors that harm a system are able to ultimately break a system (Taleb, 2012; Taleb and Douady, 2013; Gorgeon, 2015). Since risk management is about the identification, evaluation, and prioritisation of risks the topic of stressors, resilience and antifragility are relevant for risk management (Hutchins, 2018; Aven, 2015; Wikipedia contributors - B, 2019o).

1.7.1 Risk Management - Design for survival

The triad (fragile, robust and antifragile) is relevant in the design for the survival of a system since fragility is, in essence, the sensitivity of a system of a given risk measure to an error (Taleb and Douady, 2013, p. 7).

Risk management aims to minimise, monitor, and control the probability or impact of unfortunate events or to maximise the realisation of opportunities (Hutchins, 2018; Wikipedia contributors - B, 2019o). This is why risk management is closely linked to the topics of resilience and antifragility.

1.7.2 Risk Management - Moving away from fragile and robust

Fragility is the reason to apply risk management in an organisation.

Risk management is as a discipline moving away from the minimisation of unfortunate events and effects. It is moving towards the maximisation of the realisation of opportunities. The minimisation of unfortunate events can be found in robust, engineering resilience and systems resilience.

The implicit goal has shifted from designing (predictable) robust organisations to the need for designing resilience and antifragility organisations (Hutchins, 2018). This since a robust organisation requires planning and it showed that strategic planning is not successful (Mintzberg, 1994b,a; Derbyshire and Wright, 2014; Hoogervorst, 2017).

1.7.3 Risk Management - Moving towards antifragility

The maximisation of the realisation of opportunities can be found in Complex Adaptive Systems resilience and antifragility.

Risk management also 'includes to improve the understating of risk by identifying signals and warnings and acknowledging uncertainties and the importance of knowledge' (Aven, 2015, p. 480). The definition of risk management is further explored in section 2.5 (Risk Management).

1.7.4 Uncertainty in a volatile and complex world

Most, if not all, organisations operate in a context which is described as Volatile, Uncertain, Complex and Ambiguous (VUCA) (Bennett and Lemoine, 2014b,a; Mack et al., 2015; Hutchins, 2018; Wikipedia contributors - B, 2019t).

> "We live in a ... VUCA time. ... In terms of ISO 31000:2018[5] and ISO 9001:2015[6], the concept of 'uncertainty' is integrated throughout the standards."
> - (Hutchins, 2018, chapter 1)

> "We're entering a period of heightened volatility for leading companies across a range of industries, with the next ten years shaping up to be the most potentially turbulent in modern history."
> - (Anthony et al., 2016, p. 3).

[5] https://en.wikipedia.org/wiki/ISO_31000 (Wikipedia contributors - B, 2020a)
[6] https://en.wikipedia.org/wiki/ISO_9000 (Wikipedia contributors - B, 2020b)

The uncertainties that (Aven, 2015, p. 480) names are part of a larger domain of stressors which is called the 'disorder cluster' also known as VUCA (Taleb, 2012, p. 436; Gorgeon, 2015, p. 3).

Black swans (or X-events) are defined as stressor events in the VUCA domain that have a disruptive impact on a fragile and robust system and are non-predictable (Taleb, 2007; Bennett and McGinnis, 2008; Taleb, 2012, p. 18; Casti, 2012; Johnson and Gheorghe, 2013; Taleb and Douady, 2013 Aven, 2015, p. 479; Hole, 2016, p. 14; Ghasemi and Alizadeh, 2017, p. 23).

1.7.5 Antifragility is mandatory to stay relevant in a VUCA world

By learning from the past and by being a resilient organisation it is possible to extend the period of being relevant as an organisation.

> "After all, we can't know for sure what the future holds. But companies can adapt to change by launching new growth ventures that move them beyond their historic core business. Our work shows that the companies that continually find ways to reinvent themselves are the ones that control their own destiny."
> - (Anthony et al., 2016, p. 8).

Taleb reasons that an antifragile system is mandatory to survive a black swan event and therefore is mandatory to stay relevant in a VUCA world (Taleb, 2012). Antifragile systems have a positive sensitivity for disorder (Taleb and Douady, 2013, p. 1).

1.7.6 Antifragility provides design guidelines for Risk Management

An enterprise is an intentionally created Complex Adaptive System (CAS) consisting of co-operating human beings with a certain social purpose, whereby it is impossible to determine the ultimate (operational) reality of the enterprise down to the minute details (Dietz et al., 2013, p. 93-94). A CAS[7] is a type of a non-linear dynamical system in the field of Complexity Science and Systems Engineering (Lansing, 2003).

In the scope of organisations, antifragile plays a role in the domain of organisation design and in the sub-domain of risk management (Aven, 2011, 2012; Scholz et al., 2012; Aven, 2015; Hutchins, 2018).

1.7.7 Organisations, Resilience, Antifragile and System-of-Systems

Sometimes I wonder if it is better to rephrase 'antifragile is the antithesis of fragile' into 'antifragile behaviour is the antithesis of fragile behaviour of a system'. Since an antifragile system needs to have a fragile part of the system that creates the hurt that enables the system as a whole to react on to get stronger.

For example, in the case of our immune system. First cells need to die and the host needs to get (a little bit) sick to develop immunity to the disease.

An antifragile system needs to have a fragile sub-system

It also can be reasoned that when there is a fragile sub-system, there also needs to be a robust sub-system. When the body of Hydra dies when one head is chopped off, then Hydra as a whole is as fragile as the head. The same for a body that is getting sick. When the disease leads to immediate death then the body as a whole is fragile.

An antifragile system needs to have a robust sub-system

Martin-Breen and Anderies (2011) state that a system in the scope of resilience is seen as a System-of-Systems. Hutchins (2018) states that a system in the scope of Risk Management is seen as a System-of-Systems. Dietz et al. (2013) state that an organisation is a Complex-Adaptive-System. A Complex-Adaptive-System is a System-of-Systems.

[7] https://en.wikipedia.org/wiki/Complex_adaptive_system, (Wikipedia contributors - A, 2019i)

1.8 Examples of the application of antifragility

1.8.1 Summary of the Body of Knowledge on antifragility

In section 3.4 the Literature review concerning antifragility is addressed. The summary of that section is that there are not that many real-life examples of the designed antifragile systems. The examples above in section 1.8.3 (Examples of implementation of antifragility) are the most vivid and recent. Most books and papers discuss possible applications and/or retrospective questionnaires on factors that have had a possible impact.

1.8.2 Examples by Taleb

Taleb provides examples of antifragile systems from the domain of old Greek mythology (Taleb, 2012). Hydra[8] is a creature with numerous heads. When one head is cut off, then two grow back. Harming Hydra would make it stronger. Phoenix[9] is a bird that is born again by rising from its own ashes.

Taleb states that the Phoenix is an example of a robust system and Hydra is an example of an antifragile system. Taleb states that the human immune system is an example of an antifragile system (Taleb, 2012).

1.8.3 Examples of implementation of antifragility

The following examples are referred to in the context of resilient systems and that of antifragile systems.

1. Holacracy is based on work from Robertson in 2007 and published in the book Holocracy in 2015 (Robertson, 2015; Wikipedia contributors - A, 2019r). This method is referred to as a way to create an antifragile organisation.

2. Zwieback wrote a book on DevOps as a way to implement an antifragile organisation (Zwieback, 2014). The reasoning is that DevOps organisations embrace "Fail fast, fail often" to become stronger (Hole, 2016).

3. The tool Chaos Monkey has been invented in 2011 by Netflix to test and evolve the resilience of its IT infrastructure (Wikipedia contributors - A, 2019h). This tool is part of the discipline of Chaos Engineering (Netflix, 2011; Chaos-Community, 2018; Tseitlin, 2013; Shelly et al., 2015; Hole, 2016; Wikipedia contributors - A, 2019g).

4. An approach to creating Antifragile software architecture is written by O'Reilly (2019) and provides a set of steps that enables the design of antifragile software solutions. The course on this approach is provided in Europe to various software engineers.

1.8.4 Live an antifragile life

"...anything that has more upside than downside from random events (or certain shocks) is antifragile ... the reverse is fragile." - (Taleb, 2012, p. 5).

This leads us to the philosophical principle to live an antifragile life: "The purpose of life is to enjoy every moment." (figure 1.7).

FIGURE 1.7: Antifragile Wisdom from tea.

[8] https://en.wikipedia.org/wiki/Lernaean_Hydra (Wikipedia contributors - B, 2019d)
[9] https://en.wikipedia.org/wiki/Phoenix_(mythology) (Wikipedia contributors - B, 2019i)

1.9 Problem Statement & Research question

1.9.1 Why the focus on organisation systems?

Since we are living in a VUCA world antifragile (IT) systems and organisations have never been more relevant. This also includes the design of antifragile systems.

As a response to deal with this VUCA reality organisations are focusing on implementing an agile way of working (Gorgeon, 2015; Kastner, 2017). Introducing an agile way of working into an organisation changes the fabric of the organisation (Janssen, 2015, 81, 110-115; Proper and Lankhorst, 2014, 12,15; Ambler, 2009). Since the agile way of working is about decentralised autonomous teams Beck et al. (2001), most organisations do not have the enterprise architecture and the enterprise governance to support decentralised autonomous teams. Most organisation do not have a strategy that supports decentralised autonomous teams. This is relevant since resilience and antifragile prescribe decoupling of systems.

The challenge of organisations, that consist of decentralised autonomous teams, is that the bottom-up strategy leads to it not being clear what the added value of initiatives are (Op't Land et al., 2008). A way to deal with this challenge is to make strategy of the organisation unambiguous, measurable, relevant and actionable (Op't Land et al., 2008).

1.9.2 Finding a research question

Iteration 0

My original goal of this research was to combine the existing literature and literature research on: (1) the definition of fragile, (2) the definition of robust, (3) the definition of antifragile, (4) the definition of an antifragile system, (5) the definition of an antifragile organisation and (6) the definition of the value that antifragility adds to an organisation.

To answer the following research question:

> *"Can we prove that antifragility, as it is defined by Taleb, can be applied with valuable effect to an Enterprise? "*

The conclusion is that this is not possible.

There is no clear definition in the literature on what the attributes are of an antifragile system. There is no quantitative or qualitative research on the topic of antifragility, not for the context of organisation as in the context of (information) systems. There is no clear definition of resilience.

1.9.3 Final research questions

Iteration 1

The lack of a clear definition of antifragility created the need for a new research question. I concluded that first it should be clear if antifragile is relevant for an organisation. Only when this question is answered positive then it would make sense to find common ground on what defines an antifragile system.

This reasoning resulted in the following research questions:

> *Can leaders determine if their organisation must be resilient or antifragile?*
>
> *When applicable, does the "resilient ór antifragile model" support the leadership in determining what change is needed to achieve a resilient or antifragile organisation?*

2 Theoretical background

Introduction

Part of scientific research is to make the (applied) theoretical framework explicit. My theoretical framework is the context for my reasoning and the (applied) research.

The process of creating my theoretical framework follows the following (iterative) steps: (1) Findings of many studies; (2) Understanding Relationships; (3) Theory; (4) Theoretical Framework (Chumney Phd, 2016). See figure 2.1.

The theoretical framework is composed out of two parts. First, there is the theoretical background that is relevant for the topic antifragile. This is the content of this chapter. The theoretical background from this chapter is used in the construction of the Conceptual model in chapter 4.

Second, there is the relevant literature selected to create the conceptual model. The literature strategy is part of the Methodology in chapter 3. The selected literature is part of chapter 4 (Conceptual model).

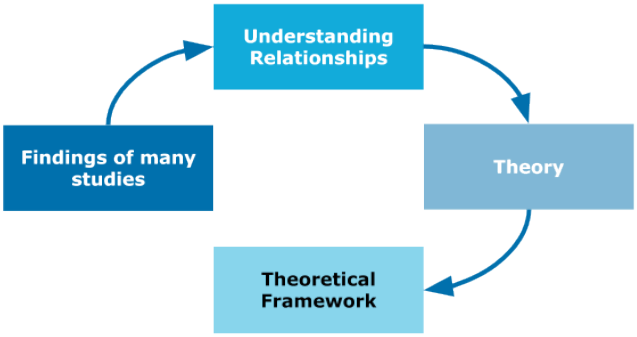

FIGURE 2.1: Process of creating a theoretical framework.

The theories that are part of the theoretical background are being discussed in the following sections:

2.1 System

I start with defining what a system is, since a system is a more abstract definition then the definition of an organisation (Hoogervorst, 2017, p. 210). The following consensus exists on the four characteristics of a system provided by Janssen (2015) on page 13.

1. *Composition*
   The system consists of various elements.
2. *Structure*
   The elements in the system affect each other.
3. *Production*
   The system generates good or services.
4. *Environment*
   There is a clear boundary between the system and the environment

2.2 Organisation

I originally aimed to find a model describing how to create an antifragile organisation. The aim of this research is to keep my original goal in mind, so that the result of my research written in this thesis can be applied to organisations.

An organisation is a specialisation of a system. Hoogervorst (2017) and Daft et al. (2010) state that there are four characteristics that define an organisation.

1. Organisations are Social Entities.
2. Organisations are Purposeful and goal-directed.
3. Organisations are Intentionally designed as systems of activity.
4. Organisations are Linked to the external environment.

2.2.1 Description of what an organisation is

Dietz et al. (2013) describe on page 94 an organisation which is in line with the previously provided characteristics:

> "An enterprise is an intentionally created cooperative of human beings with a certain societal purpose."
> - (Dietz et al., 2013, p. 94)

Hoogervorst (2017) expands on page 8 the description of Dietz et al. (2013) with the following description:

> "The purpose and function express that enterprises aim to fulfil or address certain (perceived) wants and needs of (certain) societal member of society at large by delivering products and/or services."
> - (Hoogervorst, 2017, p. 8).

In my view, this last description is most in line with what Taleb is portraying as an organisation, since it describes an organisation as a social construct to deliver products and/or services.

2.3 Organisation Design

When an organisation is purposeful, and it is intentionally designed then the organisation design plays an important role (Hoogervorst, 2017, p. 8; Dietz et al., 2013, p. 94; Daft et al., 2010). A valuable extension to the description of an Organisation (2.2) is therefore a description of the main functions within an organisation. An organisation consists of three main functions that should be addressed in the design of the organisation (Janssen, 2015, p. 48).

1. Governance
2. Run (Execution)
3. Change (Implementation & Improvement)

2.3.1 Organisations are in non-stop change from the outside

It can be argued that the run and change are one and the same. Since organisations are operating in a context that is changing highly frequent (Hutchins, 2018). Making sense of the high frequent changing context is very difficult, resulting in changed interpretations, which result in an even higher change frequency for the organisation.

In section 2.9 (VUCA) I address the volatility, uncertainty, complexity and ambiguity (VUCA) of the current world. In section 2.10 (The Cynefin Framework) I will introduce the Cynefin framework by Dave Snowden. The Cynefin framework can be used to make sense of the context per sub-system of the organisation.

2.3.2 Organisations are in non-stop change from within

Change in the organisational context is from the inside also non-stop, since people within the organisation change non-stop (Hoogervorst, 2017; Hutchins, 2018).

In section 1.7 (Introduction into Risk Management) I addressed the challenges for organisation design in the domain of Risk Management.

2.3.3 Reductionistic approach versus a holistic approach

There are various ways to look at the world. A classical dissection of ways to look at the world is one of reductionistic versus holistic.

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 contributors - B, 2020d).

The holistic view is 'the idea that various systems . . . should be viewed as wholes, not merely as a collection of parts' (Wikipedia contributors - C, 2020k).

In business management the approach by Taylor (Scientific Management[1]) is an example of a reductionistic approach to look at the management (and design) of an organisation. See figure 2.2 for a visualisation of the two approaches.

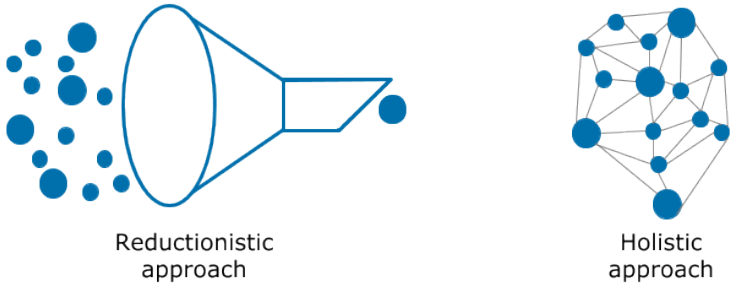

FIGURE 2.2: Reductionistic and Holistic approach.

[1] https://en.wikipedia.org/wiki/Scientific_management (Wikipedia contributors - B, 2019q)

2.3.4 Organisation design should not be done in a reductionist approach

It can be questioned if the holistic approach or the reductionistic approach is best in the effort of designing an organisation. There is a large set of literature that argues that the reductionistic approach is not the best approach for designing an organisation (Makridakis et al., 2009; Hoogervorst, 2017; Dietz et al., 2013; Janssen, 2015; Dahlberg, 2015; Taleb, 2012).

2.3.5 Change hurts the reductionist designed system

Systems have a tendency to be fragile (Johnson and Gheorghe, 2013, p. 162). IT systems are fragile (Lehman, 1980; Taleb, 2012, p. 55; Dahlberg, 2015, p. 17). Organisms are anti-fragile (Taleb, 2012, p. 55). This leads to the conclusion that using scientific management (reductionism) to design organisation leads to fragile organisations (Dahlberg, 2015, p. 11).

That non-stop change leads to fragility is also something Lehman (1980) stated, in the context of software, long before the concept of antifragility.

> "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)

Taleb (2012) states also what Lehman stated and put this in context with how nature is reacting on change.

> "...machines are harmed by low-level stressors (material fatigue), organisms are harmed by the absence of low-level stressors (hormesis) ..."
> - (Taleb, 2012, p. 55)

Dahlberg (2015) rephrases the words of Taleb (2012) in such a way the application is clearer to us, or at least to me.

> "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)

2.3.6 The reductionist approach to a complex system

An organisation is a specific type of a Complex Adaptive System (Dietz, 2012, p. 11, 93-94). Dahlberg (2015) conclusion is that a reductionistic approach to a complex system will be without fruit.

> "The reductionist approach to a complex system will never bear fruit. Likewise, traditional command and control-style management approaches are impossible to implement in the complex domain."
> - (Dahlberg, 2015, p. 11)

Therefore, reductionistic approach to an organisation will be without fruit.

> "Enterprises are complex adaptive systems whereby it is impossible to determine the ultimate (operational) reality of the enterprise down to the minute details."
> - (Dietz et al., 2013, p. 93)

The field of Enterprise Engineering, underwrites the relevance of finding a way to deal with chaos, complexity and non-stop change. This for me is an extra reason that this research is relevant for the field of Enterprise Engineering.

2.3.7 Enterprise Engineering, antifragility and the black swan

The relevance of the research on antifragility goes beyond the theme of non-stop change and unpredictability. The field of Enterprise Engineering also defines the importance of dealing with black swans (X-events).

> "This type of learning acknowledges the non-planned, emerging character of many enterprise developments (Hoogervorst, 2009). Hence, employee involvement and participation are essential for addressing enterprise dynamics, complexity, and uncertainty. Enterprise change, hence redesign, is thus fuelled by enterprise learning. As Weick (2001) observes, redesign is a continuous activity whereby **the responsibility for (re)design is dispersed and rests with enterprise members who are coping with the 'unexpected'**."
> - (Dietz et al., 2013, p. 91)

Black swans are the reason Taleb (2012) introduced antifragility. Both Enterprise Engineering and antifragility recognise black swans as something that is 'unexpected'.

Antifragile states that change by a black swan (X-event) are unpredictable. Run and change should be designed in such a way that the unpredictable change is supported. This needs a (new and) fitting governance paradigm. The field of antifragility is a great addition to the field of Enterprise Engineering on how to design a system that can survive black swan events.

2.3.8 Reductionistic design is being replaced by holistic design

The same reasoning that reductionistic design of organisations is not the way to go, is also found in a recent report of McKinsey & Company. This report is based on a survey and expert input.

In this report the agile organisation is re-framed as an antifragile organisation (Aghina et al., 2017). See figure 2.3 for a representation that should address issues business leaders face and are relevant in the decision on how to design the organisation.

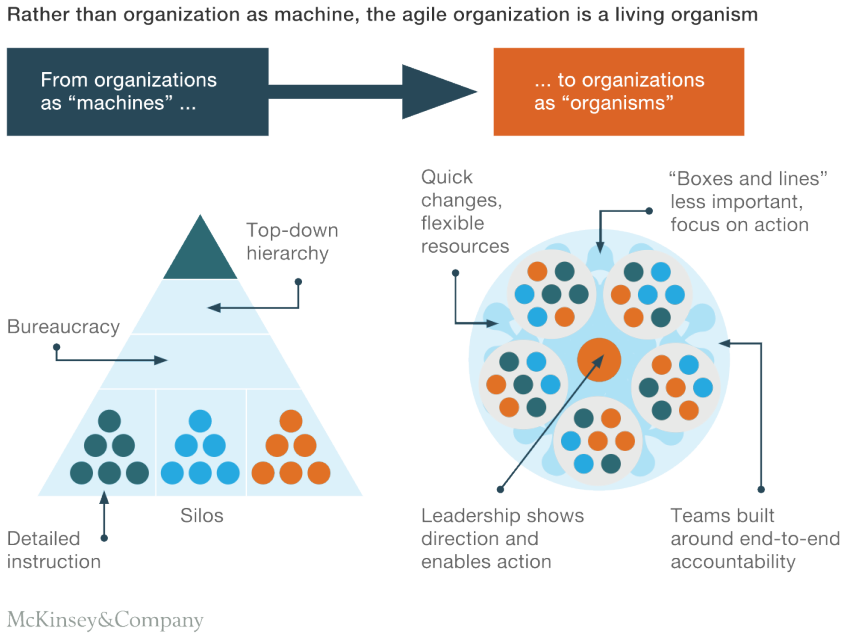

FIGURE 2.3: The agile organisation is dawning as the new dominant organisational paradigm by Aghina et al. (2017).

McKinsey identified, based on a survey and expert input, five trademarks of agile (antifragile) organisations. See figure 2.4 for these five trademarks.

I find it interesting that they added technology as trademark to the list. I placed the analysis of this report by McKinsey out of scope of this thesis because of timing constraints. I do like to include it briefly here because it shows that the topic of my thesis and the outcome of it is relevant to the current business leaders.

There are five trademarks of agile organizations.

	Trademark		Organizational-agility practices[1]
Strategy	North Star embodied across the organization		• Shared purpose and vision • Sensing and seizing opportunities • Flexible resource allocation • Actionable strategic guidance
Structure	Network of empowered teams		• Clear, flat structure • Clear accountable roles • Hands-on governance • Robust communities of practice • Active partnerships and ecosystem • Open physical and virtual environment • Fit-for-purpose accountable cells
Process	Rapid decision and learning cycles		• Rapid iteration and experimentation • Standardized ways of working • Performance orientation • Information transparency • Continuous learning • Action-oriented decision making
People	Dynamic people model that ignites passion		• Cohesive community • Shared and servant leadership • Entrepreneurial drive • Role mobility
Technology	Next-generation enabling technology		• Evolving technology architecture, systems, and tools • Next-generation technology development and delivery practices

[1]The 5 trademarks include 23 practices for organizational agility; 18 are based on survey research. Five additional practices are included that have emerged from recent experiences with large global companies transforming into agile organizations.

McKinsey&Company

FIGURE 2.4: There are five trademarks of agile organisations by Aghina et al. (2017).

2.4 Learning Organisation

To deal with non-stop change it is essential to non-stop learn (Dietz et al., 2013, p. 91). In this section I will reason that learning needs communication, no naivety and includes enriching your organisational language based on good and bad experiences. At the end I will present the selected framework for a learning organisation. Anthony et al. (2016) and Dietz et al. (2013) showed that (1) adapting to the market (the environment) and (2) non-stop learning is key to survive as a company

> "This type of learning acknowledges the non-planned, emerging character of many enterprise developments (Hoogervorst, 2009). Hence, **employee involvement and participation** are essential for addressing enterprise dynamics, complexity, and uncertainty. **Enterprise change, hence redesign, is thus fuelled by enterprise learning**. As Weick (2001) observes, **redesign is a continuous activity** whereby the responsibility for (re)design is dispersed and rests with enterprise members who are coping with the 'unexpected'."
> - (Dietz et al., 2013, p. 91)

2.4.1 Learning needs communication

The above-mentioned employee involvement and participation needs cooperation. Cooperation between people is made possible by communication (Janssen, 2015, p. 15).

Communication is an important part in the design and operation of an organisation. The definitions of fragile, robust and antifragile in the context of organisations pivot around the reaction on input from the outside the organisation by the organisation.

Communication is needed to learn and to adapt, therefore communication plays a large role in becoming resilient and antifragile. Communication is not only important for learning from the things that went good (monotonicity). Non-Monotonicity is learning from bad experiences. Communication is therefore also related to non-monotonicity.

2.4.2 Non-Monotonicity is learning from bad experiences

In various papers on antifragile the term non-monotonicity is being used. Monotonicity is a term used in the context of electrical engineering, learning and logic. Monotonicity can be summarised as: discriminate the input and only learn from improvements. Thus, exclude negative input from the learning process.

Learning in the context of antifragility can be summarised as the increase of the variety in the language that is being used (Ghaderi et al., 2016; Helbing and Kirman, 2013; Lange and Zeugmann, 1991; Voorspoels et al., 2015). Non-Monotonicity is thus about not only learning from the good experiences but also learning from the bad experiences resulting in the increase of variety of the language in the organisation.

Learning from mistakes can be an effective defence against stressors. Mistakes and failures can lead to new information. As new information becomes available it defeats previous thinking, which can result in new practices and approaches (Augusto Wrede and Simari, 2001; Nute, 2003; Governatori and Terenziani, 2007). In this way stressors cause the system to improve (Johnson and Gheorghe, 2013; Ghasemi and Alizadeh, 2017).

Learning from negative consequences induced by stressors can lead to new information. New information can result in improved practices and approaches. Stressors, when learned from, can thus cause a system to improve (Kennon et al., 2015; Ghasemi and Alizadeh, 2017; Jackson and Ferris, 2013).

2.4.3 Remove naive intervention to learn

Senge (1990) states that reacting on what happens can only be successful if the reaction is not based on a 'linear–direct–relation between cause and effect' (Janssen, 2015, p. 14). Taleb also supports this when talking about the reaction on stressors and the role of randomness in the context of stressors (Taleb, 2001, 2007, 2012). Taleb argues that systems are (almost) never linear-systems due to complexity, chaos and randomness, see also section 2.6 (Randomness).

Taleb argues to remove the 'naive intervention' since this is the manifestation of reasoning linear where it is not applicable (Taleb, 2012). Taleb promotes trusting on the instinct and behaviour that individuals or group of individuals have learned over time above the 'naive intervention' based on a linear and reductionistic view on the situation.

2.4.4 Learning organisation is relevant for antifragility

The learning organisation is a way to create a resilient organisation which let organisations cope with unknown and unpredictable events. Aven (2015) provides evidence (concerning leakages in the oil & gas industry) that resilient behaviour is needed to deal with unpredictable events.

Aven provided evidence that evolution from fragile to resilient is possible. Taleb supports that data can be used to prove this. Fragility and antifragility of the same system can be measured since these are properties of the current object (Taleb, 2012; Starossek et al., 2011; Aven, 2015, p. 477). Taleb also states that fragility of two systems can easily be compared (Aven, 2015, p. 477; Taleb, 2012, p. 22).

This can be combined into stating that an antifragile organisation can be the result of a fragile organisation, since an organisation can evolve from fragile to a resilient organisation and antifragile has overlap with the CAS resilient (type 3) organisation. Therefore, the learning organisation is of fundamental importance for an organisation to become resilient or even antifragile.

2.4.5 How to achieve a Learning Organisation

There are numerous ways to define what is needed in a learning organisation. Flood (1999) provides the following overview of frameworks for learning organisation.

1. Senge's[2] - 5th discipline[3]
   (Senge, 1990)
2. Bertalanffy's[4] - Open systems theory[5]
   (Von Bertalanffy, 1972)
3. Beer's[6] - Organisational cybernetics[7]
   also known as Viable Systems Method[8] (VSM)
   (Beer, 1974, 1979, 1981, 1985, 1989)
4. Ackoff's[9] - Interactive planning[10]
   (Askoff, 1981; Ackoff, 1997, 2001)
5. Checkland's[11] - Soft systems approach[12]
   (Checkland, 1989)
6. Churchman's[13] - Critical systemic thinking
   (Churchman, 1968, 1979, 1982)

Senge (1990) is used in several papers on antifragility (Jaaron and Backhouse, 2014a,b; Kennon et al., 2015; Nurmi et al., 2019; Maveau, 2017; van Eijnatten, 2004; van Eijnatten and Putnik, 2004). Senge (1990) is also used in the context of systems approach (Nurmi et al., 2019; Meadows and Wright, 2008; Kok and van den Heuvel, 2018; Hoogervorst, 2017).

[2] https://en.wikipedia.org/wiki/Peter_Senge (Wikipedia contributors - B, 2019h)
[3] https://en.wikipedia.org/wiki/The_Fifth_Discipline (Wikipedia contributors - B, 2019a)
[4] https://en.wikipedia.org/wiki/Ludwig_von_Bertalanffy (Wikipedia contributors - C, 2020r)
[5] https://en.wikipedia.org/wiki/Open_system_(systems_theory) (Wikipedia contributors - C, 2020t)
[6] https://en.wikipedia.org/wiki/Stafford_Beer (Wikipedia contributors - C, 2020y)
[7] https://en.wikipedia.org/wiki/Management_cybernetics (Wikipedia contributors - C, 2020s)
[8] https://en.wikipedia.org/wiki/Viable_system_model (Wikipedia contributors - C, 2020z)
[9] https://en.wikipedia.org/wiki/Russell_L._Ackoff (Wikipedia contributors - B, 2019p)
[10] https://en.wikipedia.org/wiki/Interactive_planning (Wikipedia contributors - C, 2020m)
[11] https://en.wikipedia.org/wiki/Peter_Checkland (Wikipedia contributors - C, 2020v)
[12] https://en.wikipedia.org/wiki/Soft_systems_methodology (Wikipedia contributors - B, 2019r)
[13] https://en.wikipedia.org/wiki/C._West_Churchman (Wikipedia contributors - C, 2020c)

This is the reason I choose to use the 5th discipline of Senge as the framework to capture the system attributes from the selected literature that address the learning organisation.

Senge (1990) identifies five disciplines that form together the learning organisation (Senge, 1990, p. 9-13).

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

2.5 Risk Management

ISO 31000 (Enterprise Risk Management) describes Risk Management as:

> "(Risk management is the) identification, assessment, and prioritisation of risks (effect of uncertainty on objectives, whether positive or negative) followed by effective and economic application of resources to minimise, monitor, control, and assure the probability and/or consequence of negative events or to maximise opportunities." - (Hutchins, 2018; Wikipedia contributors - B, 2019o).

2.5.1 Risk Management is about uncertainty

Risk Management is evolving to acknowledging uncertainty (Aven, 2015). The lack of methods to deal with 'surprise' events has been identified by Derbyshire and Wright (2014).

Aven (2015) and Makridakis et al. (2009) add to the description by Hutchins (2018) that Risk Management is not about models predicting the future, but is about creating a system that is resilient in regard to events.

> "The risk management has a special focus on situations that could lead to accidents. Surely, there is risk present, and the challenge is to manage this in the best way. This also includes to **improve the understating of risk by identifying signals and warnings and acknowledging uncertainties and the importance of knowledge**."
> - (Aven, 2015, p. 5, 480)

Makridakis et al. (2009) provides a long list that argues that risk cannot be managed by models:

> "A huge body of empirical evidence has led to the following conclusions.
>
> - The future is never exactly like the past. This means that the extrapolation of past patterns or relationships cannot provide accurate predictions.
> - Statistically sophisticated, or complex, models fit past data well but do not necessarily predict the future accurately.
> - "Simple" models do not necessarily fit past data well but predict the future better than complex or sophisticated statistical models.
> - Both statistical models and human judgement have been unable to capture the full extent of future uncertainty. People who have relied on these methods have been surprised by large forecasting errors and events they did not consider.
> - Expert judgement is typically inferior to simple statistical models.
> - Forecasts made by experts are no more accurate than those of knowledgeable individuals.
> - Averaging the predictions of several individuals usually improves forecasting accuracy.
> - Averaging the forecasts of two or more models improves accuracy while also reducing the variance of forecasting errors."
>
> - (Makridakis et al., 2009)

2.5.2 Risk Management and fragility

Taleb and Douady (2013) state that sensitivity to risk is the same fragility:

> "In essence, fragility is the sensitivity of a given risk measure to an error in the estimation of the (possibly one-sided) deviation parameter of a distribution, especially due to the fact that the risk measure involves parts of the distribution – tails – that are away from the portion used for estimation."
> - (Taleb and Douady, 2013, p. 7)

2.5.3 Risk Management and Risk Reduction

Derbyshire and Wright (2014) describe a variety of methods that organisations apply to reduce risk. This summary inspired me into starting to search for a pattern in the available literature on antifragility.

These methods for risk reduction are (excluding the antifragile methods) :

1. "Controlling the dispersion of outcomes
2. Hormesis[14]
3. Redundancy[15, 16]
4. Small-scale experimentation (trial and error)"

- (Derbyshire and Wright, 2014)

2.5.4 Hormesis

Hormesis is a not so commonly used term, therefore here two descriptions of this term.

> "a theoretical phenomenon of dose-response relationships in which something (as a heavy metal or ionizing radiation) that produces harmful biological effects at moderate to high doses may produce beneficial effects at low doses"
> - (Merriam Webster, 2020e)

> "Hormesis is a term used by toxicologists to refer to a biphasic dose response to an environmental agent characterised by a low dose stimulation or beneficial effect and a high dose inhibitory or toxic effect. In the fields of biology and medicine hormesis is defined as an adaptive response of cells and organisms to a moderate (usually intermittent) stress." - (Mattson, 2008)

2.5.5 Risk Management - Predicting risks is hard

Gorgeon (2015) summarised which factors make the prediction and identification of risk difficult. See also section 2.6.6 (We are limited by observation).

1. "The future is never exactly like the past.
2. Statistical models work well if the assumptions about the probability distributions are correct.
3. We have very often little or no knowledge about the nature of the distributions of events that can affect systems, positively or negatively.
4. Research has shown extensively that decision makers use heuristics to cope with the complexities of estimating probabilities (Tversky and Kahneman, 1974). While these heuristics often ease the decision process, they also have been shown to systematically bias judgement (O'Neil, 2016)."

- (Gorgeon, 2015, p. 6)

2.5.6 Risk Management - Predicting the future is hard

Humans are not able to predict the future, or at least it is proven that we are not good in predicting the future (Mintzberg, 1994b; Augusto Wrede and Simari, 2001; Governatori and Terenziani, 2007; Makridakis et al., 2009; Makridakis and Taleb, 2009b; Makridakis and Taleb, 2009a; Taleb, 2012, p. 17; Ghasemi and Alizadeh, 2017, p. 22; Hoogervorst, 2017).

Even if humans could predict the future, then this prediction should be of high quality to have a significance since a small deviation in the environment has a large (concave) effect on the fragile system (Gorgeon, 2015; Taleb and Douady, 2013; Taleb, 2007, 2012). See also section 2.6.5 (Example of a simple chaotic system).

[14] `https://en.wikipedia.org/wiki/Hormesis` (Wikipedia contributors - C, 2020l)
[15] `https://en.wikipedia.org/wiki/Redundancy_(engineering)` (Wikipedia contributors - B, 2019l)
[16] `https://www.merriam-webster.com/dictionary/redundancy` (Merriam Webster, 2020g)

2.5.7 Risk Management - Predicting the future is impossible

Reality is a collection of hyper-connected graphs of which the behaviour is random and therefore is inherently unpredictable (Taleb, 2001; Pineda et al., 2018; Kim et al., 2019). Reality is a complex adaptive System-of-Systems showing a non-linear behaviour (Dietz et al., 2013, p. 93).

An increasing part of our reality is becoming unpredictable since the number of layers of the hyper-connected graph are increasing. The increase of the number of layers is caused by for example digital transformation. Digital transformation removes the physical boundaries the are limiting the connections between objects and systems in the analogue world. The number of edges and vertices in the graphs are also increasing by for example the digital communication. A simple example of this is the network of connected IoT-devices.

The laws of Metcalfe[17] (Metcalfe, 2013) and Moore[18] (Waldrop, 2016) enforce the world becoming completely digital and hyper-connected. The unstoppable increase of the number of layers and the number of vertices of the hyper-connected graph that is our reality result that our reality is and stays fundamental unpredictable. This calls for organisations and IT systems that can operate and adapt within this reality.

[17] `https://en.wikipedia.org/wiki/Metcalfe's_law` (Wikipedia contributors - B, 2019e)
[18] `https://en.wikipedia.org/wiki/Moore's_law` (Wikipedia contributors - B, 2019g)

2.6 Randomness

2.6.1 Two types of randomness

Derbyshire and Wright (2014) states that there are two types of randomness:

1. 'epistemological randomness' or 'deterministic chaos'
   It is impossible to know everything and therefore it is impossible to predict the future.

   "Uncertainty results from the inadequacy of the procedures we use to uncover cause, which can have limited efficacy, even ex-post."
   - (Derbyshire and Wright, 2014, p. 216)

2. 'ontological randomness' or 'true randomness'
   The change in the now is no guarantee on a certain outcome.

   "A particular combination of factors may result in one outcome on one occasion and a completely different outcome on another"
   - (Derbyshire and Wright, 2014, p. 216)

Both type of randomness can be called chaos or chaotic.

2.6.2 What is chaos?

Chaos is a word often used when things get complicated. Edward Lorenz[19], recognised as one of the founders and pioneers of the chaos theory[20], describes chaos as: 'When the present determines the future, but the approximate present does not approximately determine the future.'

Dave Snowden as founder of the Cynefin framework, which contains Chaos and Complexity, defines chaos as 'Cause and effect are unclear' (Kurtz and Snowden, 2003).

I can summarise chaos theory and the Cynefin framework on chaos as that chaos is the situation where there is a lack of information and therefore lack of predictability. This lack of information can be compensated with more information and/or more knowledge, but there is a limit to the expansion of information and knowledge.

2.6.3 Exponential effect is a non-linear effect

Sometimes small deviations in the input have exponential effect on the output. When there is a combination of various systems with this behaviour the combination of systems quickly exceeds the human understanding. The weather prediction[21] is an example of this. The weather forecast in the near future has a higher predictability then the weather forecast for over a few days. The exponential growth created by the non-linear complex systems makes it very hard to predict the weather in the future.

2.6.4 The universe is unpredictable by nature

There is recent research that indicates that chaos (unpredictability) is also part of physics (quantum mechanics) (Bera et al., 2017). This implies that there is not only a limit on the information and knowledge of the observer, but also a root-cause in unpredictability.

2.6.5 Example of a simple chaotic system

Chaos and unpredictability are not exclusively relevant for large systems (weather forecasting) or small systems (quantum mechanics). It is possible to create a small wooden toy that shows chaotic behaviour.

[19] https://en.wikipedia.org/wiki/Edward_Norton_Lorenz (Wikipedia contributors - C, 2020f)
[20] https://en.wikipedia.org/wiki/Chaos_theory (Wikipedia contributors - C, 2020d)
[21] https://www.knmi.nl/kennis-en-datacentrum/achtergrond/over-de-weer-en-klimaatpluim-en-expertpluim

A double pendulum is a simple system that exhibits rich dynamic behaviour with a strong sensitivity to initial conditions (Wikipedia contributors - A, 2019n). A double pendulum is constructed from two deterministic systems. An example of a double pendulum[22] is a pole standing straight up, with at the end an axis connected to the end of a beam (1). At the end of this beam (1) another smaller beam (2) is connected through an axis (see figure 2.5). The rotation speed of a beam (wing) can be predicted in a model. The connection of the two wings results in the amplification of minimal variations in the construction and the state.

For example, a small burr on the axis that connects the two wings, or a minimal deviation of the initial energy put into the motion. This concave effect of minimal input results in a movement that cannot be predicted and therefore can be called chaotic. Reality is more complex than a double pendulum. The butterfly effect is a famous way of creating awareness of the complexity and chaos of our reality. See figure 2.5 for the double pendulum and the butterfly effect.

I personally use this example often when talking with other architects. We as architects tend to forget the behavioural effect that can occur when we let various systems react on each other in an automated way. An example of this is software behind the High Frequency Trading[23] and Algorithmic Trading[24].

FIGURE 2.5: Schematic view of a double pendulum and butterfly effect.

[22] https://www.youtube.com/results?search_query=double+pendulum+chaos
[23] https://en.wikipedia.org/wiki/High-frequency_trading (Wikipedia contributors - C, 2020j)
[24] https://en.wikipedia.org/wiki/Algorithmic_trading (Wikipedia contributors - C, 2020a)

2.6.6 We are limited by observation

One of the great ideas in the eastern and western philosophy is that we are observing a reflection of the reality. In the western philosophy this is communicated in concepts as Plato's cave[25,26] and "Dinge für mich" of Kant[27,28].

That reality is a reflection seen through a lens, implies that there is a light source that is casting shadows and light, and that there is a lens trough the light and shadows reach the observer.

2.6.7 Light creating reflections

The reflection in the cave of Plato is created by a fire. In the Demoscene[29], a popular way of simulating fire is by generating random pixels with random colours[30]. The concept of a random generator as the source of the light that provides reflections of our reality is a nice concept to think about. Since all the events in our world are resembling random events, this might imply that we are all observing reality though a random light source.

2.6.8 Our personal lens

Where the reflection of reality (our observation) is limited by our personal lens, it is also limited by the view-model we create of the world. This has two reasons.

First the view-model is limited by the language in which we create it. Gödel[31] proved with his incompleteness theorems that every language is not complete therefore limited (Hofstadter, 2000). An example of this is that you as a human cannot describe what you do not yet know, and that you don't know what you don't know. Therefore, asking someone to specify the needs delivers an incomplete answer since the answer is limited to the imagination and experience of this specific human (Gladwell, 2004).

The second reason that the view-model limits our view of the world is that the model often defines how the world is to be interpreted (translated). An example of this is the interface of a car lease company. When the IT system states that the car is outfitted with tires suitable for the winter, the experience is that it is difficult to convince the operator of the software that the physical car is outfitted with tires suitable for the summer. The information and the logic materialised in the IT system defines the view on reality of the human operating the software.

The view-model materialised in the IT system is limiting the description of the physical reality. This will result in situations described as 'Computer Says No'[32] and in situations where actions are limited by the options the model (rules) provide us (Hoogervorst, 2017; Ciborra, 2004).

2.6.9 We have inherently flawed observations of the reality

Therefore, the reflection of the world is not only limited by the random events that provide light (observations), but also limited by the lenses have by experience, social constructs, and IT systems.

[25] https://plato.stanford.edu/entries/plato-myths (Partenie, 2009)
[26] https://plato.stanford.edu/entries/plato-metaphysics (Silverman, 2003)
[27] https://plato.stanford.edu/entries/kant
[28] https://thegreatthinkers.org/kant/introduction
[29] https://en.wikipedia.org/wiki/Demoscene (Wikipedia contributors - A, 2019l)
[30] https://lodev.org/cgtutor/fire.html
[31] https://en.wikipedia.org/wiki/Godel's_incompleteness_theorems (Wikipedia contributors - A, 2019q)
[32] https://en.wikipedia.org/wiki/Computer_says_no (Wikipedia contributors - A, 2019j)

2.7 Requisite Variety

Terms that are often used interchangeable are chaos, entropy and variety. In the previous section I addressed chaos. In this section I address variety and entropy.

Requisite[33] Variety[34] is named as a system attribute of an antifragile system in various papers on antifragility (Ghasemi and Alizadeh, 2017; Kennon et al., 2015; Johnson and Gheorghe, 2013). Requisite Variety is a law first introduced by Ashby (1958) but in the context of Enterprise Engineering the application of Requisite Variety by Beer (1979) is often used. Therefore, in this section both Ashby and Beer will be used.

2.7.1 Variety is relative

The term 'variety' was introduced by Ashby to denote the count of the total number of states of a system (Ashby, 1956, 1958; Wikipedia contributors - B, 2020e).

The observer and his powers of discrimination have a great role to play when addressing variety and may have to be specified if the variety is to be well defined (Wikipedia contributors - B, 2020e). Ashby and Beer both state the following on the role of the observer:

> "*Variety*: Given a set of elements, its variety is the number of elements that can be distinguished. ...If two observers differ in the distinctions they can make, then they will differ in their estimates of the variety."
> - (Ashby, 1958, p. 1)

> "(Variety is) the number of possible states of whatever it is whose complexity we want measure."
> - (Beer, 1979, p. 32)

In my own words I would say that variety is subjective.

2.7.2 Variety is more primitive than entropy

As stated before, some people see variety and entropy as interchangeable. Ashby states that the law of requisite variety makes use of concepts more primitive than those used by entropy (Ashby, 1958).

In statistical mechanics, the entropy of a system is described as a measure of how many different microstates there are **that could give rise** to the macrostate that the system is in. The entropy S is the natural logarithm (ln) of the number of microstates (Ω), multiplied by the Boltzmann constant k_B. This formula is also known as the Ludwig Boltzmann equation[35]: $S = k_B \ln \Omega$ (Wikipedia contributors - C, 2020g).

2.7.3 Law of Requisite Variety

Ashby and Beer stated the Law of Requisite Variety as 'variety can destroy variety' (Ashby, 1956, p. 207) and 'variety absorbs variety' (Beer, 1979, p. 286).

Since the language used by Ashby and Beer is a bit difficult to apply, the following definition is a bit more easy to understand: 'If a system is to be stable, the number of states of its control mechanism must be greater than or equal to the number of states in the system being controlled' (Heylighen and Joslyn, 2001; Wikipedia contributors - B, 2020e).

2.7.4 The original and elaborate Law of Requisite Variety

The original and elaborate definition of the law of Requisite Variety is provided by Ashby (1956) as below, and I want to add this to give a nice complete view on the origin of the law of Requisite Variety:

[33] `https://www.merriam-webster.com/dictionary/requisite` (Merriam Webster, 2020h)
[34] `https://www.merriam-webster.com/dictionary/variety` (Merriam Webster, 2020k)
[35] Trivia fact: Boltzmanss's equation ($S = kLogW$) is carved on his gravestone

> " ...simply suppose that we are watching two players, R and D, who are engaged in a game. ...Let V_D be the variety of D, V_R that of R, and V_O that of the outcome (all measured logarithmically). ...If V_D is given and fixed, $V_D - V_R$ can be lessened only by a corresponding increase in V_R. Thus the variety in the outcomes, if minimal, can be decreased further only by a corresponding increase in that of R. ...This is the law of Requisite Variety. To put it more picturesquely: only variety in R can force down the variety due to D; variety can destroy variety. ...The law of Requisite Variety says that R's capacity as a regulator cannot exceed R's capacity as a channel of communication. "
> - (Ashby, 1956, p. 202, 206-207, 211)

2.7.5 Variety Engineering

In the papers that state that Requisite Variety is part of the system attributes of an antifragile system, it is not very clear to me how Requisite Variety is seen in the context of those papers (Ghasemi and Alizadeh, 2017; Kennon et al., 2015; Johnson and Gheorghe, 2013).

Ghasemi and Alizadeh (2017) and Kennon et al. (2015) state that 'When the number of regulators is inadequate, the behaviour of the system cannot be anticipated precisely and black swan events emerge. Thus the more regulators, the greater antifragility'. Stating the same as Hoogervorst (2015) that more variety is essential for a system (or organisation) to deal with the world.

Interesting is that Johnson and Gheorghe (2013) states that the lack of variety in a system-of-systems (SoS) if fixed (or compensated) by the emergent behaviour of the system itself.

> "...As the actual variety becomes less than the required or requisite variety of the SoS, regulators are not able to obtain and exchange the requisite information to control the behaviour in the SoS, and the system becomes emergent ..."
> - (Johnson and Gheorghe, 2013).

During the research into antifragility it became clear to me that most design principles and/or system attributes defined can be categorised in two types: Attenuate Variety and Amplify Variety. These terms are part of the work on cybernetics of Ashby and Beer.

Attenuate Variety is the concept of reducing the variety in a system. The absorption of change in the context of systems is called attenuate variety or variety reduction.

Amplifying Variety is the concept of increasing the Variety in a system. Amplifying Variety is about increasing the chance of a higher entropy and therefore being more capable to absorb variety increase caused by change. Emergence leads to variety amplification.

2.8 What is a stressor?

Almost all if not all papers on antifragility and resilience use the term stressor for an event from outside the system, that causes stress. Below is a very nice description of what a stressor is provided by Turner et al. (2003) found in Chrousos (2009).

> "When systems are performing effectively, they are in a predetermined condition and conversely when they are not functioning correctly, they are in an unintended state. An unintended condition can be known or unknown. Stressors are forces that threaten to transfer a system from an intended to an unintended condition.
> - (Turner et al., 2003; Chrousos, 2009).

2.9 VUCA

VUCA stands for Volatile, Uncertain, Complex and Ambiguous. The term VUCA was first used in 1987, drawing on the leadership theories of Warren Bennis and Burt Nanus (Wikipedia contributors - B, 2019t). The usage of the term evolved from usage at U.S. Army War College to usage in strategic leadership in various organisations. This term is used by ISO 31000 (Hutchins, 2018) to describe the current world. This term is coined as synonym for the disorder cluster of stressors that are used by Taleb (Taleb, 2012, p. 436; Gorgeon, 2015, p. 3). See section 1.7.4 (Uncertainty in a volatile and complex world).

The definition of VUCA in table 2.1 combines the observation with the action (Bennett and Lemoine, 2014b,a).

TABLE 2.1: VUCA abbreviation - (Bennett and Lemoine, 2014b,a).

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."

2.10 The Cynefin Framework

The agile transformation of an organisation is often explained with help of the Cynefin framework (Kurtz and Snowden, 2003). The Cynefin framework is inspired by work of Ralph D. Stacey (IBM) (Stacey, 2001). The Cynefin framework is created as a tool to be a 'sense-making device' for managers. The Cynefin framework describes five domains: (1) Simple (Obvious / Clear), (2) Complicated, (3) Complex, (4) Chaotic and (5) Disorder (Confusion).

Each domain has its own dynamic of which managers should be aware. In table 2.2 the Cynefin domains defined and provided with the appropriate advice how to act accordingly (Wikipedia contributors - A, 2019k).

TABLE 2.2: Cynefin domains defined - (Wikipedia contributors - A, 2019k).

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 rationally toward a decision but doing so requires refined judgment and expertise. The advice is to: "sense–analyse–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. Stewart The advice is to: "probe–sense–respond"
Chaotic
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.

2.10.1 Antifragile and resilience in the Cynefin framework

Resilience and agile are a way of working that fits the domain of 'Complex' and 'Chaotic'. In the domain of 'Complicated' and 'Simple' planning and reductionism work best. In the domain of 'Complex', 'Complex Adaptive Systems (CAS) resilience works best. In the domain of 'Chaotic', antifragile will work best. See figure 2.6.

2.10.2 The Learning Organisation and the Cynefin framework

The domain 'Disorder' is applicable when there is no clarity about which of the other domains apply. The domains are not measurable or absolute domains. In this thesis resilience and agility will be used as (part of) the transition from robust to antifragile. The definition of the domains is tightly bound to the understanding of the domain. This implies that learning

as a person or as an organisation has influence on the positioning in the domain and therefore influence on which action is to be taken. This line of reasoning has similarities with the descriptions of chaos and of variety.

Variety and the Cynefin framework

Cynefin interlinks with the application of higher variety in the organisation that Hoogervorst (2015) describes in the Enterprise Engineering theory Sigma. An organisation in the state of order, has a lower variety than an organisation in disorder. By reducing the variety of an organisation, the emergence (innovation and creativity) is also reduced. Hoogervorst (2015) states that increasing the (internal) variety improves the capability of an organisation to cope with the variety of the outside world. Hasan and Kazlauskas (2014) provide an example of this.

> "Once the telco corporatised and indoctrinated the smaller company's personnel and practice into its bureaucratic culture, their innovation and creativity disappeared. We suggest that if the telco wanted to support the innovation and creativity they thought that they had acquired, they should have allowed the group flexible and self-directed arrangements more suited to unorder and complexity. Cynefin provides a framework within which to do this."
> - (Hasan and Kazlauskas, 2014)

Chaos domain is inevitable

As mentioned in section 2.5.7 (Risk Management - Predicting the future is impossible). When the hyper-connected graphs that is our world is growing in size and connections, then 'Chaos' and 'Complexity' as defined by Kurtz and Snowden (2003) in the 'Cynefin framework' are inevitable to become a larger part of the reality we occupy. The VUCA'ness of our reality will keep increasing.

Considering this I come to the following conclusions/advice:

- Embrace the chaos in all what we do.
- Add tools, methods to our toolbox that can be utilised in the domain of 'Chaos' and 'Complexity'.

The goal of the model(s) presented in this thesis is to add tools to our toolbox for us to use in the 'Chaos' and 'Complex' domain.

FIGURE 2.6: Cynefin Framework by cognitive-edge by Bailie (2011).

2.11 Enterprise Engineering

The discipline of Enterprise Engineering can best be described by one of the founders of this discipline.

> "Enterprise engineering is a new, holistic approach to address enterprise changes, of all sizes and in all kinds of enterprises. Because of its holistic, systemic, approach, it resembles systems engineering (Sage, 1992; Stevens et al., 1998). But it differs from it in an important aspect: enterprise engineering aims to do for enterprises (which are basically conceived as social systems) what systems engineering aims to do for technical systems."
> - (Dietz et al., 2013, p. 92)

2.11.1 Fundamentals of Enterprise Engineering

Enterprise engineering consists out of the following fundamentals (Dietz et al., 2013) that are part of a larger context (see figure 2.7):

1. Strict distinction between function and construction
2. Focus on essential transactions and actors
3. Rigorous distinction between design and implementation
4. Diligent application of design principles
5. Distributed operational responsibility
6. Distributed governance responsibility
7. Human-centred and knowledgeable management

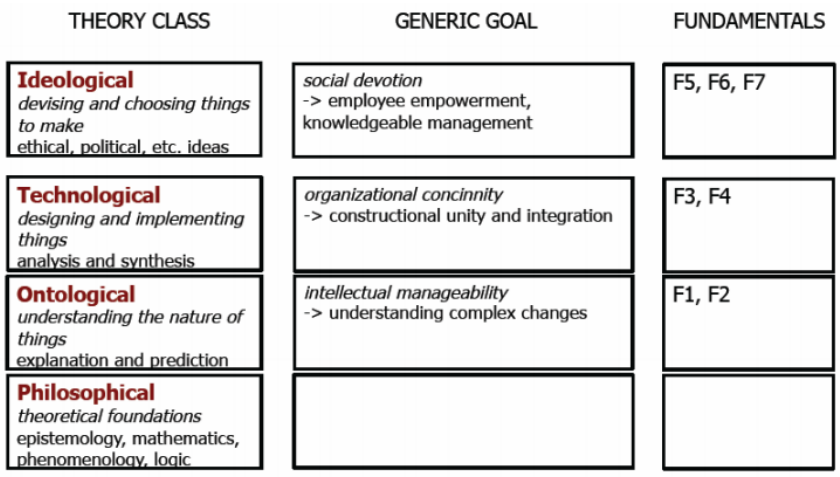

FIGURE 2.7: EE generic goals and fundamentals in the classification scheme by Dietz et al. (2013) p. 103.

2.11.2 Antifragility and Enterprise Engineering

Antifragility and Enterprise Engineering have many overlapping views on the world.
A few examples are:

1. The concepts of function and construction (EE Fundamentals 1) are also used in the definition of resilience types: Engineering resilience, Systems resilience and Complex Adaptive Systems (CAS) resilience.
   See section 1.6 (Introduction into Resilience).

2. Antifragile and Enterprise Engineering both address the design of organisations in the Complex Adaptive Systems (CAS) domain.
   See section 1.7 (Introduction into Risk Management).

3. Antifragile and Enterprise Engineering both state that organisations are in non-stop change.
   See section 2.3.1 (Organisations are in non-stop change from the outside).

4. Antifragile and Enterprise Engineering both address the existence and relevance of black swans or X-events.
   See section 2.3.7 (Enterprise Engineering, antifragility and the black swan).

5. Antifragile and Enterprise Engineering both address that reality is not to be understood by observation.
   See section 3.1.2 (Taleb and Enterprise Engineering).

6. Antifragile and Enterprise Engineering both state that operational responsibility and governance responsibility should be distributed (EE Fundamentals 5 and 7).

7. Antifragile and Enterprise Engineering both are human-centred (EE fundamentals 7).

8. Antifragile and Enterprise Engineering both address knowledgeable management (EE fundamentals 7). Taleb denounces management, by stating that 'naive interventions' should be prevented. Taleb states that management usually is not knowledgeable and therefore does more bad then good (Taleb, 2012).
   See section 2.4.3 (Remove naive intervention to learn).

9. Antifragile and Enterprise Engineering both believe that increasing the variety of the humans in the organisation is the best way to deal with the VUCA world (EE fundamentals 7) (Hoogervorst, 2015; Taleb, 2012).
   See section 2.7 (Requisite Variety) and section 2.10.2 (Variety and the Cynefin framework).

2.12 Enterprise Architecture

Enterprise Architecture is the discipline that aims to provide insight in the relationship between the parts of an organisation and managing the sense-making of the change in the organisation. There are various descriptions of Enterprise Architecture. These are the three main descriptions of Enterprise Architecture:

> "The fundamental organisation of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution. " - IEEE 1471:2000 (IEEE, 2000), ISO/ICE/IEEE 42010:2011 (ISO/IEC/IEEE, 2011)

> "Architecture has two meanings depending upon its contextual usage: (1) A formal description of a system, or a detailed plan of the system at component level to guide its implementation. (2) The structure of components, their interrelationships, and the principles and guidelines governing their design and evolution over time." - (Haren, 2011, TOGAF 9.1)

> "A concise set of principles and models that provide guidance to the design and realisation of processes organisational change information and technical infrastructure." - DYA (van den Berg et al., 2005)

2.12.1 Enterprise Architecture and antifragility

These three descriptions describe a set of models (etc) that provide value to the organisation. These three views on Enterprise Architecture are not yet embracing the field of Systems Theory. Where antifragility and Enterprise Engineering are embracing the field of Systems Theory. Nurmi et al. (2019) provides a study on the use of Systems Theory in the field of Enterprise Architecture and provides an alternative description of Enterprise Architecture (EA) by Lapalme (2012) that would fit the domain of Systems theory better in my opinion.

> "EA should be understood as being constituted of the essential elements of a socio-technical organisation, their relationships to each other and to their changing environment as well as the principles of the organisation's design and evolution. Enterprise architecture management is the continuous practice of describing and updating the EA in order to understand complexity and manage change."
> - (Nurmi et al., 2019; Lapalme, 2012),
> based upon ISO/ICE/IEEE 42010:2011 (ISO/IEC/IEEE, 2011)

3 Methodology

Introduction

The goal of this chapter is to provide an overview of the reasoning behind the selection of the research method, insight in the selected research method and the implementation of the selected research method. At the end of this chapter I give a detailed overview of my research infrastructure that I applied from the moment I started at the Antwerp Management School in September 2018.

The content of this chapter is the following:

3.1 The replication challenge

The following section describes the replication challenge. This topic is relevant for the topics of antifragility and risk management. It also is relevant for the scope of my research questions and the methodology applies.

3.1.1 Antifragile and scientific models created by observations

In the scientific world there is a discussion that overlaps with the point of view of Taleb that he describes in his books Black Swan (Taleb, 2007) and Antifragile (Taleb, 2012). In this section an introduction into this field, that can be summarised to the statement that models cannot be used to predict and replicate outcome.

3.1.2 Taleb and Enterprise Engineering

Taleb states that every model created by humans based on observations is faulty on a fundamental level (Taleb, 2001, 2007, 2012). This is a premise that is also fundamental to the field of Enterprise Engineering (Dietz et al., 2013; Dietz, 2017). The reasoning of Enterprise Engineering. Enterprise Engineering reasons that observation is always subjective and therefore representing a single instance of a personal view on reality (Hoogervorst, 2017). Enterprise Engineering and the reasoning of Taleb are complementary to each other.

3.1.3 Rethinking Economics

In the scientific economical world, there is the movement called "*Rethinking Economics*". This movement started in 1991 (Hodgson and Screpanti, 1991; Helbing and Kirman, 2013) This movement states that all economical models that are being used are based on measurements (quantitative science) and models based on these measurements and that this method is flawed. The economic models are flawed because this approach lacks the involvement of the human factor and the notion that not everything is rational and can be explained by reductionism. The economic crisis of 2008 is one of the big arguments of this movement to include qualitative (empirical) research into the field.

3.1.4 Replication Crisis

In the field of psychology there is the movement called "*the replication crisis*" (Hakhverdian, 2018; McRaney, 2017; Engber, 2016). Models in the more social sciences are based on qualitative (empirical) studies. In this area of science, the human factor is crucial in explaining why things happen. Scientists tried to reproduce one of the pinnacle studies in the field of psychology called the Ego experiment. Initial the replication of this study did not success and when over 60 different group of researchers failed in replicating this research the "replication crisis" became relevant for the whole field of social studies (Hagger et al., 2016). This replication crisis is older and more generic then only the ego depletion study (Ioannidis, 2005). The centre for open science facilitated a project with 270 scientists that sought to replicate 100 different studies published in 2008. In the end two-thirds failed to replicate (Holcombe, 2016; Open Science Collaboration et al., 2015).

3.1.5 Black swans and scientific models

Taleb argues in Black Swan (2007) that quantitative research only states about the data in the data-set that is collected and states nothing about the reality. Taleb also argues in Antifragile (2012) that qualitative research is very tricky since it states something on the current context and the current context is non-stop changing and not comparable to the context of a different situation.

It is apparent that Taleb is of the same thought-school as Karl Popper[1] (Open Science Collaboration et al., 2015; Veronesi, 2014).

[1] `https://plato.stanford.edu/entries/popper` (Thornton, 2019)

> "He (Karl Popper) saw falsifiability as the logical part and the cornerstone of his scientific epistemology, which sets the limits of scientific inquiry. He proposed that statements and theories that are not falsifiable are unscientific. Declaring an unfalsifiable theory to be scientific would then be pseudoscience. "
> - (Wikipedia contributors - B, 2019b)

The underpinning issue of the 'replication crisis' and 'rethinking economics' is that observations are based on the relation between the human and the artefact or other humans. In addition, the scientific models are based on observations done by humans. This issue is also fundamental in the origin of Enterprise Engineering (Dietz et al., 2013) and part of the books written by J. Hoogervorst (Hoogervorst, 2015; Hoogervorst, 2017). It is the human factor that makes replication of the effect described or prescribed in a model or method in reality practically impossible.

> "The problems experienced today are caused by 'solutions' of the past. This has to do with the dominant and incorrect idea that there is a linear–direct–relation between cause and effect that are in close proximity of each other, in terms of time and space. "
> - (Senge, 1990; Janssen, 2015, p. 14).

3.1.6 Replicating antifragile research

The replication dilemma became also apparent when summarising the current Body of Knowledge on antifragile. I was in search of a model of an antifragile organisation to replicate. This model was not found by me.

I think that there are two reasons for this: firstly, the field is very young, this can be deducted from the fact that most papers discuss possible applications of antifragility.

Secondly, since the field is young there is not yet a clear shared mental model that enables the creation of models that does prescribe how to become antifragile. Therefore, the studies that interact with organisations are applying questionnaires with retrospective questions. This is a method that helps in determining terminology that is relevant in the research context. This is a good thing and enabled me to create a summary of all the work done by others.

3.1.7 Maturity of the field

Why do I call the current antifragile field "young"? Recker provides us with a checklist for scientific work, that can be used to determine the maturity of the field (Recker, 2012, p. 16) .

1. Replicability
2. Falsification
3. Independence
4. Precision

Recker: Replicability

None of the research consists of research that can be replicated in such a way that it results in an antifragile organisation. The studies that consists only out of reasoning, make use of elements from the field of Complexity Science and therefore the reasoning can always be challenged. The studies that applied interviews make use of a (small) set of companies (1 up to 5). Interviews are difficult to replicate since they are always limited to: (1) the person that asks the question, (2) the subject that is being interviewed and (3) the system or context of the subject. The studies do prove that it is possible to use language from the domain of resilience and antifragility and relate that to the language that the subject is using to describe the past in that specific context.

Recker: Replicability & Falsification

Antifragile is part of the Complex Adaptive Systems domain. This makes it difficult to replicate and falsify the research, since every situation is unique and complex. The only exception is the Chaos Engineering software that Netflix provided (Wikipedia contributors - A, 2019g). The concept of the simian army toolbox has been applied by various companies (Wikipedia contributors - A, 2019h). I did not find any (meta) study on the results (value creation) in the various companies that applied the chaos engineering concepts.

Recker: Precision

Every research makes use of a different list of antifragile attributes. See also section 4.1 (The selected antifragile literature) and appendix F (Appendix - Antifragility descriptions in the literature) This results in that the definition what the attributes of an antifragile system is far from consistent and precise.

3.1.8 Replication crisis and the relevance of this thesis

If replication in the context of organisation design is (almost) impossible, what is the relevance of this study? There are three options to contributed to science (Recker, 2012, p. 13-14).

1. **Theory** - How good are our explanations.
   "We can improve our explanation of a particular phenomenon."
2. **Evidence** - How good are our observations.
   "We can improve our collections of scientific evidence."
3. **Measurements** - How good are our measurements.
   "We can better our methods for collecting observations in relation to theory."

The next frog-leap in the theory domain can only be achieved when it is possible to find some evidence that there is a correlation between one (or more) of the antifragile attributes and the value of an organisation.

3.1.9 Limitations of this study

I did limit my research to the attributes of resilient and antifragile systems found in the literature. I did not include an in-depth research on why these attributes have the effect they have. I also did not include research on the construction of resilient or antifragile systems. The model that I created based on the available research is nothing more than a summary and a comprehensive model for a way-of-thinking.

3.1.10 Replication possibilities of this study

Steps to replicate this study

The steps in this research that created the model are easy to replicate. I think replication of my research is possible since:

1. The literature list can be reproduced and expanded.
2. The normalisation of the collected attributes into the set of attributes that are part of the model can be reproduced.
3. The clustering of the attributes based on the steps provided in the conceptual model are discretionary and therefore reproducible.
4. The interviews with the experts on the validation of the model are not complex or extensive therefore easy to replicate.
5. The interview with the leadership of organisations are not complex therefore easy to replicate.

3.2 A review of current methods

The research applied in my thesis is focused on Qualitative Naturalistic research (Chesebro and Borisoff, 2007). I choose to make use of Triangulation in my research setup (Hussein, 2009; Jick, 1979), which is a Post-positivist methodological (Denzin and Lincoln, 2017).

3.2.1 Observation, Induction, and Deduction

Recker (2012) states that there are three elements important to be present inside of research design:

1. 'Exploration – where we build an understanding of the phenomena that interests us.'
2. 'Rationalisation – where we begin to make sense of the puzzle or problem that interests us.'
3. 'Validation – where we appropriately subject our emergent or developed theory to rigorous examination.'

Recker (2012) also states that there are three themes always present in all types of research design. See also figure 3.1.

1. 'Observation concerns the discovery of things encountered in common experience. It promotes the desire to understand these observable things by discovering some systematic order in them. '
2. 'Induction is reasoning that involves moving from a set of specific facts to a general conclusion or from specific observations to broader generalisations and theories.'
3. 'Deduction is reasoning that involves deriving arguments as logical consequences of a set of more general premises. Deduction is commonly used to predict the results of the hypotheses or propositions.'

The research I carried out employed a combination of observation, induction and deduction, in a meaningful mix of exploration, rationalisation and validation.

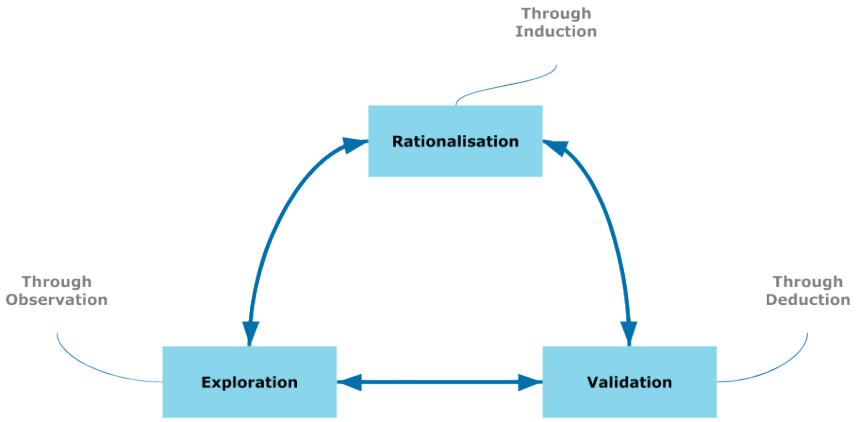

FIGURE 3.1: Exploration, rationalisation and validation in research design Recker (2012).

3.2.2 Research Design Decisions

I aimed for this research to be more exploratory then explanatory, more a field study then a laboratory setting, with an outcome that is more descriptive then causal with the ambition to create more understanding then designing (Recker, 2012; Emory and Cooper, 1991).

3.2.3 Qualitative research

The research goal I am aiming for is to create a model that defines the system attributes of an antifragile system and that of resilient systems. I created this model because replication and experimentation on an antifragile organisation was not possible since there is no clear (baseline) definition, on what antifragility is, was available to validate a replication against.

And because the mechanics (causality) between the attributes of a system and the behaviour of that same system is not known to me, I need to use qualitative research to validate the model.

3.2.4 Naturalistic research

Naturalistic research is described as: 'the researcher seeks to make the research experience as much a part of the subjects' everyday environment as possible' (Chesebro and Borisoff, 2007) and as 'research method to be set in a natural setting in an attempt to explain or interpret a certain phenomenon.' (Henriksson et al., 2016; Alvesson and Sköldberg, 2009).

Since the topic of risk management, complexity theory and complex adaptive systems is mostly unknown to the various experts and c-level managers, the naturalistic research is the most logical research method for the validation of the EAAL model.

3.2.5 Qualitative Naturalistic research

Qualitative Naturalistic is also in line with the Sigma theory of Hoogervorst (2015), since he states that organisations should provide freedom to employees to increase the internal variety to compensate for the external variety. This is important for the relevance of this research for the discipline of Enterprise Engineering.

3.2.6 Triangulation

Triangulation is defined as the use of multiple methods mainly qualitative and quantitative methods in studying the same phenomenon (Hussein, 2009; Jick, 1979).

Campbell and Fiske (1959) where the first to introduce Triangulation (Drisko, 2011).

Triangulation has the following sub-types: (1) Data, (2) Investigator, (3) Theory, (4) Methodological, (5) Environmental and (6) Multiple method triangulation. These sub-types are defined by Denzin (1970, 2017), Webb et al. (1966), Guion et al. (2011) and Kimchi et al. (1991) (Hussein, 2009).

When applying triangulation and qualitative naturalistic research it is key to recognise the following Validation types: (1) Internal, (2) External, (3) Content, (4) Construct, (5) Ecological, (6) Cultural, (7) Catalytic, (8) Criterion-related. This subset of validation types is provided by dr Ayaz (Afsar, 2015). This list of validation types is arbitrary. Prof Paul E. Newton, provided a lecture on the February conference at the University of Oxford, Department of Education titled 'Does it matter what 'validity' means?' containing a very elaborate overview of the various forms and function of validation types. His closing remark was: 'Validity is dead. Long live evaluation.' (Newton, 2013).

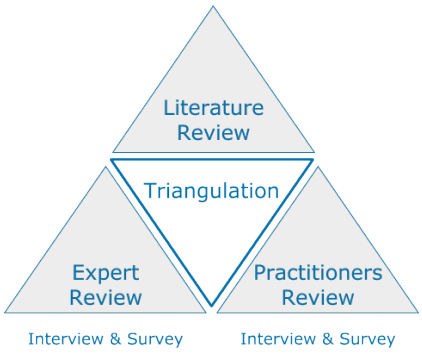

FIGURE 3.2: Triangulation research method Alassafi et al. (2017).

3.2.7 Positivism and Naturlism

Positivism is dedicated to empirical (qualitative) research. Positivism is also called Logical Positivism. Naturlism is also called natural philosophy and is dedicated to qualitative research (Andersen and Hepburn, 2015). See also section 3.1 on replication which is a theme that plays a role in the discussion between the Logical Positivism and natural philosophy resulting in the Post-positivist era.

3.2.8 Post-positivist methodological

Ryan (2006) states that post-positivist research is being characterised by:

1. 'Research is broad rather than specialised' ;
2. 'Theory and practice cannot be kept separate' ;
3. 'The researcher's motivations for and commitment to research are central and crucial to the enterprise' ;
4. 'The idea that research is concerned only with correct techniques for collecting and categorising information is now inadequate '.

3.2.9 Triangulation and Applied Science

Denzin and Lincoln (2017) states that triangulation is a post-positivist methodological strategy. The description provided by Ryan (2006) fits the aim of the Antwerp Management School as an Applied Science university. The goal of the Antwerp Management school is to have impact at the organisation the students of the executive program are employed. Therefore, the research method of triangulation fits the research subject and the context for which the research is executed.

3.3 Applied research method for this thesis

3.3.1 Triangulation applied - validation and relevance

I created the following conceptual research model (see figure 3.3) by applying Triangulation to the research topic.

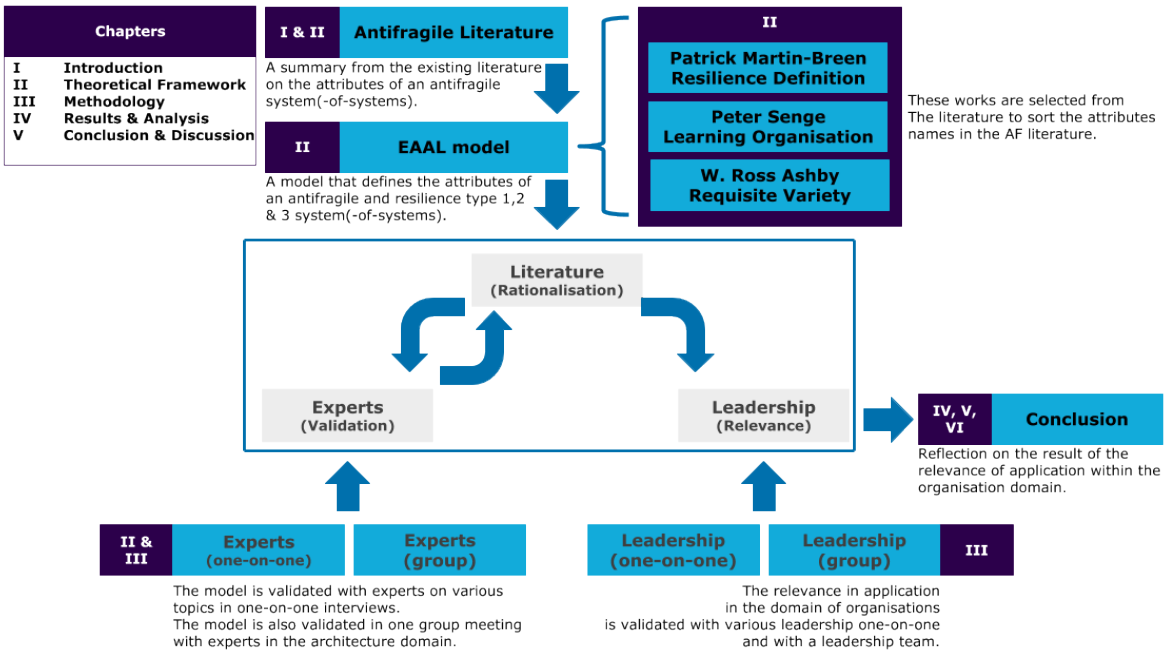

FIGURE 3.3: Conceptual Research Model.

3.3.2 Literature Review

The literature review (section 3.4) is translated into the behaviour model (figure 4.4) and the EAAL model (figure 4.5) by combining three main theories from the literature into the decision tree (figure 4.3) and applying this decision tree to the collected system attributes (figures 4.1 & 4.2).

The EAAL model, that is created by me, is a summary of the available literature on the topic of antifragile systems.

3.3.3 Expert Review

For the Expert Review I decided to apply a mix on topic of expertise of the experts. I also applied a variety of methods to interact with the expert (group and one-on-one). I choose to do this, so that I have validations within the validation step itself. This resulted in the validation of the model being validated inside the same approach.

3.4 Literature review

3.4.1 Literature review approach

For the creation of an overview of the current Body of Knowledge, that is relevant to Antifragility, I used the divergent and convergent process (see figure 3.4). To diverge is in this context to move in different directions from a common point creating choices by including more and more in the collection (Merriam Webster, 2020d). To converge is in this context to move towards one another by making choices that determine if something is in scope or out of scope (Merriam Webster, 2020b). Both my divergent and convergent processes were iterative. Iterations where triggered by the 'understanding relationships' step (figure 2.1).

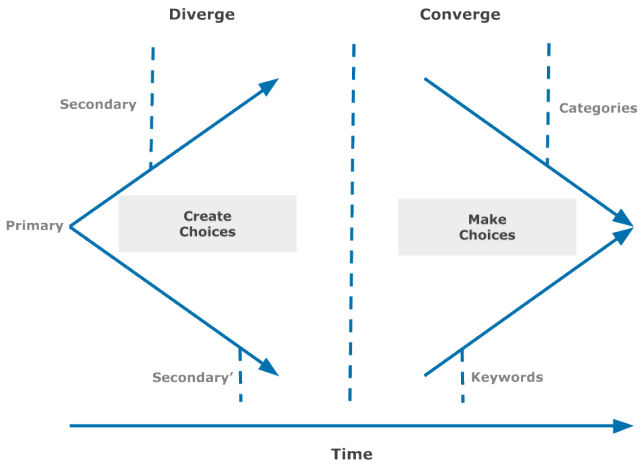

FIGURE 3.4: Diverge and Converge process.

My approach is inspired by the snowball[2] method (Wohlin, 2014; Groningen, 2020) as part of a systematic[3] literature review (Wikipedia contributors - D, 2020t). I retrieved relevant literature from three groups of sources: 'primary sources' for literature from the source material, 'secondary sources' for literature from academic search engines and an 'extension on the secondary sources' for literature from book, thesis and dissertation search engines. See section 3.4.2.

Size of the snowball

The primary sources are the start of the divergence step in my literature research. This resulted in:

- 358 sources cited in this thesis (Bibliography).
- 87 sources categorised (Appendix D).
- 9 sources selected as source for the attributes of the EAAL model (section 4.1.3).

[2] https://libguides.rug.nl/c.php?g=470628&p=3218096
[3] https://en.wikipedia.org/wiki/Systematic_review

3.4.2 Creating the overview of the Body of Knowledge

Primary sources

As 'primary sources' for the literature I used references from the book Antifragile (Taleb, 2012), and the references from the Wikipedia pages on Antifragile (Wikipedia contributors - A, 2019b) and Antifragility (Wikipedia contributors - A, 2019c).

Secondary sources

In addition to the literature found in the 'primary sources' I added literature found via various academic search engines: I used (1) Google Scholar[4], (2) Bing Academic[5], (3) Semantic Scholar[6], (4) ReseachGate[7], (5) Citationsy[8] and the (6) Library of Antwerp Management School[9].

Extension on the secondary sources

I used the following search engines for finding books: (1) Amazon.de[10], (2) Goodreads[11] and (3) Google Books[12]. Via this way I found the thesis of Dennis Kastner (Kastner, 2017).

The thesis of Kastner (2017) and Henriksson et al. (2016) inspired me to search in public thesis databases: (4) Diva[13] (Sweden), (5) Scripties Online[14] (the Netherlands), (6) Narcis[15] (the Netherlands), (7) OpenThesis.org[16] (USA), (8) OATD[17] (Global) and (9) Sci-Hub[18] (Global) .

Search keywords

I used the following keywords during my initial searches:
'antifragile'; 'anti-fragile';
'antifragility'; 'anti-fragility';
'Taleb'; 'Nassim Taleb';
'antifragile organisations'; 'antifragile organizations';
'anti-fragile organisations'; 'anti-fragile organizations'.
After using these keywords my research queries became more organic and iterative based on the literature found in the reference lists of the found literature.

Body of Knowledge is made openly available

An overview of the current (2019) Body of Knowledge on the topic of antifragile is presented in Appendix D (Appendix - Antifragility Papers) and also available via the wiki[19] of this public research project on Gitlab.

Reference of this thesis is made openly available

The reference list of this thesis is a sub-set of the collected Body of Knowledge.

[4] https://scholar.google.com
[5] https://www.bing.com/academic
[6] https://www.semanticscholar.org
[7] https://www.researchgate.net
[8] https://citationsy.com
[9] https://vpn1.uantwerpen.be/+CSCOE+/logon.html
[10] https://www.amazon.de/
[11] https://www.goodreads.com/
[12] https://books.google.com/
[13] http://www.diva-portal.org/
[14] http://scripties.ned.ub.rug.nl/
[15] https://www.narcis.nl/
[16] http://www.openthesis.org/
[17] https://oatd.org/
[18] https://sci-hub.tw/
[19] https://gitlab.com/edzob/antifragile-research/wikis/Antifragility-Literature-Research

The reference list created during this research is available via the BiBTeX[20] files of this research project.

[20] https://gitlab.com/edzob/antifragile-research/-/tree/master/AntifragileThesis

3.4.3 Keywords relevant to antifragile

Part of the convergence process is understanding the relationship between the theories. I created a list of the identified relevant scientific keywords. These keywords can be used by everyone that is researching antifragility or for who that is aiming to replicate my research.

Keywords - Systems and Complexity Theories

Complexity Science[21], Emergence[22], Self-organisation[23], Collective behaviour[24], Network Science[25], Evolution[26] and adaptation[27], Game Theory[28], non-Linear Dynamic Systems[29], Systems Theory[30], Systems Engineering[31], Systems of Systems[32], Complex Adaptive Systems (CAS)[33], Complexity Management[34], Chaos Engineering[35], Entropy[36], Distributed Systems[37], Site Reliability Engineering[38]

Keywords - Organisation Design

Risk Management[39], Barbell Strategy[40], Requisite Variety[41], Emergence[42], Holacracy[43], Taylorism (Scientific Management)[44], Enterprise Engineering[45], Enterprise Architecture[46], Enterprise Design[47], Enterprise Governance[48], Employee Empowerment[49], Autonomy[50], Resilience[51], Decoupling[52], Knowledge Management[53]

[21] https://en.wikipedia.org/wiki/Complex_system
[22] https://en.wikipedia.org/wiki/Emergentism
[23] https://en.wikipedia.org/wiki/Self-organisation
[24] https://en.wikipedia.org/wiki/Collective_behavior
[25] https://en.wikipedia.org/wiki/Network_science
[26] https://en.wikipedia.org/wiki/Evolution
[27] https://en.wikipedia.org/wiki/Adaptation
[28] https://en.wikipedia.org/wiki/Game_theory
[29] https://en.wikipedia.org/wiki/Dynamical_system
[30] https://en.wikipedia.org/wiki/Systems_theory
[31] https://en.wikipedia.org/wiki/Systems_engineering
[32] https://en.wikipedia.org/wiki/System_of_systems
[33] https://en.wikipedia.org/wiki/Complex_adaptive_system
[34] https://en.wikipedia.org/wiki/Complexity_management
[35] https://en.wikipedia.org/wiki/Chaos_engineering
[36] https://en.wikipedia.org/wiki/Entropy
[37] https://en.wikipedia.org/wiki/Distributed_computing
[38] https://en.wikipedia.org/wiki/Site_Reliability_Engineering
[39] https://en.wikipedia.org/wiki/ISO_31000
[40] https://en.wikipedia.org/wiki/Barbell_strategy
[41] https://en.wikipedia.org/wiki/Variety_(cybernetics)
[42] https://en.wikipedia.org/wiki/Emergence
[43] https://en.wikipedia.org/wiki/Holacracy
[44] https://en.wikipedia.org/wiki/Scientific_management
[45] https://en.wikipedia.org/wiki/Enterprise_engineering
[46] https://en.wikipedia.org/wiki/Enterprise_architecture
[47] https://en.wikipedia.org/wiki/Organizational_architecture
[48] https://en.wikipedia.org/wiki/Corporate_governance
[49] https://en.wikipedia.org/wiki/Empowerment
[50] https://en.wikipedia.org/wiki/Autonomy
[51] https://en.wikipedia.org/wiki/Business_continuity_planning
[52] https://en.wikipedia.org/wiki/Decoupling_(organisational_studies)
[53] https://en.wikipedia.org/wiki/Knowledge_management

3.4.4 Categories to organise the Body of Knowledge

Based on the relationships I recognised in the collected literature, I determined the following six categories to label and sort the found literature: (1) 'Antifragile'; (2) 'Antifragile & IT'; (3) 'Organisation'; (4) 'Risk and Resilience'; (5) 'Complexity Science'; (6) 'Science'.

For 'Organisation' I recognised papers that focus on organisations, how they respond to stress and the role of the human factor.

For 'Risk and Resilience' I recognised papers that, focus on risk, robust, fragile, resilience, emergence, entropy, chaos, unpredictability and/or stress.

For 'Science' I recognised papers that, focus on science and how it is limited by observation. I based my approach of categorisation on Wolcott (1990). See Appendix D (Appendix - Antifragility Papers) for the sorted list of the papers found.

3.5 Expert Review - individuals

First the validation is done by one-on-one iterative interviews with various experts. I made certain that these experts know each other so that cross-validation can take place. The expertise topic of the experts are at least one of the following list: Antifragility, Enterprise Architecture, Enterprise Engineering, Organisation design, Organisation Change.

The group of experts are from the Netherlands, Belgium, Germany and Sweden. Some have no connection with me (for example people that have written thesis and academic articles on antifragility), some have a connection with the Antwerp management school (for example professors, former students and guest lecturers) and some have a connection with me via my employer Sogeti as co-workers.

The question asked to them was "Does it make sense what I am telling you?", "Do you see any big mistakes, blind spots or contrary statements?".

The two points of feedback on the EAAL model was first that the learning organisation is relevant for all the resilience types and secondly that it seems as a cumulative model and therefore can possibly be used as a growth model. The first remark resulted in the second and final iteration of the EAAL model. The second remark I placed out of scope since I do not claim that there is a causal link between the attributes and the type of behaviour, and I also do not claim the list to be complete.

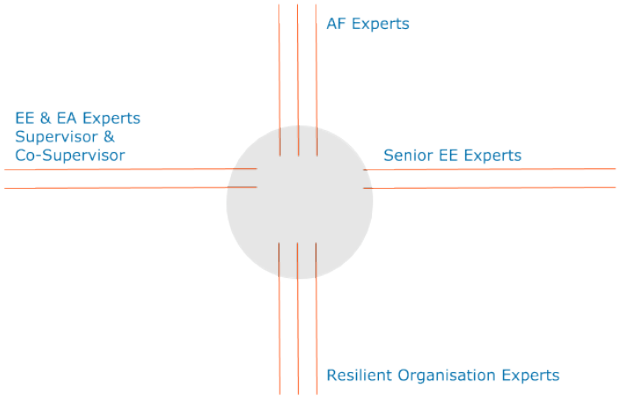

FIGURE 3.5: Validation by individual experts the circle is the work presented.

3.5.1 Expert Review - groups

Secondly, I organised the validation by the groups. See figure 3.6. This validation was done in three steps. First the validation by my two supervisors, and after that the validation by the Sogeti Architecture leadership. One supervisor was part of this second group and therefore could validate the outcome of this group-validation. After this there was a group validation with 10 Enterprise Architect, Solution Architect and Business Analysts from the Sogeti Architecture Community. Of this group of 10 experts two persons of the architecture leadership team where present to validate this validation step.

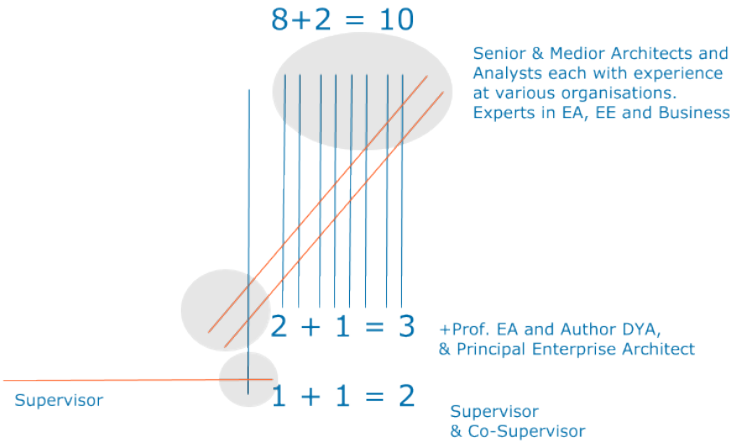

FIGURE 3.6: Validation and Relevance by group of experts, the circle is the work presented.

3.5.2 Practitioners Review

For the practitioners review I mainly focused on C-level leadership from organisations. I used the method of unstructured interview with the maximal duration of one hour.

The companies interviewed where.

1. A large aviation company
   FTE 70.000 - 90.000, revenue 20-40 1000xM EUR
2. A smaller aviation company
   FTE 1.000 - 5.000, revenue 1-2 1000xM EUR
3. A smaller governmental organisation
   FTE 10-200
4. A smaller good-cause / non-profit organisation
   FTE 10-200
5. A private university
   FTE 200-400, 2000-5000 students
6. A public university
   FTE 1.000 - 5.000, 10.000 - 25.000 students
7. A scale-up company in retail with recent funding in a round-c funding.

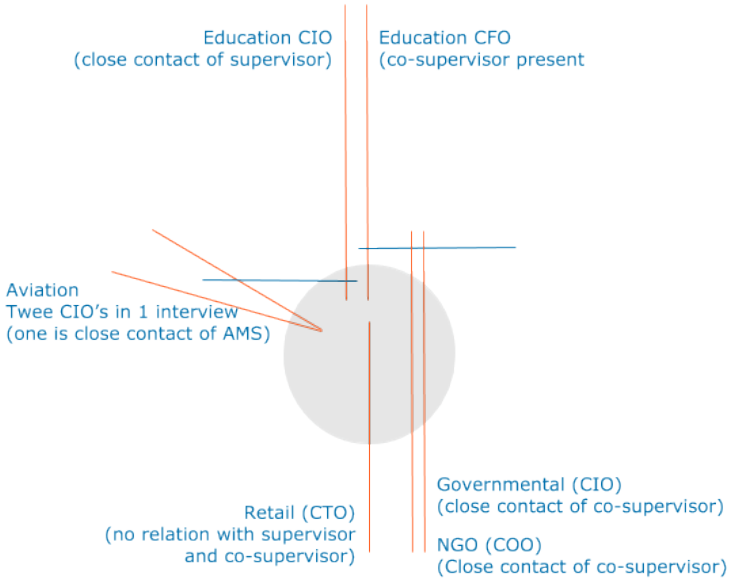

FIGURE 3.7: Relevance by Practitioners.

3.6 Applied research tooling and infrastructure

From the start of the masters program I setup my research infrastructure. It was clear from the beginning that open source and open access is my way to go. The goal of my setup is that everybody can clone a repository, and can replicate or elaborate on the work that I have done. Therefore, from the beginning I put all my work under Creative Commons[54] BY-SA 4.0[55]. It is free for all to copy and change the content and use it for commercial purposes, with the condition that they include a reference to the source material. This way I am free from all ties and alternative motives.

I choose to use LaTeX[56] to write my thesis in. LaTeX is based upon TeX and is a text based document preparation system and allows me to use various (plain)text editors of various platforms and devices for writing my thesis. This enables me to de-couple the content from the layout. Another benefit of using a pure text-based approach is that I can use Git[57] for versioning, and synchronise all the decentralised working copies with one central repository[58] on Gitlab[59].

Furthermore supports Gitlab a wiki for research documentation and a kanban board for workflow management. Gitlab is a service that will not quickly go offline since various global organisations make use of it.

By applying BibTeX[60] as my literature library I can quickly share all information on the literature I have collected. See for example my BibTeX file[61] containing just the papers. I made it a personal quest to add public links to all the literature used, so that when someone wants to look up a quote or wants to check a reference, this can be done without any roadblocks.

For writing text, I used the following plain text editors: online code editor AWS Cloud9[62], Sublime Text v3[63] on Windows and Linux and the editor Caret[64] on Chrome OS. Later in the process I started using Overleaf[65] since this enabled online collaboration including the document generation (compiling) of the thesis. Overleaf was advised to me[66] by a professor at the University of Groningen.

Overleaf is a commercial LaTeX tool, which is very nice to use. I checked and the LaTeX files are also functional when compiled on a separate machine. There is no lock-in with Overleaf for people that want to use my work.

By applying this research infrastructure, I have backups (working copies) of my thesis at the Overleaf server, Gitlab server, and the three laptops I work from. A backup of the collected papers is also on these locations, since they are part of the Git repository, and on my Google Drive.

See table 3.1 for the research infrastructure used.

[54] https://en.wikipedia.org/wiki/Creative_Commons_license (Wikipedia contributors - C, 2020e)
[55] https://creativecommons.org/licenses/by-sa/4.0/
[56] https://en.wikipedia.org/wiki/LaTeX (Wikipedia contributors - C, 2020o)
[57] https://en.wikipedia.org/wiki/Git (Wikipedia contributors - C, 2020h)
[58] https://en.wikipedia.org/wiki/Repository_(version_control) (Wikipedia contributors - C, 2020w)
[59] https://en.wikipedia.org/wiki/GitLab (Wikipedia contributors - C, 2020i)
[60] https://en.wikipedia.org/wiki/BibTeX (Wikipedia contributors - A, 2019d)
[61] https://gitlab.com/edzob/antifragile-research/-/blob/master/AntifragileThesis/bib-antifragile-papers.bib
[62] https://aws.amazon.com/cloud9/
[63] https://www.sublimetext.com/3
[64] http://thomaswilburn.net/caret/
[65] https://www.overleaf.com/about
[66] https://twitter.com/edzob/status/1110283982476922881

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Wiki versioning service	Gitlab
Wiki versioning web	Gitlab
Wiki versioning Windows/Linux	Git
Research Data Related	
Editor Web	AWS Cloud9, Overleaf
Editor Windows/Linux	Sublime Text 3
Versioning service	Gitlab
Versioning web	Gitlab
Versioning Windows/Linux	Git

TABLE 3.1: Research Infrastructure

4 Conceptual model

Introduction

The Theoretical background from chapter 2 combined with the Methodology from chapter 3 make it possible to create a Conceptual model.

This chapter starts with the selected literature in section 4.1. In section 4.2 design statements are provided, that provide constraints to the design of the binary decision tree in section 4.3. I applied the decision tree in sorting the attributes of a system described in the selected literature.

I then summarised the sorted list of the attributes from the literature. The result of this action is presented in section 4.4 (The attributes of a resilient and antifragile System-of-Systems). The Conceptual model in section 4.5 is the visualisation of the summary combined with the design statements of section 4.2.

The content of this chapter is the following:

4.1 The selected antifragile literature

4.1.1 Steps that lead to the literature selection

In section 3.4 (Literature review) I described how I collected, labelled and selected the papers and books that I added to the Body of Knowledge. Every step in this process is an arbitrary step, therefore I tried to document all the steps, so that everyone is able to replicate, validate and improve every step. I am convinced this is better for replication and for adjustment then providing one black box step with as input all papers collected and as output the created summary. The steps have been documented in the following Appendices:

1. I have written down the papers sorted into categories, in Appendix D (Appendix - Antifragility Papers);
2. I added a short summary to the papers that address antifragility, in Appendix E (Appendix - Antifragile literature Summary);
3. I provide the selection of papers that provide a list of attributes of an antifragile system, in Appendix E (Appendix - Antifragile literature Summary) and section E.2 (Field of Antifragile - Body of Knowledge on Antifragile properties).

4.1.2 Literature selection

I selected the following papers, master theses and books to provide the set of antifragile attributes that I intend to summarise in the model:

1. System Criteria to analyse antifragility *from*
   'Evaluating organisational antifragility via fuzzy logic. The case of an Iranian company producing banknotes and security paper'
   (Ghasemi and Alizadeh, 2017, p. 25).
2. Assessing Antifragility in Complex Adaptive Systems *from*
   'Antifragility analysis and measurement framework for systems of systems'
   (Johnson and Gheorghe, 2013, p. 163).
3. Antifragile System Assessment Criteria *from*
   'An alternative view to assessing antifragility in an organisation: A case study in a manufacturing SME'
   (Kennon et al., 2015, p. 179).
4. Antifragile attributes *from*
   'Antifragile'
   (Taleb, 2012).
5. Antifragile organisation design *from*
   'Antifragile Organisation Design: A framework of Self-Organisation practices in today's complex and unpredictable economy'
   (Kastner, 2017).
6. Antifragile organisation aspects *from*
   'To Master Disaster: How SME managers can thrive and benefit from economic crises'
   (Henriksson et al., 2016, p. 18-30).
7. AntiFragile Information Systems: Some Guidelines *from*
   'Antifragile Information Systems'
   (Gorgeon, 2015, p. 6-11).
8. Anti-fragile principles for a complex adaptive ICT system *from*
   'Anti-fragile ICT Systems'
   (Hole, 2016, p. 35-57).

9. Properties of systems demonstrating high levels of antifragility *from* 'No More Snake Oil: Architecting Agility through Antifragility' (O'Reilly, 2019, p. 886).

10. The hero archetype *from* 'Antifragility, the Black Swan and psychology' (Markey-Towler, 2018, p. 5).

4.1.3 Antifragile attributes from the literature selection

The attributes that I collected from the selected literature are to be found in figures 4.1, 4.2 and in Appendix F, (Appendix - Antifragility descriptions in the literature).

System	System	System
Ghasemi 2017	Kennon 2015	Johnson 2013
Absorption	Emergence	Entropy
Redundancy	Efficiency vs Risk	Emergence
Introduction of low level stress eliminating stress	Requisite Variety	Efficiency vs Risk
Non-Monotonicity	Stress Starvation	Balancing Constraints vs Freedom
Requisite Variety	Redundancy	Couping (Loose/Tight)
Emergence	Absorption	Requisite Variety
Uncoupling	Induced small stressors	Stress Starvation
	Non-monotonicity	Redundancy
		Non-Monotonicity
		Absorption

FIGURE 4.1: The antifragile attributes (one-of-two) selected as input for the creation of the model (Appendix F).

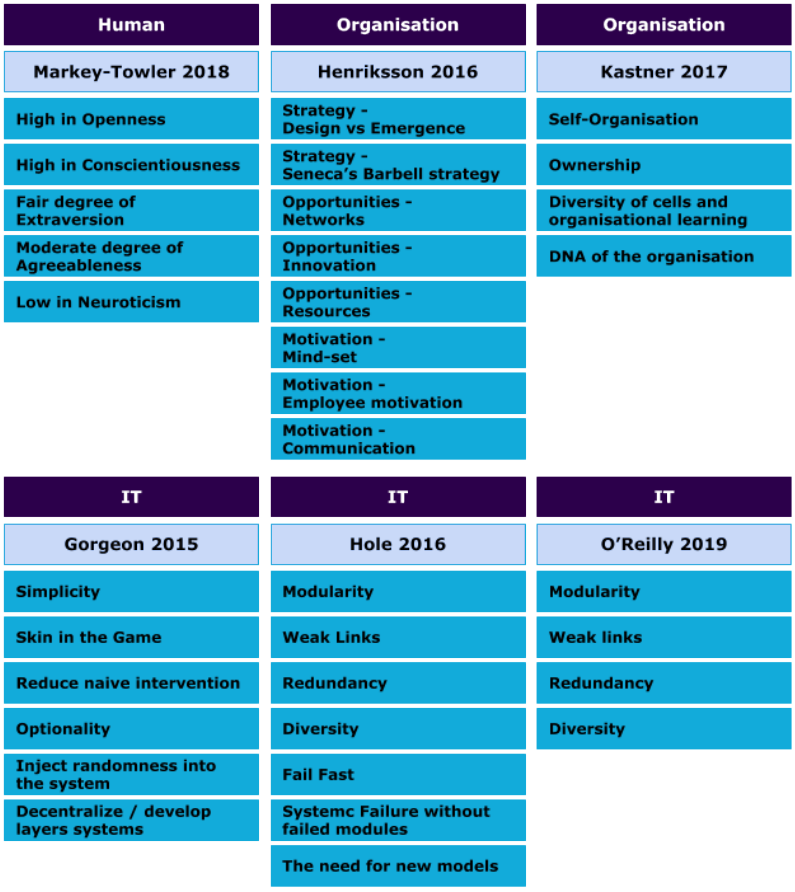

FIGURE 4.2: The antifragile attributes (two-of-two) selected as input for the creation of the model (Appendix F).

4.1.4 Diversity in papers in the Body of Knowledge

Since the field of antifragility is new and not yet into consolidation or convergence, there are many papers not specifically on antifragility added by me to the Body of Knowledge. It is interesting to note that papers and books on antifragility have in common that they reference Taleb, and that there is limited overlap in referencing other existing papers and books. The literature set created and used in this research is not complete. This set of literature is not complete because every paper (size M) is referencing a unique set of different papers (size N) making the size of the set of all literature referenced very big (size $M \times N$).

4.1.5 Diversity in research method in the Body of Knowledge

When I apply the Pareto[1] principle, 80% of the papers on antifragile are literature studies inspired by Taleb (2012) reasoning to apply an approach in the design activity in their field. 20% of the papers are applying qualitative research via retrospective interviews at a select (1-5) number of companies. See for this Appendix F (Appendix - Antifragility descriptions in the literature).

4.1.6 Existing research difficult to compare

The research that I selected as mainly applicable to the topic of antifragility can be found in Appendix C (Appendix - Antifragile literature Highlights). The selected literature on antifragility did not contain a large number of measurements and I did not see a possibility to replicate the findings. The work consists of a small amount of (retrospective) interviews combined with a large amount of related existing theoretical work. In my opinion, the reasoning in the highlighted work is strong. The selected literature on antifragility combines into a large Body of Knowledge to study. Every piece of work from the selected work is referencing a different (sub-)set of literature. In most of the work that I found, the terminology used in that work is not made explicit in meaning and function. These observations together make it difficult for me to compare and match the reasoning between the independent research papers and books.

4.1.7 Highlights from and summary of the Body of Knowledge

The Antifragile Body of Knowledge is young and the amount of papers is large and diverse. In Appendix C (Appendix - Antifragile literature Highlights) I have written down the work that I see as highlights of the literature in the field of antifragility. I have written summaries of a selection of the papers found and these summaries are available in Appendix E (Appendix - Antifragile literature Summary).

[1] `https://en.wikipedia.org/wiki/Pareto_principle` (Wikipedia contributors, 2020)

4.2 Design Statements applied in building the Conceptual model

Since there is no clear model on antifragility, it helps to combine the available criteria, properties and attributes in a conceptual model (Recker, 2012, Ch. 5). The aim of a conceptual model is to provide meaning to the various viewpoints on this topic. The provided meaning then can be used to provide insight in how to become antifragile, and which steps might add value to the organisation but might not be the steps that will create antifragility.

The following statements I used in the design of the conceptual model.

4.2.1 Statement 1 - The Triad

The triad of Taleb is the basis of the conceptual model: Fragile, Robust and Antifragile.
See section 1.5.1 (Definition of fragile, robust and antifragile).

4.2.2 Statement 2 - System-of-Systems

A system has various sub-systems and various dimensions. It is possible that several subsystems and dimensions have a different position in the triad.
See section 1.5.2 (Behaviour of fragile, robust and antifragile).

4.2.3 Statement 3 - Resilience is not a state

Resilience is the transition between robust and antifragile.
See section 1.6 (Introduction into Resilience).

4.2.4 Statement 4 - Three type of Resilience

There are three types of resilience: Engineering Resilience, Systems Resilience and Complex Adaptive (CAS) Resilience.
See section 1.6 (Introduction into Resilience).

4.2.5 Statement 5 - The Learning Organisation is always applicable

The attributes of a Learning Organisation are relevant for a System-of-Systems (SoS) irrespective of the classification of resilience or antifragility. When a system shows Engineering Resilient, Systems Resilient, CAS Resilient or Antifragile behaviour, the learning organisation attributes are always relevant.
See section 2.4 (Learning Organisation).

4.2.6 Statement 6 - Requisite Variety is applied by Attenuate and Amplify

Requisite Variety from the antifragile literature is applied to the conceptual model, and thus to the topics of a system showing Engineering Resilient, Systems Resilient, CAS Resilient or Antifragile behaviour as attributes that Attenuate or Amplify Variety.
See section 2.7 (Requisite Variety).

4.2.7 Statement 7 - Antifragility is defined by Taleb

Antifragility attributes are those that are defined by Taleb. All other attributes in the antifragile literature are assigned to one of the three types of resilience.

4.3 Conceptual model creation by a binary Decision Tree

4.3.1 Decision tree to sort the attributes

To sort all the available attributes described in the literature on antifragility, I created a decision tree to help in the sorting process. This tree consists out of four steps. In the next sections I describe the separate steps that together form the tree and in section 4.3.6 (The Decision tree) the tree is displayed.

4.3.2 Step 1 - Learning Organisation

See also section 2.4 (Learning Organisation) and 2.4.5 (How to achieve a Learning Organisation) on the learning organisation and the 5th discipline of Senge (1990). This step is in line with Statement 5 - The Learning Organisation is always applicable.

Attributes from the literature

The attributes that I found in the selected literature are: fail fast (Hole, 2016), reduce naive interventions, inject randomness into the system (Gorgeon, 2015), self-organisation (Kastner, 2017), emergence (Ghasemi and Alizadeh, 2017; Kennon et al., 2015; Johnson and Gheorghe, 2013), balancing constraints vs freedom (Johnson and Gheorghe, 2013; Kennon et al., 2015; Henriksson et al., 2016), diversity of cells and organisational learning (Kastner, 2017).

Attributes from the 5th Discipline

All the explicit and also the implicit attributes on the learning organisation from the antifragile literature I have normalised, translated and captured into the attributes described by Senge (1990) as the 5th discipline. These are:

1. Personal mastery,
2. Shared mental models,
3. Building shared vision,
4. Team learning,
5. Systems thinking.

Decision tree Step 1: is the attribute part of 5th discipline?

This is the first step in the decision tree. Can the attribute (explicit or implicit) found in the literature be translated to one of the five attributes of Senge? If so, then mark this and continue with the next attribute. If not, then continue with this attribute to the next step.

4.3.3 Step 2 - Requisite Variety

See also section 2.7 (Requisite Variety). This step is in line with Statement 6 - Requisite Variety is applied by Attenuate and Amplify.

Decision tree Step 2: Does it attenuate Variety?

This is the second step in the decision tree. In this step I determine if the attribute Attenuate (dampens) the Variety or if it Amplifies the Variety. For example, 'redundancy' absorbs the stressors and therefore attenuates the variety, where 'diversity' directly amplifies the variety.

4.3.4 Step 3a - Resilience that absorbs stressors

This is in line with statement Statement 4 - Three type of Resilience. I grouped Engineering Resilience and Systems Resilience together as types of resilience that absorb stressors, and therefore they are both in the Attenuate Variety lane of the decision tree.

Decision tree Step 3a: Does it resemble top-down C&C?

This is the third step in the decision tree. The discriminant between Engineering Resilience and Systems Resilience is that Engineering Resilience is focused on top-down Command and Control (C&C). That leaves all other attributes that Attenuate Variety are assigned to Systems Engineering.

4.3.5 Step 3b - Antifragile by Taleb

This is in line with statement Statement 7 - Antifragility is defined by Taleb. For the Amplify Variety lane there is Complex Adaptive System (CAS) Resilience and Antifragile (left).

Decision tree Step 3b: is it part of the definition of Antifragile by Taleb?

The discriminant between CAS Resilience and Antifragile is the definition by Taleb of what Antifragile is. Taleb states that the following are essential for an antifragile system:

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

I excluded optionality from this list since the overlap with diversity. See section 4.4.3 (Diversity).

4.3.6 The Decision tree

The result of the combination of the steps into a visual model of a binary decision tree is seen in figure 4.3.

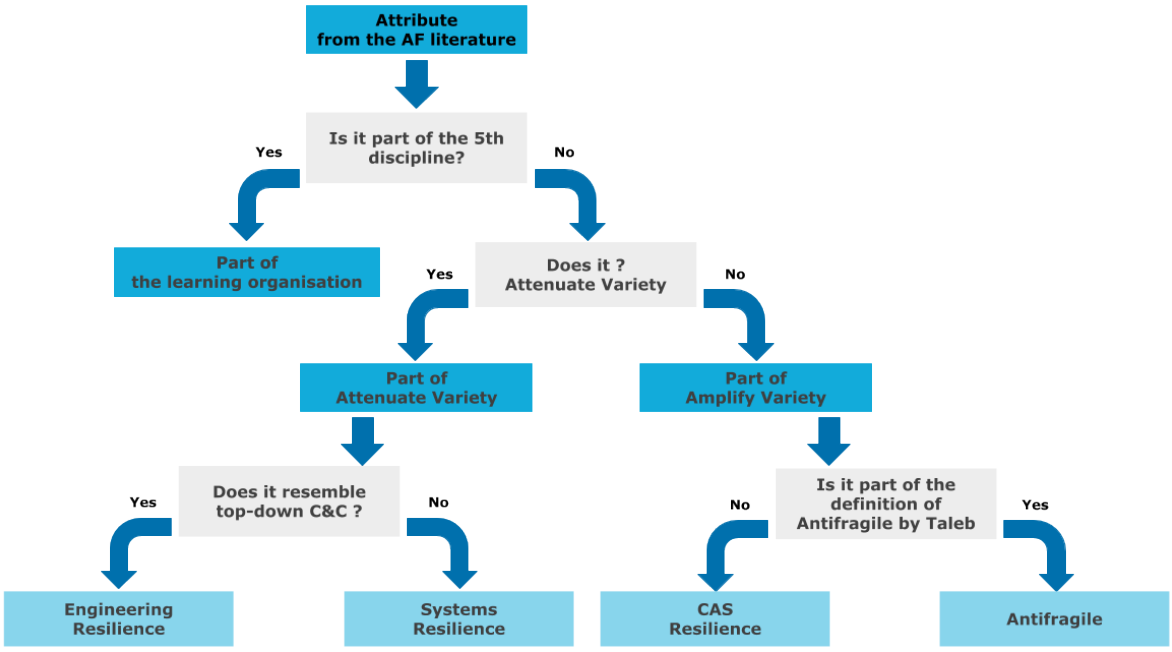

FIGURE 4.3: Decision tree to order the attributes.

4.4 The attributes of a resilient and antifragile System-of-Systems

4.4.1 Engineering Resilience attributes

In the papers the attribute that I grouped into Engineering Resilience is 'balancing constraints vs freedom' (Johnson and Gheorghe, 2013; Kennon et al., 2015; Henriksson et al., 2016). The selected literature addressed the attributes "Top-down Command & Control" and "Micro-Management".

Top-down C&C

Top-Down command and control in an organisation is that a employee is not free to decide to go left or right but has to follow orders. The careful design of an iPhone or a good pen is also an example of limited freedom of movement in the product itself.

Micro-Management

Micro-management is about the freedom in the use of the product. When there are detailed working instructions available in a business process, the employee has no freedom in the execution of the job. Another great example is a Lego building block. It is engineered and fabricated into the greatest detail creating a building block that is almost completely robust. Lego has a very small resilience behaviour through engineering.

4.4.2 Systems Resilience attributes

Redundancy

Redundancy is about having not a single point of failure by making use of duplication. An example is a backup electricity generator. Another example is local government as backup system of the central government.

Redundancy is the duplication of critical components or functions of a system with the intention of increasing reliability of the system, usually in the form of a backup or fail-safe, or to improve actual system performance (Wikipedia contributors - B, 2019l).

Duplication of components to meet the same objective create excess capacity in a system and are effective tools for extreme stressor defences. Redundancy tends to stabilise systems and improve robustness (Kennon et al., 2015).

The presence of more than one component to cope with failure. Redundancy may also have the perverse effect of increasing complexity, raising the likelihood of failure (Perrow, 1984).

Modularity

Modularity is the degree that components may be separated and recombined, often with the benefit of flexibility (Hole, 2016; O'Reilly, 2019; Santos, 2012; Gorgeon, 2015; Martin-Breen and Anderies, 2011; Liu and Thompson, 2002). For example the finance team and the marketing team. Another example is the user-interface module and the data storage module.

Loosely coupled

Loosely coupled is the degree of dependency on the exact working of another module. For example, when the colour-schema of a website is changed it is preferred that this does not impact the functioning of the website. Another example is that when there are new employees introduced at the finance department this should not impact the taste of the coffee. It is important to understand that there is always some degree of coupling.

Loosely coupled is also known as 'Weak links', 'uncoupling', 'loose / tight coupling' and 'a low level of interconnectedness between components' (Hole, 2016; O'Reilly, 2019; Ghasemi and Alizadeh, 2017; Johnson and Gheorghe, 2013).

4.4.3 Complex Adaptive System Resilience attributes

Diversity

Diversity is also known as optionality, the ability to solve a problem in more than one way with different components (Hole, 2016, p. xiii, 38; Martin-Breen and Anderies, 2011, p. 9, 17, 32, 33; Gorgeon, 2015, p. 5,9; Kastner, 2017; O'Reilly, 2019, p. 886,888).

Diversity is used in various forms. For example, the usage of different programming languages or different programming patterns/solutions. This way the collection of systems is more diverse. An example of this is the company Booking.com that runs in production various A/B tests with a wide variety of features (Kaufman et al., 2017, p. 1). Another example is that within a team you want diverse co-workers since other type of people come up with other type of solutions.

Taleb (2012) and Gorgeon (2015) both use the term optionality. This is a more specific form of diversity. Optionality is the availability of options (Taleb, 2012, p. 176-177; Gorgeon, 2015, p. 9).

For example, retrieving weather information from two different API end-points and not from one weather information supplier. Another example is having four delivery companies that transport goods from your warehouse to your customers instead of having only contracted one delivery company. Henriksson et al. (2016) is using the term Networks with the same intention. The network is there to have opportunities in the context of having options. The combination of Emergence, innovation and networks support that diversity can be used as common attribute.

For the EAAL model I have made the design decision to exclude optionality from the antifragile group and put it in the CAS resilience group under diversity, since the most of the impact is in creating diversity.

Additional work on optionality

In the context of CAS the term diversity is commonly used. Interesting is that optionality as term is used by Taleb, Martinetti and Derbyshire. Optionality can be seen as an extension of flexibility (Martinetti et al., 2017, p. 237; De Florio, 2014, p. 839; Holling, 1996, p. 31,32; Janssen, 2015, p. 7).

> "Optionality is seen as both building flexibility to increase the range of strategic options as well as an enabler for convexity to respond to unpredictable events"
> - (Derbyshire and Wright, 2014, p. 219).

Non-Monotonicity

See also section 2.4.2 (Non-Monotonicity is learning from bad experiences).

Learning from mistakes can be an effective defence against stressors. Mistakes and failures can lead to new information. As new information becomes available it defeats previous thinking, which can result in new practices and approaches.

In this case, stressors can actually cause the system to improve (Johnson and Gheorghe, 2013; Ghasemi and Alizadeh, 2017). Learning from negative consequences induced by stressors can lead to new information. New information can result in improved practices and approaches. Stressors, when learned from, can thus cause a system to improve (Kennon et al., 2015; Ghasemi and Alizadeh, 2017).

In Hole (2016) this is described as 'Fail Fast' and in Gorgeon (2015) as 'inject randomness into the system'.

Emergence

When there is little or no traceable relation between the 'micro and macro level output' then emergence is there. This the situation where random things ('unintended states') appear more often and X-Events (black swans) appear. The law or Requisite Variety applied in this reasoning, leads to that internal emergence counters external emergence, and this leads then to antifragility (Christen and Franklin, 2002; Kennon et al., 2015; Ghasemi and Alizadeh, 2017; Goldstein, 1999; Menzies, 1988; Johnson and Gheorghe, 2013).

Self-Organisation

Self-Organisation is a process where some form of overall order arises from local interactions between parts of an initially disordered system (Wikipedia contributors - D, 2020p). For example, students sitting together in the school cafeteria.

Insert low-level stress

Continuous Improvement is achieved by inserting low-level of stress continuously into a learning system. This will keep the system sharp all the time.

Network-connections

A network is created by connections to other nodes. More connections increase the potential for optionality for new constructions and also new functionalities.

Fail Fast

The other attributes in this group combined enables the possibility to execute the strategy "Fail Fast" (Kennon et al., 2015; Gorgeon, 2015; Hole, 2016; Ghasemi and Alizadeh, 2017).

4.4.4 Antifragile attributes.

Resources to invest

Opportunities can only be seized when there are resources free to do see. This can be money but also time and labour. To survive a black swan investment should be possible (Taleb, 2012; Gorgeon, 2015; Kastner, 2017; Henriksson et al., 2016).

Seneca's barbell

To be antifragile you need a robust sub-system to which 80-90% predictable value with low risk is situated. The 10-20% should be used for high return on investment activities (Taleb, 2012; Johnson and Gheorghe, 2013; Kennon et al., 2015; Henriksson et al., 2016).

Insert randomness

When insert-low-level stress and fail fails delivers no issues the next step is to insert randomness into the systems. A great example of this is Chaos Engineering by Netflix or the HackerOne bug-bounty system (Taleb, 2012; Kennon et al., 2015; Gorgeon, 2015; Ghasemi and Alizadeh, 2017).

Reduce naive intervention

Naive intervention is an intervention based on a model and reductionistic logic and ignoring the experience. An example is not listening to the experienced but not so articulate employee, or by ignoring the balance nature has found in an ecosystem (Taleb, 2012; Gorgeon, 2015; Kastner, 2017).

Skin in the game

Make certain that the one making the decision and doing the work has a pain and gain relation with the outcome. This goes beyond having a feedback system in place. This goes beyond having KPI's in place. An example is that when working Agile scrum, the product owner should be a co-worker in the team for whom the solution is being build (Taleb, 2012; Kastner, 2017).

4.4.5 Learning Organisation attributes

Personal mastery

> "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, p. 7)

Shared mental models

> "Mental models are deeply ingrained assumptions, generalizations, or even pictures of images that influence how we understand the world and how we take action."
> - (Senge, 1990, p. 8)

Building shared vision

> "Building shared vision - a practice of unearthing shared pictures of the future that foster genuine commitment and enrolment rather than compliance."
> - (Senge, 1990, p. 9)

Team learning

> "Team learning starts with 'dialogue', the capacity of members of a team to suspend assumptions and enter into genuine 'thinking together'."
> - (Senge, 1990, p. 10)

Systems thinking

> "Systems thinking - The Fifth Discipline that integrates the other four. . . . Systems thinking also needs the disciplines of building shared vision, mental models, team learning, and personal mastery to realize its potential. Building shared vision fosters a commitment to the long term. Mental models focus on the openness needed to unearth shortcomings in our present ways of seeing the world. Team learning develops the skills of groups of people to look for the larger picture beyond individual perspectives. And personal mastery fosters the personal motivation to continually learn how our actions affect our world."
> - (Senge, 1990, p. 12)

4.5 Conceptual model

4.5.1 Behaviour of a System-of-Systems

Based on the literature the following conceptual model is created. This model contains the behaviour of a system on stress or time resulting in a value. See figure 4.4.

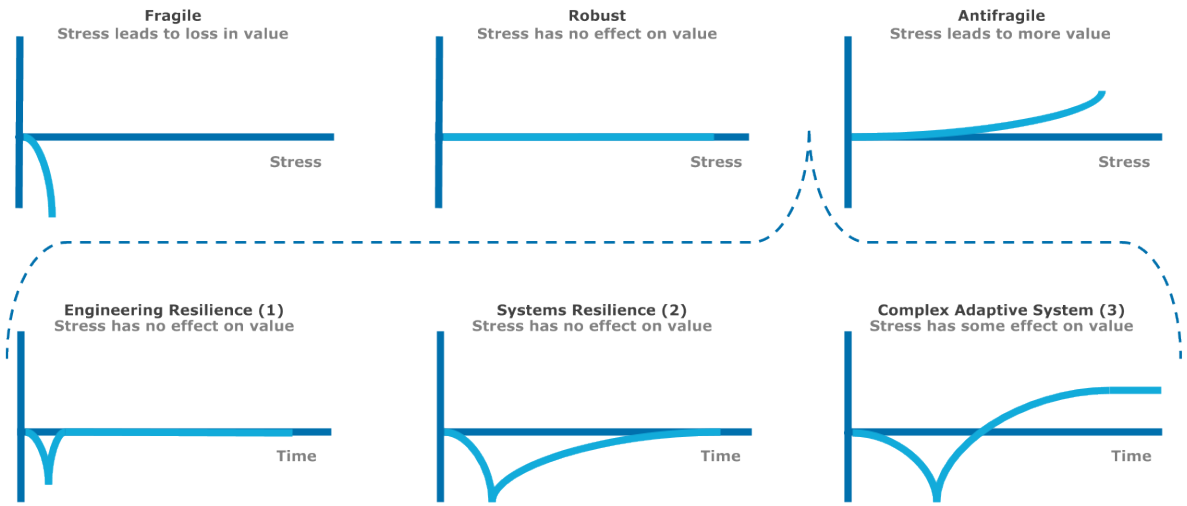

FIGURE 4.4: Behaviour of a System-of-Systems in value on time or stress.

4.5.2 Attributes of an Antifragile System-of-Systems

Following the steps defined in section 4.1 and 4.1.3 the EAAL model (figure 4.5) is created. The EAAL model is a summary of the available literature on the attributes of a resilient and antifragile System-of-Systems.

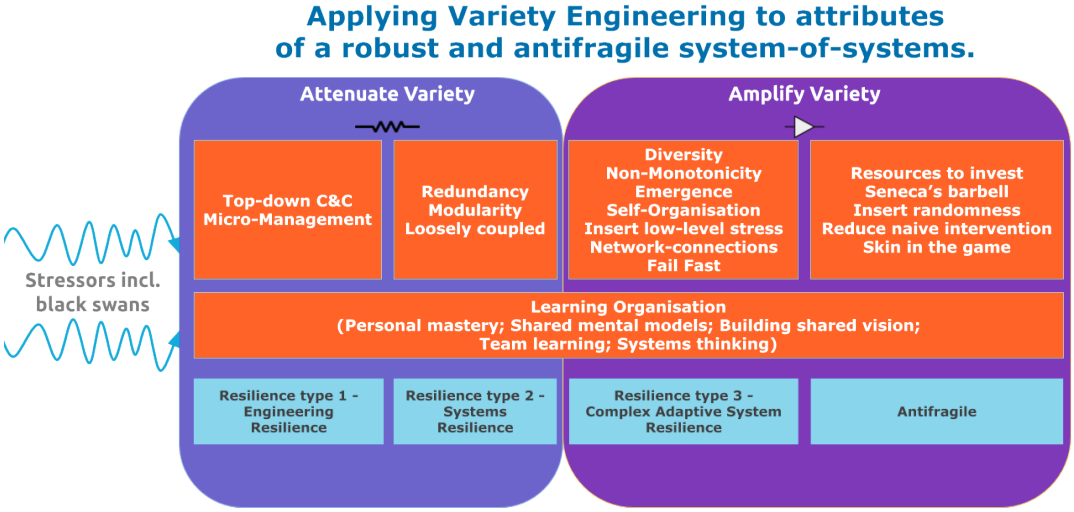

FIGURE 4.5: The EAAL Model.

5 Results & Analysis

Introduction

The goal of this chapter is to provide insight in the data collection process, the results and the analysis on these results.

The content of this chapter is the following:

5.1 Data collection

I collected data from three groups: (1) Experts on individual level, (2) Experts Groups and (3) Practitioners on individual level. The number of experts that I used for individual validation is 10 (figure 3.5). The number of groups I used for validation is three with a total amount of 12 persons (figure 3.6). The number of practitioners that I used for individual validation on application is seven (7) (figure 3.7).

5.1.1 Information products used for Data collection

During the interviews I used two information products. Mainly I used a slide deck[1,2] (the Chaos deck) containing the following:

1. Aimed at individual experts and interviews with C-level managers:
   Slides 3-7
   Core slides are slides 4,6,7.

2. Aimed at group presentations:
   Slides 15-38
   Part 1) Introduction into chaos and complexity.
   Part 2) Design of system behaviour in a chaotic world.

3. Additional slides:
   Slides 8-14, per attribute a short summary.
   Slide 39-40, overview of attributes in the literature, and the sorting tree.

Next to the deck I used the most recent version of the Management Summary that I extracted from the working version of my thesis.

5.1.2 Data collection from expert individuals

The data collection with the experts is done via various communication ways (Skype, Google Hangout, Email, Phone and face-to-face) in an unstructured way.

Pretty quickly I used the conceptual model of the Attributes of an Antifragile System-of-Systems (figure 4.5) as main talking point. To all experts I did send my management summary.

5.1.3 Data collection from expert groups

For the expert groups I used face-to-face communication, supported by 'the Chaos deck'. My presentation consists out of two parts. Part 1 describes chaos and complexity, and Part 2 describes the conceptual models created by me. These are the two conceptual models from section Behaviour of a System-of-Systems (figure 4.4) and from section Attributes of an Antifragile System-of-Systems (figure 4.5).

5.1.4 Data collection from practitioners

The data collection with the practitioners was done via unstructured interviews that lasted maximal one hour, as described in section 3.5.2 (Practitioners Review). For the interviews with the Practitioners I used the conceptual model of the Behaviour of a System-of-Systems (figure 4.4) and The EAAL Model. (figure 4.5). To all practitioners that participated I did send my management summary.

[1] https://docs.google.com/presentation/d/1F-ISVgXP4O8NXLk2AFrQlQuLiFmUj_S5fojs8sZ1drM/edit?usp=sharing

[2] https://gitlab.com/edzob/antifragile-research/-/tree/master/AntifragileThesis/pdf

5.1.5 Data collection Questions

At all the three data collection variants I asked the following questions:

1. "Do you see or do you hear something that is not right?"
   This is my check on inconsistencies and white rabbits.
2. "Do you see or do you hear anything that sounds too far-fetched and only theory based?"
   This is my check on being caught in a theoretical discussion without any touch with reality.
3. "Does what I tell you resonate with you?"
   This is my check if the information communicated addresses an application in reality with the interviewee.

5.2 Data analysis strategy

Since I am reluctant in applying quantitative analysis, and also reluctant in using qualitative analysis for causal relationships, I restricted myself to this limited line of questioning, and also limited the analysis to the following checks:

1. Did I miss something big?
2. Did I create something that is wrong?
3. Did I create something that inspires people to design their reality differently?

5.3 Data collected

5.3.1 Data collected from Expert Review - individuals

The overall feedback from the one-on-one expert reviews was that the EAAL model sparked inspiration and was relevant to their individual expertise.

Main feedback that I took into account and resulting into (re)designing the EAAL model where the following feedback points.

1. All the aspects as described by Senge (1990) of a learning organisation are always relevant.
2. It is impossible to find out based on observation why something is working.
   Here the person was referencing to the function and construction dilemma and to the issue of determining causal relations based on observation.

5.3.2 Data collected from Expert Review - groups

The overall feedback from the group validations was also that the EAAL model sparked inspiration and was relevant for the future. This group of 10 experts also provided feedback that the topic was pretty complex and would need examples on how to apply this in their day-to-day work. The feedback of the smaller group of 3 was that the topic was fit to be included in a book on Enterprise Architecture. Based on this feedback I created section 1.8.3 (Examples of implementation of antifragility).

5.3.3 Data collected from Practitioners Review

The overall feedback from the practitioners was that the EAAL model sparked inspiration but it could not be used in the boardroom in this form . The EAAL model should be used in the department that advises the board during the analysis and design process. Based on the EAAL model 'smart' question could be created and asked in the boardroom.

Highlights of the feedback of the interviews are:

1. "For the first time I see a holistic overview of the field of antifragility, resilience and agile."
2. "This is a powerful tool to think about the future design of the company."
3. "This all sounds very logical and clear to me. Great to have it in one image."
4. "After your talk with our CTO he is researching Holacracy and the possibilities in the transformation of our organisation."
5. But not all the feedback was positive.
   "This does not resonate with me. I do not understand what you are trying to tell me."

5.4 Data analysis

The overall feedback on the presented model was positive.

There was one negative feedback that the model and story did not resonate. This datapoint is only one and therefore not significant for the positive end result. More on this in section 6.2.3 (Reflections on the data, improvements and antifragility).

There was one feedback that the attributes are in the functional domain and that the translation to the construction of the system could be very difficult. This topic is out of scope and therefor part of chapter 6.3.4 (Future research in Enterprise Engineering theories).

6 Conclusion & Discussion

Introduction

The goal of this chapter is to provide a conclusion, reflection and recommendations for future research.

The Conclusions of this research (section 6.1) are based on the theoretical framework, research design, research execution and data collected. Limitations are applicable to the conclusions.

In section 6.2 (Discussion on what can be improved) I will address some critical thinking on the theoretical framework, research design, research execution, data collected and actions that I could have done differently.

I will provide Recommendations for future research (section 6.3) on actions and next steps for organisations on one side and for future research on the other hand.

The content of this chapter is the following:

6.1 Conclusions of this research

6.1.1 Research questions

The research questions are:

"Can leaders determine if their organisation must be resilient or antifragile? When applicable, does the "resilient ór antifragile model" support the leadership in determining what change is needed to achieve a resilient or antifragile organisation?"

6.1.2 Research conclusion

Given the limitations of my research, I can say that:

1. The leaders of an organisation can determine if their organisation must be resilient or antifragile with the behaviour model (figure 4.4) and the EAAL model (figure 4.5).
2. The EAAL model provides a definition of resilience.
3. The leaders of an organisation are supported in the design of their organisational change with the attributes of a resilient System-of-Systems as defined in the EAAL model.
4. The EAAL model provides a definition of antifragility.
5. The leaders of an organisation are supported in the design of their organisational change with the attributes of an antifragile System-of-Systems as defined in the EAAL model.

6.1.3 Limitations to the conclusion and research

The EAAL model is limited by that it is a reflection of the available literature.

The EAAL model is limited by that it is based on literature only and is not supported by validation through experimentation. The literature is limited to what I could find. The interpretation (reflection) of the literature is limited by that an interpretation is always personal.

The EAAL model is limited by that the attributes are not complete and not concise defined.

The list of the attributes in the EAAL model is limited since the attribute's origin from a limited set of literature. The literature is limited by an arbitrary selection. The list of attributes is the result of a creative process of interpretation and summarisation executed by me.

The EAAL model is limited by that it is not supported by proof of causal relationships.

In the studied literature there is no or very little proof of a causal relation between an attribute and the behaviour of the System-of-Systems.

The EAAL model is the result of my research. My research does not include any experiments to proof a causal relation between a set of attributes and the behaviour of the System-of-Systems. The interdependence between the attributes in the EAAL model are not part of my research. This also limits the EAAL model.

See also section 1.3.5 (The goal(s) of this thesis) and 3.1.9 (Limitations of this study).

6.2 Discussion on what can be improved

6.2.1 Critical Thinking on models and science

. . . on the limits of models

I find it 'interesting' that the result of my research and (hard) work on this thesis is 'another' model. The main reasoning in my thesis is that every model[1] is limited by the randomness of the world. A coach once told me that I eventually would see the omnipresent paradox in the world and would find infinite pleasure in it.

. . . on the limits of science when humans are involved

The field of Complexity Science[2] is relatively young. Complexity Science is also a complex domain. Complex Adaptive Systems (CAS[3]) are complex in itself. Humans are unpredictable (section 3.1). When humans are added to a system, the system becomes complex. Every CAS system increases in complexity when humans are added into the system. An organisation is a type of CAS system that is more complex than other CAS systems.

Organisations are part of the Social Science[4] domain. Within science there is a 'replication crisis' (section 3.1). There is no method available to prove causal relations where there are humans involved. This makes replication studies very difficult when humans are involved. When replication is not possible, the question of what science is becomes relevant (section 3.1).

6.2.2 Discussion on social science and ethical implications

. . . on the relevance of social science in Enterprise Design

The COVID-19 pandemic accelerated the digital transformation of many organisations (Iansiti, 2020). Digital transformation increases the internal and external connectivity of an organisation. These extra connections make an organisation more fragile. The increased fragility of organisations makes social science more relevant then before.

Another development next to the digital transformation is the adoption of the agile organisations as being the norm (section 2.3). The agile organisation is a decentralised organisation. The agile organisation is more complex than the reductionistic organisation.

As far as I can see do Enterprise Design and Enterprise Governance not yet support the agile transformation of the organisation (sections 6.3.3, 6.3.4). Not yet in practise as in theory. This makes the design and operations of these organisations fragile.

I realise that I know nothing and that I am very limited in experience, skills and knowledge. That having said, I think that it is important that we as Enterprise Architects and Enterprise Engineers are very humble in prescribing an organisation design. We need to be humble in our perception and communication of what is right and what is wrong. In our domain there are (many) tools and techniques that are based on a reductionist approach (Lapalme, 2012, p. 38). Reductionism can be applied to the Simple or Complicated domains of the Cynefin framework (section 2.9). We know that many of our fellow architects also apply these tools to Complex domain without these tools providing a holistic and integrated view (Hoogervorst, 2017; Dietz and Hoogervorst, 2011). More on this in the section on recommendations (section 6.3.3).

. . . on the ethical implications on humans in a fragile system

An antifragile system favours harm (sections 1.5.1, 1.8.2). An antifragile system needs to have a fragile sub-system to be harmed (section 1.5.2). Organisations include humans by definition (section 2.2). An antifragile organisation consists of a fragile sub-system that than probably include humans. When designing or aiming for an antifragile organisation this results in an ethical dilemma (Taleb, 2012, Chapter 23-24).

[1] https://en.wikipedia.org/wiki/All_models_are_wrong (Wikipedia contributors - D, 2020a)
[2] https://en.wikipedia.org/wiki/Complex_system (Wikipedia contributors - D, 2020c)
[3] https://en.wikipedia.org/wiki/Complex_adaptive_system (Wikipedia contributors - A, 2019i)
[4] https://en.wikipedia.org/wiki/Social_science (Wikipedia contributors - D, 2020r)

For an antifragile organisation to gain value, it needs to sacrifice a fragile sub-system with people in it that have something to lose (skin in the game, section 4.4.4). This is an old ethical[5,6] dilemma also known as "The need of the many outweigh the need of the few ..." (Mintz, 2015).

... on the ethical implications on the match of organisation design and personality type

Another ethical dilemma is that not every personality type prospers in an antifragile organisation (Kastner, 2017; Markey-Towler, 2018). Kastner stated in a conversation with me that the antifragile companies he studied replaced their complete workforce over time. I talked to two companies that embrace Holacracy (Robertson, 2015) which both stated their antifragile enterprise culture and governance is best suited for a specific type of person. They stated that they are putting a lot of effort into finding the right type of employees.

The ethical questions here are: If the organisation becomes antifragile, is it still the same organisation as the one before? In section 1.6.5 a similar question is asked from a functional and constructional point of view. What is the impact of the remark by the two companies on diversity when knowing that an attribute of a CAS resilient organisation is diversity? Is there a place for an employee with a non-antifragile personality type in a robust sub-system of an antifragile employee?

6.2.3 Reflections on the data, improvements and antifragility

... on that the EAAL model provides inspiration.

I observed that the EAAL model provided inspiration with the experts and with the practitioners. My inference[7] based on this observation is that the experts and the practitioners can use the EAAL model for *discussions* on the design of organisations / their organisation.

Based on this observation, I also conclude that the EAAL model can function as a stepping stone for further research.

... on the awareness of an organisation being a System-of-Systems

An organisation is a System-of-Systems. For me this is a learning experience. Before this research I looked at an organisation through the lens of it being an organism. The lens of looking at an organisation as a System-of-Systems is something I learned during the research.

When discussing the behaviour of the organisation with the practitioners it became quickly apparent they view an organisation as a System-of-Systems. It was part of all the conversations. In every conversation we discussed that different parts of the organisation should behave differently.

I did not expect, from my personal development context, that every practitioner already reasons from a System-of-Systems perspective.

... on that causal relations are needed as extension of the EAAL model

Feedback from the experts and the practitioners in the conversations was that the model supports the design of the organisation by providing a holistic overview. In the conversations with the practitioners it became clear that an extension of the EAAL model is needed.

The implementation of one or more system attributes in their organisation needs more insight on the causal relationship between the various attributes. The impact of the operational change on the organisation needs to be clear. More on this in section 6.3.

... on the gathered data

I am very proud of the one negative feedback, since this implied that the conversation was an open and trustworthy conversation. I think it is very difficult to 'proof' why this the

[5] `https://plato.stanford.edu/entries/utilitarianism-history` (Driver, 2014)
[6] `https://en.wikipedia.org/wiki/Utilitarianism` (Wikipedia contributors - D, 2020v)
[7] `https://www.merriam-webster.com/dictionary/inference` (Merriam Webster, 2020f)

feedback was negative. See also the previous sections on The replication challenge (3.1) and Randomness (2.6). This one data-point has no impact on my conclusion of this research, since the other C-level leaders did find the presented EAAL model relevant.

My personal speculation is that there are certain type of people that just see the world in different way. It is very good to have this diversity in a leadership team. Another manager in this same leadership team stated to be very interested in the presented work. Through the lens of my research I can only endorse this diversity. That I only interviewed one leader that did not resonate with the EAAL model, also could imply that I unknowingly applied a bias when selecting the leadership for the interviews. See section 6.3.2 for recommendation on future research on this.

In retrospect all the feedback was very positive. No big caveats where found or at least not communicated to me. This overall conclusion is emphasised by the following two examples: First, one of the experts is going to do his PhD on Complex Systems and Software Engineering and was very happy with the work presented. Second, one of the C-level managers that I approached is also an expert on Agile organisations and Enterprise Architecture. I was told that this was a very nice holistic representation of this field that has not been seen before.

. . . on what could I have done differently

What would I have done differently? Many things, but these are my personal top two.

First, the **scope** of the research. The topics of antifragility and decentralised enterprise governance fascinates me for many years and will fascinate me for many more years. My personal fascination is also the pitfall of my research. For the topic of our master thesis, our professors told us often : "Smaller is better!"

The topics of "randomness", "reflection of reality", and "how to control by having no control" are very big topics. This is a big gamble to include as topic for a master thesis. The broad scope of the topic combined with my personality type of seeking for confirmation and dyslexia, makes the creation of this thesis a steep learning curve.

Second, I am not content with the **rigour** of the analysis and selection of the papers. I could be more thoroughly in the registration and categorisation of the papers. I could have asked a co-writer to replicate during the research the registration and categorisation. This would improve the rigour of the research. My research was an emergent and an arbitrary process. I am proud of the validation and the level of rigour I could reach. The research could be more concise if there was more focus, time and help.

. . . on antifragility

During the research I gained new insights on the topic of fragility and antifragility. My personal reflections on the topic of antifragility can be summarised in the following six statements.

1. Antifragile systems can survive in any of the contexts of the Cynefin framework (Chaos, Complex, Complicated, Simple and Disorder).
2. To thrive in chaos, it is essential to accept there is no real knowledge and understanding of the current context. The mantra should be: "It is".
3. Antifragile systems thrive in and gain from chaos where in contrast fragile systems thrive in and by controlled environments achieved by assumption, scoping and protection.
4. Fragile systems are created by humans. Thus are related to scoping and therefore can only exist in an artificially created context.
5. There is an inclusive (cumulative) growth path of System-of-Systems from fragile, to robust and then from engineering resilience and systems resilience to CAS resilience and finally to Antifragile (see figure 4.4).
6. It is better to rephrase ‘antifragile is the antithesis of fragile‘ into ‘antifragile behaviour is the antithesis of fragile behaviour of a system‘.

6.3 Recommendations for future research

The need for CAS Resilience and Antifragility is clear

The COVID-19[8] pandemic emphasised the importance of resilient organisations.

The financial crisis of 2008 'sparked' the Lean Startup[9] and the Ideation[10] ,[11] movement resulting in the hype of (exiting) tag-lines like 'innovate or die' and 'design to disrupt'.

We can learn from the financial crisis of 2008 and the COVID-19 crisis of 2020 that engineering resilience and systems resilience is not enough for an organisation to survive these events. Since the Lean Startup and Ideation movement is focused not only on creating a resilient enterprise construction but also on the adaptable function of the organisation. We can (re-)learn from 2008 and 2020 that the world is a dynamic place and models of this world are fragile and we need to design organisation accordingly

For an organisation to survive these big events non-stop reinvention by continuous learning and continuous adoption is needed. The adoption of the more resilient organisation design after 2008 could have a positive contribution to the absorption of the impact of COVID-19. There are various examples of continuous learning in inspiring global cooperation's on sharing COVID-19 data[12],[13],[14],[15].

Reinvention of the organisation has impact on the essence of the organisation. Reinvention changes the function and construction of the organisation. Therefore, reinvention exceeds engineering and systems resilience. Reinvention needs tools, techniques, processes (etc.) that amplify the variety. Amplification of the variety is needed for Information Systems and for Organisational Systems. There is much to be done, to guarantee organisations that non-stop reinvention is possible.

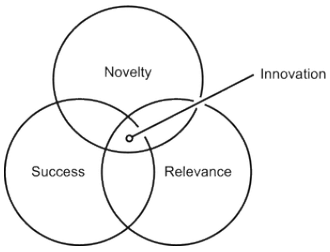

FIGURE 6.1: Innovation by Huber et al. (2017).

Summary of recommendations for future research

1. ...on managerial application.
   First there is need for a next step in bringing the EAAL model to the business organisation.

2. ...on replication and extension.
   Second, there is the need for replication and extension of the EAAL model. Since the content of the EAAL model is a summary of the available literature, there is a need for research on completeness and causality.

3. ...on increasing predictability
   Third, there is the need for research on the transition between the predictable and unpredictable contexts, with the focus on the transition from complex to complicated.

4. ...on Enterprise Engineering and Antifragile systems.
   Fourth, there is the need for future research in the enterprise engineering theories.

[8] https://en.wikipedia.org/wiki/Coronavirus_disease_2019 (Wikipedia contributors - D, 2020e)
[9] https://en.wikipedia.org/wiki/Lean_startup (Wikipedia contributors - D, 2020l)
[10] https://en.wikipedia.org/wiki/Ideation_(creative_process) (Wikipedia contributors - D, 2019a)
[11] https://en.wikipedia.org/wiki/Design_sprint, (Wikipedia contributors - D, 2020g)
[12] https://www.rivm.nl/en/novel-coronavirus-covid-19/spread
[13] https://ourworldindata.org/coronavirus
[14] https://covidgraph.org
[15] https://nextstrain.org/ncov/global

6.3.1 Future research on managerial application

I see two specific ways in which future research could bring business management value in their aim to become antifragile. First there is the tool of a maturity model, and second there is the assessment of the existing best practises that label themselves with antifragility.

Future research - Creating a maturity model as a tool for management

Based on the interviews with the various companies there is a need for a growth model that would include the following steps (Johner et al., 2018, p. 19).

1. Determine SOLL situation.
   Use the behaviour model (figure 4.4) to determine which behaviour should be best fitting to the organisation and fitting to the strategy. This can also be applicable to a team of four or to a department of various teams.

2. Determine IST situation.
   Use the behaviour model (figure 4.4) combined with the System Attributes model (figure 4.5) to determine which attributes are already present and validate if this results in the behaviour displayed by the system.

   It is for example possible that Redundancy, Modularity and Loosely Coupled are attributes of the system but that the system is not yet capable of combining these into a systems resilience behaviour. In this case it would be logical to see the system displaying Engineering Resilience behaviour.

3. Determine GAP and way forward.
   The GAP is in between the IST and SOLL situation. It appears to be logical to define the three types of resilience seem logical platforms in the maturity model, where antifragile behaviour is at the outer limits of the maturity model.

COBIT and DYA provide tools to gradually improve the organisation on various aspects (van den Berg et al., 2005; De Haes and Van Grembergen, 2015; De Haes et al., 2019). Both COBIT and DYA have data that show a positive correlation between the maturity levels and the effect (De Haes et al., 2015, 2016; Wu et al., 2015; Steenbergen, 2011).

The EAAL model is only a summary of the existing Body of Knowledge. For a maturity model to be applicable it needs a insight in the causal relations, tools, processes and techniques to facilitate an organisation to mature. The creation of a maturity model is a very complex endeavour of many years.

What the maturity models as for example in COBIT 2019, DYA and CMMI, have in common is that it is not optimal to grow to maximum maturity on all the aspects. Situational application is important to keep in mind when aiming at an certain level from a maturity model.

As long we do not have fixed the problems around social science (section 3.1), the implementation of CAS Resilience and Antifragile systems will be based on experimentation and heuristics.

That having said, I think that having the discussion based on the resilience/antifragile behaviour and the attributes in itself can bring value to an organisation. Since this discussion will provide reflection around a shared mental model.

Future research - Implementation of antifragility based on best practises

For Information Systems (IS) there is some guidance based on heuristics on how to become antifragile as for example Chaos Engineering by Netflix (2011), Antifragile Systems and teams by Zwieback (2014), Antifragile ICT Systems by Hole (2016) and Antifragile Software Engineering by O'Reilly (2019). For Organisational Systems (OS) the only practical guide I could find is Robertson (2015). Large organisations in the Netherlands as the airline Transavia (in 2018, revenue: 1.61 billion euros[16], employees: 2000[17]) and the online-retailer

[16] https://www.statista.com/statistics/409284/transavia-total-annual-passenger-revenues/
[17] https://corporate.transavia.com/nl-NL/organisatie/kerncijfers/

Bol.com (in 2018, revenue: 2.1 billion euros[18], employees: 1500[19]) apply Holacracy under the label of antifragility. Both the antifragile IS and OS approaches are not based on a scientific coherent understanding but on strong logical reasoning.

Some antifragile attributes from the literature are plotted onto resilient behaviour in the EAAL model (figure 4.5). The EAAL model enables a more granular validation of the system attributes and system behaviour.

I would imagine that it makes a difference to a business manager if the implementation of a set of attributes delivers Systems Resilience behaviour and not CAS resilience behaviour.

This critical thinking can provide business managers sense-making and enable them in a more informed strategic dialogue and investment decisions.

6.3.2 Future research on replication and extension

In my thesis the concept of replication has an important place. It is my personal conviction that science which cannot be replicated is not science but a believe. See section 1.4.1, 1.6, 3.1, 4.1, and appendix A for more on replication. I see the following for future research on replication and extension.

Replication and validation of my literature research

When searching for literature a different person will find different sources. A replication study could be to search for relevant sources on antifragility as described in section 3.4 and use the decision tree (figure 4.3) to recreate the EAAL model (figure 4.5). The increase of variety of used people and sources can improve the quality of the decision tree and the EAAL model. This is also the reason that I applied CC BY-SA 4.0 as copyright license to my work.

Replication and validation of my field study

The diversity and number of organisations interviewed is limited. The research would benefit from an increase in diversity of organisations interviewed. The organisations interviewed are limited to the Netherlands, and lacking sectors like finance, healthcare, the military and hospitality.

Extension on to the causal relations between the attributes

It is possible that the attributes defined in the EAAL model (figure 4.5) have a causal relationship with the behaviour type they are linked to. The validation of this was not part of my research scope. An extension of my research would be to set up experiments that prove causal relationship between the attributes of the system and the behaviour of the system.

[18] https://www.aholddelhaize.com/media/8606/190123_aholddelhaize-_q4-trading-statement.pdf
[19] https://pers.bol.com/app/files/2019/10/Spreekbeurtpakket-bol.com_.pdf

6.3.3 Future research on increasing predictability

A theory central in my thesis is the Cynefin framework (Kurtz and Snowden, 2003). In figure 6.2 (Future research hypothesise model.) I combined the Cynefin framework and various theories from chapter 2 (Theoretical background).

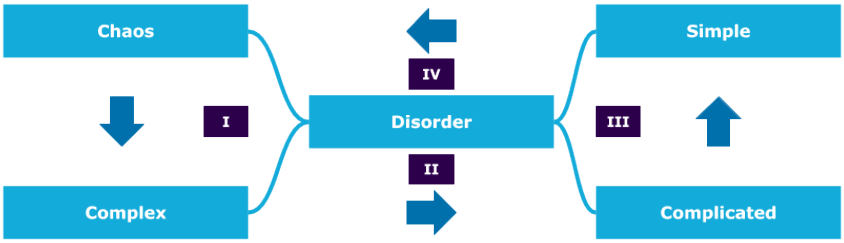

FIGURE 6.2: Future research hypothesise model.

The theory from section 2.10 (The Cynefin Framework) states that acting, sensing and then responding is the right way of behave in a chaotic context. The theory also states that chaos is subjective, thus by act-sense-respond you are getting aware of what is going on and can learn in retrospect (see table 2.2). In retrospect the systems within the context can be identified, but the causal relation is still unknown. Why, when and what something is happening is unknown. This is also called the "unknown unknowns". Through information, knowledge, and sense-making[20] it is possible to see the complexity in the chaos. The act-sense-respond and learning is in the transition from chaos to complexity (**I** in figure 6.2). See also section 2.4.

Future research - From Complex to Complicated

As chaos is subjective, so is also complexity subjective. When enough knowledge (by experimentation) is collected, causal relations between systems can be found and proven. This would create the transformation from complex to complicated (**II** in figure 6.2).

But chaos theory teaches us with the double pendulum[21] and the Lorentz system[22], that a small set of deterministic systems creates a non-deterministic (non-linear) system (section 2.6). This is what *emergence* is in Hoogervorst (2017) and in the EAAL model (figure 4.5, section 4.5.2). This implies that insight into the causal relation alone will not be enough for a complex context to become complicated (**II** in figure 6.2).

When knowing is not enough and accepting is not an option, then the only way forward is change. Since chaos theory states that non-linear behaviour is created by the interaction (feedback) of the systems including an amplification of small deviations, the transformation from complex to complicated (**II**) is to be found in the de-coupling of the systems. This can be done by introducing circuit breakers.

For future research it would be interesting to research how Normalized Systems Theory (NST) (Mannaert et al., 2016) and Enterprise Engineering (EE) (Dietz and Mulder, 2020; Hoogervorst, 2017) can play a role in the transformation from a Complex Adaptive System (CAS) into a system in the domain of General Systems Theory (GST) (see figure 6.3). I personally think that the fusion between Complexity Science, Systems Engineering, Enterprise Engineering and Normalized Systems Theory could be very effective. Since COBIT 5 (De Haes and Van Grembergen, 2015; De Haes et al., 2015; Wu et al., 2015) and COBIT 2019 (De Haes et al., 2019) state there is a positive correlation between Business & IT alignment and value (creation) of an enterprise (figure 6.4), and Hoogervorst (2017) on page 258 and 441 state that structures are interconnected with behaviour (figure 6.5). This would imply that the human centred understanding of the essence of an organisation (Dietz and Mulder, 2020) would provide value for an organisation and that the design and understanding of culture and behaviour should be an integral part of this.

[20] `https://en.wikipedia.org/wiki/Sensemaking`, (Wikipedia contributors - D, 2020q)
[21] `https://en.wikipedia.org/wiki/Double_pendulum`, (Wikipedia contributors - A, 2019n)
[22] `https://en.wikipedia.org/wiki/Lorenz_system`, (Wikipedia contributors - C, 2020q)

A research topic could be:
Is it possible to design an organisation on a constructional level by applying DEMO and incorporating Game Theory[23,24]*?*

Another research topic could be:
Is it possible to combine the Complexity Science and Software Engineering methods described by O'Reilly (2019) with Normalized Systems Theory to achieve highly frequent adaptive self-evolving software?

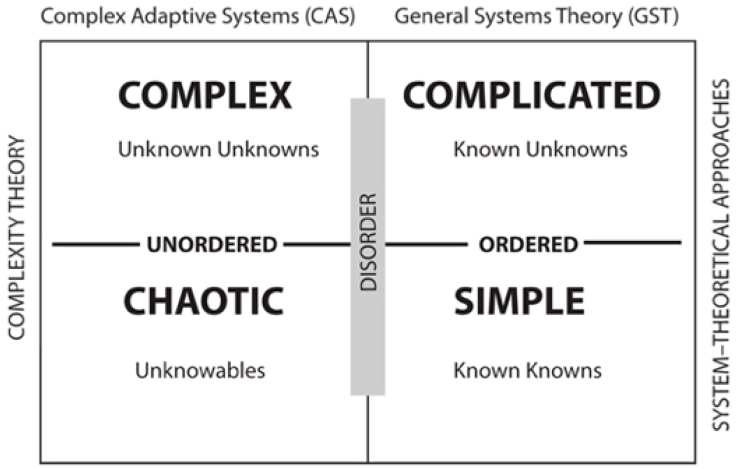

FIGURE 6.3: Cynefin, CAS and GST by Turner and Baker (2019) p. 16.

[23] https://en.wikipedia.org/wiki/Complex_system (Wikipedia contributors - D, 2020c)
[24] https://en.wikipedia.org/wiki/Game_theory (Wikipedia contributors - D, 2020i)

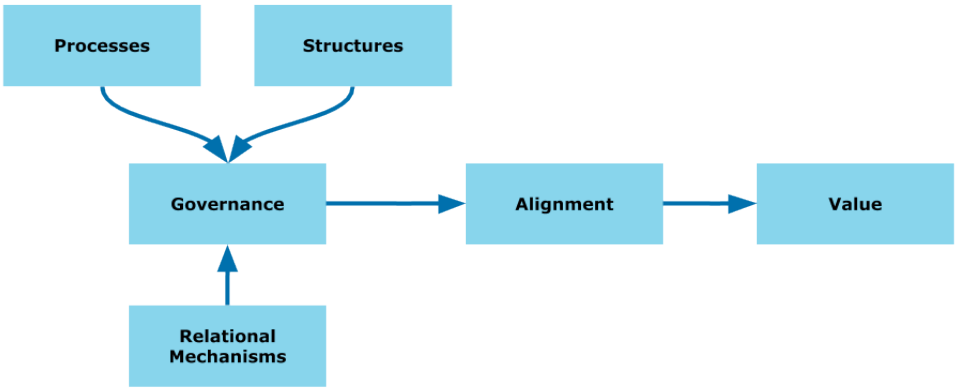

FIGURE 6.4: Governance Framework (De Haes and Van Grembergen, 2015, p. 2, 12).

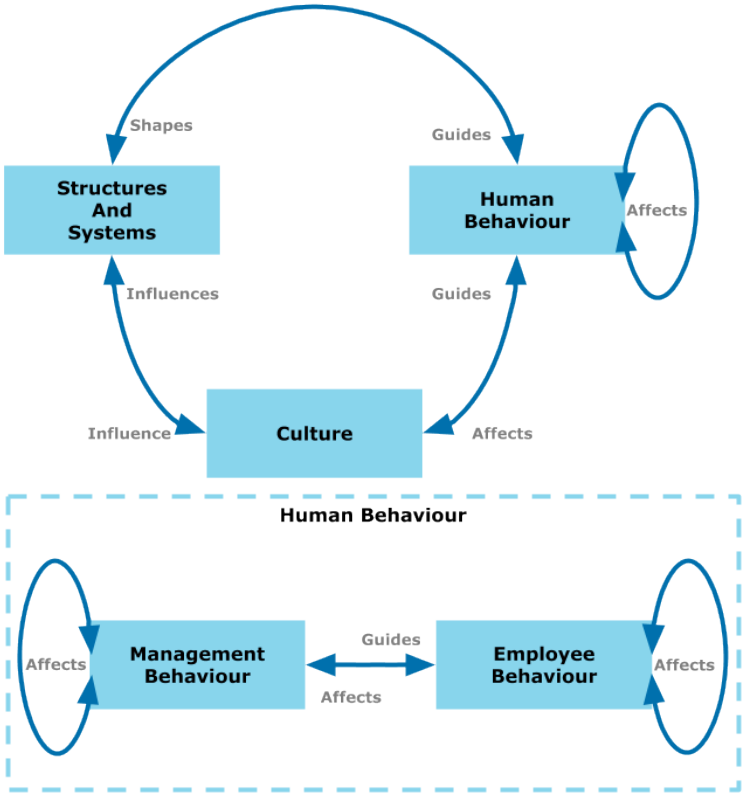

FIGURE 6.5: Morphogenic social system and enterprise behaviour models (Hoogervorst, 2017, p. 258, 441).

6.3.4 Future research in Enterprise Engineering theories

In the previous sections the focus of my proposals for future research on replication and extension is aiming on improvement of the research itself, and the proposals for future research on managerial application and increasing predictability aims for more business impact. For this section I am addressing a more fundamental question.

I have learned that resilience can be achieved by reducing (attenuate) the variety, or by amplifying the variety in a system. I also have learned that the learning organisation is a mandatory part of the systems to be resilient. If the system cannot learn, it is not able to adapt and therefore it is robust or even fragile. If a system does not evolve in the long term it dies.

I think that Enterprise Engineering as a discipline should be able to be applied/used to design resilient and even antifragile systems. The following three arguments of Enterprise Engineering brought me to this assumption.

First Enterprise Engineering identifies an enterprise as an intentionally created Complex Adaptive System (CAS) consisting of cooperating human beings with a certain social purpose, whereby it is impossible to determine the ultimate (operational) reality of the enterprise down to the minute details (Dietz et al., 2013, p. 93-94). Second, Enterprise Engineering defines the following three goals for itself: (1) intellectual manageability, (2) organisational concinnity, and (3) social devotion (Dietz and Mulder, 2020, Chap. 2; Dietz et al., 2013, p. 90). Third, in Hoogervorst (2017) it is stated that human behaviour has a large role in the functioning of a system (see section 6.3.3).

It can be argued the learning organisation and the other system attributes from the EAAL model (figure 4.5) should fit in the Enterprise Engineering discipline goals and definitions.

After reading the separate Enterprise Engineering theories as preparation for section 2.11 (Enterprise Engineering) and re-reading them in Dietz and Mulder (2020) I did not find it arbitrary to make the mapping between the Enterprise Engineering theories and the Resilient and Antifragile System Attributes (figure 6.6).

A research topic could be:
Is it possible to design an antifragile organisation or an CAS Resilient organisation by applying the Enterprise Engineering discipline? Let the matrix as visualised in figure 6.6 be the first check if the toolbox of Enterprise Engineering provides the right tools for the job.

In the case that the existing Enterprise Engineering theories are not sufficient to design an antifragile enterprise, then a possible follow up research could be:
Develop the Eta-B (ηB)[25] theory to design to the Enterprise Antifragile Behaviour.

[25] `https://en.wikipedia.org/wiki/Eta` (Wikipedia contributors - D, 2020h).
The Greek capital letter Eta (H) is used for Entropy (section 2.7).
The Greek letter Eta (η) is used for viscosity (section 1.6.6)

			Attenuate Variety				Amplify Variety			
	Variety		Engineering Res.		Systems Res.		CAS Res.		Antifragile	
EE th.	Attenuate	Amplify	Learning Org.	System Attr.	Learning Org.	System Attr.	Learning Org.	System Attr.	Learning Org.	System Attr.
SIGMA		Y								
BETA										
IOTA										
NU										
ALPHA										
DELTA										
PSI										
OMEGA										
MU										
TAO										
FI										

FIGURE 6.6: Can Enterprise Engineering be used to design Resilient and Antifragile System-of-Systems?

6.3.5 Future research in Fundamental Science

The Complexity Science field, and systems thinking discipline do not believe that scientific management and the reductionistic[26] way is a "correct" way to describe the world.

In the various books of Enterprise Engineering this is also addressed. In Enterprise Engineering (EE) the current living philosopher Habermas[27] provides the basic foundation for the EE lens to look at the world.

There are two future studies that I see in this. I placed them below in order of magnitude.

Future research - Where do emotions fit in structuralism and post-structuralism?

Barry (2002) addresses various theories on how a text can be analysed and the relation to the view on the world. Chapter 2 of Barry (2002) contains a summary on structuralism[28] and in chapter 3 a summary on post-structuralism[29] is provided. Structuralism is also called constructionism[30]. Post-structuralism is also called deconstructionism[31].

Structuralism sees meaning in words and the relationship in words, and states that what is written also that is what is true reality in the world. Post-structuralism states that the world is not that universal deterministic. "Post-structuralism discards the idea of interpreting media or the world within pre-established, socially constructed structures." (Wikipedia contributors - D, 2020o).

I see similarity between the method of analysing a text as described in chapter 2 of Barry (2002) on structuralism and the approach that is taught in DEMO[32] on how to create an Organisation Construction Diagram (OCD) (Dietz and Mulder, 2020, Chap. 12). To create an OCD, it is needed to identify three categories, the O-organisation, I-organisation and the D-organisation, in the relevant text that describes the scope of the OCD. See also the *A* theory in section 4.47 in Dietz and Mulder (2020).

I also see similarity in the way of encoding as in the way of identifying functions defined in a text and normalise them in the context of Normalized Systems Theory.

[26] https://en.wikipedia.org/wiki/Reductionism (Wikipedia contributors - B, 2020d)
[27] https://en.wikipedia.org/wiki/Jurgen_Habermas (Wikipedia contributors - D, 2020j)
[28] https://en.wikipedia.org/wiki/Structuralism (Wikipedia contributors - D, 2020s)
[29] https://en.wikipedia.org/wiki/Post-structuralism (Wikipedia contributors - D, 2020o)
[30] https://en.wikipedia.org/wiki/Constructivist_epistemology (Wikipedia contributors - D, 2020d)
[31] https://en.wikipedia.org/wiki/Deconstruction (Wikipedia contributors - D, 2020f)
[32] Fun fact: Jürgen Habermas is referenced on the wikipedia page of Structuralism as 'Critical theorist Jürgen Habermas' and on the wikipedia page of Postmodernism as 'pragmatist philosopher Jürgen Habermas'

Enterprise Engineering is based on textual input and you can even argue that it is best applied in a legal context.

As discussed before, it is my believe that there is something crucial with the element of human behaviour in the behaviour of enterprises. A friend of mine teaches neuropsychology[33] at a Dutch university. He stated the following when I create a picture of a resilient organisation by drawing circles:

> '...it is funny how you draw the organisation sub-systems as circles. It is my view that the space between the sub-systems are emotions. The difference between a system that performs and a system that does not performs is not only about communication, it is about more, it is about emotions. Emotions might be the x-factor.'

Research by Google also points in this direction. Their research is made available via their project Re:Work[34,35,36,37]. Their studies resulted in the Modern Agile[38] approach. The summary of their research is that the best performing teams (High Performance Teaming) are also the teams where the team members experience the highest psychological safety.

Emotions is a much broader topic than psychological safety. I am convinced this is a very big part missing in the disciplines of Enterprise Engineering, Enterprise Design, Enterprise Architecture and Enterprise Governance.

The role of Emotions in the previously named disciplines is not an easy topic, since it combines philosophical questions (see figure 6.7), with the practical questions on how to design, with the highly experimental domain of other social sciences (psychology and neuropsychology). Design and implementation can not be blindly separated in this.

A research topic could be:
Where is the role of emotions in Systems Theory[39] (as part of Complexity Science) and how can this be applied to organisational design?

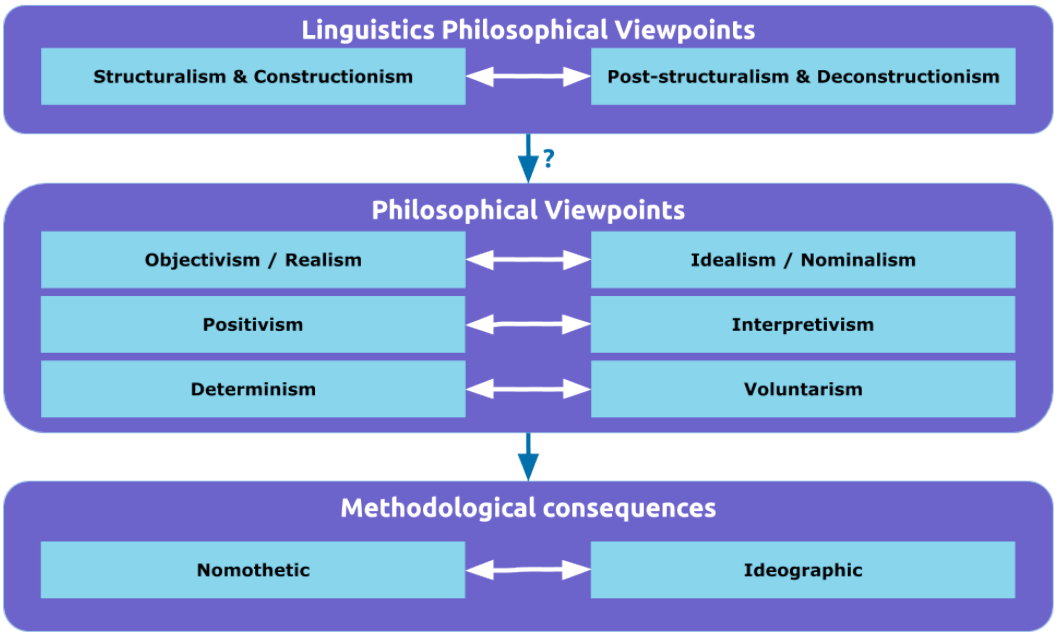

FIGURE 6.7: Fundamental philosophical assumption extended (Hoogervorst, 2017, p. 197).

[33] https://en.wikipedia.org/wiki/Neuropsychology (Wikipedia contributors - D, 2020n)
[34] https://rework.withgoogle.com/print/guides/5721312655835136
[35] https://rework.withgoogle.com/blog/five-keys-to-a-successful-google-team
[36] https://rework.withgoogle.com/guides/understanding-team-effectiveness/steps/introduction
[37] https://rework.withgoogle.com/about
[38] http://modernagile.org/
[39] https://en.wikipedia.org/wiki/Systems_theory (Wikipedia contributors - D, 2020u)

Future research - Fix the replication crisis for Social Sciences

This is a subject for a PhD study that would possibly take multiple lifetimes to complete and doubtful if it is even possible at all.

As argued in section 3.1 (The replication challenge), the replication crisis within psychology and economics is also applicable to all social sciences including Enterprise Architecture, Enterprise Engineering and areas of Complexity Science. I think that the human factor is one of the reasons or probably 'the reason'.

We have made great steps in the field of social science compared to 100 years ago. We applied psychology in business via popular science via books as 'The Tipping Point' (Gladwell, 2001), and in *ethical questionable* professions as Neuromarketing[40]. It is amazing how far we are now and we are not even able to replicate studies that we used as basis for our current achievements.

It would be amazing if we would find out how to fix the replication crisis that most if not all fields of science are dealing with. For this I even don't know where to start in formulating a question, topic or statement.

[40] `https://en.wikipedia.org/wiki/Neuromarketing` (Wikipedia contributors - D, 2020m)

Appendices

FIGURE 6.8: A letter-board on the mantelpiece at our home.

A Appendix - Why Antifragile - My personal why

A.1 My motivation for this thesis, a journey

For me there are two main pillars that motivate me to choose antifragility as topic for my master thesis.

Pillar 1 - decentralised governance When I was young (8-12) i loved to read about Galileo Galilee[1], Isaac Newton[2] and Leonardo da Vinci[3]. These three scientists where able to study nature by writing down observations and then imagine a model that would explain their observations.

Leonardo designed gas-masks, helicopters, encryption, sewage systems and created beautiful inventions[4] and paintings such as the Mona Lisa[5]. Newton his principia[6] mathematica[7] is incredible value to the field of science. Galileo proved that gravity is about acceleration and stated that the earth is not the centre of the universe for which he got imprisoned.

My religious upbringing highly motivated me to study the creation of the things around me, since this reality we live in is a great work of art. I was thought that studying the creation was equal to studying god and that this would be enlightening.

This motivated me to continue and go deeper into the observational studies of the old scientists and start reading about the things we can not see directly. I started with reading Stephen Hawking for a school-paper on Black Holes I wanted to write. This was when I was 11 years old. Stephen Hawking[8] introduced me to work of Albert Einstein[9] and Richard Feynman[10]. Through their stories I understood that the world is not best described as a precise mathematical formula like Galileo, Newton and da Vinci stated. This new group of scientists wrote that *reality is strange and random.*

Hawking wrote for example that out of nothing two particles could just popup and disappear into another (annihilation[11]). Except when it happens near the event horizon of a black hole, then one particle has a higher chance than the other type of particle to be sucked into the black hole, making a black hole lose matter. *In nature random stuff just happens* is what I took away from Hawking[12].

> "Not only does God play dice, but... he sometimes throws them where they cannot be seen. " - (Hawking and Penrose, 2000)

Feynman wrote about strange elements that build the universe (quantum electrodynamics[13] and quantum gravity[14]). He wrote that things could be there and not there, being a

[1] https://en.wikipedia.org/wiki/Galileo_Galilei (Wikipedia contributors - A, 2019o)
[2] https://en.wikipedia.org/wiki/Isaac_Newton (Wikipedia contributors - A, 2019o)
[3] https://en.wikipedia.org/wiki/Personal_life_of_Leonardo_da_Vinci (Wikipedia contributors - C, 2020u)
[4] https://en.wikipedia.org/wiki/Science_and_inventions_of_Leonardo_da_Vinci (Wikipedia contributors - C, 2020x)
[5] https://en.wikipedia.org/wiki/List_of_works_by_Leonardo_da_Vinci (Wikipedia contributors - C, 2020p)
[6] https://plato.stanford.edu/entries/newton-principia/ (Smith, 2007)
[7] https://plato.stanford.edu/archives/win2008/entries/newton-principia/ (Smith, 2008)
[8] https://en.wikipedia.org/wiki/Stephen_Hawking (Wikipedia contributors - B, 2019s)
[9] https://en.wikipedia.org/wiki/Albert_Einstein (Wikipedia contributors - A, 2019a)
[10] https://en.wikipedia.org/wiki/Richard_Feynman (Wikipedia contributors - B, 2019m)
[11] https://en.wikipedia.org/wiki/Black_hole_information_paradox (Wikipedia contributors - A, 2019e)
[12] http://www.hawking.org.uk/does-god-play-dice.html (The Stephen Hawking Foundation, 1999)
[13] https://en.wikipedia.org/wiki/Quantum_electrodynamics (Wikipedia contributors - B, 2019j)
[14] https://en.wikipedia.org/wiki/Quantum_gravity (Wikipedia contributors - B, 2019k)

particle and energy, that it was impossible to know because knowing would change it, etc. *Reality is strange and non-deterministic* is what I took away from Feynman[15].

> "given an arbitrary accuracy, no matter how precise, one can find a time long enough that we cannot make predictions valid for that long a time." - (Feynman et al., 1963)

In order there is beauty but there is also beauty in disorder. The scientists from the era of Newton wrote that there is beauty in the simplicity and symmetry of mathematical equations that define the world. Later on scientists write down that there is beauty in quantum mechanics because it introduces non-deterministic uniqueness to the world. I find it funny that some people in the world like to have order in everything, and I am convinced that the Dutch and Japanese culture are a very typical example of this need for (discrete) order, and on the other side there are people in the world that accept that stuff just happens and that you need to except this. This paper is my journey in the acceptance of the chaos and unpredictability around us and the way how to accept this and organise accordingly. Or as I used to coin when I was a student '*You can not fight a tornado.*'.

This is also why I love lectures of Jan Hoogervorst[16] and his vision on Enterprise Engineering. What I took away from Hoogervorst is that we need to focus on the people around us and that stuff just will happen.

When I was young we at home had a computer with Internet at 1993, and thus from my 12th I was able to browse the internet. I loved the connection with all the knowledge online. The idea that information is now for everybody on the globe really connected with me. The concept that knowledge how to purify water, how to increase the crop yield, or how to create paracetamol was now not limited by companies and politics, but available to people everywhere in the world makes me happy every time I think about it. The previous sentence also reflects my personal distaste with authorities. This is also the reason for me not fully go religious, since how could one person explain with full confidence how the world works? We are all formed by the things we have experienced. That is how we write things down, how we read things and interpreted them. Even the brilliant minds of the previous scientists where every time reaching new levels of inside and had real big problems in conveying their ideas to the people around them. Galileo was even burned alive because people around him could not understand or accept the ideas he communicated.

Information is free and available to everyone, so the way of reasoning for people has to change. there is no superior intellect any more, nobody is subject matter experts after finishing an education on that topic. What is true, what is right, what is reality has changed fundamentally in our world after the introduction of the internet.

The free information, communication and even free knowledge sparked innovation around me during the period of 1999-2006. People at the university created the most beautiful software solutions cooperating globally. We used to collaborate via Bulletin Board Systems[17] and later on via IRC channels[18]. For the IT nerds in the period of 1993-2003 remote working was the normal. This trend of the power of the network continued over the years. The creation of open source by Richard Stallman[19] is in my opinion after the invention of the Internet the biggest force in creating the current technological innovations. Stallmans' ideas enabled knowledge to multiply and spread and so accumulating more and more value.

I am a strong believer in open source. This aligns with my conviction is that people should help each other to have a better life. It is strange to keep inventions to yourself when you needed others to create you invention. Nobody invented from scratch something. We are all standing on the shoulders of giants and should be humble about that. The only nuance in this I found in something written by Nietzsche that states that not everybody can see as far. My believe is that with over 7 billion inhabitants in the world and knowledge being free available, then chance is very slim that your view is very unique is approximately zero. This was even the case before the internet when the printing press and the microscope

[15] (Feynman, 1662)
[16] https://en.wikipedia.org/wiki/Jan_Hoogervorst (Wikipedia contributors - C, 2020n)
[17] https://en.wikipedia.org/wiki/Bulletin_board_system (Wikipedia contributors - A, 2019f)
[18] https://en.wikipedia.org/wiki/Internet_Relay_Chat (Wikipedia contributors - A, 2019s)
[19] https://en.wikipedia.org/wiki/Richard_Stallman (Wikipedia contributors - B, 2019n)

where invented at different places at the same time. Coining knowledge or an invention for yourself and only yourself is disrespectful to life and the universe.

The network as a structure became also part of organisations (agile). In agile I recognised the rice of the network organisation and the acceptance of decentralised control. Most literature about organisation design was focused on hierarchy and not on Autonomy, purpose and mastery. The lack of design patterns to support decentralised control was also not available in field as Human Resource Management, Psychology, Enterprise Architecture. Most companies operated from a command & control structure. Thus we also learned to put people to work in this frame.

During my period as a student (1999-2006) I made a few connections. I notices that database design was all about writing down relations. I noticed that matter was not matter, but just a state of energy in a certain place, but all mater was connected since it all was energy. I noticed that knowledge is not controlled by an institute but is free for everybody (information anarchy or democratisation of information). I noticed that with the mathematical work of Dijkstra[20] we could use the power of graphs as a representation of the world (just as route planners do). And that when everything is becoming more connected, then we will see more and more innovation, disruption and not by design, but just because it happens. Since the world is not a logical chain of Boolean equations anymore but a chaotic system of energy that is full of feedback loops, chaos is inevitable.

I learned later that this observation is combined in the term of living in a VUCA[21] world. The impact of this is the following:

> *You as a company or organisation can not control any more what people do, and what happens in your context.*
>
> *Random stuff will just happen.*

When I read the book the black swan from Taleb it was phrasing what I also knew: observations are not enough to predict and model the world. This made me a bit sad because this would mean the end of doing science like my big heroes, but also happy because it resonated more with my sole and expressed my dis grief with people that want to create a financial model of the world to control the live of others (insurance, mortgages, investments etc).

When I read the book antifragile from Taleb it kindled a spark inside of me. I already read a few things in this area like the s 'Teampark' (Brugman et al., 2010) and 'Schitterend Organiseren' (Hoogendoorn et al., 2006). Now Taleb wrote down what I already was feeling. We as a people need to harness the concept of antifragility to survive in this world that keeps on increasing in unpredictability and volatility. This book made me happy because it showed light at the end of the tunnel. It showed a way to create a stable place in an unstable world. How to become zen in a chaotic context.

The impact of this is big. If we learn how to organise companies to be antifragile the impact will be huge on the happiness of people. Most people work at a company and most companies are designed from a command & control structure perspective. Within these companies work is decomposed into small meaningless work packets for the employees to execute. This is called efficiency. In Europe there as a period that lean and Six Sigma where the high point of the Taylorism[22] way of optimising processes within companies. By optimizing the work the real reason (the goal) of the work is removed from the process. People are positioned to do their work as a small piece of a clockwork. Charlie Chaplin created a very nice film on this topic called "Modern Times[23]". The Dutch version of this film "Glass[24]" is also a great example of this production facility state of mind.

By designing enterprises and software from a decomposition and process optimisation point of view we achieved that most enterprises and software are effectively designed to torture people.

[20] `https://en.wikipedia.org/wiki/Dijkstra's_algorithm` (Wikipedia contributors - A, 2019m)

[21] `https://en.wikipedia.org/wiki/Volatility,_uncertainty,_complexity_and_ambiguity` (Wikipedia contributors - B, 2019t)

[22] `https://en.wikipedia.org/wiki/Scientific_management` (Wikipedia contributors - B, 2019q)

[23] `https://en.wikipedia.org/wiki/Modern_Times_(film)` (Wikipedia contributors - B, 2019f)

[24] `https://en.wikipedia.org/wiki/Glass_(1958_film)` (Wikipedia contributors - A, 2019p)

This is why I think that antifragility is relevant for the field of organisational design. Since we need a different field of design that can cope with the VUCA world around us, and the lack of purpose, mastery and autonomy is also part of the design philosophy behind antifragile. The process decomposition, the optimisation based on value measuring is the movement that triggered Taleb to look critical at how the design models and how we design companies.

We need an answer on how to design organisations that are build around decentralised autonomous units, and in such a way that people are happy and inspired to change with an positive attitude when strange stuff happens around them.

to summarise: when the world is becoming more networked (organisations, information, transportation) etc., the world is becoming more VUCA and then we need an antifragile organisation design to deal with it.

> "If you do not expect the unexpected, you will not recognise it when it arrives."
> - Heraclitus

Pillar 2 - science == hypothesis, experiment, repeat The second pillar is about science. As stated my big hero's are Galileo, Newton and da Vinci. I even have a replication of the famous self portrait of Leonardo at our kitchen wall. I believe in that reality is something else then the models we create. There are so many smart people and eloquent people out there that I can get myself to trust the reasoning of a person, I need to see it with my own eyes. This is why I could not become a big fan of Einstein, Hawking and Feynman because even their brilliant work it is so hard to see and validate if they are right. and this is perhaps just a matter of time, it took a few years before we could validate the existence of planets that Galileo and newton predicted. and it took a few years to create an atomic bomb or detect a black hole.

But until we can validate a theory and repeat the observation, until that time it is just a theory.

In computer science it is often possible to replicate a theory by just writing the algorithm yourself or by executing a load test to validate the Big O prediction of the algorithm. But when we enter organisation design, psychology and also the field of enterprise architecture, I was confronted by nothing else then theories. In a podcast of "Piece of red-meat"[25] it was stated that many research in science appeared to be proven by p-hacking, and could not be replicated. This triggered me a lead me to a podcast by "Your Not So Smart"[26] and an article published in Science (Open Science Collaboration et al., 2015) on a research[27] of 20+ international research-groups that collaborated (via the Open Science Framework platform) to individually trying to replicate the ego study, and failing.

This was striking a nerve with me. How could we call something science if we could not replicate it? in physics we build global radio dishes, or a Large Hadron Collider[28] to proof theories. Galileo threw metal balls from the tower of Pisa to proof his ideas of gravity. Why did we not do this in psychology or organisational design? Or better yet, why could we not replicate the ego-study amongst other studies.

If it is not possible to replicate the outcome of an experiment, then the theory that depends on the outcome is not good enough.

I had this discussion when I was a student with many other students. Most fellow students that studied psychology "just" took a few interviews to base their theory on. In those days I found this so very difficult to understand, and 10 years later I learned that the same is common practice in the field of Enterprise Engineering that I love so much.

And the impact of nudging is disputable, but the impact of the organisation design, where people work together more hours per day then they see their significant other has at least a big impact on the lives of people.

For me it is difficult to accept that everything we do in Enterprise Governance, Enterprise Architecture and Enterprise Engineering is without causal proof. Here and there we might have some meta studies about some kind of correlation between some high level indicators, but basically we have no idea what we are doing and why.

[25] (Hakhverdian, 2018)
[26] (McRaney, 2017)
[27] (Holcombe, 2016)
[28] `https://en.wikipedia.org/wiki/Large_Hadron_Collider` (Wikipedia contributors - B, 2019c)

During my research on this topic, I experienced how difficult it is to define at least one attribute of antifragility, and find a way to observe/measure it in a way the hints at a causal relationship. Even defining some measurements that would not affect the study object (thank you Schrödinger for messing up our view on measurements), and might hint at some correlation is very difficult. This is a field that might be to challenging for me.

So my two pillars or 'holy grail' are

1. Govern and design decentralised autonomous organisations that can survive in this VUCA world by making use of antifragile design patterns
2. create an addition to the existing Body of Knowledge that brings the field one step closer to scientific theories that can be validated and replicated.

The relevance of finding a solution to black swan problem

My experience in business and IT with over 25 companies provides me with a large quantity of examples of models that are created based on correlation in the observation and are misused as causal or deterministic models. The most recent example of this is the hype around Machine Learning (O'Neil, 2016).

My field of work is that of Enterprise and Solution Architecture. The aim of the discipline of Enterprise Architecture is to provide a coherent set of models to guide an organisation during their change activities. See also section 2.12 (Enterprise Architecture). But since most models were created by observations and therefore these models are fragile for things that happen in reality.

I prefer implementing project based on experience of people in the company where the models are used to support internal communication. This would limit the risk since practical experience trumps theoretical knowledge (Taleb, 2007).

I am very reluctant in implementing organisational and IT changes through projects whose design is purely based on models. Since this would result in creating a fragile organisation or IT solution for my clients.

For example: implementing the scaled agile model of Spotify, a company with 30 teams, at a big organisation of 300+ teams is, in my opinion, a risky endeavour. Since you create a very large organisation that is fragile to a black swan event, and the costs of this black swan and time needed to recuperate is at the scale of 300+ teams many times higher then at the scale of 30 teams. This is why the work of Taleb is relevant for my work and has led to the topic of my thesis.

A small addition to the existing Body of Knowledge.

My original goal was to find an existing model that would define how to create/design an antifragile organisation. I could not find this existing model or methods. I could also not find a shared definition on what antifragility is, and how to become antifragile. This also made it impossible to replicate and evaluate an existing study on designing an antifragile organisation.

There are various papers and a few master theses that provide a collection of attributes of a system that are needed to become resilient or even antifragile. See also section 3.4 (Literature review). One of the observations made is that every paper and thesis is referencing supportive papers from other domains, but there is not that much overlap in referencing other work on antifragility.

I provide in Appendix C a highlight selection from the existing Body of Knowledge. In section 1.8 (Examples of the application of antifragility) I provide some examples from the Body of Knowledge on the creation of antifragile systems.

Since the field of antifragility is very young I am able to include a large portion of the available Body of Knowledge in my thesis. My hope is that by making this research publicly available, other researchers are able to add to the collected Body of Knowledge and extend on the summary I present in this thesis. See also section 3.6 (Applied research tooling and infrastructure).

In retrospect I am proud of the work done, thankful for have been given this opportunity and humbled by how strange and complex the world is.

B Five page Executive Summary

An enterprise is an intentionally created Complex Adaptive System (CAS) consisting of co-operating human beings with a certain social purpose, whereby it is impossible to determine the ultimate (operational) reality of the enterprise down to the minute details (Dietz et al., 2013, p. 93-94). A CAS is a type of a non-linear dynamical system in the field of Complexity Science and Systems Engineering (Lansing, 2003). Most, if not all, enterprises operate in a context which is described as Volatile, Uncertain, Complex and Ambiguous (VUCA) (Hutchins, 2018; Mack et al., 2015; Bennett and Lemoine, 2014b,a). Black swans (or X-events) are defined as an stressor events in the VUCA domain that have a disruptive impact on a fragile and robust system and are non-predictable (Taleb, 2007; Casti, 2012; Hole, 2016, p. 14).

B.1 Staying relevant as an enterprise

The goal of an enterprise is to remain significant for its stakeholders. Stakeholders are owners, employees and consumers (Op't Land et al., 2008, p. 10, 13). The challenge for enterprises is to stay relevant in the current VUCA world and regain their 'value' after being disrupted by a black swan stressor event.

B.1.1 Antifragile: Staying relevant as an enterprise in a VUCA world

Nassim Taleb provides in his book "Antifragile" (2012) a way of thought that there is an organisation implementation which enables an organisation to gain value from the exposure to (outside) stressors. Antifragile organisations are placed within the domain of CAS (Kennon et al., 2015). An organisation is a System-of-Systems (SEBoK, 2019; Senge, 1990; Taleb, 2012). An Antifragile organisation is a System-of-Systems that contains at least one fragile and one robust system. Taleb provides numerous examples and principles of antifragility. Taleb reasons that an antifragile organisation is the only way to survive a black swan event and therefore is mandatory to stay relevant in a VUCA world (Taleb, 2012).

B.2 The triad: fragile, robust and antifragile

Antifragile is the antithesis of fragile. Antifragile is the concept of gaining value from exposure to stressors. Fragile is the concept of losing value from exposure to stressors. The concept of stressors having no effect on the value is called robust. Fragile, robust and antifragile form together a triad (Taleb, 2012, p. 34; Gorgeon, 2015, p. 3; Hole, 2016, p. 7). Resilience is used in overlap with antifragility and robust systems. There is no clear definition of resilience. In this study we use the definition of resilience given by Martin-Breen and Anderies (2011). Resilience is placed in between robust and antifragility (see figure B.1).

B.3 Fragile, robust and antifragile are behaviours on stress.

Fragile systems behave concave & antifragile systems behave convex in value as response to volatility and stressors (see figure B.2) (Ghasemi and Alizadeh, 2017, p. 24). Robust systems are ignorant to volatility and stressors. Fragile, robust and antifragile is behaviour of a system that is defined by the value as output where stress is provided as input of the system.

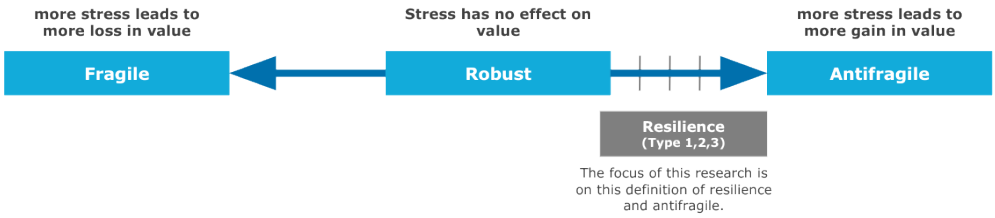

FIGURE B.1: Fragile, Robust, Antifragile and Resilience.

B.4 Resilience is behaviour in time.

Resilience is a type of a system between being a robust system and an antifragile system (Taleb, 2012, p. 17; De Florio, 2014, p. 838; Aven, 2015, p. 477; Gorgeon, 2015, p. 4; Ghasemi and Alizadeh, 2017, p. 23; Passos et al., 2018, p. 7). Resilience is the behaviour of a system expressed in the value over time after an stressor event (see figure B.2). For resilience we adopt the definition provided by (Kastner, 2017, sec. I.2.2) and (Martin-Breen and Anderies, 2011, p. 5).

1. **Engineering Resilience** is the behaviour of a system where the function and the construction of the system stays the same over time.
2. **Systems Resilience** is the behaviour of the system where the function of the systems stays the same over time, the construction of the system may change.
3. **Complex Adaptive Systems Resilience** is the behaviour of the system where the function of the system may change and the construction of the system may change over time.

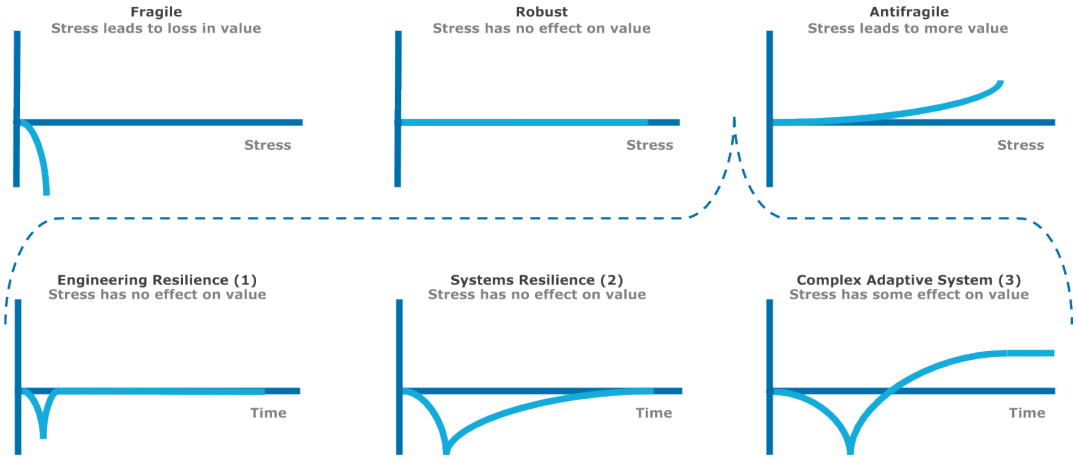

FIGURE B.2: Fragile systems behave concave to stress.
Antifragile systems behave convex to stress.
Robust systems are ignorant to stress.
Resilience sits between robust and antifragile.

B.5 Research on the definition of Antifragility

Since 2012 many articles, research papers, master theses and books were published on the topic of antifragility. The definitions in the literature of antifragile and resilience overlap. Most of the literature reasons which attributes *might* play a role for a system to be antifragile, or how the concept of antifragile *can* add value to a specific domain. Some of the existing research *prescribe* design activities on how to create antifragile software as a specific system domain (O'Reilly, 2019; Zwieback, 2014; Wikipedia contributors - A, 2019g).

I did not find a clear set of attributes on how to design an antifragile organisation. I did not find a clear overall set of attributes applicable to an antifragile system. I provide in this thesis an overview of the attributes that a resilient and/or antifragile system needs to have.

B.5.1 Research Question

The research questions are: *"Can leaders determine if their organisation must be resilient or antifragile? When applicable, does the "resilient ór antifragile model" support the leadership in determining what change is needed to achieve an resilient or antifragile organisation?"*

B.5.2 Research Method

This research applies the triangulation method and consists of the following steps (figure B.3).

1. Create a model based on existing literature.
2. Validate the model with experts.
3. Validate the model with practitioners.

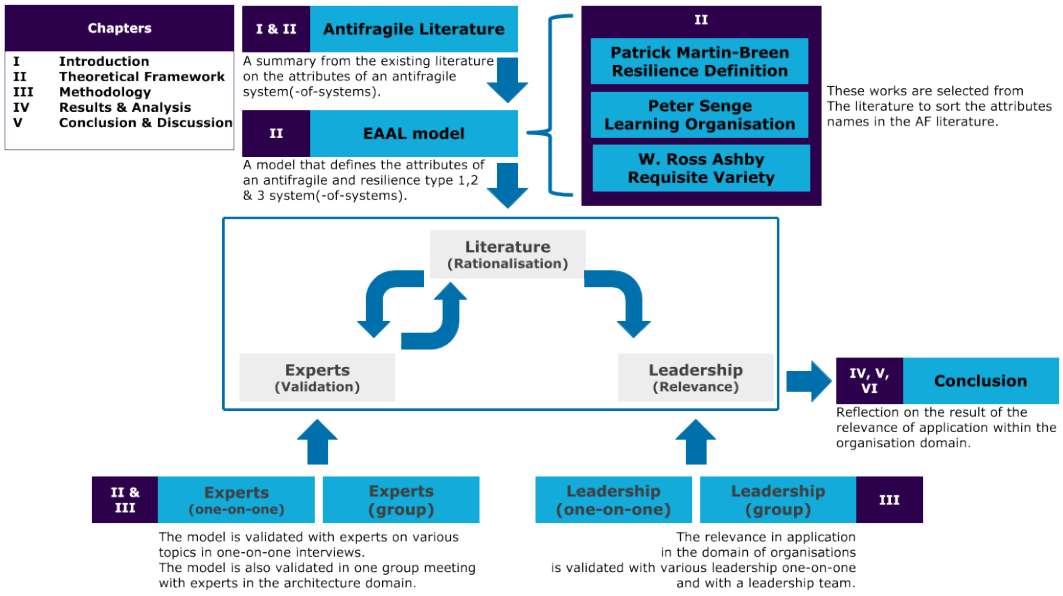

FIGURE B.3: Conceptual Research Model.

B.5.3 Research step one - Create a model based on existing literature

Most papers on antifragility discuss the theoretical application of the antifragile concept. Most papers on antifragility combine resilience and antifragility in their list of attributes of an antifragile system. During this research a holistic model is created. This model is created by grouping the attributes found in the literature applying a decision-tree. Followed by summarising (normalising) the attributes per created group.

I have created the decision-tree by combining the three types of resilience provided by Martin-Breen and Anderies (2011), the 5th discipline defined by Senge (1990); Flood (1999), Requisite Variety as defined by Ashby (1958); Hoogervorst (2015) and the definition of antifragility as provided by Taleb (2012). This results in the model visualised in figure B.4.

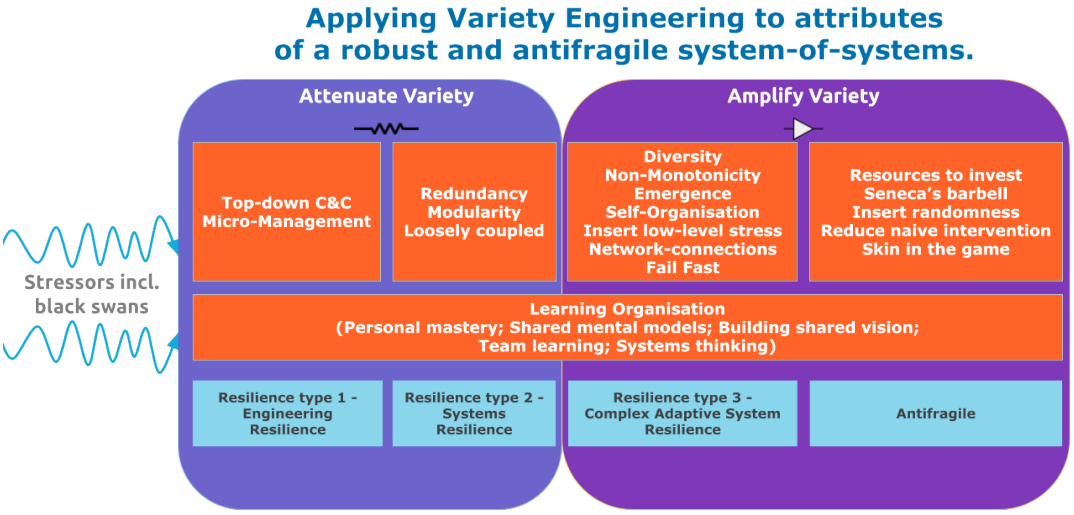

FIGURE B.4: Applying Variety Engineering
to attributes of a resilient and antifragile system-of-systems.

B.5.4 Research step two - Validate the model with experts

The validation of the model is done by applying two methods. Method one is approaching various experts in one-on-one conversations and use the feedback to improve the model. Experts from the field of Enterprise Engineering (5[1]) and of Antifragility (5[2]) where involved. Method two is presenting the model to a group. The model was presented to two different groups. One group of three[3] Enterprise architects and one group of ten[4] Enterprise Architects. Since the literature offers no concrete guidelines on methodology, models and definitions, this double loop method is used to ensure that the model is consistent and not contrary to existing models and theories. By involving the Enterprise Engineering and Antifragility experts the double loop ensures that the model is a realistic representation of the existing view on resilient and antifragile organisations.

B.5.5 Research step three - Validate the model with Practitioners

The model has value when it can be applied. Application of the model in the organisation domain is done by leadership that has the authority to (re-)design organisations. Therefore the validation of the application of this model needs to be done with leadership in organisations. This research applied interviews with five leaders separately and one interview with a group of two. The organisations were two in aviation, one in retail, one government, one NGO and two universities.

[1] HM, HN, AvdH, BN, MvD
[2] BO, NvL, DK, DvH, CvH
[3] MvS, TE, HN
[4] MvS, TE, AvdH, MA, WdN, WdB, YC, PA, RK, MB

B.5.6 Research result

This research adds to the current Body of Knowledge:

1. A model (figure B.1) that provides an overview of the three types of resilience positioned between robust and antifragile, so that behaviour of the system-of-systems can be identified.
2. A model (figure B.4) that provides a definition of antifragility and the three types of resilience.
3. A process of validation by experts that can easily be replicated.
4. A process of validation of application that can easily be replicated and/or extended to other application domains.

This research adds to the organisations:

1. the ability to discuss and identify the behaviour that they see indispensable for their organisation.
2. having a discussion and analysis of the attributes in the organisation, including the sub-systems in the organisation.

B.6 Conclusion

Within the limitations of the research, the created model provides a definition of Antifragility based on the available Body of Knowledge. This model provides insight into which attributes are relevant for a resilient system-of-systems and which attributes are relevant for a antifragile system-of-systems. The model provides inspiration with experts and practitioners. This model serves as a stepping stone for further research and discussion about the design of an organisation.

C Appendix - Antifragile literature Highlights

introduction

This selection of research has been highlighted since it provides a nice overview of the antifragile Body of Knowledge.

Each of these are a pleasure to read.

The combination of the work below do not create a complete overview of the field of antifragility. In defence of the highlighted work, this is also the case for all work on antifragility combined. See also section 3.1.7.

C.1 Books

1. Antifragile: Things That Gain from Disorder (Taleb, 2012).
2. The Black Swan: The Impact of the Highly Improbable (Taleb, 2007).
3. Anti-fragile ICT Systems (Hole, 2016).

C.2 Master Thesis

1. Antifragile Organisation Design: A framework of Self-Organisation practices in today's complex and unpredictable economy (Kastner, 2017).
2. To Master Disaster: How SME managers can thrive and benefit from economic crises (Henriksson et al., 2016).

C.3 Papers

1. Antifragility analysis and measurement framework for systems of systems (Johnson and Gheorghe, 2013).
2. Anti-Fragile Information Systems (Gorgeon, 2015).
3. An alternative view to assessing antifragility in an organisation: A case study in a manufacturing SME (Kennon et al., 2015).
4. On some recent definitions and analysis frameworks for risk, vulnerability, and resilience (Aven, 2011).
5. The risk concept—historical and recent development trends (Aven, 2012).
6. The Concept of Antifragility and its Implications for the Practice of Risk Analysis (Aven, 2015).
7. No More Snake Oil: Architecting Agility through Antifragility (O'Reilly, 2019).

D Appendix - Antifragility Papers

Introduction

In this appendix I collected the papers read on the topic of antifragility and categorized them.

The content of this Appendix is the following:

D.1 Organisation

These are papers mentioned in the antifragile literature and focus mainly on organisations and the human factor. This list is alphabetical organised.

1. Ahuja and Katila, 2004, Where do resources come from? the role of idiosyncraticsituations. Strategic Management Journal, 25(8-9):887–907.
2. Ambler, 2009, The agile scaling model (asm): Adapting agile methods for complex environments. Environments, pages 1–35.
3. Beck et al., 2006, The determinants of financing obstacles. Journal of International Money and Finance, 25(6):932–952.
4. Dobbs and Hamilton, 2007, Small business growth: recent evidence and new directions. International journal of entrepreneurial behaviour & research, 13(5):296–322.
5. Eckardt, 2018, Company maturity matrix. EMAJ: Emerging Markets Journal, 8(1):28–30.
6. Feindt et al., 2002, Identifying success factors for rapid growth in sme e-commerce. Small Business Economics, 19:51–62.
7. Jaaron and Backhouse, 2014a, Building antifragility in service organisations: Going beyond resilience. International Journal of Services and Operations Management, 19(4):491–513.
8. Jaaron and Backhouse, 2014b, Learning from chaos: the advent of antifragility in service organisations. In Proceedings of the 2014 POMS International Conference, Singapore,pages 1–8
9. Kinneen and Younas, 2018, Self-managing organisations in the context of entrepreneurial innovation. Master's thesis, Uppsala University, Department of BusinessStudies, Uppsala, Sweden.
10. Love and Roper, 2015, SME innovation, exporting and growth: A review of existing evidence. International small business journal, 33(1):28–48.
11. Madrid-Guijarro et al., 2009, Barriers to innovation among spanish manufacturing smes. Journal of Small Business Management, 47(4):465–488.

12. Maveau, 2017, Agile organisations and human potential: in need for fast zebra's? Master's thesis, University of Gent, Master of Science in de Handelswetenschappen, Gent, Belgium.

13. Mazzei and Ravazzani, 2015, Internal crisis communication strategies to protect trust relationships: A study of italian companies. International Journal of Business Communication, 52(3):319–337.

14. Pincus et al., 2017, Nonlinear dynamical systems and humanistic psychology. Journal of Humanistic Psychology, 58(3):343–366

15. Porter, 1996, What is strategy? Harvard Business Review, 74(6):61–78

16. Rupeika-Apoga and Danovi, 2015, Availability of alternative financial resources for smes as a critical part of the entrepreneurial ecosystem: Latvia and Italy . Procedia Economics and Finance, 33:200–210

17. Simpson et al., 2012, Towards a new model of success and performance in smes. International journal of entrepreneurial Behavior & Research,18(3):264–285

18. Smallbone et al., 2012, small business responses to a major economic downturn: Empirical perspectives from New Zealand and the United Kingdom. International Small Business Journal, 30(7):754–777.

19. Vargo and Seville, 2011, Crisis strategic planning for smes: finding the silver lining. International Journal of Production Research, 49(18):5619–5635.

D.2 Risk and Resilience

These are papers mentioned in the antifragile literature and focus mainly on Risk, Robust, fragile, resilience, emergence, entropy, chaos, unpredictability and stress

1. Aven, 2011, On some recent definitions and analysis frameworks for risk, vulnerability,and resilience. Risk Analysis: An International Journal, 31(4):515–522
2. Aven, 2012, The risk concept — historical and recent development trends. Reliability Engineering & System Safety, 99:33–44.
3. Aven, 2015, The concept of antifragility and its implications for the practice of risk analysis.Risk Analysis, 35(3):476–483.
4. Augusto Wrede and Simari, 2001, Temporal defeasible reasoning.Knowl. Inf. Syst.,3:287–318
5. Bennett and Lemoine, 2014a, What a difference a word makes: Understanding threats to performance in a vuca world.Business Horizons, 57(3):311 – 317
6. Bera et al., 2017, Randomness inquantum mechanics: philosophy, physics and technology.Reports on Progress in Physics,80(12):124001.
7. Bradnick, 2008, A pentecostal perspective on entropy, emergent systems, and eschatology. ZygonR©, Journal of Religion and Science, 43:925–942
8. Bradt, 2011, The fractography and crack patterns of broken glass.Journal of Failure Analysis and Prevention, 11(2):79–96
9. Chakrabarti and De, 2000, Boltzmann-gibbs entropy: Axiomatic characterisation and application.International Journal of Mathematics and Mathematical Sciences, 23:243–251.
10. Christen and Franklin, 2002, The concept of emergence in complexity science:Finding coherence between theory and practice.Proceedings of the Complex Systems Summer-School, 4
11. Chrousos, 2009, Stress and disorders of the stress system.Nature reviews endocrinology,5(7):374–381
12. Crutchfield, 2009, The hidden fragility of complex systems— consequences of change,changing consequences.Cultures of Change: Social Atoms and Electronic Lives, 98-111:98–111
13. Derbyshire and Wright, 2014, Preparing for the future: Development of an 'antifragile'methodology that complements scenario planning by omitting causation.Technological Forecasting and Social Change, 82:215–225
14. Governatori and Terenziani, 2007, Temporal extensions to defeasible logic. In Orgun,M. A. and Thornton, J., editors,AI 2007: Advances in Artificial Intelligence, pages 476–485,Berlin, Heidelberg, Germany. Springer
15. Kraus et al., 2012, Entrepreneurial orientation and the business performance of smes: a quantitative study from the Netherlands. Review of Managerial Science, 6(2):161–182
16. Liu and Thompson, 2002, Randomness: Rethinking the foundation of probability.In Proceedings of the twenty fourth annual meeting of the North American chapter of the International Group for the Psychology of Mathematics Education, Athens, GA, volume 3, pages1331–133
17. Makridakis and Taleb, 2009a, Forecasting and uncertainty in the economic and business world.International Journal of Forecasting, 25(4):794–812
18. Makridakis and Taleb, 2009b, Decision making and planning under low levels of predictability.International Journal of Forecasting, 25(4):716–733.
19. Martin-Breen and Anderies, 2011, The bellagio initiative, background paper, resilience: A literature review. In Resilience: A Literature Review, Brighton:IDS.

20. Nute, 2003, Defeasible logic. In Bartenstein, O., Geske, U., Hannebauer, M., and Yoshie,O., editors,Web Knowledge Management and Decision Support, pages 151–169, Heidelberg,Berlin, Germany. Springer Berlin Heidelberg

21. Potsangbam, 2017, Adaptive performance in vuca era – where is research going?International Journal of Management (IJM), 8(6):99–108.

22. Santos, 2012, why resilience?ä review of literature of resilience and implications for further educational research. In Review of Resilience Research, Claremont, CA. Claremont Graduate University & San Diego State University

23. Scholz et al., 2012, Risk, vulnerability, robustness, and resilience from a decision-theoretic perspective.Journal of Risk Research, 15(3):313–330

24. Ruiz-Martin et al., 2018, What we know and do not know about organisational resilience.International Journal of Production Management andEngineering, 6(1):11–28

25. Taleb et al., 2009, The six mistakes executives make in risk management.Harvard Business Review, 87(10):78–81

26. Walker et al., 2004, Resilience, adaptabilityand transformability in social–ecological systems.Ecology and society, 9(2).

27. Wang et al., 2017, Analysis of the definitions of resilience.IFAC-PapersOnLine, 50(1):10649–10657.

D.3 Antifragile

These are papers mentioned in the antifragile literature and focus mainly on antifragility itself.

1. Ansar et al., 2017, Big is fragile: An attempt at theorising scale.The Oxford Handbook of Mega project Management, 84:60–95

2. Danchin et al., 2011, Antifragility and tinkering in biology (and in business) flexibility provides an efficient epigenetic way to manage risk.Genes, 2(4):998–1016

3. Feygenson and Feygenson, 2017, Modern triz and the concept of antifragility.friends, enemies or frenemies? In The 13th International Conference. TRIZfest-2017

4. Ghasemi and Alizadeh, 2017, Evaluating organisational antifragility via fuzzy logic. the case of an Iranian company producing banknotes and security paper.Operations Research and Decisions, 1:21–43.

5. Grube et al., 2013, Niches and Adaptations of Polyextremotolerant Black Fungi, volume 27, pages 551–566. Springer, Dordrecht, the Netherlands

6. Jones, 2014, . Engineering antifragile systems: A change in design philosophy. Procedia computer science, 32:870–875

7. Kennon et al., 2015, An alternative view to assessing antifragility in an organisation: A case study in a manufacturing sme. CIRP annals :manufacturing technology, 64:177–180.

8. Markey-Towler, 2018, Antifragility, the black swan and psychology.Evolutionary and Institutional Economics Review, 15(2):367–384

9. Martinetti et al., 2017, Storytelling as a strategy in managing complex systems: using antifragility for handling an uncertain future in reliability.Safety and Reliability, 37(4):233–247

10. Passos et al., 2018, From resilience to the design of antifragility. In pesaro 2018, volume 1, pages 7–11.

11. Pineda et al., 2018, Antifragility of random booleannetworks.arXiv preprint arXiv:1812.06760, abs/1812.06760

12. Starossek et al., 2011, Report of the terminology and procedures sub-committee (sc1): Recommendations for design against disproportionate collapse of structures. In Structures Congress 2011,pages 2090–2103

13. Taleb and Douady, 2013, Mathematical definition, mapping, and detection of(anti) fragility.Quantitative Finance, 13(11):1677–1689

14. Tseitlin, 2013, The antifragile organisation.Communications of the ACM, 56(8):40–44

D.4 Complexity Science

These are papers mentioned in the antifragile literature and focus mainly on Complexity Science.

1. Bennett and McGinnis, 2008, Coupled and complex: Human–environment interaction in the greater Yellowstone ecosystem, USA. Geoforum, 39(2):833–845

2. Buldyrev et al., 2010, Catastrophic cascade of failures in interdependent networks.Nature, 464(7291):1025

3. Dahlberg, 2015, Resilience and complexity: Conjoining the discourses of two contested concepts. Culture Unbound: Journal of Current Cultural Research, 7(3):541–557.

4. Dietz et al., 2013, The discipline of enterprise engineering.International Journal of Organisational Design and Engineering, 3:86–114

5. Kurtz and Snowden, 2003, The new dynamics of strategy: Sense-making in a complex and complicated world.IBM systems journal, 42(3):462–483

6. Liening, 2013, The breakdown of the traditional mechanistic worldview, the development of complexity sciences and the pretence of knowledge in economics.Modern Economy, 4(04):305

7. Nurmi et al., 2019, Systems Approaches in the Enterprise Architecture Field of Research: A Systematic Literature Review, pages 18–38. Springer International Publishing, Cham.

8. Wojcik and Hoffman, 2006, Systems of systems engineering in the enterprise context: a unifying framework for dynamics. In 2006 IEEE/SMC International Conference on System of Systems Engineering, pages 8–pp

D.5 Antifragile & IT

These are papers mentioned in the antifragile literature and focus mainly on antifragility and IT.

1. Proper and Lankhorst, 2014, Enterprise architecture – towards essential sense-making. Enterprise Modelling and Information Systems Architectures, 9:5–21.

2. Abid et al., 2014, Toward antifragile cloud computing infrastructures. Procedia Computer Science, 32:850– 855.

3. Monperrus, 2017, In Companion to the First International Conference on the Art, Science and Engineering of Programming, Programming '17, pages 1–4, New York, NY, USA. ACM.

4. Ramirez and Itoh, 2014, An initial approach towards the implementation of human error identification services for antifragile systems. In 2014 Proceedings of the SICE Annual Conference (SICE), pages 2031–2036.

5. Rinaldi et al., 2001, Identifying, understanding, and analyzing critical infrastructure interdependencies. IEEE Control Systems, 21(6):11–25.

6. Müller et al., 2013, Resilience-a new research field in business information systems? In International Conference on Business Information Systems, pages 3–14.

7. O'Reilly, 2019, No more snake oil: Architecting agility through antifragility. Procedia Computer Science, 151:884–890.

8. Russo and Ciancarini, 2016, A proposal for an antifragile software manifesto. Procedia Computer Science, 83:982–987.

9. Gorgeon, 2015, Anti-fragile information systems (completed research paper). In Anti-fragile Information Systems, Fort Worth.

10. Guang et al., 2014, Positioning antifragility for clouds on public infrastructures. Procedia Computer Science, 32:856–861

11. Kim et al., 2019, A multilayer structure facilitates the production of antifragile systems in boolean network models. arXiv preprint arXiv:1902.11214, abs/1902.11214:15

12. Monperrus, 2017, Principles of antifragile software. In Companion to the First International Conference on the Art, Science and Engineering of Programming, Programming '17, pages 1–4, New York, NY, USA. ACM.

13. Lehman, 1980, Programs, life cycles, and laws of software evolution. Proceedings of the IEEE, 68(9):1060–1076.

14. Lehman, 1996 Laws of software evolution revisited. In Proceedings of the 5th European Workshop on Software Process Technology, EWSPT '96, pages 108–124, Berlin, Heidelberg. Springer-Verlag.

D.6 Science

These are papers mentioned in the antifragile literature and focus mainly on that science is limited by observation.

1. Bar-Yam, 2013, The limits of phenomenology: From behaviorism to drug testing and engineering design. New England Complex Systems Institute (NECSI) Report, 2013-08-01.

2. Turner et al., 2003, A framework for vulnerability analysis in sustainability science. Proceedings of the national academy of sciences, 100(14):8074–8079.

3. Tversky and Kahneman, 1974, Judgment under uncertainty: Heuristics and biases. Science, 185(4157):1124–1131.

4. Open Science Collaboration et al., 2015, Estimating the reproducibility of psychological science. Science, 349(6251).

5. Zeng et al., 2017 The science of science: From the perspective of complex systems. Physics Reports, 714:1–73.

E Appendix - Antifragile literature Summary

Introduction

For a selection of the papers read on antifragility, I kept notes on the summary of the content of these papers. In addition I categorized the content of the paper on scientific relevance.

The content of this Appendix is the following:

E.1 Summary of Body of Knowledge on the relevance of Antifragile

1. (Abid et al., 2014) - proposal to use Simian Army concepts for cloud infrastructure (VM's).
   Mainly reasoning

2. (Guang et al., 2014) - argumentation that cloud services should be designed to be antifragile.
   Mainly reasoning

3. (Aven, 2015) - usage of a high-low indicator of vulnerability and a non disclosed dataset of oil-spills and leakages.
   Mainly reasoning.

4. (Eckardt, 2018) - combining antifragile theory into a two-by-two maturity matrix for companies.
   Mainly reasoning.

5. (Feygenson and Feygenson, 2017) - exploration of antifragile to the Theory of Inventive Problem Solving (TRIZ).
   Mainly reasoning.

6. (Grube et al., 2013) - Study on one type of fungi if the attribute of resilience by redundancy can be observed.

7. (Helbing, 2010) - the role of network (organisation) in dealing with the unknown unknown (black swan) in Dynamic complex environment (complexity science).
   Mainly reasoning.

8. (Jones, 2014) - reasoning that antifragile is not yet applied in aerospace (NASA) but can add value and provides examples of ongoing research towards this goal.
   Mainly reasoning.

9. (Kinneen and Younas, 2018) - this study interviewed 5 companies on their organisation achievements. (holocracy, sociocrazy). Antifragile was one of the attributes of the companies.
   No clear conclusion.

10. (Martinetti et al., 2017) - this paper states that the dutch railway company (NS) needs to embrace and being able to deal with antifragile context. and that storytelling can be a way to deal with antifragile problems.
Mainly reasoning.

11. (Monperrus, 2017) - this paper states that Software Engineering needs to adopt the ideas behind antifragility. It states "This is only the beginning of antifragile software engineering. Beyond the vision presented here, research now has to devise sound engineering principles and techniques regarding self-checking, self-repair and fault injection in production."
Mainly reasoning.

12. (Müller et al., 2013) - this paper argues that the field of resilience needs definitions and empirical research (antifragile is not named but the content is near this topic): "Despite the wide spread of resilience across multiple disciplines, a number of open research issues remain. These encompass conceptual and definitions vagueness of resilience, a lack of empirical research and a lack of applicable (organisational) solutions and IT-artifacts to bring resilience into action."
Mainly reasoning.

13. (Passos et al., 2018) - this paper defines antifragility as a new form of resilience based on literature study. "at the end of this work and after a vast review of the studies cited here, it is noticed that the increase in complexity and the introduction of ICT in our daily life triggered the process of evolution of resilience, which in its most advanced stage appears as antifragility."
Mainly reasoning.

E.2 Field of Antifragile - Body of Knowledge on Antifragile properties

(a) (Derbyshire and Wright, 2014) - literature based definition of antifragile. Proposal for a strategy workshop implementing Antifragile.
Mainly reasoning. —> EB These methods are (exclusive Antifragilemethods) [Derbyshire and Wright, 2014]:1) "Controlling the dispersion of outcomes"2) "Hormesis"3) "Redundancy"4) "Small-scale experimentation (trail and error)"

(b) (Ghasemi and Alizadeh, 2017) - "This paper describes questionnaire research based on a field survey. ... The study population consists of about 70 employees who are familiar with strategic and quality management." one company (TAKAB). List of criteria is based upon (Jackson and Ferris, 2013). See also appendix F.2.

(c) (Gorgeon, 2015) - A list of properties provided by Taleb is validated by literature and combine it with COBIT5 framework on Information System (IS) related processes into a mapping of antifragile properties vs IS processes.
Mainly reasoning. See also appendix F.5.

(d) (Helbing, 2013) - Drivers and examples of systemic instabilities (anti-antifragile properties)
EB: to be added into appendices

(e) (Henriksson et al., 2016) - Extensive literature study combined with Qualitative case studies by semi-interviews of seven Swedish SMEs.

(f) (Jaaron and Backhouse, 2014a) - introduced the Vanguard method for learning organisations, covered two case study companies. Also extensive reasoning.
EB: to be added into appendices

(g) (Johnson IV et al., 2013) - Theory of SOS Entropy and Emergence. Nice list of attributed that optimize (positive) emergent. research on an ant colony. Mainly reasoning.
EB: to be added into appendices?

(h) (Johnson and Gheorghe, 2013) - List of criteria composed by summarizing (Jackson and Ferris, 2013) (based upon 10 case studies), (Taleb, 2012) and (Casti, 2012). Reused by (Kennon et al., 2015) and (Ghasemi and Alizadeh, 2017)
Mainly reasoning.

(i) (Kennon et al., 2015) - Applied the criteria defined by (Johnson and Gheorghe, 2013) and applied it to an/one electro-vehicle assembly company based in the Western Cape, South Africa.

14. (Markey-Towler, 2018) - attributes of antifragile personality defined, based on literate.
Mainly reasoning.

15. (Maveau, 2017) - attributes of an fast zebra organisation that should also be antifragile.
Mainly reasoning.

16. (Ramirez and Itoh, 2014) Carlos A. Ramirez - This paper defines three areas a antifragile systems should include. Learning of what happened, modelling of external systems, self assessment. It results in a model of a software system to build.
Mainly reasoning.

E.3 Field of Antifragile - Body of Knowledge on Fragile properties

1. (Ansar et al., 2017) - Theoretical definition of fragile and argument that bigger dams are more fragile.
Mainly reasoning.

E.4 Field of Antifragile - Body of Knowledge that I don't understand

1. (Kim et al., 2019) - we recently proposed a novel metric that quantifies antifragility (Pineda et al., 2018). By comparing single-layer and multi-layer Boolean networks based on our recently proposed antifragility measure, we found that the multi-layer structure facilitated the production of antifragile systems.

2. (Pineda et al., 2018) - Here we propose a simply calculable measure of antifragility, based on the change of "satisfaction" before and after adding perturbations, and apply it to random Boolean networks (RBNs). Using the measure, we found that ordered RBNs are the most antifragile.

F Appendix - Antifragility descriptions in the literature

In several papers and books there is a description of attributes of antifragile systems. In this appendix the attribute sets that I could find in the Body of Knowledge.

The content of this Appendix is the following:

F.1 Asymmetry test

The Symmetry test is quoted in (Aven, 2015, p. 480) as a way to determine antifragility and fragility.

> "We can estimate and measure fragility and antifragility, as they are part of the current property of an object (Taleb, 2012), (Starossek et al., 2011)."

1. **Asymmetry Test 1**

   > "Anything that has more upside than downside from random events (or certain shocks) is antifragile, the reverse is fragile."

2. **Asymmetry Test 2**

   > "For the fragile, shocks bring higher harm as their intensity increases (up to a limit), and for the antifragile, shocks bring more benefit (equivalently less harm) as their intensity increases (up to a point)."

F.2 System Criteria to analyze antifragility

"Antifragility cannot be increased without decreasing fragility, just as light cannot be made more intense without reducing darkness, or wealth raised without diminishing poverty. Hence, we can assess antifragility and fragility through a test of asymmetry: any system that responds negatively to unexpected events or certain types of stress is fragile; the reverse situation corresponds to antifragility. Accordingly, we can specify the fragility of a system and decrease it, in order to increase antifragility" (Ghasemi and Alizadeh, 2017, p. 25)

1. **Absorption**

   "The ability of a system to absorb shocks will increase as a result of designing margins to increase the magnitude and duration of shocks that the system can withstand during a crisis, to ensure that it continues being in an intended state. The greater the robustness, the higher the level of antifragility."

2. **Redundancy**

   "Having multiple criteria that can carry out a function, or multiple ways of meeting the same purpose, creates excess system capacity and is an effective form of defense when X-events happen. Redundancy tends to enhance robustness and make systems less fragile and more antifragile."

3. **Introduction of low level stress Eliminating stress**

   "Eliminating stress from systems or attempting to reduce uncertainty in them can lead to weakness, fragility, and expose them to serious X-events. Regularly exerting low levels of stress on a system increases its robustness and can result in antifragility when the system learns from these controlled levels of stress."

4. **Non-monotonicity**

   "Learning from failures and negative consequences can be an effective defense against stressors and create new information. As new data become available, it overcomes previous thinking (Augusto Wrede and Simari, 2001), (Governatori and Terenziani, 2007), which can lead to new approaches, improve the system and increase antifragility."

5. **Requisite variety**

   "There are regulators in the system attempting to control the consequences of the behavior of agents. When the number of regulators is inadequate, the behavior of the system cannot be anticipated precisely and black swan events emerge. Thus the more regulators, the greater antifragility."

6. **Emergence**

   "When there is little or no traceability between the micro and macro level, output is said to be emergent, the frequency of unintended states increases and X-events appear. Conversely, when there are cause-effect relationships between the activity of criteria at micro level and outcomes at macro level, the system output is said to be resultant which results in greater antifragility (Christen and Franklin, 2002)."

7. **Uncoupling**

   "Failures can reverberate through firmly coupled systems increasing in amplitude and potentially leading to disaster. The lower the degree of coupling between systems and system criteria, the more antifragile the system becomes."

F.3 Antifragile organisation design

“tbd (Kastner, 2017)“

1. **Self-organisation**
   tbd
2. **Ownership (result based system /’Skin in the game’)**
   tbd
3. **Diversity of Cells and organisational Learning**
   tbd
4. **DNA- Shared purpose, values and culture**
   tbd

F.4 Antifragile organisation aspects

To understand how managers can influence towards an antifragile organisation, the areas Strategy, Opportunity and Motivation are defined by (Henriksson et al., 2016, p. 18-30).

1. **Strategy**

   "The strategy of an SME has a clear importance of how the SME perform; the different strategies of the firms affect the survival and growth. The strategy is the core of a firm's performance and the way they interact with the external environment. The different strategies of the SMEs are a clear factor in the success of the firm (Philip, 2011), (Simpson et al., 2012). Nevertheless the strategy of a firm is hard to define and is different for every firm (Smallbone et al., 2012), (Vargo and Seville, 2011). ... (Taleb, 2012) and (Tseitlin, 2013) go beyond and explain, that every random event brings its own opportunity in the form of a variation, which implicates the importance of keeping the strategy current and adopting it based on the changing circumstances (Porter, 1996), (Mintzberg, 1994b), (Kotler and Caslione, 2009)."

2. **Strategy - Design versus emergence**

   "As a manager you can choose if you want formulate a company's strategy throughout a rational systematic process on one hand (Porter, 1996), or on the other hand react fast to events in a turbulent world within guidelines and goals (Grant, 2013), (Mintzberg, 1994b). ... (Grant, 2013) named Bain & Company advocates as an example which used of strategic principles to combine flexibility with adaptability and keep a consistent focus. Also (Vargo and Seville, 2011) found that adaptability and flexibility regarding the strategy especially during times of economic crisis is very important."

3. **Strategy - Seneca's barbell strategy**

   "In his literature "Antifragile: Things that gain from Disorder", (Taleb, 2012) describes Seneca's barbell as a strategy, in which a barbell comprehends a solution to uncertainty. The author found that a so called bimodal strategy is necessary to maintain a balance between the low risk 'down' and high risk 'up'. ... This approach is also supported by Kotler and Caslione (Kotler and Caslione, 2009) in the book "Chaotics". Kotler and Caslione (2009) call it a "two playbook strategy" in which two different strategies for one subject are found; one for down-markets and one other for upmarkets. ... But Kotler and Caslione (Kotler and Caslione, 2009) show, that managers must see change first-hand. Managers must eliminate the filters and must accept the inevitability of strategy decay."

4. **Opportunities**

   "(Peters and Peters, 1987) explains that an opportunity is a chance for a company to change or expand the business. An opportunity is something for example: a new market or new technology that comes along that a manager can take advantage off to get ahead of the competition."

5. **Opportunities - Networks**

   "In an economic crisis the network of a manager plays an important role of the success of the SMEs organisation. Furthermore the network becomes an important tool for profiting from the current situation (Feindt et al., 2002), (Mukumba, 2014), (Simpson et al., 2012). Managers are able to use their contacts and relationships to use opportunities and become antifragile. Using these networks in an effective way can be identified as a key factor in the success of a manager (Feindt et al., 2002), (Mukumba, 2014)."

6. **Opportunities - Innovation**

"Innovation has long been recognized as a key driver of competitive advantage and a core area a manager should use in dynamic efficiency of markets and a competitive environment (Lin, 1998), (Feindt et al., 2002), (Ahuja and Katila, 2004), (Dobbs and Hamilton, 2007), (Dibrell et al., 2008), (Madrid-Guijarro et al., 2009), (Dervitsiotis, 2012), (Love and Roper, 2015). In the present era of a global economy the need to find new opportunities that generate new revenues and profits become more important. The increase of never-ending uncertainty, leads to shifts from quality excellence to innovation excellence (Dervitsiotis, 2012)."

7. **Opportunities - Resources**

"SME managers generally lack access to business resources compared to the way Large Enterprises have access to these assets. To acquiring enough business resources, SME managers have to be particularly creative (Beck et al., 2006), (Xiang and Worthington, 2015). ... Especially the family-owned and managed SMEs show that revenue generating actions rise above cost-cutting measures in terms of company growth. Company that were also self-financed to a larger extent showed a higher performance than companies relying on means of finance (Smallbone et al., 2012). (Rupeika-Apoga and Danovi, 2015) have found that if a manager controls an SME that is in a larger extent involved in the internationalization process the availability of business resources becoming more apparent."

8. **Motivation**

"(Smallbone et al., 2012) explained that managers leading SMEs during terms of turbulence that performed better, in a large extent didn't focus on cutting cost but instead trying to find revenue generating operations. SMEs should focus on motivating employees and try to increase sales, instead of cutting down staff and try to save money. This offers the possibility to increase staff during times of economic crisis, because during an economic crisis companies let people go and this becomes an opportunity for managers to acquire new personal and new knowledge (Kotler and Caslione, 2009). shows that firms that cut down a lot during economic crises, have a hard time to rebuild the moral they lost when the market turns."

9. **Motivation - Mind-set**

"In order to thrive in turbulence a manager need the right mind-set. Instead of a being defensive a manager need to become tough. Believing in the company and being practical is key to thriving. A manager needs to be prepared for the situations to come and know what type of strategy to adopt to handle it. ... opportunity for managers to acquire new personal and new knowledge (Kotler and Caslione, 2009). ... The manager that wants to build an antifragile organisation must love the uncertainty and adapt to the environment (Taleb, 2012). ... The manager's mind-set will affect the company and the outcome of the performance of the company (Kraus et al., 2012). ... To become antifragile a manager cannot be shaken by the crisis but instead attack it head on (Taleb, 2012)."

10. **Motivation - Employee motivation**

"In times of economic crisis, the employees need to be motivated to keep up their performance. Different factors influences this motivation in the workplace, the employees need to feel as if they are contributing even during an economic crisis. ... There is also a correlation between knowledge from previous crisis and the way organisations handle upcoming ones. If a manager has survived a previous crisis they are more confident to take on the next. The 29 more experience an organisation has with crises the better they perform during these situations. The experience of different crisis needs to be stored and used in the future events."

11. **Motivation - Communication**

> "(Kotler and Caslione, 2009) explained that during an economic crisis it's important for a manager to speak often to their staff about how they are feeling and what they think is going to happen. Finding out the employees problems and finding ways to turn them around to something positive helps keep up motivation. ... There need to be a strategy in place for communicating for the employees. Make sure that they are attacking the situation from the beginning and head on (Mazzei and Ravazzani, 2015)."

F.5 Antifragile Information Systems

Some Guidelines (Gorgeon, 2015, p. 6-11)

1. **Simplicity**

   "Driven by globalization, the customization of their products and services, and an increasing information processing needs, organisations and their Information Systems have grown more complex over the years (Galbraith, 1974), (Galbraith, 2012). They are fragile because the number and variety of their constitutive elements together with the dynamics of their interactions and interdependencies make them difficult to apprehend cognitively as a whole, and their non-linear emergent behaviors are very often very hard, if not impossible, to predict. ... In all, (Taleb, 2012) suggests that simplicity is a powerful and more efficient way to apprehend the complexity and uncertainty of our environments. As a result, when exercised, simplicity, in all its forms, has not only the potential of reducing the fragility of systems but also the power of enhancing their antifragility."

2. **Skin in the Game**

   "organisations are increasingly complex and specialized and thus difficult to control (Vaughn, 1983). In such an environment, information opacity and asymmetry arise and are conducive to moral hazard. Moral hazard can be defined as "any situation in which one person makes the decision about how much risk to take, while someone else bears the cost if things go badly" (Krugman, 2009). Moral hazard is a source of fragility for organisations because they potentially suffer the downsides of risky decisions made by a few who in the process create high potential upsides for themselves and become more antifragile."

3. **Reduce Naive Interventions**

   ""Festina lente," make haste slowly, encapsulates well the principle of reducing naïve intervention. Antifragility implies that the old is superior to the new (Taleb, 2012) simply because it has survived the test of time, while the fragile has not. Doing nothing or delaying action is a way to respect the old or give it the time to exercise its natural antifragility."

4. **Optionality**

   "Optionality, the availability of options, allows systems to benefit from the positive side of uncertainty without suffering serious harm from the negative side (Taleb, 2012). In the face of uncertainty, to have the option but not the obligation to engage in a course of action is a source of antifragility (Taleb, 2012). ... Another source of optionality is redundancy. ... Redundancy has, however, a direct and an opportunity cost that organisations rarely have the desire to bear in the name of optimization and efficiency. Redundancy may also have the perverse effect of increasing complexity, raising the likelihood of failure (Perrow, 1984)."

5. **Inject Randomness into the System**

   "While organisations treat randomness with suspicion and anxiety, it has benefited many to extraordinary extents. Randomness is indeed at the heart of serendipity, which has been at the source of many of the greatest and most lucrative discoveries of the latest century Harré 2012, (Harré, 1981)."

6. **Decentralize / Develop Layered Systems**

"Decentralization and developing layered systems have the same main objective: the contention of the effects from harmful events. As (Taleb et al., 2009, p. 163) mentions: "The idea is simply to let human mistakes and miscalculations remain confined, and to prevent their spreading through the system, as Mother Nature does." ... Paradoxically, antifragile systems rely on the fragility of their components, without which they would be merely robust. Under stress, these fragile subcomponents break, allowing the system to improve."

F.6 Antifragile principles for a complex adaptive ICT system)

Principles Ensuring Antifragility (for a complex adaptive ICT system) (Hole, 2016, p. 35-57).

1. **Modularity**

   "Because a system of tightly interconnected units facilitates systemic failures, we need a system of modules with weak links ... that break when modules experience local failures (Meadows and Wright, 2008), (Crutchfield, 2009), (Helbing, 2010), (Helbing, 2012), (Helbing, 2013), (Rinaldi et al., 2001)."

2. **Weak Links**

   "Different dependencies have varying strengths (Rinaldi et al., 2001). We can measure the strength of a dependency by determining the damage a misbehaving module causes in the dependent module. ... A weak link can be compared to a circuit breaker that protects an electrical system against excessive current."

3. **Redundancy**

   "Since the goal of anti-fragile systems is to thrive in randomness, the systems contain "inefficiencies" through layered redundancies. ... we note that the secondary system should differ from the primary system to avoid both failing for the same reasons."

4. **Diversity**

   "A modular system has diversity (Page, 2010) when it contains differently designed or implemented modules with (nearly) the same functionality ... Diversity makes it less likely that many modules will fail at the same time."

5. **Fail Fast**

   "To create complex adaptive systems that are anti-fragile to classes of negative events, it is necessary to learn from problems and downright failures in the systems because it is effectively impossible to predict all future incidents with a large negative impact."

6. **Systemic Failure Without Failed Modules**

   "Swans are often caused by internal and external changes that affect the global pattern of interactions between the modules, between the stakeholders, and between the stakeholders and modules. The changes all seem reasonable when studied in isolation. It is only the combination of the changes that causes a systemic failure (Dekker, 2014)."

7. **The Need for Models**

   "While it is quite easy to understand the descriptions of the five principles, it is hard to determine how to realize them in complex adaptive ICT systems to achieve antifragility to a particular type of impact. Paraphrasing Yaneer Bar-Yam (Bar-Yam, 2013), we argue that it is necessary to create system models, especially during the design phase, to ensure antifragility."

F.7 Assessing Antifragility in Complex Adaptive Systems.

Assessing Antifragility in Complex Adaptive Systems (Johnson and Gheorghe, 2013, p. 163). Also re-used in (Kennon et al., 2015, p. 179) as Analytical criteria of a system of systems. Based on work of (Jackson and Ferris, 2013).

1. **Entropy**

   "Systems tend to increase in complexity over time. In doing so they lose the ability to use information to transform inputs into desired outputs; the number of potential system states relative to known system states increase (that is, disorder grows); and X-Events emerge (Chakrabarti and De, 2000), (Atkins, 2003), (Bradnick, 2008))."

2. **Emergence**

   "The relationship between the outputs of a system at the macro level and the actions of the micro level components in the system is either resultant or emergent (Goldstein, 1999). When system outputs can be directly traced to activities or functions of its components and there are cause-effect relationships between micro level component activity and macro level results, then the system output is said to be resultant. However, when no such traceability can be constructed, the output is said to be emergent and X-Events are produced (Menzies, 1988), (Christen and Franklin, 2002)."

3. **Efficiency vs. Risk**

   "Efficiencies are gained at the expense of increased potential for harm due to stress. For example, redundant components may reduce the potential for system failure, but at the expense of more resources without more functionality or output. Less redundant systems designs are more efficient but are more fragile."

4. **Balancing Constraints vs. Freedom**

   "The optimum condition for a system is a balance of constraints and degrees of freedom. A system that is too open (that is, high degrees of freedom, minimum constraints, maximum interactions and dependencies with other systems, and so on) has increased exposure to X-Events."

5. **Coupling (Loose/Tight)**

   "Failures can reverberate through tightly coupled (that is, linked) systems increasing in amplitude and potentially leading to catastrophic failure. The greater the degree of coupling between systems and system components, the more fragile the system becomes."

6. **Requisite Variety**

   "There are regulators in a SOS that attempt to control the outcome and behaviors of the agents in the system. When the number of regulators is insufficient relative to the number of agents, the behavior of the system becomes unpredictable and extreme hazardous events emerge. In other words, a gap in complexity of the systems and its agents or subsystems causes X-Events to occur."

7. **Stress Starvation**

   "Withholding stress from systems or attempting to reduce uncertainty in them can cause weakness, fragility, and expose them to hazardous X-Events. Applying regular and controlled stress to a system can increase its robustness and potentially lead to antifragility."

8. **Redundancy**

> "Having duplicate components that are required for a function or duplicate functions to meet the same objective, are to create excess system capacity and are effective hazard defenses. This is good for building robustness to a degree, but falls short when it is based on estimates from historical worse case events. When X-Events reoccur, they can do so with an impact that is more or less than the historical levels. Redundancy tends to stabilize systems and make them more robust (that is, less fragile but not antifragile)."

9. **Non-Monotonicity**

> "Learning from mistakes can be an effective defense against stressors. Mistakes and failures can lead to new information. As new information becomes available it defeats previous thinking, which can result in new practices and approaches (Augusto Wrede and Simari, 2001), (Nute, 2003), (Governatori and Terenziani, 2007). In this case, stressors can actually cause the system to improve."

10. **Absorption**

> "Systems shall have design margins that can encompass (that is, absorb) the magnitude and duration of the potential stress it may encounter and continue in an intended state. The greater the absorption, the greater the robustness and the less the fragility. Absorption does not increase antifragility."

F.8 Antifragile System Assessment Criteria

> "The system assessment criteria were mapped to a key (shown in 1st column) to allow for ease of representation in tables, graphs and discussions" (Kennon et al., 2015, p. 179)

based on "Assessing Antifragility in Complex Adaptive Systems" (Johnson and Gheorghe, 2013, p. 163).

1. **Fragile**
   (a) **Emergence**
   > "Emergent outputs, there is little/no traceability between micro- and macro-level results of a system, has greater black swan event exposure compared to resultant due to an increase in the amount of unintended system states."

   (b) **Efficiency and risk**
   > "Efficiencies are often gained at the expense of increased potential for harm due to stress. Less redundant systems designs are more efficient, but more fragile."

   (c) **Requisite variety**
   > "Regulators in a system of systems attempt to control the outcome and behaviors in the system. Black swan events increase as a result of the number of regulators being insufficient relative to the number of agents (unpredictable behavior)."

   (d) **Stress starvation**
   > "Protecting a system from stress or attempting to reduce uncertainty can cause weakness, fragility and expose them to hazardous Black Swan events."

   (e) **Redundancy**
   > "Duplication of components to meet the same objective create excess capacity in a system and are effective tools for extreme stressor defenses. Redundancy tends to stabilize systems and improve robustness."

   (f) **Absorption**
   > "Absorption in systems can be used to improve robustness. Design margins that increase the magnitude and duration it can take during potential stresses to ensure it continues functioning as it should increases the absorption ability of the system."

2. **Antifragile**
   (a) **Induced small stressors**
   > "Some systems are found to improve with greater exposure to stress. Controlled stress to a system can increase its robustness and potentially lead to antifragility where the system 'learns' from these controlled responses."

   (b) **Non-monotonicity**
   > "Learning from negative consequences induced by stressors can lead to new information. New information can result in improved practices and approaches. Stressors, when learned from, can thus cause a system to improve."

F.9 Antifragility, the Black Swan and psychology

(Markey-Towler, 2018)

> "We also discovered the symmetry between this and the archetypal personality of the Hero studied at length by Carl Jung, Joseph Campbell and Jordan Peterson. ... In terms of the Big Five personality traits, this personality is:"

- high in Openness,
- high in Conscientiousness,
- has a fair degree of Extraversion,
- a moderate degree of Agreeableness,
- and is low in Neuroticism.

F.10 Antifragile by being a fast zebra

(Maveau, 2017)

- Adaptivity
- Obliquity
- Failing Forward
- System Thinking
- (low) Need for Closure

G Appendix - Cover Story

Introduction

The front cover visualises for me the interesting loop we are in. The urge to try to define the world in deterministic formulas that create chaos by interacting, which chaos we try to bind in models, which in themselves are fragile for black swans which are created by the chaos we tried to harness. It can be said that with the means we use to try and reduce the chaos we create chaos itself.

G.1 Double Pendulum

'In physics and mathematics, in the area of dynamical systems, a double pendulum is a pendulum with another pendulum attached to its end, and is a simple physical system that exhibits rich dynamic behaviour with a strong sensitivity to initial conditions.[1] The motion of a double pendulum is governed by a set of coupled ordinary differential equations and is chaotic.'
- https://en.wikipedia.org/wiki/Double_pendulum[1]

G.2 Lorenz system

'The Lorenz system is a system of ordinary differential equations first studied by Edward Lorenz. It is notable for having chaotic solutions for certain parameter values and initial conditions. In particular, the Lorenz attractor is a set of chaotic solutions of the Lorenz system. In popular media the 'butterfly effect' stems from the real-world implications of the Lorenz attractor, i.e. that in any physical system, in the absence of perfect knowledge of the initial conditions (even the minuscule disturbance of the air due to a butterfly flapping its wings), our ability to predict its future course will always fail. This underscores that physical systems can be completely deterministic and yet still be inherently unpredictable even in the absence of quantum effects. The shape of the Lorenz attractor itself, when plotted graphically, may also be seen to resemble a butterfly.'
- https://en.wikipedia.org/wiki/Lorenz_system[2]

G.3 Butterfly effect

'In chaos theory, the butterfly effect is the sensitive dependence on initial conditions in which a small change in one state of a deterministic nonlinear system can result in large differences in a later state.'
- https://en.wikipedia.org/wiki/Butterfly_effect[3]

G.4 Left & Right brain

'The lateralization of brain function is the tendency for some neural functions or cognitive processes to be specialized to one side of the brain or the other. The

[1] (Wikipedia contributors - A, 2019n)
[2] (Wikipedia contributors - C, 2020q)
[3] (Wikipedia contributors - C, 2020b)

medial longitudinal fissure separates the human brain into two distinct cerebral hemispheres, connected by the corpus callosum. Although the macrostructure of the two hemispheres appears to be almost identical, different composition of neuronal networks allows for specialized function that is different in each hemisphere. ...Some popularizations oversimplify the science about lateralization, by presenting the functional differences between hemispheres as being more absolute than is actually the case.'
- https://en.wikipedia.org/wiki/Lateralization_of_brain_function[4]

'My Stroke of Insight: A Brain Scientists Personal Journey, (2008) is a New York Times bestselling and award-winning book written by Dr. Jill Bolte Taylor, a Harvard-trained and published neuroanatomist. In it, she tells of her experience in 1996 of having a stroke in her left hemisphere and how the human brain creates our perception of reality and includes tips about how Dr. Taylor rebuilt her own brain from the inside out.'
- https://en.wikipedia.org/wiki/My_Stroke_of_Insight[5]

'Unlike the top-down perspective, whereby the enterprise is managed as an 'object' (positivist view), leader and followers are co-creating emergent outcomes. The relationship between leader and followers concerns and affects the motivation of followers, based on mutual needs, expectations and values. An important element of leadership therefore concerns moral aspects that shape and give meaning to the relationship with followers.'
- (Hoogervorst, 2015)

'The SIGMA theory submits a fundamentally different perspective by arguing that variability in employee behaviour is crucial for operational and strategic performance. ...It is argued that employee variability is an absolute prerequisite for aligning employee interests with enterprise performance interests.'
- (Dietz and Mulder, 2020)

G.5 Models and pre-scriptive work

'Traditional thinking about enterprises considers (executive) management the primary and exclusive custodians of enterprise performance. Employees, under management control, must behave instrumentally as parts of the enterprise machine. There is no employee variability: standard, predefined instrumental behaviour is required and expected.'
- (Dietz and Mulder, 2020)

'The black swan theory or theory of black swan events is a metaphor that describes an event that comes as a surprise, has a major effect, and is often inappropriately rationalised after the fact with the benefit of hindsight. The term is based on an ancient saying that presumed black swans did not exist – a saying that became reinterpreted to teach a different lesson after black swans were discovered in the wild.'
- https://en.wikipedia.org/wiki/Black_swan_theory[6]

'So, uncertainty, unpredictability, and chaos are inherent in complex systems, which are non-linear, open, and processing a high degree of freedom. Assumptions of a cause and effect nature between action and outcome prove invalid since these causal links disappear in the complexity of reality'
- (Hoogervorst, 2017, p. 242-243)

[4](Wikipedia contributors - D, 2020k)
[5](Wikipedia contributors - D, 2019b)
[6](Wikipedia contributors - D, 2020b)

Bibliography

Abid, A., Khemakhem, M. T., Marzouk, S., Jemaa, M. B., Monteil, T., and Drira, K. (2014). Toward antifragile cloud computing infrastructures. *Procedia Computer Science*, 32:850–855.
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2014.05.501,
https://www.sciencedirect.com/science/article/pii/S1877050914007017.

Ackoff, R. L. (1997). Systems, messes and interactive planning. *The Societal Engagement of Social Science*, 3(1997):417–438.
Retrieved from:
http://www.moderntimesworkplace.com/archives/ericsess/sessvol3/Ackoffp417.opd.pdf.

Ackoff, R. L. (2001). A brief guide to interactive planning and idealized design. *self-published, no journal*, page 15.
Retrieved from:
https://www.ida.liu.se/~steho87/und/htdd01/AckoffGuidetoIdealizedRedesign.pdf,
https://eaasos.info/Content/Downloads/AckoffGuidetoIdealizedRedesign.pdf,
https://www.researchgate.net/publication/228755237,
https://www.ida.liu.se/~steho87/und/htdd01/AckoffGuidetoIdealizedRedesign.pdf.

Afsar, A. (2015). (Accessed on 03/03/2020)
Retrieved from:
https://slideplayer.com/slide/8649668/,
bit.ly/india-doc,
bit.ly/usa-doc.

Aghina, W., Ahlbäck, K., De Smet, A., Fahrbach, C., Handscomb, C., Lackey, G., Woxholth, J., Lurie, M., and Murarka, M. (2017). The 5 trademarks of agile organizations. *McKinsey & Company, New York City*, pages 2–5.
Retrieved from:
https://www.mckinsey.com/business-functions/organization/our-insights/the-five-trademarks-of-agile-organizations.

Ahuja, G. and Katila, R. (2004). Where do resources come from? the role of idiosyncratic situations. *Strategic Management Journal*, 25(8-9):887–907.
Retrieved from:
https://dx.doi.org/10.1002/smj.401,
https://onlinelibrary.wiley.com/doi/pdf/10.1002/smj.401,
https://citationsy.com/archives/q?doi=10.1002/smj.401.

Alassafi, M. O., Alshdadi, A., Walters, R. J., and Wills, G. B. (2017). A framework for critical security factors that influence the decision of cloud adoption by saudi government agencies. *Telematics and Informatics, Elsevier*, 31(7):996–1010.
Retrieved from:
https://dx.doi.org/10.1016/j.tele.2017.04.010,
https://www.researchgate.net/publication/316595509,
https://www.semanticscholar.org/paperd9ce729103f58e549a87341d6de579a6d01cfbb5,
http://dblp.uni-trier.de/db/journals/tele/tele34.html#AlassafiAWW17,
https://dl.acm.org/doi/10.1016/j.tele.2017.04.010.

Alvesson, M. and Sköldberg, K. (2009). *Reflexive Methodology: New Vistas for Qualitative Research*. SAGE Publications, London, UK.
Retrieved from:
https://books.google.nl/books?id=32G4M7-20xgC,
https://www.goodreads.com/book/show/16606877,
http://www.worldcat.org/oclc/958564082.

Ambler, S. W. (2009). The agile scaling model (asm): Adapting agile methods for complex environments. *Environments*, pages 1–35.
Retrieved from:
https://www.researchgate.net/publication/268424579,
https://www.agilealliance.org/wp-content/uploads/2016/01/Agile-Scaling-Model-RAW14204USEN.pdf.

Andersen, H. and Hepburn, B. (2015). Scientific method (stanford encyclopedia of philosophy). https://plato.stanford.edu/entries/scientific-method/. (Accessed on 03/03/2020).

Ansar, A., Flyvbjerg, B., Budzier, A., and Lunn, D. (2017). Big is fragile: An attempt at theorizing scale. *The Oxford Handbook of Megaproject Management*, 84:60–95.
Retrieved from:
https://arxiv.org/pdf/1603.01416.pdf,
https://arxiv.org/abs/1603.01416,
https://www.researchgate.net/publication/296701755,
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2741198,
https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780198732242.001.0001/oxfordhb-9780198732242-e-5.

Anthony, S. D., Viguerie, S. P., and Waldeck, A. (2016). Corporate longevity: Turbulence ahead for large organizations. *Strategy & Innovation*, 14(1):1–9.
Retrieved from:
https://www.innosight.com/wp-content/uploads/2016/08/Corporate-Longevity-2016-Final.pdf.

Ashby, W. R. (1956). *An Introduction to Cybernetics*. Chapman & Hall and University Paperbacks, London, UK.
Retrieved from:
https://books.google.com/books?id=Z51EAAAAIAAJ,
https://www.goodreads.com/book/show/583911,
http://www.worldcat.org/oclc/247619994,
http://dspace.utalca.cl/bitstream/1950/6344/2/IntroCyb.pdf,
http://pcp.vub.ac.be/books/IntroCyb.pdf.

Ashby, W. R. (1958). Requisite variety and its implications for the control of complex systems. *Cybernetica*, 1(2):83–99.
Retrieved from:
http://cleamc11.vub.ac.be/books/AshbyReqVar.pdf,
http://134.184.131.111/Books/AshbyReqVar.pdf.

Askoff, R. L. (1981). *Creating the Corporate Future: Plan Or be Planned For*. J. Wiley, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=8EEO2L4cApsC,
https://www.goodreads.com/book/show/97973,
http://www.worldcat.org/oclc/299414606.

Atkins, P. W. (2003). *Galileo's Finger: The Ten Great Ideas of Science*. Oxford University Press, Oxford, NY, USA.
Retrieved from:
https://archive.org/details/galileosfingerte00atki,
https://books.google.am/books?id=UlmjniqglYgC,

https://www.goodreads.com/book/show/2219005,
http://www.worldcat.org/oclc/250037461.

Augusto Wrede, J. and Simari, G. (2001). Temporal defeasible reasoning. *Knowl. Inf. Syst.*, 3:287–318.
Retrieved from:
https://dx.doi.org/10.1007/PL00011670,
https://www.researchgate.net/publication/220283852,
http://hssc.sla.mdx.ac.uk/staffpages/juanaugusto/AugustoS2001.pdf.

Aven, T. (2011). On some recent definitions and analysis frameworks for risk, vulnerability, and resilience. *Risk Analysis: An International Journal*, 31(4):515–522.
Retrieved from:
https://dx.doi.org/10.1111/j.1539-6924.2010.01528.x,
https://onlinelibrary.wiley.com/doi/full/10.1111/j.1539-6924.2010.01528.x.

Aven, T. (2012). The risk concept — historical and recent development trends. *Reliability Engineering & System Safety*, 99:33–44.
Retrieved from:
https://dx.doi.org/10.1016/j.ress.2011.11.006,
https://www.sciencedirect.com/science/article/pii/S0951832011002584,
http://sci-hub.se/10.1016/j.ress.2011.11.006.

Aven, T. (2015). The concept of antifragility and its implications for the practice of risk analysis. *Risk Analysis*, 35(3):476–483.
Retrieved from:
https://dx.doi.org/10.1111/risa.12279,
https://www.researchgate.net/publication/266149936,
https://www.semanticscholar.org/paper/7488d14eacdb998ede95238573936a9b499112fb,
https://onlinelibrary.wiley.com/doi/abs/10.1111/risa.12279,
https://citationsy.com/archives/q?doi=10.1111/RISA.12279.

Bailie, R. A. (2011). The cynefin framework (cognitive-edge.com). https://www.slideshare.net/rahelab/the-content-strategy-paradox-10193839/55-The_Cynefin_framework_cognitiveedgecomPattern_Analytical. (Accessed on 01/04/2020).

Bar-Yam, Y. (2013). The limits of phenomenology: From behaviorism to drug testing and engineering design. *New England Complex Systems Institute (NECSI) Report*, 2013-08-01.
Retrieved from:
https://arxiv.org/abs/1308.3094.

Barry, P. (2002). *Beginning Theory: An Introduction to Literary and Cultural Theory*. Beginnings (Manchester University Press). Manchester University Press, Manchester, United Kingdom.
Retrieved from:
https://books.google.nl/books?id=SNy26bx7L5UC,
https://www.goodreads.com/book/show/376554,
http://www.worldcat.org/oclc/925782889.

Beck, K., Beedle, M., Van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Grenning, J., Highsmith, J., Hunt, A., Jeffries, R., Kern, J., Marick, B., C., M. R., Mellor, S. J., Ken, S., Sutherland, J., and Thomas, D. (2001). Manifesto for agile software development. https://agilemanifesto.org. (Accessed on 01/10/2020)
Retrieved from:
https://moodle2016-17.ua.es/moodle/pluginfile.php/80324/mod_resource/content/2/agile-manifesto.pdf,
https://www.semanticscholar.org/paper/3edabb96a07765704f9c6a1a5542e39ac2df640c,
https://www.agilealliance.org/agile101/the-agile-manifesto.

Beck, T., Demirgüç-Kunt, A., Laeven, L., and Maksimovic, V. (2006). The determinants of financing obstacles. *Journal of International Money and Finance*, 25(6):932–952.
Retrieved from:
https://dx.doi.org/10.1016/j.jimonfin.2006.07.005,
https://www.sciencedirect.com/science/article/pii/S0261560606000520,
http://documents.worldbank.org/curated/en/479441468761438467/117517322_20041117173035/additional/wps3204.pdf,
https://pure.uvt.nl/ws/portalfiles/portal/1270552/bdlm.pdf,
https://citationsy.com/archives/q?doi=10.1016/j.jimonfin.2006.07.005.

Beer, S. (1974). *Designing Freedom.* John Wiley & Sons, Chichester, West Sussex, UK.
Originally broadcast as audio-book. The text of six radio broadcasts given in the autumn of 1973 as the thirteenth series of Massey Lectures which were established in 1961 by the Canadian Broadcasting Corporation to enable distinguished authorities in fields of general interest and importance to present the results of original study or research.
Retrieved from:
https://books.google.nl/books?id=MOXsAAAAMAAJ,
https://www.goodreads.com/book/show/2096540,
http://www.worldcat.org/oclc/246315517,
https://monoskop.org/images/e/e3/Beer_Stafford_Designing_Freedom.pdf,
https://archive.org/stream/DesigningFreedom/Designing%20Freedom_djvu.txt.

Beer, S. (1979). *The heart of enterprise: the managerial cybernetics of organization*, volume 2 of *Managerial cybernetics of organization*. John Wiley & Sons, Chichester, West Sussex, UK.
Retrieved from:
https://books.google.com/books?id=1tlfAAAAIAAJ,
https://www.goodreads.com/book/show/472955,
http://www.worldcat.org/oclc/972026416.

Beer, S. (1981). *Brain of the firm: the managerial cybernetics of organization*. John Wiley & Sons, Chichester, West Sussex, UK.
Retrieved from:
https://books.google.nl/books?id=bVK3AAAAIAAJ,
https://www.goodreads.com/book/show/2197958,
http://www.worldcat.org/oclc/970446624,
https://eclass.duth.gr/modules/document/file.php/ENG112/The%20Brain%20of%20the%20Firm.pdf.

Beer, S. (1985). *Diagnosing the system for organizations*. Managerial cybernetics of organization. John Wiley & Sons Inc, Chichester, West Sussex, UK.
Retrieved from:
https://books.google.nl/books?id=nqsOAQAAMAAJ,
https://www.goodreads.com/book/show/3664974,
http://www.worldcat.org/oclc/318329076.

Beer, S. (1989). The viable system model: It's provenance, developments, methodology and pathology. In *The Viable System Model – Interpretations and Applications of Stafford Beer's VSM*, chapter 1, pages 11–39. John Wiley, Chichester, West Sussex, UK.
Retrieved from:
https://books.google.nl/books?id=a-axAAAAIAAJ,
https://www.goodreads.com/book/show/1694504,
http://www.worldcat.org/oclc/1038549069,
https://kybernetik.ch/dwn/Viable_System_Model.pdf,
http://www.kybernetik.ch/dwn/Beer_Bibliography.pdf.

Bennett, D. and McGinnis, D. (2008). Coupled and complex: Human–environment interaction in the greater yellowstone ecosystem, usa. *Geoforum*, 39(2):833–845.
Retrieved from:
https://dx.doi.org/10.1016/j.geoforum.2007.05.009,
https://www.sciencedirect.com/science/article/pii/S0016718507000917,

https://www.researchgate.net/publication/248434064,
https://www.semanticscholar.org/paper/d8eaf5083282306da37c6e6fe027cd0779089495,
https://citationsy.com/archives/q?doi=10.1016/j.geoforum.2007.05.009.

Bennett, N. and Lemoine, G. J. (2014a). What a difference a word makes: Understanding threats to performance in a vuca world. *Business Horizons*, 57(3):311 – 317.
Retrieved from:
https://dx.doi.org/10.1016/j.bushor.2014.01.001,
http://www.sciencedirect.com/science/article/pii/S0007681314000020,
https://www.researchgate.net/publication/260313997,
https://citationsy.com/archives/q?doi=10.1016/j.bushor.2014.01.001.

Bennett, N. and Lemoine, G. J. (2014b). What vuca really means for you. *Harvard Business Review*, 92(1/2).
Retrieved from:
https://hbr.org/2014/01/what-vuca-really-means-for-you (Online; accessed 15-july-2019).

Bera, M. N., Acín, A., Kuś, M., Mitchell, M. W., and Lewenstein, M. (2017). Randomness in quantum mechanics: philosophy, physics and technology. *Reports on Progress in Physics*, 80(12):124001.
Retrieved from:
urlhttps://dx.doi.org/10.1088/1361-6633/aa8731,
https://iopscience.iop.org/article/10.1088/1361-6633/aa8731/meta,
https://arxiv.org/pdf/1611.02176.pdf.

Bradnick, D. (2008). A pentecostal perspective on entropy, emergent systems, and eschatology. *Zygon®, Journal of Religion and Science*, 43:925–942.
Retrieved from:
https://dx.doi.org/10.1111/j.1467-9744.2008.00969.x,
https://www.researchgate.net/publication/229614862,
https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-9744.2008.00969.x,
https://citationsy.com/archives/q?doi=10.1111/j.1467-9744.2008.00969.x.

Bradt, R. C. (2011). The fractography and crack patterns of broken glass. *Journal of Failure Analysis and Prevention*, 11(2):79–96.
Retrieved from:
https://dx.doi.org/10.1007/s11668-011-9432-5,
https://www.researchgate.net/publication/226276004,
https://www.semanticscholar.org/paper/639c4a241077a24276b030570c13e2dd9e6ce95a,
https://search.proquest.com/openview/b2b1863f05dc1d79011f9adb622d5967,
https://citationsy.com/archives/q?doi=10.1007/s11668-011-9432-5.

Brugman, A., Hofland, W., and Savalle, P. (2010). *Teampark: From crowd to community: vision and inspiration*. Sogeti Netherlands, Rotterdam, The Netherlands.
Retrieved from:
https://books.google.nl/books?id=EJqkSQAACAAJ,
http://www.worldcat.org/oclc/742020805,
https://www.ict-books.com/topics/teampark-from-crowd-to-community-hardcover-en-info.

Buldyrev, S. V., Parshani, R., Paul, G., Stanley, H. E., and Havlin, S. (2010). Catastrophic cascade of failures in interdependent networks. *Nature*, 464(7291):1025.
Retrieved from:
https://dx.doi.org/10.1038/nature08932,
https://www.researchgate.net/publication/43148428,
https://www.semanticscholar.org/paper/51cea59c89470dd68f5fa74ee4d089e0abd4a3c7,
https://www.nature.com/articles/nature08932#supplementary-information,
https://www.ncbi.nlm.nih.gov/pubmed/20393559,
https://arxiv.org/abs/0907.1182.

Campbell, D. T. and Fiske, D. W. (1959). Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological bulletin*, 56(2):81–105.
Retrieved from:
https://dx.doi.org/10.1037/h0046016,
https://psycnet.apa.org/record/1960-00103-001,
https://www.researchgate.net/publication/235726235,
https://www.semanticscholar.org/paper/7752e0835506a6629c1b06e67f2afb1e5d2bb714.

Casti, J. L. (2012). *X-events: The collapse of everything*. Harper Collins / William Morrow, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=0yP7Tr1TDGUC,
https://www.goodreads.com/book/show/13426206,
http://www.worldcat.org/oclc/795366995.

Chakrabarti, C. and De, K. (2000). Boltzmann-gibbs entropy: Axiomatic characterization and application. *International Journal of Mathematics and Mathematical Sciences*, 23:243–251.
Retrieved from:
https://dx.doi.org/10.1155/S0161171200000375,
https://www.researchgate.net/publication/26536402,
https://www.semanticscholar.org/paper/885ed6fbf52cd28f004a1ab03c6978a37871480a,
https://www.hindawi.com/journals/ijmms/2000/151569/abs,
https://citationsy.com/archives/q?doi=10.1155/s0161171200000375.

Chaos-Community (2018). Principles of chaos engineering. http://principlesofchaos.org/?lang=ENcontent. (Accessed on 01/02/2020).

Checkland, P. B. (1989). Soft systems methodology. *Human systems management*, 8(4):273–289.
Retrieved from:
https://dx.doi.org/10.3233/HSM-1989-8405,
https://content.iospress.com/articles/human-systems-management/hsm8-4-05.

Chesebro, J. W. and Borisoff, D. J. (2007). What makes qualitative research qualitative? *Qualitative Research Reports in Communication*, 8(1):3–14.
Retrieved from:
https://dx.doi.org/10.1080/17459430701617846,
https://www.tandfonline.com/doi/full/10.1080/17459430701617846,
https://biotap.utk.edu/wp-content/uploads/2019/10/What-Makes-Qualitative-Research-Qualitati
pdf.pdf.

Christen, M. and Franklin, L. R. (2002). The concept of emergence in complexity science: Finding coherence between theory and practice. *Proceedings of the Complex Systems Summer School*, 4.
Retrieved from:
http://www.hugoperezidiart.com.ar/debates-pdf/christen-franklin.emergence.pdf,
https://www.encyclog.com/_upl/files/2002_emergence.pdf.

Chrousos, G. P. (2009). Stress and disorders of the stress system. *Nature reviews endocrinology*, 5(7):374–381.
Retrieved from:
https://dx.doi.org/10.1038/nrendo.2009.106,
https://www.nature.com/articles/nrendo.2009.106,
https://www.pnas.org/content/100/14/8074.full.pdf,
https://www.ncbi.nlm.nih.gov/pubmed/19488073,
https://www.medscape.com/viewarticle/704866_2,
https://www.researchgate.net/publication/26258826,
https://www.semanticscholar.org/paper/236001faa47a572d257767d30d22f41d902a4be9.

Chumney Phd, F. (2016). Framing the dissertation - theoretical & conceptual frameworks in the dissertation - youtube. https://www.youtube.com/watch?v=oBRkbNDqpMM&feature=youtu.be&t=73. (Accessed on 03/08/2020)
Retrieved from:
https://youtu.be/oBRkbNDqpMM?t=73
CV Frances Chumney : https://www.westga.edu/share/documents/vitae/vita_090589.pdf?updated=2018-02-1213:08:53.

Churchman, C. W. (1968). *The Systems Approach*. A Delta book. Dell Publishing Company, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=vaAtAAAAIAAJ,
https://www.goodreads.com/book/show/4949170,
http://www.worldcat.org/oclc/918211521.

Churchman, C. W. (1979). *The systems approach and its enemies*. Basic Books, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=i4tHAQAAIAAJ,
https://www.goodreads.com/book/show/6113508,
http://www.worldcat.org/oclc/797414254.

Churchman, C. W. (1982). *Thought and Wisdom*. Systems inquiry series. Intersystems Publications.
Retrieved from:
https://books.google.nl/books?id=bgsRAQAAIAAJ,
https://www.goodreads.com/book/show/5519526,
http://www.worldcat.org/oclc/9936597.

Ciborra, C. (2004). *The Labyrinths of Information: Challenging the Wisdom of Systems*. Oxford University Press.
Retrieved from:
http://dx.doi.org/10.1093/acprof:oso/9780199275267.001.0001,
https://www.oxfordscholarship.com/10.1093/acprof:oso/9780199275267.001.0001/acprof-9780199275267,
https://www.researchgate.net/publication/30522510,
https://books.google.nl/books?id=4IVSAwAAQBAJ,
https://www.goodreads.com/book/show/1358529,
http://www.worldcat.org/oclc/870526146.

Crutchfield, J. (2009). The hidden fragility of complex systems— consequences of change, changing consequences. *Cultures of Change: Social Atoms and Electronic Lives*, 98-111:98–111.
Retrieved from:
https://dx.doi.org/10.1.1.629.4786,
http://csc.ucdavis.edu/~cmg/papers/FOCS.pdf,
https://www.santafe.edu/research/results/working-papers/the-hidden-fragility-of-complex-systems-consequenc,
http://csc.ucdavis.edu/~cmg/compmech/pubs/focs.htm.

Daft, R., Murphy, J., and Willmott, H. (2010). *organisation Theory and Design*. Organisation Theory and Design. South-Western Cengage Learning, Andover, UK.
Retrieved from:
https://en.wikiquote.org/wiki/Richard_L._Daft,
https://books.google.nl/books?id=s6MAkpcuaZQC,
https://www.goodreads.com/book/show/13113683,
http://www.worldcat.org/oclc/761007858.

Dahlberg, R. (2015). Resilience and complexity: Conjoining the discourses of two contested concepts. *Culture Unbound: Journal of Current Cultural Research*, 7(3):541–557.
Retrieved from:

https://dx.doi.org/10.3384/cu.2000.1525.1572541,
https://www.researchgate.net/publication/283445051,
https://www.semanticscholar.org/paper/a13a86461c45afdca30b10e38060a1ec3f237cbf,
http://www.cultureunbound.ep.liu.se/v7/a30/cu15v7a30.pdf.

Danchin, A., Binder, P. M., and Noria, S. (2011). Antifragility and tinkering in biology (and in business) flexibility provides an efficient epigenetic way to manage risk. *Genes*, 2(4):998–1016.
Retrieved from:
https://dx.doi.org/10.3390/genes2040998,
https://www.mdpi.com/2073-4425/2/4/998,
https://citationsy.com/archives/q?doi=10.3390/genes2040998.

De Florio, V. (2014). Antifragility = elasticity + resilience + machine learning models and algorithms for open system fidelity. *Procedia Computer Science*, 32:834–841. The 5th International Conference on Ambient Systems, Networks and Technologies (ANT-2014), the 4th International Conference on Sustainable Energy Information Technology (SEIT-2014)
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2014.05.499,
http://www.sciencedirect.com/science/article/pii/S1877050914006991.

De Haes, S., Huygh, T., Joshi, A., and Van Grembergen, W. (2016). Adoption and impact of it governance and management practices: a cobit 5 perspective. *International Journal of IT/Business Alignment and Governance (IJITBAG)*, 7(1):50–72.
Retrieved from:
https://www.igi-global.com/article/adoption-and-impact-of-it-governance-and-management-prac
149647,
https://econpapers.repec.org/article/iggjitbag/v_3a7_3ay_3a2016_3ai_3a1_
3ap_3a50-72.htm.

De Haes, S., Joshi, A., and Van Grembergen, W. (2015). Benchmarking and business value assessment of cobit 5. Technical report, ISACA.
Retrieved from:
https://www.isaca.org/bookstore/bookstore-wht_papers-digital/whpbbva5.

De Haes, S. and Van Grembergen, W. (2015). *Enterprise Governance of Information Technology: Achieving Alignment and Value, Featuring COBIT 5*. Management for Professionals. Springer International Publishing, Cham, Switzerland.
Retrieved from:
https://www.springer.com/gp/book/9783319145464,
https://books.google.nl/books?id=zNgRBwAAQBAJ,
https://www.goodreads.com/book/show/26496980,
http://www.worldcat.org/oclc/970589735.

De Haes, S., Van Grembergen, W., Joshi, A., and Huygh, T. (2019). *Enterprise Governance of Information Technology: Achieving Alignment and Value in Digital Organizations*. Management for Professionals. Springer International Publishing, Cham, Switzerland.
Retrieved from:
https://www.springer.com/gp/book/9783030259174,
https://books.google.nl/books?id=AmKtDwAAQBAJ,
http://www.worldcat.org/oclc/1128840393.

Dekker, S. (2014). *Safety Differently*. CRC Press, Boca Raton, 2nd edition.
Retrieved from:
https://dx.doi.org/10.1201/b17126,
https://books.google.nl/books?id=MefMAwAAQBAJ,
https://www.goodreads.com/en/book/show/20917908,
http://www.worldcat.org/oclc/906874954,
https://www.semanticscholar.org/paper/ac4e4a6a66ced2ab6b90aec20731a3927954adee.

Denzin, N. K. (1970). *The research act: a theoretical introduction to sociological methods*. Methodological perspectives. Aldine Pub. Co., Chicago, IL, USA.
Retrieved from:
https://books.google.nl/books?id=JWLJwgEACAAJ,
https://www.goodreads.com/book/show/50337324,
http://www.worldcat.org/oclc/1137789902.

Denzin, N. K. (2017). *The research act: A theoretical introduction to sociological methods*. Methodological perspectives. Routledge / Taylor & Francis Ltd.
Retrieved from:
https://books.google.nl/books?id=UjcpxFE0T4cC,
https://www.goodreads.com/book/show/39229758,
http://www.worldcat.org/oclc/1003798389.

Denzin, N. K. and Lincoln, Y. S. (2017). *The SAGE Handbook of Qualitative Research*. SAGE Publications, Los Angles, USA.
Retrieved from:
https://books.google.nl/books?id=l35ZDwAAQBAJ,
https://www.goodreads.com/book/show/30955849,
http://www.worldcat.org/oclc/1128885685.

Derbyshire, J. and Wright, G. (2014). Preparing for the future: Development of an 'antifragile' methodology that complements scenario planning by omitting causation. *Technological Forecasting and Social Change*, 82:215–225.
Retrieved from:
https://dx.doi.org/10.1016/j.techfore.2013.07.001,
https://strathprints.strath.ac.uk/52933,
https://www.researchgate.net/publication/260029387,
https://www.semanticscholar.org/paper/bcff9cbb210c626024efe9511c0df86e5301e63f,
https://www.sciencedirect.com/science/article/pii/S0040162513001534.

Dervitsiotis, K. N. (2012). An innovation-based approach for coping with increasing complexity in the global economy. *Total Quality Management & Business Excellence*, 23(9-10):997–1011.
Retrieved from:
https://dx.doi.org/10.1080/14783363.2012.728849,
https://www.tandfonline.com/doi/abs/10.1080/14783363.2012.728849,
https://www.researchgate.net/publication/263339155,
https://www.semanticscholar.org/paper/8e371b23a3ae7354dec35ca6d405a72d39d3e56b,
https://citationsy.com/archives/q?doi=10.1080/14783363.2012.728849.

Dibrell, C., Davis, P., and Craig, J. (2008). Fueling innovation through information technology in smes. *Journal of small business management*, 46(2):203–218.
Retrieved from:
https://dx.doi.org/10.1111/j.1540-627X.2008.00240.x,
https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1540-627X.2008.00240.x,
https://www.scholars.northwestern.edu/en/publications/fueling-innovation-through-information-technology-in-smes,
https://www.semanticscholar.org/paper/7cf9a3cdbadb6df28253c77e7b147907b2ca033c,
https://citationsy.com/archives/q?doi=10.1111/j.1540-627x.2008.00240.x.

Dietz, J. (2012). *Red garden gnomes don't exist*. Sapio Enterprise engineering.
Retrieved from:
https://books.google.nl/books?id=BySsAQAACAAJ,
http://www.worldcat.org/oclc/962259227,
https://www.bol.com/nl/f/red-garden-gnomes-don-t-exist/9200000049215052.

Dietz, J. L. (2017). The fi theory - understanding information and factual knowledge. *unknown journal*, pages 1 – 20.
Retrieved from:
https://www.researchgate.net/publication/320298867.

Dietz, J. L. and Hoogervorst, J. A. (2011). A critical investigation of togaf - based on the enterprise engineering theory and practice. In Albani, A., Dietz, J. L. G., and Verelst, J., editors, *Advances in Enterprise Engineering V*, pages 76–90, Berlin, Heidelberg, Germany. Springer Berlin Heidelberg.
Retrieved from:
https://dx.doi.org/10.1007/978-3-642-21058-7_6,
https://link.springer.com/chapter/10.1007/978-3-642-21058-7_6,
https://www.semanticscholar.org/paper/40b59a4bbf0c98b24147cfc8965436e6073b1735,
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.460.6241&rep=rep1&type=pdf.

Dietz, J. L., Hoogervorst, J. A., Albani, A., Aveiro, D., Babkin, E., Barjis, J., Caetano, A., Huysmans, P., Iijima, J., Kervel, S., Mulder, H., Op 't Land, M., Proper, H., Sanz, J., Terlouw, L., Tribolet, J., Verelst, J., and Winter, R. (2013). The discipline of enterprise engineering. *International Journal of Organisational Design and Engineering*, 3:86–114.
Retrieved from:
https://www.researchgate.net/publication/263068480,
https://www.semanticscholar.org/paper/046562d0e57bc203a3f693c86d4574a899c50073,
http://www.inderscience.com/storage/f546732111109812.pdf,
https://www.inderscience.com/info/inarticle.php?artid=53669.

Dietz, J. L. and Mulder, H. B. (2020). *Enterprise Ontology: A Human-Centric Approach to Understanding the Essence of Organisation*. The Enterprise Engineering Series. Springer International Publishing.
Retrieved from:
https://books.google.nl/books?id=DNJRzAEACAAJ,
http://www.worldcat.org/oclc/1130644032,
https://www.springer.com/de/book/9783030388539.

Dobbs, M. and Hamilton, R. (2007). Small business growth: recent evidence and new directions. *International journal of entrepreneurial behavior & research*, 13(5):296–322.
Retrieved from:
https://dx.doi.org/10.1108/13552550710780885,
https://www.emerald.com/insight/content/doi/10.1108/13552550710780885,
https://www.researchgate.net/publication/240258952,
https://citationsy.com/archives/q?doi=10.1108/13552550710780885.

Drisko, J. (2011). Triangulation - social work - oxford bibliographies. https://www.oxfordbibliographies.com/view/document/obo-9780195389678/obo-9780195389678-0045.xml#firstMatch. (Accessed on 03/03/2020)
Retrieved from:
https://www.oxfordbibliographies.com/view/document/obo-9780195389678/obo-9780195389678-0045.xml.

Driver, J. (2014). The history of utilitarianism (stanford encyclopedia of philosophy). https://plato.stanford.edu/entries/utilitarianism-history/. (Accessed on 05/09/2020).

Eckardt, O. (2018). Company maturity matrix. *EMAJ: Emerging Markets Journal*, 8(1):28–30.
Retrieved from:
http://dx.doi.org/10.5195/emaj.2018.148,
http://emaj.pitt.edu/ojs/index.php/emaj/article/view/148,
https://www.researchgate.net/publication/327078955,
https://citationsy.com/archives/q?doi=10.5195/emaj.2018.148.

Emory, C. and Cooper, D. R. (1991). *Business Research Methods*. Kent International Dimensions of. Irwin, Homewood, Illinois, USA.
Retrieved from:
https://books.google.nl/books?id=OGy1AAAAIAAJ,
https://www.goodreads.com/book/show/1115003,
http://www.worldcat.org/oclc/932289746.

Engber, D. (2016). Ego depletion, an influential theory in psychology, may have just been debunked. http://www.slate.com/articles/health_and_science/cover_story/2016/03/ego_depletion_an_influential_theory_in_psychology_may_have_just_been_debunked.html?via=gdpr-consent. (Accessed on 01/10/2020).

Feindt, S., Jeffcoate, J., and Chappell, C. (2002). Identifying success factors for rapid growth in sme e-commerce. *Small Business Economics*, 19:51–62.
Retrieved from:
https://dx.doi.org/10.1023/A:1016165825476,
https://link.springer.com/article/10.1023/A:1016165825476,
https://www.researchgate.net/publication/5158123,
https://citationsy.com/archives/q?doi=10.1023/A:1016165825476.

Feygenson, O. and Feygenson, N. (2017). Modern triz and the concept of antifragility. friends, enemies or frenemies? In *The 13th International Conference. TRIZfest-2017*.
Retrieved from:
https://www.researchgate.net/publication/325616046.

Feynman, R. (1662). The feynman lectures on physics vol. iii ch. 2: The relation of wave and particle viewpoints. http://www.feynmanlectures.caltech.edu/III_02.html. (Accessed on 08/16/2019).

Feynman, R. P., Leighton, R. B., and Sands, M. L. (1963). *The Feynman Lectures on Physics*. Addison-Wesley world student series. Addison-Wesley Publishing Company.
Retrieved from:
https://books.google.nl/books?id=Cdd7vQEACAAJ,
https://www.goodreads.com/book/show/867821,
http://www.worldcat.org/oclc/531535.

Flood, R. L. (1999). *Rethinking The Fifth Discipline: Learning Within the Unknowable*. Routledge, Taylor & Francis Ltd.
Retrieved from:
https://books.google.nl/books?id=3H65KbRvdLQC,
https://www.goodreads.com/book/show/262076,
http://www.worldcat.org/oclc/40305701,
https://stcollab.com/wp-content/uploads/2016/02/TNST2014_1_003-Fifth.pdf.

Galbraith, J. (2012). The future of organisation design. *Journal of organisation Design*, 1(1):3–6.
Retrieved from:
https://dx.doi.org/10.7146/jod.6332,
https://www.jorgdesign.net/article/view/6332,
https://citationsy.com/archives/q?doi=10.7146/jod.6332.

Galbraith, J. R. (1974). organisation design: An information processing view. *INFORMS Journal on Applied Analytics*, 4(3):28–36.
Retrieved from:
https://dx.doi.org/10.1287/inte.4.3.28,
https://pubsonline.informs.org/doi/abs/10.1287/inte.4.3.28,
https://citationsy.com/archives/q?doi=10.1287/inte.4.3.28.

Ghaderi, M., Ruiz, F., and Agell, N. (2016). A linear programming approach for learning non-monotonic additive value functions in multiple criteria decision aiding. *European Journal of Operational Research*, 259.
Retrieved from:
https://dx.doi.org/10.1016/j.ejor.2016.11.038
https://www.researchgate.net/publication/310837599,
https://www.semanticscholar.org/paper/1a02893310518bb839e0f4c953b5119903e9b614,
https://www.sciencedirect.com/science/article/abs/pii/S0377221716309638 3.

Ghasemi, A. and Alizadeh, M. (2017). Evaluating organisational antifragility via fuzzy logic. the case of an iranian company producing banknotes and security paper. *Operations*

Research and Decisions, 1:21–43.
Retrieved from:
https://dx.doi.org/10.5277/ord170202,
https://www.researchgate.net/publication/325385576,
https://econpapers.repec.org/article/wutjournl/v_3a2_3ay_3a2017_3ap_3a21-43_3aid_3a1311.htm,
https://ideas.repec.org/a/wut/journl/v2y2017p21-43id1311.html,
http://orduser.pwr.wroc.pl/DownloadFile.aspx?aid=1311,
https://www.semanticscholar.org/paper/706abe9a615c552e81118774b915b15d9126b307.

Gladwell, M. (2001). *The Tipping Point: How Little Things Can Make a Big Difference*. Little, Brown and Company, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=yBDBEGBIUmgC,
https://www.goodreads.com/book/show/854997,
http://www.worldcat.org/oclc/960429629.

Gladwell, M. (2004). Malcolm gladwell: Choice, happiness and spaghetti sauce | ted talk. https://www.ted.com/talks/malcolm_gladwell_choice_happiness_and_spaghetti_sauce. (Accessed on 01/03/2020).

Goldstein, J. (1999). Emergence as a construct: History and issues. *Emergence*, 1(1):49–72.
Retrieved from:
https://dx.doi.org/10.1207/s15327000em0101_4,
https://www.researchgate.net/publication/243786253,
https://www.semanticscholar.org/paper/e38d356ba87ea578bb805f4daa38c4943d8506f7,
https://www.tandfonline.com/doi/abs/10.1207/s15327000em0101_4.

Gorgeon, A. (2015). Anti-fragile information systems (completed research paper). In *Anti-fragile Information Systems*, Fort Worth.
Retrieved from:
https://www.researchgate.net/publication/285288834,
https://aisel.aisnet.org/icis2015/proceedings/BreakoutIdeas/6,
https://www.semanticscholar.org/paper/Anti-Fragile-Information-Systems-Gorgeon/62159e3b5591ad850fc2aa402920352d2137d99a,
https://bsahely.com/wp-content/uploads/2017/12/21ba7f06ee170aca94123d9d7f83a8e80466.pdf.

Governatori, G. and Terenziani, P. (2007). Temporal extensions to defeasible logic. In Orgun, M. A. and Thornton, J., editors, *AI 2007: Advances in Artificial Intelligence*, pages 476–485, Berlin, Heidelberg, Germany. Springer.
Retrieved from:
https://dx.doi.org/10.1007/978-3-540-76928-6_49,
https://www.researchgate.net/publication/43469140,
https://www.semanticscholar.org/paper/bb826c37e82a8066aef060a586c3deee91848cbd,
https://espace.library.uq.edu.au/data/UQ_7749/guido1.pdf,
https://link.springer.com/chapter/10.1007/978-3-540-76928-6_49.

Grant, R. M. (2013). *Contemporary strategy analysis: text and cases*. John Wiley & Sons, Chichester, West Sussex, UK, 8th edition edition. Previous edition: 2010, Original edition: 1991
Retrieved from:
https://trove.nla.gov.au/work/36581337,
https://books.google.nl/books?id=S_4NMAEACAAJ,
https://www.goodreads.com/book/show/17056355,
http://www.worldcat.org/oclc/909495397.

Groningen, U. L. (2020). Search methods - information literacy history - libguides at university of groningen. https://libguides.rug.nl/c.php?g=470628&p=3218096. (Accessed on 05/13/2020).

Grube, M., Muggia, L., and Gostinčar, C. (2013). *Niches and Adaptations of Polyextremotolerant Black Fungi*, volume 27, pages 551–566. Springer, Dordrecht, the Netherlands.
Retrieved from:
https://link.springer.com/chapter/10.1007/978-94-007-6488-0_25,
https://www.researchgate.net/publication/257761713.

Guang, L., Nigussie, E., Plosila, J., and Tenhunen, H. (2014). Positioning antifragility for clouds on public infrastructures. *Procedia Computer Science*, 32:856–861.
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2014.05.502,
https://www.sciencedirect.com/science/article/pii/S1877050914007029?via%3Dihub.

Guion, L. A., Diehl, D. C., and McDonald, D. (2011). Triangulation: Establishing the validity of qualitative studies (fcs6014). *EDIS*, 2002(6).
Retrieved from:
https://journals.flvc.org/edis/article/view/108267,
https://sites.duke.edu/niou/files/2014/07/W13-Guion-2002-Triangulation-Establishing-the-Validity.pdf,
https://www.scribd.com/doc/255266673.

Hagger, M. S., Chatzisarantis, N. L. D., Alberts, H., Anggono, C. O., Batailler, C., Birt, A. R., Brand, R., Brandt, M. J., Brewer, G., Bruyneel, S., Calvillo, D. P., Campbell, W. K., Cannon, P. R., Carlucci, M., Carruth, N. P., Cheung, T., Crowell, A., Ridder, D. T. D. D., Dewitte, S., Elson, M., Evans, J. R., Fay, B. A., Fennis, B. M., Finley, A., Francis, Z., Heise, E., Hoemann, H., Inzlicht, M., Koole, S. L., Koppel, L., Kroese, F., Lange, F., Lau, K., Lynch, B. P., Martijn, C., Merckelbach, H., Mills, N. V., Michirev, A., Miyake, A., Mosser, A. E., Muise, M., Muller, D., Muzi, M., Nalis, D., Nurwanti, R., Otgaar, H., Philipp, M. C., Primoceri, P., Rentzsch, K., Ringos, L., Schlinkert, C., Schmeichel, B. J., Schoch, S. F., Schrama, M., Schütz, A., Stamos, A., Tinghög, G., Ullrich, J., vanDellen, M., Wimbarti, S., Wolff, W., Yusainy, C., Zerhouni, O., and Zwienenberg, M. (2016). A multilab preregistered replication of the ego-depletion effect. *Perspectives on Psychological Science*, 11(4):546–573.
Retrieved from:
https://dx.doi.org/10.1177/1745691616652873,
https://journals.sagepub.com/doi/10.1177/1745691616652873,
https://research.tilburguniversity.edu/en/publications/a-multi-lab-pre-registered-replication-of-the-ego-depletion-effec,
https://www.ncbi.nlm.nih.gov/pubmed/27474142,
https://www.researchgate.net/publication/272241774.

Hakhverdian, A. (2018). De stuk rood vlees podcast, aflevering 7 (deel 1): Daniël Lakens over de replicatiecrisis in de wetenschap - StukRoodVlees. http://stukroodvlees.nl/de-stuk-rood-vlees-podcast-aflevering-7-deel-1-daniel-lakens-over-de-replicatiecrisis-in-de-we
(Accessed on 08/15/2019).

Haren, V. (2011). *TOGAF Version 9.1*. Van Haren Publishing, 10th edition.
Retrieved from:
https://books.google.nl/books?id=6_UZyQEACAAJ,
https://www.goodreads.com/book/show/14727731,
http://www.worldcat.org/oclc/768595653,
https://pubs.opengroup.org/architecture/togaf91-doc/arch/chap02.html.

Harré, R. (1981). *Great Scientific Experiments: Twenty Experiments that Changed Our View of the World*. Science and Society. Phaidon Press Ltd, Oxford, UK.
Retrieved from:
https://openlibrary.org/books/OL2585963M,
https://archive.org/details/greatscientifice00romh.

Hasan, H. and Kazlauskas, A. (2014). The cynefin framework: putting complexity into perspective. In Hasan, H., editor, *Being Practical with Theory: A Window into Business Research*, pages 55–57. Faculty of Business, University of Wollongong, Wollongong,

Australia.
Retrieved from:
https://books.google.nl/books?id=Te7SoAEACAAJ,
https://www.goodreads.com/book/show/22545580,
http://www.worldcat.org/oclc/885293602,
https://www.semanticscholar.org/paper/f4e2f6c538a19badaca46e29aad6456ce137a8f2,
https://ro.uow.edu.au/buspapers/411,
https://eurekaconnection.files.wordpress.com/2014/02/
p-55-57-cynefin-framework-theori-ebook_finaljan2014-v3.pdf.

Hawking, S. and Penrose, R. (2000). *The Nature of Space and Time*. Isaac Newton Institute series of lectures. Princeton University Press.
Retrieved from:
https://books.google.nl/books?id=LstaQTXP65cC,
https://www.goodreads.com/book/show/2103,
http://www.worldcat.org/oclc/635691226.

Helbing, D. (2010). Systemic risks in society and economics. *SSRN Electronic Journal*, November 2010.
Retrieved from:
https://dx.doi.org/10.2139/ssrn.2413205,
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2413205,
https://www.researchgate.net/publication/228666065,
www.santafe.edu/media/workingpapers/09-12-044.pdf,
https://citationsy.com/archives/q?doi=10.2139/ssrn.2413205.

Helbing, D. (2012). *Systemic Risks in Society and Economics*, pages 261–284. Springer Berlin Heidelberg, Berlin, Heidelberg, Germany.
Retrieved from:
https://dx.doi.org/10.1007/978-3-642-24004-1_14,
https://link.springer.com/chapter/10.1007/978-3-642-24004-1_14,
https://citationsy.com/archives/q?doi=10.1007/978-3-642-24004-1_14.

Helbing, D. (2013). Globally networked risks and how to respond. *Nature*, 497:51–59.
Retrieved from:
https://dx.dio.org/10.1038/nature12047,
https://www.nature.com/articles/nature12047,
https://citationsy.com/archives/q?doi=10.1038/nature12047.

Helbing, D. and Kirman, A. (2013). Rethinking economics using complexity theory. *SSRN Electronic Journal - real-world economics review*, 2 July 2013(64):29.
Retrieved from:
https://dx.doi.org/10.2139/ssrn.2292370,
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2292370,
https://hal.archives-ouvertes.fr/hal-01499608,
https://www.researchgate.net/publication/272241774,
https://www.semanticscholar.org/paper/7bf25340a21dbbf9ec8bbc3175524a0fe4618f07,
http://www2.econ.iastate.edu/tesfatsi/RethinkingEconomicsUsingComplexityTheory.
DHelbingAKirman2013.pdf.

Henriksson, V., Spiss, M., and van Houten, C. (2016). To master disaster: How sme managers can thrive and benefit from economic crises. Master's thesis, Linnaeus University, School of Business and Economics, Department of Marketing., Växjö, Sweden.
Retrieved from:
http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A934567&dswid=-7618.

Heylighen, F. and Joslyn, C. (2001). The law of requisite variety - principia cybernetica web. http://pespmc1.vub.ac.be/REQVAR.html. (Accessed on 01/05/2020).

Hodgson, G. M. and Screpanti, E., editors (1991). *Rethinking economics: markets, technology, and economic evolution*. In Association with the European Association for Evolutionary

Political Economy (EAEPE) Series. Edward Elgar Publishing, Aldershot, Hampshire, UK.
Retrieved from:
https://books.google.nl/books?id=SePrAAAAMAAJ,
https://www.goodreads.com/book/show/617914,
http://www.worldcat.org/oclc/860509540,
https://EconPapers.repec.org/RePEc:elg:eebook:227.

Hofstadter, D. R. (2000). *Gödel, Escher, Bach: An Eternal Golden Braid*. Harvester studies in cognitive science. Penguin.
Retrieved from:
https://books.google.nl/books?id=grzEQgAACAAJ,
https://www.goodreads.com/book/show/24115,
http://www.worldcat.org/oclc/970552996.

Holcombe, A. O. (2016). Osf | participating labs wiki. https://osf.io/92dhr/wiki/home/. (Accessed on 08/15/2019).

Hole, K. J. (2016). *Anti-fragile ICT Systems*. Simula SpringerBriefs on Computing. Springer International Publishing, Cham, Switzerland.
Retrieved from:
https://doi.org/10.1007/978-3-319-30070-2,
https://books.google.nl/books?id=_Ud1jwEACAAJ,
https://www.goodreads.com/book/show/28653187,
http://www.worldcat.org/oclc/992927590,
https://link.springer.com/chapter/10.1007%2F978-3-319-30070-2_2.

Holling, C. S. (1996). Engineering resilience versus ecological resilience. *Engineering within Ecological Constraints*, 31(1996):31–43.
Retrieved from:
https://www.researchgate.net/publication/266149936,
https://www.semanticscholar.org/paper/ab0dc6785ebbae3904aace0cb9e243d5379acd75,
https://www.scirp.org/(S(czeh2tfqyw2orz553k1w0r45))/reference/ReferencesPapers.aspx?ReferenceID=1804343,
https://www.nap.edu/read/4919/chapter/4.

Hoogendoorn, B., Vos, M., Crijns, E., Kuhlmann, M., and Bierman, M. . (2006). *Schitterend organiseren - Creëren van vonken in mensen en organisaties*. BIM Media BV, Academic Service, The Hague, The Netherlands.
Retrieved from:
https://www.managementboek.nl/boek/9789052615660,
http://www.worldcat.org/oclc/150168588,
https://www.bol.com/nl/f/schitterend-organiseren/34694968.

Hoogervorst, J. A. (2009). *Enterprise Governance and Enterprise Engineering*. The Enterprise Engineering Series. Springer, Berlin Heidelberg, Germany.
Retrieved from:
https://books.google.nl/books?id=Jtmojz3k1mMC,
http://www.worldcat.org/oclc/318215348,
https://www.goodreads.com/book/show/10627150.

Hoogervorst, J. A. (2015). The sigma theory - socially inspired governance and management approach. *unknown*, ?:1–33. Publication source is unknown.

Hoogervorst, J. A. (2017). *Foundations of Enterprise Governance and Enterprise Engineering - Presenting the Employee-Centric Theory of organisation*. Springer.
Retrieved from:
https://www.springer.com/gp/book/9783319721064.

Huber, D., Kaufmann, H., and Steinmann, M. (2017). *Innovation: An Abiding Enigma*, pages 11–19. Springer International Publishing, Cham.
https://books.google.nl/books?id=rzckDwAAQBAJ,

http://www.worldcat.org/oclc/7039605966,
https://dx.doi.org/10.1007/978-3-319-55498-3_2.

Hussein, A. (2009). The use of triangulation in social sciences research: Can qualitative and quantitative methods be combined. *Journal of comparative social work*, 1(8):1–12.
Retrieved from:
https://dx.doi.org/10.31265/jcsw.v4i1.48,
http://www.bnemid.byethost14.com/NURSING%20RESEARCH%20METHODOLOGY%205.pdf?i=1,
https://www.researchgate.net/publication/260041595,
https://www.semanticscholar.org/paper/6c630b666b15849536a32bbf8bf2b123bafc6d64.

Hutchins, G. (2018). *ISO 31000: 2018 Enterprise Risk Management*. CERM Academy Series on Enterprise Risk Management. Certified Enterprise Risk Manager(R) Academy.
Retrieved from:
https://books.google.nl/books?id=csx7DwAAQBAJ,
https://www.goodreads.com/book/show/42974780,
http://www.worldcat.org/oclc/1125105820.

Iansiti, M. (2020). Coronavirus is widening the corporate digital divide - hbr. https://hbr.org/2020/03/coronavirus-is-widening-the-corporate-digital-divide. (Accessed on 05/09/2020).

IEEE (2000). Ieee-std-1471-2000 recommended practice for architectural description of software-intensive systems. *IEEE*, pages 1–30.
Retrieved from:
https://dx.doi.org/10.1109/IEEESTD.2000.91944,
https://ieeexplore.ieee.org/document/875998,
http://www.iso-architecture.org/ieee-1471/ieee-std-1471-2000.html,
https://www.iso.org/standard/50508.html,
http://cabibbo.dia.uniroma3.it/ids/altrui/ieee1471.pdf.

IEEE (2019). *ISO/IEC/IEEE 21839:2019(E): ISO/IEC/IEEE International Standard – Systems and software engineering – System of systems (SoS) considerations in life cycle stages of a system*. IEEE.
Retrieved from:
https://www.sis.se/api/document/preview/80013928,
https://standards.ieee.org/standard/21839-2019.html,
http://www.worldcat.org/oclc/1125784069.

Ioannidis, J. P. A. (2005). Why most published research findings are false. *PLOS Medicine*, 2(8):6.
Retrieved from:
https://dx.doi.org/10.1371/journal.pmed.0020124,
https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.0020124,
http://robotics.cs.tamu.edu/RSS2015NegativeResults/pmed.0020124.pdf,
https://www.researchgate.net/publication/7686290,
https://en.wikipedia.org/wiki/John_Ioannidis.

ISO/IEC/IEEE (2011). Systems and software engineering – architecture description. *ISO/IEC/IEEE 42010:2011(E) (Revision of ISO/IEC 42010:2007 and IEEE Std 1471-2000)*, pages 1–46.
Retrieved from:
https://dx.doi.org/10.1109/IEEESTD.2011.6129467,
https://www.bibsonomy.org/bibtex/27f1bf1f6675a8d557d76347a3411f76f/stammel.

Jaaron, A. and Backhouse, C. (2014a). Building antifragility in service organisations: Going beyond resilience. *International Journal of Services and Operations Management*, 19(4):491–513.
Retrieved from:

https://www.inderscience.com/info/inarticle.php?artid=65671,
https://www.researchgate.net/publication/268148748.

Jaaron, A. A. and Backhouse, C. J. (2014b). Learning from chaos: the advent of antifragility in service organisations. In *Proceedings of the 2014 POMS International Conference, Singapore*, pages 1–8.
Retrieved from:
https://staff.najah.edu/media/sites/default/files/Jaaron%26Backhouse_Singapore_2014.pdf,
https://www.semanticscholar.org/paper/bdd5d3a0631a0b984be04bc79945e7b9696d685b,
https://www.researchgate.net/publication/268148841.

Jackson, S. and Ferris, T. L. (2013). Resilience principles for engineered systems. *Systems Engineering*, 16(2):152–164.
Retrieved from:
https://dx.doi.org/10.1002/sys.21228,
https://onlinelibrary.wiley.com/doi/abs/10.1002/sys.21228,
https://citationsy.com/archives/q?doi=10.1002/sys.21228.

Janssen, T. (2015). *Enterprise Engineering: Sustained Improvement of organisations*. Springer Publishing Company, Incorporated, New York, NY, USA, 1st edition.
Retrieved from:
https://books.google.nl/books?id=TNHjCgAAQBAJ
https://www.goodreads.com/book/show/26498846,
http://www.worldcat.org/oclc/946894158,
https://play.google.com/store/books/details/?id=TNHjCgAAQBAJ,
https://www.springer.com/gp/book/9783319241708#reviews.

Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly*, 24(4):602–611.
Retrieved from:
https://dx.doi.org/10.2307/2392366,
http://www.jstor.org/stable/2392366,
https://www.researchgate.net/publication/280696811,
https://www.semanticscholar.org/paper/609ab78579f2f51e4677715c32d3370899bfd3a7.

Johner, P., Bürgi, D., and Längle, A. (2018). *Existential Leadership zum Erfolg: Philosophie und Praxis der Transformation*. Haufe Fachbuch. Haufe-Lexware, Stuttgart, Germany.
https://books.google.nl/books?id=mp0qDwAAQBAJ,
https://www.goodreads.com/book/show/40693672,
http://www.worldcat.org/oclc/1048621961.

Johnson, J. and Gheorghe, A. V. (2013). Antifragility analysis and measurement framework for systems of systems. *International Journal of Disaster Risk Science*, 4(4):159–168.
Retrieved from:
https://dx.doi.org/10.1007/s13753-013-0017-7,
https://link.springer.com/content/pdf/10.1007%2Fs13753-013-0017-7.pdf,
https://www.semanticscholar.org/paper/cba954bae35ee7594e17a75cc978b9dafb714502.

Johnson IV, J. J., Tolk, A., and Sousa-Poza, A. (2013). A theory of emergence and entropy in systems of systems. *Procedia Computer Science*, 20:283–289.
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2013.09.274,
http://www.sciencedirect.com/science/article/pii/S1877050913010740.

Jones, K. H. (2014). Engineering antifragile systems: A change in design philosophy. *Procedia computer science*, 32:870–875.
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2014.05.504,
https://www.sciencedirect.com/science/article/pii/S1877050914007042.

Kastner, D. (2017). Antifragile organisation design: A framework of self-organisation practices in today's complex and unpredictable economy. Master's thesis, Central Saint Martins - University of the Arts London, Master innovation management, London, United Kingdom.
Retrieved from:
https://www.goodreads.com/book/show/37703370,
https://www.amazon.de/gp/product/B0746J5RXJ.

Kaufman, R. L., Pitchforth, J., and Vermeer, L. (2017). Democratizing online controlled experiments at booking. com. *arXiv preprint arXiv:1710.08217*, abs/1710.08217:1–7.
Retrieved from:
https://arxiv.org/abs/1710.08217,
https://www.researchgate.net/publication/320582817,
https://www.semanticscholar.org/paper/d9f40571cafab5f17153076e29e4e3364635e0d4.

Kennon, D., Schutte, C., and Lutters, d. D. (2015). An alternative view to assessing antifragility in an organisation: A case study in a manufacutring sme. *CIRP annals: manufacturing technology*, 64:177–180.
Retrieved from:
https://dx.doi.org/10.1016/j.cirp.2015.04.024,
https://epdoc.utsp.utwente.nl/100574,
https://www.researchgate.net/publication/276164208,
https://www.semanticscholar.org/paper/f7336fe49bc59e7d6b3bb407b9dc860d04c212d8,
https://www.sciencedirect.com/science/article/pii/S0007850615000323.

Kim, H., Pineda, O. K., and Gershenson, C. (2019). A multilayer structure facilitates the production of antifragile systems in boolean network models. *arXiv preprint arXiv:1902.11214*, abs/1902.11214:15.
Retrieved from:
https://arxiv.org/abs/1902.11214,
https://arxiv.org/pdf/1902.11214.pdf.
https://www.researchgate.net/publication/331429477,
https://www.semanticscholar.org/paper/e8d10c8896c12a7517255e3c3c1614719e584fe0,
https://github.com/bin20005/antifragility.

Kimchi, J., Polivka, B., and Stevenson, J. S. (1991). Triangulation: operational definitions. *Nursing research*, 40(6):364–366.
Retrieved from:
https://dx.doi.org/10.1097/00006199-199111000-00009,
https://journals.lww.com/nursingresearchonline/citation/1991/11000/triangulation__operational_definitions.9.aspx.

Kinneen, K. and Younas, S. (2018). Self-managing organisations in the context of entrepreneurial innovation. Master's thesis, Uppsala University, Department of Business Studies, Uppsala, Sweden.
Retrieved from:
http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1228343&dswid=569,
https://www.semanticscholar.org/paper/f8ce7a79d05efe6045bfe318669a48e15b325bbd.

Kok, J. and van den Heuvel, S. (2018). *Leading in a VUCA World: Integrating Leadership, Discernment and Spirituality*. Contributions to Management Science. Springer International Publishing.
Retrieved from:
https://books.google.nl/books?id=NuovuQEACAAJ,
https://www.goodreads.com/book/show/45176754,
http://www.worldcat.org/oclc/1108519792,
https://www.springer.com/gp/book/9783319988832.

Kotler, P. and Caslione, J. A. (2009). *Chaotics: The business of managing and marketing in the age of turbulence*. American Management Association (AMACOM), New York, NY, USA.
Retrieved from:

https://books.google.nl/books?id=IKNH4C0B8DUC,
https://www.goodreads.com/book/show/16440346,
http://www.worldcat.org/oclc/426021780.

Kraus, S., Rigtering, J. C., Hughes, M., and Hosman, V. (2012). Entrepreneurial orientation and the business performance of smes: a quantitative study from the netherlands. *Review of Managerial Science*, 6(2):161–182.
Retrieved from:

urlhttps://dx.doi.org/10.1007/s11846-011-0062-9,
https://link.springer.com/article/10.1007/s11846-011-0062-9,
https://dspace.library.uu.nl/bitstream/1874/282360/2/rigtering.pdf,
https://citationsy.com/archives/q?doi=10.1007/s11846-011-0062-9.

Krugman, P. (2009). *The Return of Depression Economics and the Crisis of 2008*. W. W. Norton Company Limited., New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=0B_8f3BBwdwC,
https://www.goodreads.com/book/show/5740446,
http://www.worldcat.org/oclc/855705418.

Kurtz, C. F. and Snowden, D. J. (2003). The new dynamics of strategy: Sense-making in a complex and complicated world. *IBM systems journal*, 42(3):462–483.
Retrieved from:
https://dx.doi.org/10.1109/emr.2003.24944,
https://ieeexplore.ieee.org/abstract/document/5386804,
https://www.semanticscholar.org/paper/c9b427a98caeacb7f5ce1441df89bb1f923c34d7,
https://citationsy.com/archives/q?doi=10.1109/emr.2003.24944.

Lange, S. and Zeugmann, T. (1991). Monotonic versus non-monotonic language learning. In Brewka, G., Jantke, K. P., and Schmitt, P. H., editors, *Nonmonotonic and Inductive Logic*, pages 254–269, Berlin, Heidelberg, Germany. Springer, Springer Berlin Heidelberg.
Retrieved from:
https://dx.doi.org/10.1007/BFb0030397,
https://link.springer.com/chapter/10.1007/BFb0030397,
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.57.479&rep=rep1&type=pdf,
https://www.researchgate.net/publication/220993000.

Lansing, J. S. (2003). Complex adaptive systems. *Annual Review of Anthropology*, 32(1):183–204.
Retrieved from:
https://www.semanticscholar.org/paper/a1342a50da1ca195ac5219170fdf78b7ede15cd2,
https://www.researchgate.net/publication/235737529.

Lapalme, J. (2012). Three schools of thought on enterprise architecture. *IT Professional*, 14(6):37–43.
Retrieved from:
https://dx.doi.org/10.1109/MITP.2011.109,
https://ieeexplore.ieee.org/document/6109219,
https://www.researchgate.net/publication/260329507,
https://www.semanticscholar.org/paper/2b59e5f7bb2b3e979246953fad6f8828e803d9ed,
http://www2.mitre.org/public/eabok/pdf/three_schools_of_thought.pdf.

Lehman, M. M. (1980). Programs, life cycles, and laws of software evolution. *Proceedings of the IEEE*, 68(9):1060–1076.
Retrieved from:
https://www.semanticscholar.org/paper/77db6881dcce0302d4b1a0d6652d7ed61542c5b7,
https://www.semanticscholar.org/paper/f997b973e85f48a0a14907ab3c5ff2b852236ab0,
https://www.researchgate.net/publication/2996158,
https://ieeexplore.ieee.org/abstract/document/1456074,

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.116.3108&rep=rep1&type=pdf.

Lehman, M. M. (1996). Laws of software evolution revisited. In *Proceedings of the 5th European Workshop on Software Process Technology*, EWSPT '96, pages 108–124, Berlin, Heidelberg. Springer-Verlag.
Retrieved from:
https://dx.doi.org/10.1007/BFb0017737,
https://www.researchgate.net/publication/225106306,
https://citationsy.com/archives/q?doi=10.1007/bfb0017737.

Liening, A. (2013). The breakdown of the traditional mechanistic worldview, the development of complexity sciences and the pretence of knowledge in economics. *Modern Economy*, 4(04):305.
Retrieved from:
http://dx.doi.org/10.4236/me.2013.44034,
https://www.scirp.org/journal/PaperInformation.aspx?PaperID=30762,
https://www.scirp.org/pdf/ME_2013043013053402.pdf.

Lin, C. Y.-Y. (1998). Success factors of small-and medium-sized enterprises in taiwan: An analysis of cases. *Journal of small business management*, 36(4):43–56.
Retrieved from:
https://search.proquest.com/openview/9693c278a320d3e05c884ae1da9962ba,
http://nccur.lib.nccu.edu.tw/handle/140.119/70898,
https://www.researchgate.net/publication/279540808,
https://www.semanticscholar.org/paper/6eac6d829c59934ce33a3bb61a50cc4ea4006bb4.

Liu, Y. and Thompson, P. (2002). Randomness: Rethinking the foundation of probability. In *Proceedings of the twenty fourth annual meeting of the North American chapter of the International Group for the Psychology of Mathematics Education, Athens, GA*, volume 3, pages 1331–1334.
Retrieved from:
https://www.researchgate.net/publication/264119415,
https://www.semanticscholar.org/paper/3060b7f01b4caa8f2e3ef42e61d422ea09926640.

Love, J. H. and Roper, S. (2015). Sme innovation, exporting and growth: A review of existing evidence. *International small business journal*, 33(1):28–48.
Retrieved from:
https://dx.doi.org/10.1177/0266242614550190,
https://journals.sagepub.com/doi/abs/10.1177/0266242614550190,
https://www.enterpriseresearch.ac.uk/wp-content/uploads/2013/12/ERC-White-Paper-No_5-Innovation-final.pdf,
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.827.4609&rep=rep1&type=pdf,
https://citationsy.com/archives/q?doi=10.1177/0266242614550190.

Mack, O., Khare, A., Krämer, A., and Burgartz, T. (2015). *Managing in a VUCA World*. Springer, Cham, Switzerland.
Retrieved from:
https://books.google.nl/books?id=5TgwCgAAQBAJ,
https://www.goodreads.com/book/show/32066978,
http://www.worldcat.org/oclc/943905828,
https://dx.doi.org/10.1007/978-3-319-16889-0.

Madrid-Guijarro, A., Garcia, D., and Van Auken, H. (2009). Barriers to innovation among spanish manufacturing smes. *Journal of Small Business Management*, 47(4):465–488.
Retrieved from:
https://dx.doi.org/10.1111/j.1540-627X.2009.00279.x,
https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1540-627X.2009.00279.x,
https://www.researchgate.net/publication/228197219,
https://citationsy.com/archives/q?doi=10.1111/j.1540-627x.2009.00279.x.

Makridakis, S., Hogarth, R. M., and Gaba, A. (2009). Forecasting and uncertainty in the economic and business world. *International Journal of Forecasting*, 25(4):794–812.
Retrieved from:
https://dx.doi.org/10.1016/j.ijforecast.2009.05.012,
https://www.sciencedirect.com/science/article/pii/S0169207009000855,
https://citationsy.com/archives/q?doi=10.1016/j.ijforecast.2009.05.012.

Makridakis, S. and Taleb, N. (2009a). Decision making and planning under low levels of predictability. *International Journal of Forecasting*, 25(4):716–733.
Retrieved from:
https://dx.doi.org/10.1016/j.ijforecast.2009.05.013,
https://www.sciencedirect.com/science/article/pii/S0169207009000831,
https://citationsy.com/archives/q?doi=10.1016/j.ijforecast.2009.05.013.

Makridakis, S. and Taleb, N. (2009b). Living in a world of low levels of predictability. *International journal of forecasting*, 25(4):840–844.
Retrieved from:
https://dx.doi.org/10.1016/j.ijforecast.2009.05.008,
http://www.sciencedirect.com/science/article/pii/S0169207009000776,
https://citationsy.com/archives/q?doi=10.1016/j.ijforecast.2009.05.008.

Mannaert, H., Verelst, J., and De Bruyn, P. (2016). *Normalized Systems Theory: From Foundations for Evolvable Software Toward a General Theory for Evolvable Design*. NSI-Press powered by Koppa, Kermt, Hasselt, Belgium.
Retrieved from:
https://books.google.nl/books?id=0rA_tAEACAAJ
https://www.goodreads.com/book/show/41568821,
http://www.worldcat.org/oclc/1050060943.

Markey-Towler, B. (2018). Antifragility, the black swan and psychology. *Evolutionary and Institutional Economics Review*, 15(2):367–384.
Retrieved from:
https://dx.doi.org/10.2139/ssrn.3130038,
https://link.springer.com/article/10.1007/s40844-018-0097-6,
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3130038,
https://www.researchgate.net/publication/325879950.

Martin-Breen, P. and Anderies, J. M. (2011). The bellagio initiative, background paper, resilience: A literature review. In *Resilience: A Literature Review*, Brighton:IDS.
Retrieved from:
http://opendocs.ids.ac.uk/opendocs/handle/123456789/3692.

Martinetti, A., Moerman, J.-J., and Dongen, v. L. A. (2017). Storytelling as a strategy in managing complex systems: using antifragility for handling an uncertain future in reliability. *Safety and Reliability*, 37(4):233–247.
Retrieved from:
https://dx.doi.org/10.1080/09617353.2018.1507163,
https://www.tandfonline.com/doi/full/10.1080/09617353.2018.1507163,
https://research.utwente.nl/en/publications/storytelling-as-a-strategy-in-managing-complex-syst
https://www.researchgate.net/publication/327918347,
https://www.semanticscholar.org/paper/eda45fd9d6f90438aabebd3f552d2e4b623fb483.

Mattson, M. P. (2008). Hormesis defined. *Ageing research reviews*, 7(1):1–7.
Retrieved from:

urlhttps://dx.doi.org/10.1016/j.arr.2007.08.007,
https://www.sciencedirect.com/science/article/pii/S1568163707000712,
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2248601/pdf/nihms39393.pdf,
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2248601.

Maveau, M. (2017). Agile organisations and human potential: in need for fast zebra's? Master's thesis, University of Gent, Master of Science in de Handelswetenschappen, Gent, Belgium.
Retrieved from:
https://lib.ugent.be/fulltxt/RUG01/002/350/751/RUG01-002350751_2017_0001_AC.pdf.

Mazzei, A. and Ravazzani, S. (2015). Internal crisis communication strategies to protect trust relationships: A study of italian companies. *International Journal of Business Communication*, 52(3):319–337.
Retrieved from:
https://dx.doi.org/10.1177/2329488414525447,
https://journals.sagepub.com/doi/abs/10.1177/2329488414525447,
https://www.researchgate.net/publication/277887037,
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.844.3050&rep=rep1&type=pdf,
https://citationsy.com/archives/q?doi=10.1177/2329488414525447.

McRaney, D. (2017). Yanss 100 – the replication crisis – you are not so smart. https://youarenotsosmart.com/2017/07/19/yanss-100-the-replication-crisis/. (Accessed on 08/15/2019).

Meadows, D. and Wright, D. (2008). *Thinking in Systems: A Primer*. Chelsea Green Publishing.
Retrieved from:
https://books.google.nl/books?id=JSgOSP1qklUC,
https://www.goodreads.com/book/show/3828902,
http://www.worldcat.org/oclc/781476273,
https://wtf.tw/ref/meadows.pdf,
http://donellameadows.org/systems-thinking-resources.

Menzies, P. (1988). Against causal reductionism. *Mind*, 97(388):551–574.
Retrieved from:
https://www.mq.edu.au/pubstatic/public/download.jsp?id=63467.

Merriam Webster (2020a). Concave | definition of concave by merriam-webster. https://www.merriam-webster.com/dictionary/concave. (Accessed on 03/04/2020).

Merriam Webster (2020b). Converge | definition of converge by merriam-webster. https://www.merriam-webster.com/dictionary/converge. (Accessed on 03/03/2020).

Merriam Webster (2020c). Convex | definition of convex by merriam-webster. https://www.merriam-webster.com/dictionary/convex. (Accessed on 03/04/2020).

Merriam Webster (2020d). Diverge | definition of diverge by merriam-webster. https://www.merriam-webster.com/dictionary/diverge. (Accessed on 03/03/2020).

Merriam Webster (2020e). Hormesis | definition of hormesis by merriam-webster. https://www.merriam-webster.com/medical/hormesis. (Accessed on 03/12/2020).

Merriam Webster (2020f). Inference | definition of inference by merriam-webster. https://www.merriam-webster.com/dictionary/inference. (Accessed on 05/10/2020).

Merriam Webster (2020g). Redundancy | definition of redundancy by merriam-webster. https://www.merriam-webster.com/dictionary/redundancy. (Accessed on 03/12/2020).

Merriam Webster (2020h). Requisite | definition of requisite by merriam-webster. https://www.merriam-webster.com/dictionary/requisite. (Accessed on 03/12/2020).

Merriam Webster (2020i). Resilience | definition of resilience by merriam-webster. https://www.merriam-webster.com/dictionary/resilience. (Accessed on 01/09/2020).

Merriam Webster (2020j). Stressor | definition of stressor by merriam-webster. https://www.merriam-webster.com/dictionary/stressor. (Accessed on 03/04/2020).

Merriam Webster (2020k). Variety | definition of variety by merriam-webster. https://www.merriam-webster.com/dictionary/variety. (Accessed on 03/12/2020).

Metcalfe, R. (2013). Metcalfe's law after 40 years of ethernet. *Computer*, 46(12):26—-31.
Retrieved from:
https://dx.doi.org/10.1109/MC.2013.374,
https://ieeexplore.ieee.org/abstract/document/6636305,
https://researchers.dellmed.utexas.edu/en/publications/metcalfes-law-after-40-years-of-ethernet,
https://dl.acm.org/doi/10.5555/2635508.2635526,
https://www.researchgate.net/publication/260711519.

Mintz, S. (2015). Do the needs of the many outweigh the needs of the few? - ethics sage. https://www.ethicssage.com/2015/03/do-the-needs-of-the-many-outweigh-the-needs-of-the-few.html. (Accessed on 05/09/2020)
https://www.cob.calpoly.edu/directory/profile/steven-mintz/.

Mintzberg, H. (1994a). The fall and rise of strategic planning. *Harvard Business Review*, JANUARY–FEBRUARY 1994(94107):107–114.
Retrieved from:
https://hbr.org/1994/01/the-fall-and-rise-of-strategic-planning,
https://www.researchgate.net/publication/40961011,
https://pdfs.semanticscholar.org/89d3/153825e9606a67934df5a7a03125faddd825.pdf.

Mintzberg, H. (1994b). *The rise and fall of strategic planning: reconceiving roles for planning, plans, planners*. Free Press ; Maxwell Macmillan Canada.
Retrieved from:
https://books.google.nl/books?id=VznxpTe8b00C,
https://www.goodreads.com/book/show/726422,
http://www.worldcat.org/oclc/28675146,
https://openlibrary.org/books/OL24832559M,
https://archive.org/details/risefallofstra00mint.

Monperrus, M. (2017). Principles of antifragile software. In *Companion to the First International Conference on the Art, Science and Engineering of Programming*, Programming '17, pages 1–4, New York, NY, USA. ACM.
Retrieved from:
https://dx.doi.org/10.1145/3079368.3079412,
https://www.semanticscholar.org/paper/33889d523362aefe0cc08cdfccbc228340df0a88,
https://www.researchgate.net/publication/261597855,
https://2017.programming-conference.org/details/refuses-2017/14/Principles-of-Antifragile-Software,
https://refuses.github.io/preprints/antifragile.pdf,
https://arxiv.org/abs/1404.3056.

Mukumba, T. (2014). Overcoming smes challenges through critical success factors: A case of smes in the western cape province, south africa. *Economic & Business Review*, 16(1):19–38.
Retrieved from:
http://ojs.ebrjournal.net/ojs/index.php/ebr/article/view/338,
http://ojs.ebrjournal.net/ojs/index.php/ebr/article/view/338/pdf_5,
https://www.semanticscholar.org/paper/ebe9739b6122924af23fe9d509f658126876d0d3.

Müller, G., Koslowski, T. G., and Accorsi, R. (2013). Resilience-a new research field in business information systems? In *International Conference on Business Information Systems*, pages 3–14.
Retrieved from:

https://dx.doi.org/10.1007/978-3-642-41687-3_2,
https://link.springer.com/chapter/10.1007/978-3-642-41687-3_2,
https://www.researchgate.net/publication/268134677,
https://www.semanticscholar.org/paper/9139e5450049db8eab6e2a1fa837af2618e3563c,
https://citationsy.com/archives/q?doi=10.1007/978-3-642-41687-3_2.

Netflix (2011). The netflix simian army - netflix techblog - medium. https://medium.com/netflix-techblog/the-netflix-simian-army-16e57fbab116. (Accessed on 01/02/2020).

Newton, P. E. (2013). Does it matter what 'validity' means. *Lecture given at University of Oxford, Department of Education*.
Retrieved from:
http://oucea.education.ox.ac.uk/wordpress/wp-content/uploads/2013/06/2013-Meaning-of-validity-Oxford-v4-slides.pdf.

Nurmi, J., Pulkkinen, M., Seppänen, V., and Penttinen, K. (2019). *Systems Approaches in the Enterprise Architecture Field of Research: A Systematic Literature Review*, pages 18–38. Springer International Publishing, Cham,Switzerland.
Retrieved from:
https://dx.doi.org/10.1007/978-3-030-06097-8_2,
https://www.researchgate.net/publication/330008469,
https://link.springer.com/chapter/10.1007/978-3-030-06097-8_2.

Nute, D. (2003). Defeasible logic. In Bartenstein, O., Geske, U., Hannebauer, M., and Yoshie, O., editors, *Web Knowledge Management and Decision Support*, pages 151–169, Heidelberg, Berlin, Germany. Springer Berlin Heidelberg.
Retrieved from:
https://link.springer.com/chapter/10.1007/3-540-36524-9_13,
https://www.researchgate.net/publication/226978014,
https://www.semanticscholar.org/paper/57536a715c06de4c37601d49144460d715892fe8,
https://citationsy.com/archives/q?doi=10.1007/3-540-36524-9_13.

O'Neil, C. (2016). *Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy*. Crown Publishing Group, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=CxD-DAAAQBAJ,
https://www.goodreads.com/book/show/28186015,
https://www.worldcat.org/oclc/1039545320,
https://dl.acm.org/citation.cfm?id=3002861.

Open Science Collaboration, Aarts, A., Anderson, J., Anderson, C., Attridge, P., Attwood, A., Axt, J., Babel, M., Bahnik, S., Baranski, E., Barnett-Cowan, M., Bartmess, E., Beer, J., Bell, R., Bentley, H., Beyan, L., Binion, G., Borsboom, D., Bosch, A., Bosco, F., Bowman, S., Brandt, M., Braswell, E., Brohmer, H., Brown, B., Brown, K., Bruening, J., Calhoun-Sauls, A., Callahan, S., Chagnon, E., Chandler, J., Chartier, C., Cheung, F., Christopherson, C., Cillessen, L., Clay, R., Cleary, H., Cloud, M., Cohn, M., Cohoon, J., Columbus, S., Cordes, A., Costantini, G., Hartgerink, C., Krijnen, J., Nuijten, M., van 't Veer, A., Van Aert, R., van Assen, M., Wissink, J., Zeelenberg, M., and Rahal, R. (2015). Estimating the reproducibility of psychological science. *Science*, 349(6251).
Retrieved from:
http://dx.doi.org/10.1126/science.aac4716,
https://research.tilburguniversity.edu/en/publications/estimating-the-reproducibility-of-psychological-science,
http://eprints.lse.ac.uk/65159,
https://science.sciencemag.org/content/349/6251/aac4716.full.pdf.

Op't Land, M., Proper, E., Waage, M., Cloo, J., and Steghuis, C. (2008). *Enterprise Architecture: creating value by informed governance*. The Enterprise Engineering Series. Springer Science & Business Media, Berlin, Germany.
Retrieved from:

https://www.researchgate.net/publication/234807500,
https://www.semanticscholar.org/paper/f68987d41e3c135873da817ab1f09ee0548236d2,
https://books.google.nl/books?id=4yu5yYwpmakC,
https://www.goodreads.com/book/show/3812927,
http://www.worldcat.org/oclc/1101880293.

O'Reilly, B. M. (2019). No more snake oil: Architecting agility through antifragility. *Procedia Computer Science*, 151:884–890.
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2019.04.122,
http://www.sciencedirect.com/science/article/pii/S1877050919305861.

O'Reilly, B. M. (2020). An introduction to residuality theory: Software design heuristics for complex systems. *Procedia Computer Science*, 170:875–880.
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2020.03.120,
http://www.sciencedirect.com/science/article/pii/S1877050920305585.

Page, S. E. (2010). *Diversity and Complexity*. Princeton University Press.
Retrieved from:
https://books.google.nl/books?id=Mi6zkXss14IC,
https://www.goodreads.com/book/show/9696782,
http://www.worldcat.org/oclc/849012221,
https://press.princeton.edu/titles/9208.html.

Partenie, C. (2009). Plato's myths (stanford encyclopedia of philosophy). https://plato.stanford.edu/entries/plato-myths/. (Accessed on 12/31/2019).

Passos, D. S. d., Coelho, H., and Sarti, F. M. (2018). From resilience to the design of antifragility. In *pesaro 2018*, volume 1, pages 7–11.
Retrieved from:
http://toc.proceedings.com/39327webtoc.pdf,
https://www.thinkmind.org/download.php?articleid=pesaro_2018_2_10_60003,
https://www.gbes.com/blog/from-resilience-to-antifragile.

Perrow, C. (1984). *Normal accidents: living with high-risk technologies*. Basic Books, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=N3hRAAAAMAAJ,
https://www.goodreads.com/book/show/4595994,
http://www.worldcat.org/oclc/10229932,
https://trove.nla.gov.au/work/21768515.

Peters, T. J. and Peters, T. (1987). *Thriving on chaos: Handbook for a management revolution*. A Borzoi book. Knopf, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=TETHcEqUu60C,
https://www.goodreads.com/book/show/4436173,
http://www.worldcat.org/oclc/751336504.

Philip, M. (2011). Factors affecting business success of small & medium enterprises (smes). *Amity Global Business Review*, 6(1):118–136.
Retrieved from:
https://library.laredo.edu/eds/detail?db=bth&an=64734254&isbn=0975511X.

Pincus, D., Kiefer, A. W., and Beyer, J. I. (2017). Nonlinear dynamical systems and humanistic psychology. *Journal of Humanistic Psychology*, 58(3):343–366.
Retrieved from:
https://digitalcommons.chapman.edu/psychology_articles/95,
https://journals.sagepub.com/doi/10.1177/0022167817741784,
https://www.semanticscholar.org/paper/e918217d9a760cdedaa22ffbb5d4af9cf9d9ff46,
https://www.researchgate.net/publication/321084093.

Pineda, O. K., Kim, H., and Gershenson, C. (2018). Antifragility of random boolean networks. *arXiv preprint arXiv:1812.06760*, abs/1812.06760.
Retrieved from:
https://www.researchgate.net/publication/329734088.
https://www.semanticscholar.org/paper/b7ab3ac890b747a2e762cfd439de973690413879,
https://arxiv.org/pdf/1812.06760.pdf,
https://github.com/Okarim1/RBN.

Porter, M. E. (1996). What is strategy? *Harvard Business Review*, 74(6):61–78.
Retrieved from:
https://iqfystage.blob.core.windows.net/files/CUE8taE5QUKZf8ujfYlS_Reading+1.4.pdf,
https://hbr.org/1996/11/what-is-strategy,
https://www.hbs.edu/faculty/Pages/item.aspx?num=10698.

Potsangbam, C. (2017). Adaptive performance in vuca era – where is research going? *International Journal of Management (IJM)*, 8(6):99–108.
Retrieved from:
http://www.iaeme.com/ijm/issues.asp?JType=IJM&VType=8&IType=6,
https://www.researchgate.net/publication/323218746.

Proper, H. A. and Lankhorst, M. M. (2014). Enterprise architecture – towards essential sense-making. *Enterprise Modelling and Information Systems Architectures*, 9:5–21.
Retrieved from:
https://dx.doi.org/10.18417/emisa.9.1.1,
https://www.springerprofessional.de/en/enterprise-architecture-towards-essential-sensemakin/6119312,
https://www.researchgate.net/publication/280305331,
https://www.semanticscholar.org/paper/44ec97dfe85aab849bb313a4b85f104562989d30,
https://www.emisa-journal.org/emisa/article/view/111.

Ramirez, C. A. and Itoh, M. (2014). An initial approach towards the implementation of human error identification services for antifragile systems. In *2014 Proceedings of the SICE Annual Conference (SICE)*, pages 2031–2036.
Retrieved from:
https://dx.doi.org/10.1109/SICE.2014.6935315,
https://ieeexplore.ieee.org/document/6935315.

Recker, J. (2012). *Scientific Research in Information Systems - A Beginner's Guide*. Progress in IS. Springer, Heidelberg, Berlin, Germany.
Retrieved from:
https://books.google.nl/books?id=eNjfuQAACAAJ,
https://www.goodreads.com/book/show/14644185,
http://www.worldcat.org/oclc/802633850,
https://dx.doi.org/10.1007/978-3-642-30048-6.

Rinaldi, S., Peerenboom, J., and Kelly, T. (2001). Identifying, understanding, and analyzing critical infrastructure interdependencies. *IEEE Control Systems*, 21(6):11–25.
Retrieved from:
https://citationsy.com/archives/q?doi=10.1109/37.969131.

Robertson, B. (2015). *Holacracy: The New Management System for a Rapidly Changing World*. Henry Holt and Company, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=PUREBQAAQBAJ,
https://www.goodreads.com/book/show/23526564,
http://www.worldcat.org/oclc/895500921.

Ruiz-Martin, C., López-Paredes, A., and Wainer, G. (2018). What we know and do not know about organisational resilience. *International Journal of Production Management and Engineering*, 6(1):11–28.

Retrieved from:
https://dx.doi.org/10.4995/ijpme.2018.7898,
http://hdl.handle.net/10251/100017,
https://polipapers.upv.es/index.php/IJPME/article/view/7898,
https://www.semanticscholar.org/paper/abf80ff0ef7a4150d4fe42d651577aaf7588950a.

Rupeika-Apoga, R. and Danovi, A. (2015). Availability of alternative financial resources for smes as a critical part of the entrepreneurial eco-system: Latvia and italy. *Procedia Economics and Finance*, 33:200–210.
Retrieved from:
https://dx.doi.org/10.1016/S2212-5671(15)01705-0,
https://www.sciencedirect.com/science/article/pii/S2212567115017050,
https://core.ac.uk/download/pdf/82826864.pdf,
https://www.researchgate.net/publication/290018969,
https://www.semanticscholar.org/paper/aeea8b9153838927910ad7c3dca91fbe08111b73.

Russo, D. and Ciancarini, P. (2016). A proposal for an antifragile software manifesto. *Procedia Computer Science*, 83:982–987.
Retrieved from:
https://dx.doi.org/10.1016/j.procs.2016.04.196,
http://www.sciencedirect.com/science/article/pii/S1877050916302290,
https://www.researchgate.net/publication/303028716.

Ryan, A. B. (2006). Post-positivist approaches to research. *Researching and Writing your Thesis: a guide for postgraduate students*, pages 12–26.
Retrieved from:
http://mural.maynoothuniversity.ie/874/1/post-positivist_approaches_to_research.pdf,
https://www.semanticscholar.org/paper/5b8c729175658fce52fa637a200d189855ced822,
https://www.researchgate.net/publication/265485312.

Sage, A. P. (1992). *Systems Engineering*, volume 6 of *Wiley Series in Systems Engineering and Management*. John Wiley & Sons.
Retrieved from:
https://books.google.nl/books?id=ac9qKTXqAtQC,
https://www.goodreads.com/book/show/2116941,
http://www.worldcat.org/oclc/440948238.

Santos, R. S. (2012). ẅhy resilience?ä review of literature of resilience and implications for further educational research. In *Review of Resilience Research*, Claremont, CA. Claremont Graduate University & San Diego State University.
Retrieved from:
https://www.researchgate.net/publication/291035818,
https://www.semanticscholar.org/paper/8225bf92c023959dd344784f37d52d998885b33e,
https://go.sdsu.edu/education/doc/files/01383-Qual_Defense_PPT-Santos.pdf
https://go.sdsu.edu/education/doc/files/01370-ResiliencyLiteratureReview%28SDSU%29.pdf,
https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1957059.

Scholz, R. W., Blumer, Y. B., and Brand, F. S. (2012). Risk, vulnerability, robustness, and resilience from a decision-theoretic perspective. *Journal of Risk Research*, 15(3):313–330.
Retrieved from:
https://dx.doi.org/10.1080/13669877.2011.634522,
https://www.tandfonline.com/doi/abs/10.1080/13669877.2011.634522,
https://citationsy.com/archives/q?doi=10.1080/13669877.2011.634522.

SEBoK (2019). The enterprise as a system — sebok,. [Online; accessed 20-November-2019].

SEBoK, Henshaw, M., Dahmann, J., and Lawson, B. (2019). Systems of systems (sos) — sebok,. [Online; accessed 5-March-2020].

Senge, P. M. (1990). *The Fifth Discipline: The Art and Practice of the Learning organisation*. A Currency book. Doubleday/Currency, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=OtyLDQAAQBAJ,
https://www.goodreads.com/book/show/255127,
http://www.worldcat.org/oclc/815873729.

Shelly, N., Tschaen, B., Förster, K.-T., Chang, M., Benson, T., and Vanbever, L. (2015). Destroying networks for fun (and profit). In *Proceedings of the 14th ACM Workshop on Hot Topics in Networks*, page 6. ACM.
Retrieved from:
https://dx.doi.org/10.1145/2834050.2834099,
https://dl.acm.org/doi/10.1145/2834050.2834099,
http://eprints.cs.univie.ac.at/5518,
https://ktfoerster.github.io/paper/2015-hotnets.pdf.

Silverman, A. (2003). Plato's middle period metaphysics and epistemology - 13. sun, line and cave (stanford encyclopedia of philosophy). https://plato.stanford.edu/entries/plato-metaphysics/#13. (Accessed on 12/31/2019).

Simpson, M., Padmore, J., and Newman, N. (2012). Towards a new model of success and performance in smes. *International journal of entrepreneurial Behavior & Research*, 18(3):264–285.
Retrieved from:
https://dx.doi.org/10.1108/13552551211227675,
https://www.emerald.com/insight/content/doi/10.1108/13552551211227675/full/html,
https://www.researchgate.net/publication/235320850,
https://www.semanticscholar.org/paper/30bc0aa6ed686330bd8bfa24a78b8f6a65674c59,
https://citationsy.com/archives/q?doi=10.1108/13552551211227675.

Smallbone, D., Deakins, D., Battisti, M., and Kitching, J. (2012). Small business responses to a major economic downturn: Empirical perspectives from new zealand and the united kingdom. *International Small Business Journal*, 30(7):754–777.
Retrieved from:
https://dx.doi.org/10.1177/0266242612448077,
https://journals.sagepub.com/doi/abs/10.1177/0266242612448077,
https://www.researchgate.net/publication/255960579,
https://www.semanticscholar.org/paper/1ba4036420368a01c8d6c99cfc1e7fd4c5b98846,
https://citationsy.com/archives/q?doi=10.1177/0266242612448077.

Smith, G. (2007). Newton's philosophiae naturalis principia mathematica (stanford encyclopedia of philosophy). https://plato.stanford.edu/entries/newton-principia/. (Accessed on 08/15/2019) The Stanford Encyclopedia of Philosophy is copyright © 2016 by The Metaphysics Research Lab,.

Smith, G. (2008). Newton's philosophiae naturalis principia mathematica. In Zalta, E. N., editor, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, 2008 edition.

Stacey, R. D. (2001). *Complex Responsive Processes in organisations: Learning and Knowledge Creation*. Complexity and emergence in organisations. Routledge, London, UK.
Retrieved from:
https://books.google.nl/books?id=5PmCFUFtT-YC,
https://www.goodreads.com/book/show/1052172,
http://www.worldcat.org/oclc/1024862686.

Starossek, U., Smilowitz, R., Waggoner, M., Rubenacker, K., Haberland, M., and Moore, W. P. (2011). Report of the terminology and procedures sub-committee (sc1): Recommendations for design against disproportionate collapse of structures. In *Structures Congress 2011*, pages 2090–2103.

Retrieved from:
http://dx.doi.org/10.1061/41171(401)182,
https://trid.trb.org/view/1109827,
https://www.semanticscholar.org/paper/a8508b38a87e84b4e1de998871e15269d75dc1c4,
https://www.researchgate.net/publication/228838703,
https://citationsy.com/archives/q?doi=10.1061/41171(401)182.

Steenbergen, M. v. (2011). *Maturity and effectiveness of enterprise architecture*. PhD thesis, Utrecht University.
Retrieved from:
https://dspace.library.uu.nl/handle/1874/205434,
https://dspace.library.uu.nl/bitstream/handle/1874/205434/steenbergen.pdf?sequence=2.

Stevens, R., Brook, P., Jackson, K., and Arnold, S. (1998). *Systems Engineering: Coping with Complexity*. Prentice Hall.
Retrieved from:
https://books.google.nl/books?id=PPBp2RwMFWwC,
https://www.goodreads.com/book/show/1033144,
http://www.worldcat.org/oclc/1072146344.

Taleb, N. N. (2001). *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets*. Cengage Learning, 1 edition.
Retrieved from:
https://books.google.nl/books?id=kfXFQgAACAAJ,
https://www.goodreads.com/book/show/236383,
https://www.worldcat.org/oclc/783075922.

Taleb, N. N. (2007). *The Black Swan: The Impact of the Highly Improbable*. Random House, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=gWW4SkJjM08C,
https://www.goodreads.com/book/show/242472,
http://www.worldcat.org/oclc/901632888.

Taleb, N. N. (2012). *Antifragile: Things That Gain from Disorder*. Random House, New York, NY, USA.
Retrieved from:
https://books.google.nl/books?id=5E5o3_y5TpAC,
https://www.goodreads.com/book/show/13530973,
http://www.worldcat.org/oclc/851345873.

Taleb, N. N. and Douady, R. (2013). Mathematical definition, mapping, and detection of (anti) fragility. *Quantitative Finance*, 13(11):1677–1689.
Retrieved from:
https://www.researchgate.net/publication/230609579,
https://arxiv.org/abs/1208.1189,
https://arxiv.org/ftp/arxiv/papers/1208/1208.1189.pdf,
https://hal.archives-ouvertes.fr/hal-01151340.

Taleb, N. N., Goldstein, D. G., and Spitznagel, M. W. (2009). The six mistakes executives make in risk management. *Harvard Business Review*, 87(10):78–81.
Retrieved from:
https://www.finanzaonline.com/forum/attachments/econometria-e-modelli-di-trading-operativo/1996287d1415818862-mathematical-expectation-unfair-games-gml.pdf,
https://hbr.org/2009/10/the-six-mistakes-executives-make-in-risk-management.

The Stephen Hawking Foundation (1999). Does god play dice - stephen hawking. http://www.hawking.org.uk/does-god-play-dice.html. (Accessed on 08/16/2019).

Thornton, S. (2019). Karl popper (stanford encyclopedia of philosophy). https://plato.stanford.edu/entries/popper/. (Accessed on 12/27/2019).

Tseitlin, A. (2013). The antifragile organisation. *Communications of the ACM*, 56(8):40–44.
Retrieved from:
https://dx.doi.org/10.1145/2492007.2492022,
https://queue.acm.org/detail.cfm?id=2499552,
https://www.researchgate.net/publication/262395866,
https://pdfs.semanticscholar.org/aa32/a33aad732d1a55ed11d2e3145aff0b2d1498.pdf.

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., and Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the national academy of sciences*, 100(14):8074–8079.
Retrieved from:
https://dx.doi.org/10.1073/pnas.1231335100,
https://www.pnas.org/content/100/14/8074.short,
https://www.pnas.org/content/100/14/8074.full.pdf,
https://asu.pure.elsevier.com/en/publications/a-framework-for-vulnerability-analysis-in-sus
https://www.researchgate.net/publication/10720959,
https://pdfs.semanticscholar.org/84b9/4343cb53cc1421fe6e416465d0d276c33f12.pdf.

Turner, J. R. and Baker, R. M. (2019). Complexity theory: An overview with potential applications for the social sciences. *Systems*, 7(1):4.
Retrieved from:
https://dx.doi.org/10.3390/systems7010004,
https://www.mdpi.com/2079-8954/7/1/4,
https://www.semanticscholar.org/paper/ef30b08baf36ea5377bedd9a527b6a8db620571e,
https://www.researchgate.net/publication/330500755.

Tversky, A. and Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185(4157):1124–1131.
Retrieved from:
https://dx.doi.org/10.1126/science.185.4157.1124,
https://science.sciencemag.org/content/185/4157/1124,
https://science.sciencemag.org/content/185/4157/1124.full.pdf,
http://psiexp.ss.uci.edu/research/teaching/Tversky_Kahneman_1974.pdf,
https://www.semanticscholar.org/paper/dbdb10f066b857baa6e129f49b8d832c3f6267ae.

van den Berg, M., van Steenbergen, Marlies Luijpers, J., and Wagter, R. (2005). *Dynamic Enterprise Architecture: How to Make It Work*. Wiley, Hoboken, NJ, USA.
Retrieved from:
https://books.google.be/books?id=2ziKYfrwyhIC,
https://www.goodreads.com/book/show/16592116,
http://www.worldcat.org/oclc/834776896.

van Eijnatten, F. M. (2004). Chaos and complexity: An overview of the "new science" in organisation and management. *La Revue des Sciences de Gestion*, 40:123–165.
Retrieved from:
https://www.narcis.nl/publication/RecordID/oai:pure.tue.nl:publications%2F18fe0517-6921-4538-902d-95638a463fd5,
https://research.tue.nl/nl/publications/chaos-and-complexity-an-overview-of-the-new-science.html.

van Eijnatten, F. M. and Putnik, G. D. (2004). Chaos, complexity, learning, and the learning organization. *The Learning Organization*, 11:418–429.
Retrieved from:
https://dx.doi.org/10.1108/09696470410548782,
https://www.emerald.com/insight/content/doi/10.1108/09696470410548782/full/html,
https://research.tue.nl/en/publications/chaos-complexity-learning-and-the-learning-organiza
https://www.researchgate.net/publication/241708532.

Vargo, J. and Seville, E. (2011). Crisis strategic planning for smes: finding the silver lining. *International Journal of Production Research*, 49(18):5619–5635.
Retrieved from:
https://dx.doi.org/10.1080/00207543.2011.563902,
https://www.tandfonline.com/doi/abs/10.1080/00207543.2011.563902,
https://www.researchgate.net/publication/233328007,
https://citationsy.com/archives/q?doi=10.1080/00207543.2011.563902.

Vaughn, D. (1983). *Controlling Unlawful organisational Behavior: Social Structure and Corporate Misconduct*. Studies in Crime and Justice. University of Chicago Press, Chicago, IL, USA.
Retrieved from:
https://books.google.nl/books?id=ymaYQgAACAAJ,
https://www.goodreads.com/book/show/11887461,
http://www.worldcat.org/oclc/875703449,
https://searchworks.stanford.edu/view/1056798.

Veronesi, C. (2014). Falsifications and scientific progress: Popper as sceptical optimist. *Lettera Matematica*, 1(4):179–184.
Retrieved from:
https://dx.doi.org/10.1007/s40329-014-0031-7,
https://link.springer.com/article/10.1007/s40329-014-0031-7.

Von Bertalanffy, L. (1972). The history and state of general systems theory. *Academy of management journal*, 15(4):407–426.
Retrieved from:
https://dx.doi.org/10.2307/255139,
http://perflensburg.se/Bertalanffy.pdf,
https://journals.aom.org/doi/abs/10.5465/255139,
http://www.communicationcache.com/uploads/1/0/8/8/10887248/the_history_and_status_of_general_systems_theory.pdf,
https://pdfs.semanticscholar.org/15fb/c1fb41f1e6f9ed1f8d331e6cbe60a6cc2389.pdf#page=29,
https://www.researchgate.net/publication/247896331,
https://www.semanticscholar.org/paper/b44203ec8d6cb7acd4238c67651192b48bce862e.

Voorspoels, W., Navarro, D. J., Perfors, A., Ransom, K., and Storms, G. (2015). How do people learn from negative evidence? non-monotonic generalizations and sampling assumptions in inductive reasoning. *Cognitive Psychology*, 81:1–25.
Retrieved from:
https://dx.doi.org/10.1016/j.cogpsych.2015.07.001,
https://www.sciencedirect.com/science/article/pii/S0010028515000493,
https://digital.library.adelaide.edu.au/dspace/handle/2440/101533,
https://www.researchgate.net/publication/280327383,
https://www.semanticscholar.org/paper/97427fa46391e6a6a9d08edccfb22097649fca30.

Waldrop, M. M. (2016). The chips are down for moore's law. *Nature*, 530:144–147.
Retrieved from:
https://dx.doi.org/10.1038/530144a,
https://www.nature.com/articles/530144a.

Walker, B. H., Holling, C. S., Carpenter, S. R., and Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and society*, 9(2).
Retrieved from:
http://www.ecologyandsociety.org/vol9/iss2/art5,
https://www.ecologyandsociety.org/vol15/iss4/art20/ES-2010-3610.pdf,
https://www.researchgate.net/publication/297778685,
https://pdfs.semanticscholar.org/8f28/9160976f0f830c0c74b1e4e245a90637688f.pdf,
https://asu.pure.elsevier.com/en/publications/resilience-adaptability-and-transformability-in-so

Wang, Z., Nistor, M. S., and Pickl, S. W. (2017). Analysis of the definitions of resilience. *IFAC-PapersOnLine*, 50(1):10649–10657.
Retrieved from:
https://dx.doi.org/10.1016/j.ifacol.2017.08.1756,
https://www.researchgate.net/publication/320493227,
https://www.semanticscholar.org/paper/3b8d44759a489c75093c5b722dd9ea202b2ed6b3,
https://www.sciencedirect.com/science/article/pii/S2405896317323753.

Webb, E. J., Campbell, D. T., Schwartz, R. D., and Sechrest, L. (1966). *Unobtrusive measures: nonreactive research in the social sciences*. Rand McNally sociology series. Rand McNally, Chicago, IL, USA.
Retrieved from:
https://books.google.nl/books?id=iqdEAAAAIAAJ,
https://www.goodreads.com/book/show/1039353,
http://www.worldcat.org/oclc/4769353292.

Weick, K. E. (2001). *Making Sense of the Organization*. Blackwell Publishing, Oxford, UK.
Retrieved from:
https://books.google.nl/books?id=ZJpCtAEACAAJ,
https://www.goodreads.com/book/show/134487,
http://www.worldcat.org/oclc/491348489.

Wikipedia contributors (2020). Pareto principle — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Pareto_principle&oldid=941449593. (Online; accessed 26-March-2020).

Wikipedia contributors - A (2019a). Albert einstein — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Albert_Einstein&oldid=910878377. (Online; accessed 15-August-2019].

Wikipedia contributors - A (2019b). Antifragile — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Antifragile&oldid=880884314. (Online; accessed 31-March-2019].

Wikipedia contributors - A (2019c). Antifragility — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Antifragility&oldid=929219434. (Online; accessed 27-December-2019].

Wikipedia contributors - A (2019d). Bibtex — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=BibTeX&oldid=926358916. (Online; accessed 12-March-2020).

Wikipedia contributors - A (2019e). Black hole information paradox — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Black_hole_information_paradox&oldid=909380185. (Online; accessed 15-August-2019].

Wikipedia contributors - A (2019f). Bulletin board system — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Bulletin_board_system&oldid=910695505. (Online; accessed 15-August-2019].

Wikipedia contributors - A (2019g). Chaos engineering — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Chaos_engineering&oldid=886072727. (Online; accessed 20-April-2019].

Wikipedia contributors - A (2019h). Chaos engineering - chaos monkey — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Chaos_engineering&oldid=886072727. (Online; accessed 31-March-2019].

Wikipedia contributors - A (2019i). Complex adaptive system — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Complex_adaptive_system&oldid=926932272. (Online; accessed 20-November-2019].

Wikipedia contributors - A (2019j). Computer says no — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Computer_says_no&oldid=927966321. (Online; accessed 3-January-2020).

Wikipedia contributors - A (2019k). Cynefin framework — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Cynefin_framework&oldid=906068936. (Online; accessed 15-July-2019].

Wikipedia contributors - A (2019l). Demoscene — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Demoscene&oldid=930120644. (Online; accessed 31-December-2019).

Wikipedia contributors - A (2019m). Dijkstra's algorithm — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Dijkstra\unhbox\voidb@x\bgroup\let\unhbox\voidb@x\setbox\@tempboxa\hbox{s\global\mathchardef\accent@spacefactor\spacefactor}\accent0s\egroup\spacefactor\accent@spacefactor_algorithm&oldid=908654047. (Online; accessed 15-August-2019].

Wikipedia contributors - A (2019n). Double pendulum — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Double_pendulum&oldid=921670868. (Online; accessed 3-January-2020).

Wikipedia contributors - A (2019o). Galileo galilei — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Galileo_Galilei&oldid=910820231. (Online; accessed 15-August-2019].

Wikipedia contributors - A (2019p). Glass (1958 film) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Glass_(1958_film)&oldid=904517496. (Online; accessed 15-August-2019].

Wikipedia contributors - A (2019q). Gödel's incompleteness theorems — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=G%C3%B6del%27s_incompleteness_theorems&oldid=931039278. (Online; accessed 3-January-2020).

Wikipedia contributors - A (2019r). Holacracy — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Holacracy&oldid=886839931. (Online; accessed 31-March-2019].

Wikipedia contributors - A (2019s). Internet relay chat — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Internet_Relay_Chat&oldid=910788970. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019a). The fifth discipline — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=The_Fifth_Discipline&oldid=932476548. (Online; accessed 12-March-2020).

Wikipedia contributors - B (2019b). Karl popper — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Karl_Popper&oldid=931023340. (Online; accessed 27-December-2019].

Wikipedia contributors - B (2019c). Large hadron collider — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Large_Hadron_Collider&oldid=905609284. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019d). Lernaean hydra — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Lernaean_Hydra&oldid=904724809. (Online; accessed 9-July-2019].

Wikipedia contributors - B (2019e). Metcalfe's law — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Metcalfe%27s_law&oldid=924690051. (Online; accessed 3-January-2020).

Wikipedia contributors - B (2019f). Modern times (film) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Modern_Times_(film)&oldid=908516594. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019g). Moore's law — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Moore%27s_law&oldid=932723999. (Online; accessed 3-January-2020).

Wikipedia contributors - B (2019h). Peter senge — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Peter_Senge&oldid=924502856. (Online; accessed 12-March-2020).

Wikipedia contributors - B (2019i). Phoenix (mythology) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Phoenix_(mythology)&oldid=933076480. (Online; accessed 2-January-2020).

Wikipedia contributors - B (2019j). Quantum electrodynamics — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Quantum_electrodynamics&oldid=910817508. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019k). Quantum gravity — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Quantum_gravity&oldid=909818082. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019l). Redundancy (engineering) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Redundancy_(engineering)&oldid=922533897. (Online; accessed 12-March-2020).

Wikipedia contributors - B (2019m). Richard feynman — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Richard_Feynman&oldid=910960538. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019n). Richard stallman — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Richard_Stallman&oldid=909800224. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019o). Risk management — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Risk_management&oldid=893948240. (Online; accessed 5-May-2019].

Wikipedia contributors - B (2019p). Russell l. ackoff — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Russell_L._Ackoff&oldid=925455361. (Online; accessed 12-March-2020).

Wikipedia contributors - B (2019q). Scientific management — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Scientific_management&oldid=909524479. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019r). Soft systems methodology — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Soft_systems_methodology&oldid=914740724. (Online; accessed 12-March-2020).

Wikipedia contributors - B (2019s). Stephen hawking — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Stephen_Hawking&oldid=910942254. (Online; accessed 15-August-2019].

Wikipedia contributors - B (2019t). Volatility, uncertainty, complexity and ambiguity — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Volatility,_uncertainty,_complexity_and_ambiguity&oldid=883486761. (Online; accessed 31-March-2019].

Wikipedia contributors - B (2020a). Iso 31000 — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=ISO_31000&oldid=939004105. (Online; accessed 12-March-2020).

Wikipedia contributors - B (2020b). Iso 9000 — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=ISO_9000&oldid=944680864. (Online; accessed 12-March-2020).

Wikipedia contributors - B (2020c). Open science — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Open_science&oldid=937016095. (Online; accessed 5-March-2020).

Wikipedia contributors - B (2020d). Reductionism — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Reductionism&oldid=935393908. (Online; accessed 8-March-2020).

Wikipedia contributors - B (2020e). Variety (cybernetics) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Variety_(cybernetics)&oldid=934100994. (Online; accessed 5-January-2020).

Wikipedia contributors - C (2020a). Algorithmic trading — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Algorithmic_trading&oldid=944586634. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020b). Butterfly effect — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Butterfly_effect&oldid=953740559. (Online; accessed 30-April-2020).

Wikipedia contributors - C (2020c). C. west churchman — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=C._West_Churchman&oldid=936376217. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020d). Chaos theory — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Chaos_theory&oldid=944540733. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020e). Creative commons license — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Creative_Commons_license&oldid=943005860. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020f). Edward norton lorenz — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Edward_Norton_Lorenz&oldid=936466345. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020g). Entropy — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Entropy&oldid=934064339. (Online; accessed 5-January-2020).

Wikipedia contributors - C (2020h). Git — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Git&oldid=944863910. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020i). Gitlab — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=GitLab&oldid=945005825. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020j). High-frequency trading — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=High-frequency_trading&oldid=944794752. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020k). Holism — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Holism&oldid=941425748. (Online; accessed 8-March-2020).

Wikipedia contributors - C (2020l). Hormesis — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Hormesis&oldid=938049522. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020m). Interactive planning — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Interactive_planning&oldid=943319176. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020n). Jan hoogervorst — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Jan_Hoogervorst&oldid=938447884. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020o). Latex — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=LaTeX&oldid=945009453. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020p). List of works by leonardo da vinci — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=List_of_works_by_Leonardo_da_Vinci&oldid=935791136. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020q). Lorenz system — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Lorenz_system&oldid=953895374. (Online; accessed 30-April-2020).

Wikipedia contributors - C (2020r). Ludwig von bertalanffy — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Ludwig_von_Bertalanffy&oldid=935070832. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020s). Management cybernetics — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Management_cybernetics&oldid=937886462. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020t). Open system (systems theory) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Open_system_(systems_theory)&oldid=944749894. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020u). Personal life of leonardo da vinci — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Personal_life_of_Leonardo_da_Vinci&oldid=944703503. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020v). Peter checkland — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Peter_Checkland&oldid=937427028. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020w). Repository (version control) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Repository_(version_control)&oldid=940626994. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020x). Science and inventions of leonardo da vinci — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Science_and_inventions_of_Leonardo_da_Vinci&oldid=943679609. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020y). Stafford beer — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Stafford_Beer&oldid=939010535. (Online; accessed 12-March-2020).

Wikipedia contributors - C (2020z). Viable system model — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Viable_system_model&oldid=943868272. (Online; accessed 12-March-2020).

Wikipedia contributors - D (2019a). Ideation (creative process) — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Ideation_(creative_process)&oldid=914804549. (Online; accessed 4-May-2020).

Wikipedia contributors - D (2019b). My stroke of insight — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=My_Stroke_of_Insight&oldid=915942019. (Online; accessed 30-April-2020).

Wikipedia contributors - D (2020a). All models are wrong — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=All_models_are_wrong&oldid=952863101. (Online; accessed 10-May-2020).

Wikipedia contributors - D (2020b). Black swan theory — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Black_swan_theory&oldid=953765379. (Online; accessed 30-April-2020).

Wikipedia contributors - D (2020c). Complex system — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Complex_system&oldid=955635319. (Online; accessed 9-May-2020).

Wikipedia contributors - D (2020d). Constructivist epistemology — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Constructivist_epistemology&oldid=953924816. (Online; accessed 2-May-2020).

Wikipedia contributors - D (2020e). Coronavirus disease 2019 — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Coronavirus_disease_2019&oldid=954842643. (Online; accessed 4-May-2020).

Wikipedia contributors - D (2020f). Deconstruction — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Deconstruction&oldid=954342983. (Online; accessed 2-May-2020).

Wikipedia contributors - D (2020g). Design sprint — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Design_sprint&oldid=954967496. (Online; accessed 9-May-2020).

Wikipedia contributors - D (2020h). Eta — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Eta&oldid=949407180. (Online; accessed 9-May-2020).

Wikipedia contributors - D (2020i). Game theory — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Game_theory&oldid=955714664. (Online; accessed 9-May-2020).

Wikipedia contributors - D (2020j). Jürgen habermas — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=J%C3%BCrgen_Habermas&oldid=948273001. (Online; accessed 3-May-2020).

Wikipedia contributors - D (2020k). Lateralization of brain function — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Lateralization_of_brain_function&oldid=948138733.)Online; accessed 30-April-2020).

Wikipedia contributors - D (2020l). Lean startup — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Lean_startup&oldid=950537874. (Online; accessed 4-May-2020).

Wikipedia contributors - D (2020m). Neuromarketing — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Neuromarketing&oldid=951712753. (Online; accessed 3-May-2020).

Wikipedia contributors - D (2020n). Neuropsychology — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Neuropsychology&oldid=951232066. (Online; accessed 3-May-2020).

Wikipedia contributors - D (2020o). Post-structuralism — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Post-structuralism&oldid=952147776. (Online; accessed 2-May-2020).

Wikipedia contributors - D (2020p). Self-organization — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Self-organization&oldid=945284302. (Online; accessed 13-March-2020).

Wikipedia contributors - D (2020q). Sensemaking — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Sensemaking&oldid=943891898. (Online; accessed 2-May-2020).

Wikipedia contributors - D (2020r). Social science — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Social_science&oldid=951111906. (Online; accessed 9-May-2020).

Wikipedia contributors - D (2020s). The symbolic — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=The_Symbolic&oldid=950172084. (Online; accessed 2-May-2020).

Wikipedia contributors - D (2020t). Systematic review — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Systematic_review&oldid=954700924. (Online; accessed 13-May-2020).

Wikipedia contributors - D (2020u). Systems theory — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Systems_theory&oldid=955744402. [Online; accessed 9-May-2020].

Wikipedia contributors - D (2020v). Utilitarianism — Wikipedia, the free encyclopedia. https://en.wikipedia.org/w/index.php?title=Utilitarianism&oldid=952309198. (Online; accessed 9-May-2020).

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th international conference on evaluation and assessment in software engineering*, pages 1–10.
Retrieved from:
https://dx.doi.org/10.1145/2601248.2601268,
https://www.wohlin.eu/ease14.pdf,
https://dl.acm.org/doi/pdf/10.1145/2601248.2601268,
http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A833971&dswid=3250.

Wojcik, L. A. and Hoffman, K. C. (2006). Systems of systems engineering in the enterprise context: a unifying framework for dynamics. In *2006 IEEE/SMC International Conference on System of Systems Engineering*, pages 8–pp.
Retrieved from:
https://dx.doi.org/10.1109/SYSOSE.2006.1652268,
https://ieeexplore.ieee.org/abstract/document/1652268,
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.123.5956&rep=rep1&type=pdf.

Wolcott, H. F. (1990). *Writing up qualitative research (Qualitative Research Methods)*. SAGE Publications, Inc, Newbury park, CA, USA.
https://www.amazon.de/gp/product/0803937938,
https://www.goodreads.com/book/show/1072836,
http://www.worldcat.org/oclc/856769388.

Wu, S. P.-J., Straub, D. W., and Liang, T.-P. (2015). How information technology governance mechanisms and strategic alignment influence organizational performance: Insights from a matched survey of business and it managers. *Mis Quarterly*, 39(2):497–518.
Retrieved from:
https://dx.doi.org/10.25300/MISQ/2015/39.2.10,
https://dl.acm.org/doi/10.25300/MISQ/2015/39.2.10,
https://www.semanticscholar.org/paper/7bd0ee2ab812eabc9b864961ebf2712495b4583d,
https://www.researchgate.net/publication/275214026.

Xiang, D. and Worthington, A. (2015). Finance-seeking behaviour and outcomes for small- and medium-sized enterprises. *International Journal of Managerial Finance*, 11(4):513–530.
Retrieved from:
https://dx.doi.org/10.1108/IJMF-01-2013-0005,
https://www.emerald.com/insight/content/doi/10.1108/IJMF-01-2013-0005/

full/html,
https://citationsy.com/archives/q?doi=10.1108/ijmf-01-2013-0005.

Zeng, A., Shen, Z., Zhou, J., Wu, J., Fan, Y., Wang, Y., and Stanley, H. E. (2017). The science of science: From the perspective of complex systems. *Physics Reports*, 714:1–73. *Retrieved from:* https://dx.doi.org/10.1016/j.physrep.2017.10.001, http://www.sciencedirect.com/science/article/pii/S0370157317303289.

Zwieback, D. (2014). *Antifragile Systems and Teams*. O'Reilly Media, Sebastopol, CA, USA. *Retrieved from:* https://books.google.nl/books?id=Vl63AwAAQBAJ, https://www.goodreads.com/book/show/22466476, http://www.worldcat.org/oclc/891305549, https://proquest.tech.safaribooksonline.de/9781491908587.

Defining Antifragility and the application on Organisation Design
- a literature study in the field of antifragility.

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https://www.overleaf.com/project/5d370d47ffd48718f5e0e669

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