Contributions to Management Science

Florinda Matos
Paulo Maurício Selig
Eder Henriqson *Editors*

Resilience in a Digital Age

Global Challenges in Organisations and Society

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Foreword

Surviving the Digital Tsunami

For those who are millennials—or older—the title of this volume may seem a bit odd, since neither resilience nor the digital age is news. According to McAslan (2010), resilience, as a modern scientific concept, can be traced back to how Crawford Holling applied it to characterize ecological systems (Holling, 1973). In relation to safety, the term was first used by Woods (2000) and then, famously, by the book that introduced resilience engineering (Hollnagel et al., 2006). The exact beginning of the digital age is less easy to determine, although it is commonly accepted to have taken place in the mid-twentieth century when the introduction of (digital) information technology started to change industry and business—and eventually society itself. A possible anchor point may be Norbert Wiener's book *The Human Use of Human Beings* (Wiener, 1988), which was first published in 1950.

In light of this, it may well be asked why resilience and the digital age have not been associated earlier. Instead of trying to answer that, I will briefly consider two less speculative questions, namely (1) why there seems to be a need for it now, and (2) what a combination of two such established concepts can contribute.

The need is clearly due to the uncontrolled, and increasingly uncontrollable, growth in the complexity of the digital technologies and services that provide the foundation for modern societies. While this has had many benefits, it has also led to a potentially critical vulnerability and instability of the very basis for daily life. Since we seem unwilling, or perhaps unable, to relinquish the dependence on digital technologies and hyperintegrated operations, we instead look for ways to keep the benefits with as few disadvantages as possible.

Resilience has been seen by many as a possible means of surviving the digital tsunami. But while resilience definitely is no panacea, and perhaps not even a meaningful concept, resilient performance may be the critical means to cope with the unexpected. The concept of resilient performance may provide a perspective that makes it possible to see systems as a whole rather than as collections of individual parts and thereby break out of the silos that dominate current problem-solving. It is clearly high time to take a step aside and look at the issues, to make sure that we address the right problems before we try to solve them.

One day, perhaps, when digital technologies become conscious, they may begin to build a world that is suited to them rather than to us. But for now, we should remember who we are and try to build a world that is suited for human beings.

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The Editors

About the Book

Why publish a book with the title *Resilience in a Digital Age: Global Challenges in Organisations and Society*?

In recent years, resilience has become a buzzword as it is cited regarding climate emergency, disaster management, impacts of digital transformation, and, more recently, the COVID-19 global economic crisis.

Politicians and decision-makers from all sectors refer to resilience as a keyword for managing complex disturbances in society. Among institutional policies and plans in the international community, technologies for anticipation, recovery, and adaptations are emerging within the frame of resilience.

But what is resilience? How can we benefit from integrating digital transformation into this framework? And in what areas might it be most relevant?

We invited some of the world's leading experts in resilience to participate in this book and discuss possible answers to these questions.

At the end of the book, we conclude that we had only opened a small response window, because much remains to be written and examined about this issue, and each chapter of this book would become a complete book in itself.

The editors of this book are convinced that, effectively, resilience is the master key for the future. However, people are at the base of any process of resilience, and therefore, only by placing people at the center of transformations can we aspire to have a resilient society.

The Editors

Contents

Part II Applications, Technologies and Digital Tools

About the Editors

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Chapter 1
Introduction

Florinda Matos, Paulo Maurício Selig, and Eder Henriqson

We live in a world plagued by cyclical crises where challenges constantly emerge, demanding agility in response and adaptation.

The advent of the COVID-19 crisis, which quickly spread worldwide, has accelerated transformations and anticipated many challenges in work. The crisis put even more in evidence the limitations of health systems, the precariousness of many jobs, and housing insufficiency, pointing to the fragility of human life and the global vulnerability of the planet. Many ethical and social issues were raised, making us realise that centuries of an economy centred on economic power had postponed a human-centred and environmentally responsible model. Governments and society, in general, seem to have realised that People, the Planet, and the Prosperity, as presented by the United Nations' Sustainable Development Goals, could not continue to be ignored to the detriment of greater economic and political interests.

The question that arises at the global level is rebuilding the economy, generating jobs, improving social inequalities, and dealing with the growing challenge of climate change and its impacts. One possible direction seems to be understanding and providing support for the resilience of people, organisations, countries, and society itself.

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Although resilience is a term often associated with ecology, psychology, and engineering, interest in this term has increased in the past decade in response to the growing challenges in our society. We live with increasingly more complex and technologically intense systems in several sectors, such as public administration, healthcare, oil and gas, cybersecurity, and aviation. The socio-technical combinations in these systems create and sometimes increase the residual levels of uncertainties and risks while providing support for resilient behaviour when coping with emergent disturbance and changes.

A resilient organisation, such as a chameleon, needs to adapt to the adverse context in which it must survive, continuously monitoring the risks and reinventing business and mission. A resilient society can read the present problems and manage to mimic the future problems through change and adaptation.

As it is essential to increase the resilience of organisations in society, preparing them for unexpected events and crises, this book aims to explore the different dimensions of the resilience challenges of people and organisations in a digital age.

The challenges of resilience cannot be separated from the challenges of digital transformation. Digital transformation refers to the implementation of digital technologies to change and create new products and services. It has the potential to severely impact people, organisations, business models, and society in general. Such transformations are happening at an accelerated pace, with tremendous consequences for labour, sustainability, and competitiveness in several industries.

The trends and challenges facing society, such as the ability to control CO_2 emissions or the ability to control migration or reduce poverty, are even more acute in the context of digital transformation in which disruption and acceleration for all the processes are unstoppable, and they can widen the gap between people and nations. Digital Resilience emerges as the ability of socio-technical systems, organisations, and society to prepare and respond appropriately to disturbances and changes in their environment, sustaining adaptations, mitigating, or reducing the risk imposed by digital transformation.

One problem is that digital transformation is not democratic. Thus, while some citizens have access to the top of technological development that can facilitate and speed up resilience, other citizens must learn to be resilient without access to technologies or access to technologies from the past century. Therefore, the problem of resilience, more than a problem of readaptation, can be a problem of democratised access.

As no book can cover all the topics related to it, this work aims to awaken researchers, entrepreneurs, and governments' consciences to the challenges and opportunities that digital transformation is posing to our society.

The 18 chapters of this book, divided into two parts, are an ambitious attempt to review current research and present a state of art of resilience in its different dimensions. The first part encompasses chapters from 2 to 7 and discusses the theoretical foundations of resilience and its relationship with digital transformation, including concepts and frameworks. Chapter 2 describes potentials for resilient performance and discusses how such potentials can be systematically assessed and managed. Chapter 3 explores challenges for supporting resilience in the digital transformation in oil and gas complex operations. Chapter 4 explores the relations between relational capital and a firm's resilience indicators, providing insights for assessing organisational resilience. Chapter 5 investigates the main strategies and practices that enable organisations to leverage their intellectual capital in the intrinsic aspects of resilience in the context of digital transformation. In Chap. 6, a framework for the analysis of resilient performance is suggested, based on a study of integrated safety-critical operations in the oil and gas industry. Despite several frameworks for resilience assessment, in this framework, the authors propose resilience as capability, a behaviour that a socio-technical system may manifest, depending on a set of conditioning factors. Chapter 7 investigates the possible relations between the concepts of intellectual capital, resilience, reliability, sustainability, and reputation at a national level.

The second part of the book, from Chaps. 8 to 18, explores the use of technologies and digital tools to support resilience. Chapter 8 focuses on studying the resilient internet of things and exploring its application in smart cities. Chapter 9 presents a case study of opportunities offered by digitalisation to support resilience in health care. Chapter 10 describes and applies a framework for identifying, assessing, and developing critical knowledge to the resilience potentials of anticipating, monitoring, and responding in a knowledge-intensive organisation. Chapter 11 points out directions for using digitalised simulations to support resilience, and Chap. 12 reflects on the concept of cyber-resilience and suggests a research agenda. Chapter 13 provides evidence on how digital learning tools can be used to support resilience in healthcare. Chapter 14 shows a case study of a knowledge management system applied in a hospital during the COVID-19 crisis. Chapter 15 discusses how a knowledge graph can support functional resonance analyses in safety studies. Chapter 16 explores the digitalisation of cockpit procedures in aviation, especially for emergency and abnormal flight situations. Chapter 17 shows a case of digital transformation and its interlace with organisational culture in a federal institution in charge of implementing government policies. Finally, Chap. 18 presents two cases of successful adoption of digital technologies in manufacturing and their relationship with resilience capabilities.

Part I
Foundations, Concepts and Frameworks

Chapter 2
Systemic Potentials for Resilient Performance

Erik Hollnagel

Abstract Resilience is not a unitary system quality, even though it often is treated as such. A system cannot be, and cannot have resilience, but a system can perform in a way that is resilient. Resilient performance can be understood as an ongoing condition in which problems are momentarily under control due to compensating changes. This is essential for environments where unexpected and unpredictable changes can emerge and where their consequences can propagate rapidly. To perform resiliently, a system must have the potentials to respond, to monitor, to learn, and to anticipate. The chapter describes how the four potentials can be systematically assessed and how such assessments make it possible to manage them, hence the overall resilient performance of the system.

Keywords Resilient performance · Systemic potentials · Change management

2.1 What Does Resilient Performance Mean?

The notion of resilience began to appear in safety discussions around the turn of the century (Woods, 2000) and gained a firm footing with the first workshop organised in Söderköping, Sweden, in October 2004. The discussions during this workshop (Dekker, 2006) became the basis for the first book on resilience engineering (Hollnagel et al., 2006), soon followed by several others. From this beginning, the ideas—the concepts and precepts—quickly entered the vocabulary of safety professionals to the extent that the term "resilience" today is assumed to be so well understood that it no longer is necessary to define it. It may nevertheless be useful to spend a few moments to look at how the meaning has developed since the start and consider what the term means today.

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Towards the end of the twentieth century, a growing number of people, researchers, and practitioners, found that the traditional definition of safety as the absence of accidents was sterile and in need of revision. Resilience looked like a promising candidate, and the idea of resilience engineering—as an analogy to safety engineering and system safety engineering—was welcomed by many in the safety community as a way to go beyond the conventional efforts to prevent failures and reduce risks.

Because the background was in the world of safety, resilience was initially defined as "the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress" (Hollnagel, 2006). This definition unhappily continued the legacy of juxtaposing two states—one of acceptable functioning and one of failure. Following the tradition of industrial safety thinking, resilience engineering was also initially limited to consider situations of threat, risk, or stress.

The immediate usefulness of the concept was quickly tried in practical applications. Based on the experiences from these, the definition was changed so that it 5 years—and several books—later had become "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" (Hollnagel et al., 2011). By that time the emphasis on risks and threats had been replaced by the concern for how systems performed under "expected and unexpected conditions." The focus had thus become the ability to perform or function as required in general—including performance during everyday conditions.

The scope of resilience engineering has by 2020 changed even further and gone from being the ability to recover from changes and disturbances to be the ability to perform as needed under a variety of conditions—threats and stresses as well as opportunities. The latter corresponds to a change from protective safety to productive safety (Hollnagel, 2014) and ultimately to a dissociation of resilience from the conventional interpretation of safety (Hollnagel, 2021). From this perspective, resilience is no longer a mythical property or quality that can be engineered, measured, and managed on its own. The term is now used to characterise how a system performs, hence to describe *resilient performance* rather than *resilience*. This development was foreshadowed in the *Epilogue* of the first book, which proposed that resilience was something that a system rather than something that it *had* (Hollnagel & Woods, 2006, p. 347). Such a definition requires a clarification of what the characteristics of resilient performance are and of what enables a system to perform in this way. Here the *Epilogue* also indicated a direction by noting that "(w)e can only measure the potential for resilience but not resilience itself" (op. cit.). The question is, therefore, how we can describe and manage the potentials for resilient performance.

2.2 Systemic Potentials for Resilient Performance

Trivial systems can, in principle—and often also in practice—consistently predict what will happen in the system itself as well as in the surroundings, and therefore prepare to respond appropriately. The same is not the case for non-trivial systems because internal events may be unpredictable and because the surroundings will likely be populated by other non-trivial, hence unpredictable, systems. It is nevertheless still essential that some form of appropriate response can be prepared, but with limited predictability, it is also necessary to be able to cope with complexity, to perform resiliently. It is clearly not enough for a system to continuously monitor the risks and adapt itself to the adverse context in which it must survive. It is also necessary to look for the opportunities that may arise and be prepared to use them. This will need the requisite imagination described by Adamski and Westrum (2003), not only for what can go wrong but also for what can make things go well.

In order to control or manage a system, it is necessary to understand how it functions. While it is relatively straightforward to describe and understand what leads to observable outcomes from trivial systems, non-trivial systems present a more serious problem. Since non-trivial systems usually are socio-technical systems, it is necessary to understand how people perform or act in a given situation, individually and collectively. Resilience engineering argued that it was important to consider what *enabled* resilient performance, what made it possible—and conversely, what would make it impossible if it was missing (Hollnagel & Woods, 2006). To make a long story short, it was proposed that four potentials—sometimes called cornerstones or abilities—were required in order for a system to perform as required under both expected and unexpected conditions.

Thinking about essential abilities for the purposeful activity goes back at least to MacKay's (1956) analysis of goal-directed performance. For the most basic performance, only three "functional elements" were needed, which MacKay called a receptor, a comparator, and an effector. A receptor was needed to sense or "see" any changes in the surroundings; an effector was needed to carry out the system's responses; and finally, a comparator—or controller—was needed to select from moment to moment what the effector should do, out of the range of possibilities open to it. For more complicated kinds of performance, additional functional elements would be needed. Although control in principle could be maintained by having a hierarchy of controllers, it would be more effective to have some higher level functions such as prediction and planning.

The four potentials for a resilient performance fit well with MacKay's ideas. In order for a system to survive in non-trivial surroundings, it must be able to respond (the effector), to monitor (the receptor), to learn, and to anticipate—the latter two corresponding roughly to the comparator/controller and the higher level functions. Since such potentials are relevant for most, if not all, systems, they should be characterised in a way that is independent of any specific domain. Based on the concepts and precepts developed in resilience engineering, the following definitions are proposed.

- The potential to **respond**. No system, organisation, or organism can survive for long unless it is able to respond to what happens—to changes, to threats, and to opportunities. This is so both for what happens inside the system, such as insufficient resources, changing priorities, temporarily reduced functions, etc., and for what happens in the surroundings, such as unexpected events, new demands, sudden conflicts, etc. Responses must be both timely and effective in order to ensure that the desired outcomes are achieved neither too early nor too late.
- The potential to **monitor**. It is necessary to monitor or look out for that which may change or affect the system's performance positively or negatively in the near term—within the time frame of ongoing operations. The monitoring must be of the system's own performance as well as of what happens around it. Without the potential to monitor, everything that happens will be unexpected and surprising, which clearly is not a desirable situation. In order for the monitoring to remain effective, its basis must be assessed and revised from time to time.
- The potential to **learn**. It is needed because nothing is perfectly stable or perfectly predictable. Without learning, the responses would always be the same, and without learning, monitoring would always look at the same indications. It makes good sense to try to learn from representative events, from what has gone well, in addition, to learn from failures. Since the former happens all the time while the latter (hopefully) happens rarely, learning can be continuous rather than having to wait for an unwanted event.
- The potential to **anticipate**. The difference between monitoring and anticipation is that the former keeps an eye on the current situation and activities while the latter looks at what may happen in the future. Anticipation is essential both to plan a response in the short term, e.g. what the outcome of an intervention will be, and to look at future events—conditions, threats, and opportunities that may affect the system's continued functioning. Anticipation should consider both how internal and external conditions may change and how this may affect the system's performance.

2.2.1 The Interdependence of the Potentials

Although each potential is important in itself, their significance increases when they are seen together. While a system that is unable to *respond* is doomed, possibly in the short run and definitely in the long, responding cannot be effective if it is limited to a fixed set of responses. Unless the system's environment never changes, the responses must change and develop over time, which means that the system must have the potential to *learn*. The potential to respond also depends on the potential to *monitor*. Without monitoring, without keeping track of what goes on, the system must constantly be in a high state of alert for every possible condition for which a response has been prepared. That is neither possible nor reasonable (from an economic or productivity point of view). Monitoring must furthermore be revised or adjusted based on experiences, i.e. based on *learning*. Learning serves to strengthen or reinforce that which worked well and weaken or adjust that which did not work well. The lessons learned also serve to direct anticipation. Since no system and no environment is perfectly stable, it is also necessary to *anticipate* what might happen, to be prepared for something that is hypothetically possible, although it may not have happened yet.

The dependencies can be described more systematically by applying the Functional Analysis Resonance Method (FRAM; Hollnagel, 2012). Each potential can be seen as a function and can, therefore, be characterised using the FRAM terminology. The following shows what a rather simple description might look like.

The input to responding. It is typically an interruption in the ongoing activities/ process and/ or an alarm or alert that is the result of monitoring. A precondition for responding is that the system is in or can be brought into a state of readiness. The output of responding is obviously a response, either one from a prepared set or one that is put together to match the current conditions.

The input to monitoring. It is in general terms the process indicators and trends that have been specified, specifically the key performance indicators. The outputs are, as mentioned above, alerts and alarms. Monitoring itself is controlled by a strategy for monitoring and timed by a sampling frequency.

The main input to learning. It comes from the outcomes of the actions taken. Some of these are the direct consequences of responses; some are the indirect or delayed consequences that follow responses. The main output from learning is, broadly speaking, the lessons learned—including from what has gone well—with more specific outputs being, for instance, the monitoring strategy and even the sampling frequency. The extent and role of learning, in turn, depends on the business strategy.

The main input to anticipation. It is also the lessons learned, but an additional input is expected long-term trends. The anticipation is guided by the corporate vision, and the main outputs are the priority areas.

Even this basic attempt at identifying the dependencies has shown the need for other functions. The elaboration of a FRAM model of how the potentials are coupled will not be pursued here, but a result could look something like Fig. 2.1 below.

2.3 How Can Potentials Be Managed?

Management, understood as the act of managing rather than as an organisational layer or role, can be defined as a process of preparing, organising, and controlling the resources of a system to ensure that it can perform as required. This is true regardless of whether the purpose is to control the spread of a disease, the production of consumer goods, the movement of vehicles through a section of space, or the behaviour of a crowd or an international service organisation. Common to all definitions of management are the concepts of *purposeful change* and how that change is *controlled*.

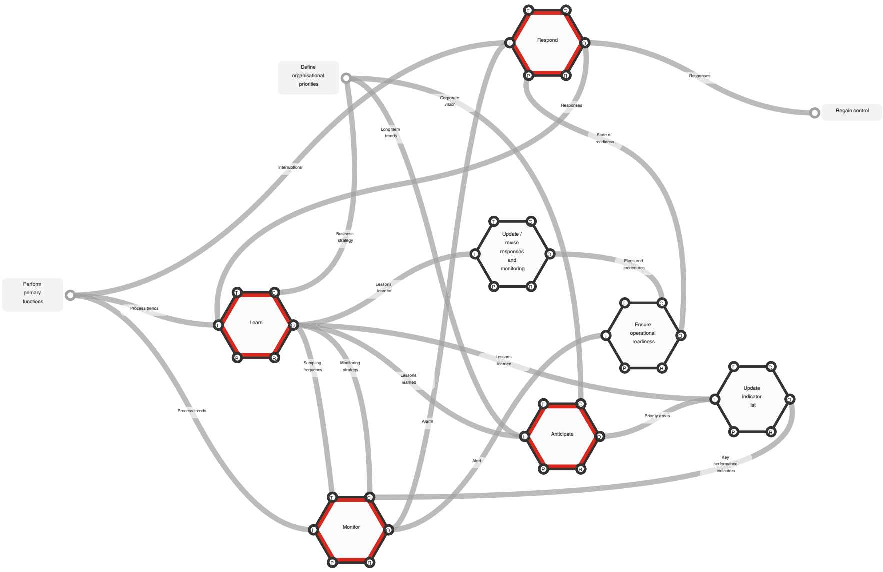

Fig. 2.1 A FRAM model of the four potentials

In order to manage or control something, it is necessary to understand how it works, to know the details of what happens inside the system. This understanding constitutes the necessary basis for determining what to do and specifically for how to respond when needed. It is also the basis for deciding what to look for (signals and trends) when monitoring the system's functioning and performance. The understanding also plays an important part in defining what the relevant experiences are that learning should be based on. It is finally important as an indication of what the future might bring, hence for deciding what anticipation should focus on.

2.3.1 Purposes of Management

The purposes of management are either to *approach* a new and more desirable state or to *avoid* or evade an existing but unwanted state, or simply to *maintain* the current state. Managing to approach a new state can be seen as the orderly movement or transition from the current to a new position or state. The expected future position should be different from the current position, and the nature of the difference constitutes the motivation for the change. Approaching a new position is associated with something positive, and making the change is therefore seen as bringing an improvement of some kind. Most changes, with the exception of safety management, are of this kind and made to ensure that something goes forward or improves. The purpose of safety management is usually to reduce an unacceptable number of unwanted outcomes or an identified risk. The focus is on the short-term results as measured by accepted standards, and it is usually assumed that the system is trivial—even though that may not actually be the case.

In addition to either approaching or avoiding something, the reason for making a change can also be to *maintain* the current position. This is not quite the paradox that it may seem. If an organisation is at the intended or desired position, then it would obviously want to remain there. Since the conditions—internal and external—in practice never are perfectly stable, changes will be needed to compensate for whatever may affect the *status quo*. One example is the dynamic positioning system that automatically maintains a vessel's position, another the corrections that a company may make to its production planning to compensate for changes in consumer preferences.

2.3.2 Three Types of Knowledge

It is convenient to use a travel or voyage metaphor to describe management and change. We often talk about keeping or improving the position, getting closer to or reaching a target, and even of roadmaps for change. The metaphor is convenient since it clearly is essential to be able to control how something moves and changes position, whether the travel is physical or abstract and whether the subject is tangible or intangible. The metaphor is also useful because it points to the need for three different types of knowledge. It is necessary to know what the current *position* is, it is necessary to know what the goal or target is, and it is necessary to know about the *means*, i.e. which changes are needed and how to make them in order to move in the direction towards the goal.

Position—Knowing Where You Are. Before beginning to make a change, it is obviously necessary to know the current state or position, regardless of whether the change is a movement in physical space or a transition in a more abstract space. In traditional safety management, the position usually represents a condition or a state that you want to get away from or hazards you want to avoid. In addition to knowing the initial position, it is equally important to know how the position changes while the change takes place. It is only by comparing the position at different times that it is possible actually to determine whether the change is in the right direction and with the right rate of change or "speed."

A system's position can be described as the extent to which each potential is present in, or expressed by, a system. (Technically speaking, this is a proxy measure.) That makes it tempting simply to ask how well a system is able to respond, how well it is able to monitor, and so on, but this temptation should be resisted. While it in some cases could be meaningful to address each potential *eo ipso* it makes more sense, and is also much easier, to look into the details of each potential. While the potential to respond obviously is needed, there are many facets of responding, such as *what* to respond to, *when* to respond, *how* to respond, etc. By using this kind of reasoning, or even a formal method such as functional decomposition, it is possible to determine which specific functions or sub-functions are needed to enable a system to respond, to monitor, etc. The answers to such detailed questions can serve as a qualitative (proxy) measurement of the degree to which each potential is present and can be used to produce a profile that effectively represents the system's position.

Goal—Knowing Where You Want To Be. In order to know whether the change is going in the right direction—and whether it happens at the appropriate rate—it is necessary to know what the goal or target is, i.e. to know where you want to be. Knowing where you want to be is also necessary in order to determine whether and when the goal has been reached. The goal should therefore be described in practical or operational terms, preferably absolute and concrete rather than relative. While this is straightforward in the case of trivial systems and material processes (such as the production of goods), it is less easy in the case of non-trivial systems and more abstract movements such as a higher level of safety or an improved safety culture/learning culture/reporting culture, etc.

Means—Knowing How To Get There. The third type of knowledge is about the effective means—how to make the change, how effectively to get closer to the goal. In the case of trivial and tangible systems—moving vessels, production of goods or energy, the transmission of information, energy, or materials—the means are usually known because the process being managed has been designed and as part of that provided with the necessary means of measurement and control. But few such means exist in the case of changes that refer to intangible or non-trivial systems, to concepts or to abstractions. Which practical means are at the disposal for changing safety? For changing quality? For improving precision or minimising delays? For changing the culture? The list could go on.

It is also important to know how long time it will take to make a change or at least to have a reliable estimate of it. This, of course, requires a good understanding of what actually goes on. Knowledge about how much time a change will require is essential both when detailed plans are made, when means of intervention are chosen and when resources are set aside. It is also valuable to know about possible side effects, about outcomes that may occur even though they were neither planned nor expected, in particular if they are detrimental or antagonistic. The better the system or process is known and understood, the fewer unexpected side effects there will be, and vice versa.

2.3.3 Assessing the Potentials

Measuring or assessing the potentials is relatively straightforward, since a set of questions can be developed for each potential. The questions can be based on a generic set of questions described in Hollnagel (2018). The questions should be *specific*, so they address issues that are important for a concrete organisation, *diagnostic* so they point to details of a potential that are meaningful to assess., and *formative* so that answers can be used more or less directly to select selecting the appropriate means. To illustrate that consider the questions shown in Table 2.1,

Table 2.1 Questions for the potential to respond (from Sekeľová & Lališ, 2019)

R1	Understandable documentation
R2	Adequate reaction to non-standard events
R3	Provision of inputs
R4	Effective communication among members
R5	Ensure information needed
R6	Process efficiency

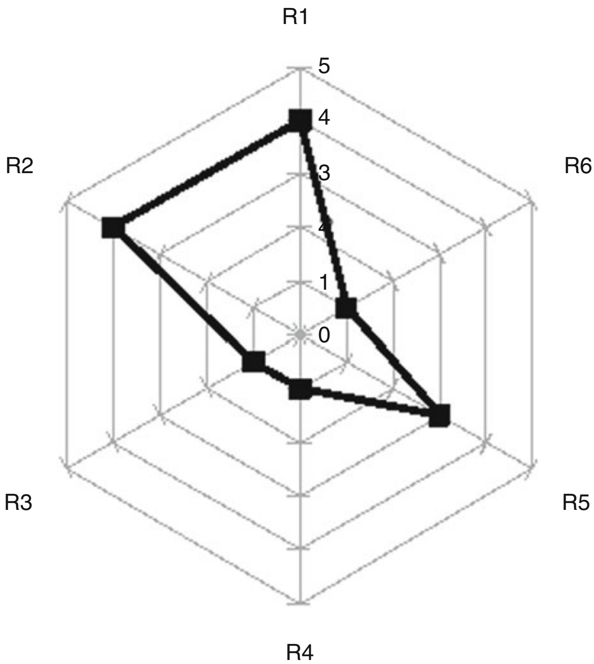

Fig. 2.2 Assessment results for the potential to respond (from Sekeľová & Lališ, 2019)

developed in the context of production of aircraft components (Sekeľová & Lališ, 2019).

Questions were also developed for the other potentials. The complete questionnaires were distributed to 14 members of the change process in the company producing aircraft components via e-mail, with a link to the questionnaire. A variety of the respondents helped to establish a wider picture of the process. Respondents assessed each question by the 5-point Likert-type scale, presenting their attitude on the statements with their full agreement, agreement, neutral attitude, disagreement, and full disagreement. This made it relatively simple to plot the answers on a net graph (also called a radar diagram) to produce an easily recognisable profile. An example is shown in Fig. 2.2.

If such questionnaires are applied regularly, the resulting series of radar charts provides an easily understandable representation of how the position of the system changes over time, hence a way to keep track of whether the changes are as intended.

2.4 Conclusion: Resilience vs. Potentials for Resilient Performance

The fundamental problem in managing non-trivial systems is captured by the Law of Requisite Variety, which basically states that an effective regulator or controller of a system—or a process—must be capable of responding to any situation that can possibly occur (Conant & Ashby, 1970), hence be able to compensate for all disturbances such that the system remains within the envelope of safe and efficient performance. Endowing the system with resilience as an exclusive quality corresponds to solving a complex problem with a simple solution. But complex problems rarely have simple solutions, and disguising complex problems as simple problems by offering apparently "simple" solutions do not make the problems any simpler—it only makes it highly likely that the solutions will not work. Paraphrasing Weick (1987), resilient performance should be understood as an ongoing condition in which problems are momentarily under control due to compensating changes. It is not possible to analyse/identify risks and opportunities once and for all, and then design or prepare the responses. Since the required resilient performance cannot be specified and designed ahead of time, the potentials are needed together with practical ways to manage them.

The potentials for resilient performance are essential for environments where changes can emerge, hence be unexpected and unpredictable, and where the consequences of changes can propagate rapidly (and have disproportionate effects). In order to survive, a system must do more than adapt itself to the adverse context in which it must survive by continuously monitoring the risks and reinventing its business and mission. It rather needs to be able to recognise (emerging) patterns and relations, and most importantly, to recognise opportunities that can be used to overcome present and future bottlenecks and hindrances. The potential to anticipate is, therefore, easily as important as the potential to respond. Anticipation tells us what we should look for and be able to notice when it happens. There is always uncertainty in anticipation, but situations that did not turn out as expected and anticipated can be excellent opportunities for learning (even if they may not be failures as such).

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Chapter 3
Resilience and Digital Transformation Challenges in Oil and Gas Integrated Operations

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Abstract High-complex operations, such as healthcare, air traffic management and oil and gas exploration, are facing increasing and new challenges concerning digital transformation. These transformations are happening due to the growing need for better and more efficient and safe work processes, precise outcomes, consistency, and continuity in operations in the face of variabilities, risks, and uncertainties. In this study, we discuss the use of FRAM (Functional Resonance Analysis Method) modelling to understand and identify variability in integrated operations by examining six instantiations of operations in the oil and gas industry. Five challenges of integrating digital transformation and support resilience in these systems are discussed: provision of support for coordination demands; provision of support for adequate human supervision of automated functions; reduction of system opacity; provision of support for adaptations; and provision of support for operators' non-technical skills. The study highlights that the operations analysed rely on human-machine interactions to perform resiliently, and workers locally manage variabilities in the system, assuring the continuity of safe operations while reconciling multiple goals (e.g. safety, efficiency, quality). The instantiations demonstrated the importance of the operators in making decisions when organising responses for disarming and recovery, which is not programmed and expected by the technical system.

Keywords Functional Resonance Analysis Method · Safety · Automation

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3.1 Introduction

There are growing initiatives of digital transformation and full automation of critical operations in the oil and gas industry. Drilling and production operations are getting more and more automated and operated remotely. It imposes new challenges of managing and supporting such transformations in an efficient and safe manner. Digital transformation is "about adopting disruptive technologies to increase productivity, value creation, and the social welfare" (Ebert & Duarte, 2018, p. 18). Oil and gas operations are considered complex socio-technical systems where several operations, often conducted by multiple teams, should occur in a coordinated and integrated manner. Such systems are defined as complex due to the fact they operate with residual uncertainties and risks, demanding capacities of coping with critical operational situations whenever they face them. Despite the large body of definitions about resilience, in this study, we adopted a Resilience Engineering approach. Resilience is defined as the ability of a system to disarm, recover, and adapt (especially when surprises challenge boundaries of normal operations) in the face of disturbances and unexpected variabilities (Nemeth & Hollnagel, 2016; Woods, 2018). There is a growing body of research in complex socio-technical systems, including oil and gas, with a focus on understanding drivers of resilience capabilities and the architecture of systemic elements supporting them (e.g. Bento et al., 2021).

Among some recent proposals of systemic modelling, Functional Resonance Analysis Method (FRAM), idealised by Hollnagel (2012) and vastly studied in several industries (e.g. aviation, healthcare, maritime, power industry), has been proving to be an adequate approach to characterise complex operations and identify emergent variabilities in them. FRAM is a method for modelling operations based on the critical functions of a system and its key aspects. It allows an appropriate description and understanding of relations among system functions and the analysis of emergent variabilities during disturbances in operations.

This chapter aims to discuss how FRAM modelling can be used to access resilience in integrated operations and how complex socio-technical systems can benefit from functional modelling to sustain safer and more efficient digital transformations. We elaborate and analyse instantiations of six large critical operations in drilling rigs and production units.

3.2 Theoretical Background

3.2.1 Integrated Operations

Integrated operations (IO) are defined as the combination of people, working processes, and technologies to enhance decision-making and operational outcomes (Albrechtsen, 2015). IO relates to the development of organisational capabilities through automation and digital transformation for better use of real-time data, onshore-offshore collaboration, and integration of know-how of different experts across geographical borders (Grøtan et al., 2011; Haavik, 2017). These capabilities are expected to offer more efficiency, process optimisation, and safety performance improvements. The oil and gas industry's tendency to remotely control operations through the increasing use of automation and digital technology is a great example of integration of operations (Haavik, 2010).

IO encompasses socio-technical challenges in the design, planning, and management of networks of interdependent functions and operations. Recent studies have focused on: the new constraints concerning the nature of operations in transformation and its associated risks (Lauche, 2008); the need for adaptation of risk analysis methods to new technologies introduced in the operations (Andersen & Mostue, 2012); the risks associated with systems becoming more complex (Johnsen, 2008); and the performance of human-machine systems concerning automation drawbacks, such as system opacity, mode confusions, critical tight-coupled emergent interactions (Besnard, 2017). Automation drawbacks may also result in a more complex operation in introduce new challenges for system coordination (Hollnagel & Woods, 2005).

3.2.2 Complex Socio-Technical Systems

Complex socio-technical systems are systems defined by goal-oriented interactions between humans, work, artefacts, and organisations (Amir & Kant, 2018). They can be delimited pragmatically based on the purpose of the analysis, ranging from a local interaction between a worker and a particular technology while performing specific activities to the larger organisational and societal level of institutions using technologies with specific purposes (Rasmussen, 1997). From the perspective of human factors and systems engineering, complex socio-technical systems have been used as a term to characterise several high-risk and intensive technology industries such as aviation, health care, nuclear power and oil and gas. Such systems, despite the intensive demands for knowledge and engineering in their design and management, for example always operate with residual levels of uncertainty and risks, therefore demanding and developing adaptive capacities to cope with a set of undesirable and unexpected events (Branlat & Woods, 2010).

While pure technological systems tend to have a tractable nature, as they can be fully modelled, described, measured, and analysed, complex socio-technical systems have an intractable nature. They are resistant to Cartesian-Newtonian analysis and cannot be completely modelled, described, and measured completely (Dekker et al., 2013). The complexity of such a system is not in its specific parts; rather, it emerges from its interactions. Such interaction can sometimes generate compensations and adaptations during disturbances and disruptions and keep the system working in a changing environment. According to Dekker (2011, p. 144), "...complex systems are adaptive, and they can be resilient precisely because of their complexity." As adaptations may happen in a faster way than the system can absorb or even in a variable manner, complex systems cannot be fully understood, and, consequently, outcomes are often not entirely comprehensible (Dekker et al., 2011; Hollnagel, 2012).

Hollnagel (2012) recognises that all socio-technical systems have some characteristics of complex systems. Perrow, otherwise, argues that different systems have different levels of complexity, for example hospitals, petrochemical plants, and nuclear power plants are more complex than other systems (Perrow, 1984). Today's oil and gas organisations operate in an increasingly technological scenario as a result of information technology and computer science advance, making socio-technical systems even more complex. Patriarca et al. (2021) suggest the notion of cyber-sociotechnical systems referring to socio-technical systems that encompass interactions with software that provides data-accessing and data-processing services with more autonomy and intelligence. Although the aim of automation is to replace human functions (Bainbridge, 1983), it is widely established in the literature of Human-Machine (cyber) Interaction that when autonomous software is introduced, the role of a human operator is necessary, more than before, to monitor and intervene when the software cannot handle a be-yond-design and unanticipated situation (Endsley, 2017; Parasuraman & Wickens, 2008). In fact, human operators can cope with local conditions, reconcile uncertainties and make proximate adjustments to balance efficiency and safety (Hollnagel, 2009). This adaptability based on intuition, expertise, competency, and knowledge-based behaviour cannot be easily implemented on machines and algorithms (see Dreyfus and Rousse (2018), for example as a discussion on the limitations of modelling human expertise and intuition).

In offshore oil and gas, daily operations require intensive use of manpower and technologies to run complex processes. Despite the intensive planning of the work, local adjustments and sacrifices of safety to the detriment of efficiency, and vice-versa, occur daily at the macro-level of large operations or the micro-level of local tasks executed. Among a plethora of models and theories, the Functional Resonance Analysis Method (FRAM) has been tested, and it is proving to be an effective way for understanding, mapping, and exploring complexities in several resilience-critical socio-technical systems (Righi et al., 2015; Woods & Hollnagel, 2006).

3.2.3 FRAM

The Functional Resonance Analysis Method (FRAM) was developed based on the principles of resilience engineering, complex socio-technical systems, and social psychology to describe how work is normally performed (Hollnagel, 2012). Unlike other systemic methods based on models [e.g. STAMP (Leveson, 2004) and ACCIMAP (Svedung & Rasmussen, 2002)], FRAM is not based on a specific model, but the method itself is a modelling tool. The model generated by the method is described in terms of functions, potential couplings between the functions, and the type of variability of the functions. Functions, for the method, represent the means (usually actions) necessary to achieve an objective. FRAM model can be used to produce different operational scenarios, i.e. instantiations. The instantiations portray the interdependence and dynamics between the functions, identifying the effects generated by the potential couplings and variability among and between the functions.

FRAM is based on four principles about how activities or events happen:

- The principle of equivalence of successes and failures: failure and success are equivalent in the sense that both have the same origin, that is, the things go right or go wrong for the same reasons.
- The principle of approximate adjustments: System complexity leads to unforeseen events that require procedures and tools to be adjusted by workers to correspond with the situation found.
- The principle of emerging results: variability originating from the adjustments will rarely be enough to cause a failure individually. However, the variability of multiple functions can coincide and interact with each other in an unexpected way and, therefore, generate unexpected and disproportionate impacts in the system.
- The principle of functional resonance: interactions between the variabilities of certain functions can occasionally be reinforced among themselves and, consequently, increase the amplitude of the variabilities (resonate) to the point where a given limit is exceeded.

The resonance analogy emphasises a systemic phenomenon, so it is not a question of cause-and-effect chains. Resonance can generate positive or negative results not only in functions with variability but in others within the system. Consequently, the impacts are emergent phenomena; that is, they appear in a way that cannot be explained or reduced to linear chance (Clay-Williams et al., 2015; Hollnagel, 2012).

3.3 Method

A multi-case study was conducted in a Drillship and in a Floating Production Storage and Offloading (FPSO) unit. Operations studied were Blowout Preventer (BOP) Running and Land-Out of (Blowout Preventer), in the Drillship, and High-Pressure (HP) Compressor Startup, in the FPSO. These operations and their related instantiated scenarios were defined according to their associated complexity and risks and prioritised for analyses after the revision of the company's safety data, eight focus groups with team leaders and one workshop with company managers.

For the operations analyses, data were collected through documental investigation, *in locus* non-participant observations, and interviews with workers in charge of these operations. In the Drillship, four researchers performed more than 100 h of observations registered in field notes and photographs and carried out sixteen interviews (17 h were recorded and transcribed). In the FPSO, three researchers accomplished more than 100 h of observations of the facilities and technologies, including those related to the HP Compressor, but its startup was not possible since it did not occur during the period when the researchers were aboard the unit. Thus, descriptions are heavily based on documental analysis and interviews of 20 operators, encompassing 18 h of data recorded and transcribed for analyses.

We adopted the following steps proposed by Hollnagel (2012) to model the work-as-done of these operations using FRAM:

- First, the definition of the modelling objective.
- Second, identification and description of the functions performed in the operations.
- Third, identification of the potential variability of each function.
- Fourth, analyses of the aggregation of variability according to the generated instantiations.
- Fifth, identification of opportunities for managing variabilities in the operations.

In a FRAM model, functions are illustrated by hexagons where its vortices represent six aspects or dependencies connecting them:

- Input (I) is what is used or transformed by the function in an output.
- Output (O) is what is the result of a function or what it delivers.
- Pre-condition (P) is a state that must be valid before starting the function.
- Time (T) represents the multiple ways of temporal relations.
- Control (C) is what regulates the function.
- Resource (R) is something that the function needs to work.

Models and instantiations generated, as well as variabilities identified in the operations, were validated with team leaders of the Drillship and FPSO in another round of interviews and deeply discussed with company managers. We used FRAM Model Visualiser Pro for illustrating the instantiations.

Oil and gas operations are complex due to the non-linear behaviour that emerges between the parts of the system during the activity being performed. This gives rise to performance variabilities that influence the way the system achieves its goals. To identify the sources of variability in the system, FRAM presents itself as a tool that may contribute to the oil and gas industry to understand how the work is actually performed.

3.4 Description of the Operations

3.4.1 Running Lower and Land-Out BOP

The BOP running lower and land-out is necessary in order to continue the process of drilling the Well with a reduced risk of blowouts. The BOP is a 350-ton piece of equipment, 12 meters high and 5 meters wide, which needs to be taken to the ocean floor at an average depth of two kilometres. To carry out the running, riser joints are installed sequentially on the drill floor, forming a riser column. This running process is interrupted when two joints are missing: the slip joint and the landing joint. This BOP running operation precedes the land-out operation. Unlike the BOP running, which is performed exclusively by the drilling and subsea team, the BOP land-out operation is also performed by the Remotely Operated underwater Vehicle (ROV) team, the team that operates the Dynamic Positioning (DP) and the Drilling Section Leader (DSL).

During the installation of the slip joint and landing joint, the ROV team monitors the position of the BOP to avoid collisions against the seabed, as well as inspects and cleans the connection nozzles. DP operators are responsible for unit navigation, and they are initially assigned to verify that the operations carried out on the deck are paralysed, such as cargo handling with a supply ship. The DP operator also asks the operators of the power control room to run all the generators so as the position accuracy of the ship and energy available are increased. With these conditions satisfied, the DP operator can adjust the preliminary position of the unit to bring the BOP horizontally closer to the well-head.

Before land-out the BOP, the team involved performs a briefing to discuss the next activities that must be carried out to land-out the BOP (the most critical moment of the entire operation). The main risk associated is missing the alignment between the well-head and the BOP, which in severe cases generates a fracture in the sealing nozzles requiring abandonment of the Well resulting in severe financial losses. After the briefing, the actions performed by the teams are coordinated by the DSL through verbal commands and communications via radio. The DSL is positioned in the ROV control room to obtain a better view of the alignment between the BOP and the well-head. When this alignment is achieved, the DSL commands the running performed by the driller on the drill floor, with the vertical movement until it fits into the well-head. After being connected, the ROV team is asked to verify that the BOP is correctly connected to the well-head so that the mechanical locking between them is accomplished. The locking is triggered by the subsea engineering through the control panel. After the lock is activated, the ROV team is asked to verify that the visual lock indicator is visible, confirming the lock condition. To complete the operation, pressure tests are carried out by the subsea team of operators to check the connection for the appropriate tightness.

A general description of the BOP running and land-out operation based on a FRAM model was created with forty functions, illustrated by hexagons, representing the integrated work of nine different teams that have to coordinate to get this operation done.

3.4.2 High-Pressure Compressor Startup

The compression systems in a production unit are responsible for maintaining incoming oil to its maximum capacity. In the cases of the unit investigated, it should be at least 40 thousand barrels per day. Each compression system is equipped with a three-stage main compressor driven by an electric engine and another high-pressure/high-capacity reinjection compressor. A compression system handles pressures of near 200 bar and volumes of gas of around three million cubic meters per day. Working with volumes and pressures of this magnitude represents an imminent risk of catastrophe in case of a severe failure. The startup of a compression system is a critical step to production because high pressures are essential to guarantee the production working at full capacity. Gas coming from the Well that cannot be stored or burnt must be reinjected due to environmental regulations; otherwise, production must be slowed down to keep gases flowing within acceptable limits. The compression system consists of a series of compressors that compresses a massive amount of gas at extremely high pressures to be reinjected by a proper well.

The HP Compressor Startup was modelled using thirty-nine functions distributed among five operating teams. The process is human-dependent but assisted with automatic systems. To startup a compression system, several requirements must be met, including multiple tasks and checks from the Area Operators (people actuating valves manually and verifying the process on the field) and from the Central Control Room (CCR) operator (worker responsible for guiding the procedures and remotely control the compressors and automatic valves). Most of the controls of the gas processing systems are located in the CCR, including the command of valves and systems operated remotely, as well as the automated system that runs the production plant under constant human supervision. Activities concerning compressor startups are coordinated by the CCR operator (CRO) following standard procedures.

During a startup sequence, actions like the opening of specific valves, verifications, and draining lines cannot be performed remotely by the CRO. It is necessary to rely on Area Operators to perform them in place directly. The CRO has to keep in coordination with other areas of the FPSO, such as the electrical generation and distribution team. They must be prepared for a compressor startup due to the amount of electrical load a compressor represents. Should all steps be completed, the compression system is started allowing gas coming from the Well to be reinjected into the reservoir.

Human performance is critical in these operations, mainly regarding decision-making and problem-solving of system's issues (e.g. automation failures, algorithm problems, regulatory demands), as well as assuring that environmental conditions do not compromise any hardware. Area Operators are responsible for verifying equipment integrity, correct alignment of valves, and sensors' reliability. All these activities are important especially considering that the FPSO is exposed to a harsh environment subject to corrosion and damage from seawater. The lack of integrity in the systems and facilities may introduce critical variabilities threatening safety and efficiency due to the possibility of leaks, damages, production losses, environmental degradation, human harm, or even larger catastrophic accidents.

3.5 Analyses of Variabilities

3.5.1 Running Lower and Land-Out BOP

3.5.1.1 First Instantiation

The FRAM instantiation of the variabilities in the riser analysis and heave monitoring is illustrated in Fig. 3.1. Seven functions are shown in the hexagons, being

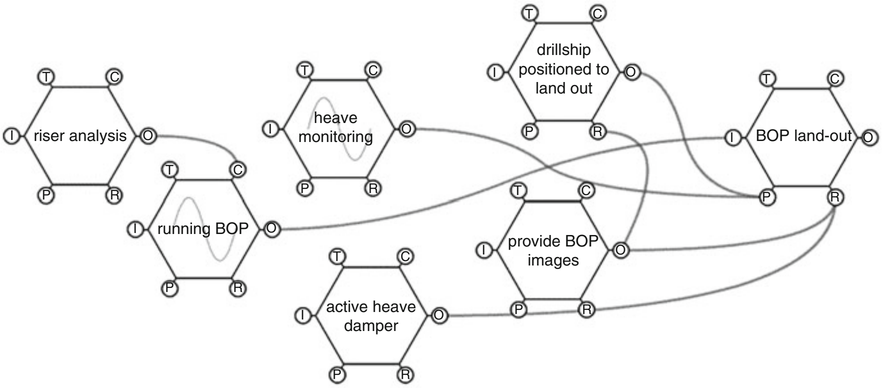

Fig. 3.1 FRAM instantiation of variabilities in the riser analysis and heave monitoring

vertices of each hexagon typical aspects or dependencies of a FRAM modelling (I—input, O—output, T—time, C—control, P—pre-condition, R—resource) (Hollnagel, 2012).

Prior to the BOP running and land-out operation, the <riser analysis> function is performed, in which the number and types of risers used for a given well are defined. This function serves as a control for the <running BOP> function. However, adaptations made by the drilling and subsea team are often necessary due to variations in deep currents. The currents deform the riser column profile, changing the depth reached. In these cases, different forms of adaptation are possible, such as changes in the configuration of the columns in relation to the riser analysis or directly in the slip joint. Once the BOP is at a depth that allows land-out, this activity can be started. During the land-out, the activities performed by the different teams are synchronised by the DSL. As described above, the commands for lateral movement (performed by the DPO) and vertical movement (performed by the driller) of the BOP are requested by the DSL. Therefore, the pre-conditions for the <BOP land-out> function are DPO must have the <drillship positioned to land-out> considering the most favourable weather conditions and must do the <heave monitoring> to identify the time window for land-out the BOP. Also, to compensate for the heave, the <active heave damper> resource is employed. Another resource employed is <provide BOP images> from different angles, performed by the ROV team. It allows the DSL to ask the DPO for precise position adjustments for alignment between BOP and well-head. In the stability window of the heave, DSL asks the driller to lower the BOP until land-out occurs.

Although the heave is monitored and compensated, the environment is a source of variability for this operation. If there are inaccuracies in <heave monitoring> or heave compensation failures (technological), the land-out may be hard (hard landing), or the structure of the BOP may collide against the well-head, which, in the worst-case scenario, generates fractures resulting in abandonment permanent Well.

3.5.1.2 Second Instantiation

The FRAM instantiation of visual checking during the BOP running and land-out operation is illustrated in Fig. 3.2.

The operation of running lower the BOP, represented by the function <running BOP>, must be supervised to assure it is happening safely. The working team in charge of the BOP itself is subsea. The subsea is responsible for conducting tests in the BOP to certify that it is working properly before the installation. This relates to the function <verify BOP pressure lines integrity> in the model. The visual check performed by the subsea team dampers possible negative variabilities that may arise, and it relates to the capacity of disarming a possible threatening scenario since no maintenance and correction can be done after its installation (i.e. landing) without pulling the BOP back onboard (represented by the function <landing out BOP>). Moreover, during the operation, the subsea team must supervise distinct activities in different places (e.g. moon pool, drill floor, hydraulic unit). Although there are cameras in these areas to monitor the operation, *in loco*, visual checks are performed by both the subsea supervisor and his team to assure everything is occurring as planned. According to the subsea and his team, the cameras cannot capture everything with the same detail as a person in the place can. Also, notes are taken of every condition that the subsea considers important. It gives them, should a problem arise after the installation of the BOP, referencing points to investigate and solve the problem.

3.5.1.3 Third Instantiation

The FRAM instantiation of variability in the dynamic positioning system during the BOP running and land-out operation is illustrated in Fig. 3.3.

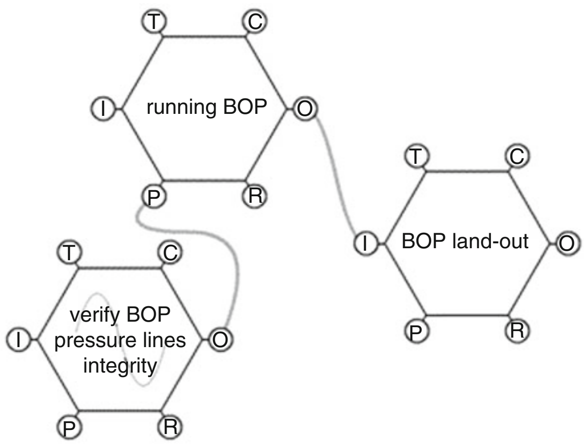

Fig. 3.2 FRAM instantiation of visual checking

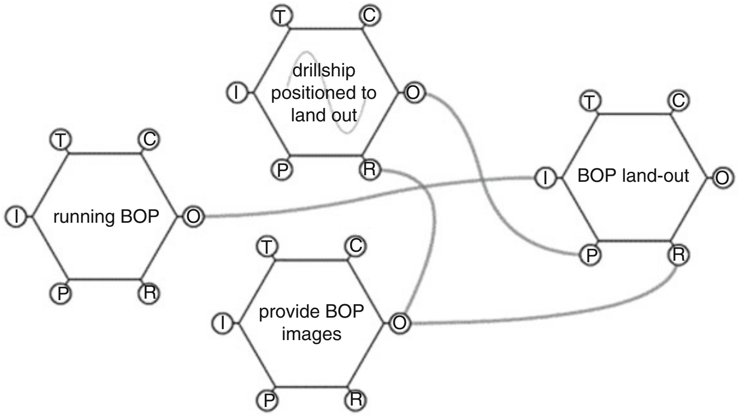

Fig. 3.3 FRAM instantiation of variability in the dynamic positioning system

From the moment the BOP is close to the depth of settlement, the dynamic positioning system becomes critical. The unit must not make significant changes in position, as the BOP may collide with the irregular seabed. In the same way, after the installation, the movement of the unit is limited by the connection through the riser column, which, if too tight, can break or cause damage to the Well. The position of the unit is represented by the function <drillship positioned to land-out>, which shows technological variabilities that can be manifested in inadvertent changes in the position of the unit. The DP system employs different types of position reference systems, such as GNSS and acoustic-inertial systems. This redundancy allows the system itself to reject data judged to be inaccurate or of low reliability. However, situations have been reported in which the automatic rejection of the DP system has aggravated the position discrepancy causing the unit to move to a new position automatically. Such cases required the DPO to switch to manual control mode and manually reject the position provided by the inaccurate position system. Therefore, the variability of this function can be manifested in the function <running BOP> in which there is the potential for a collision of the BOP against the seabed or in the impossibility of <BOP land-out>.

3.5.2 High-Pressure Compressor Startup

3.5.2.1 First Instantiation

Figure 3.4 illustrates the FRAM instantiation of the variability of monitoring burning gas maximum limit in the HP Compressor Startup operation while reducing the oil production rate of the plant.

The compression system is responsible for guarantying the production of oil at its maximum. Gas coming from the Well cannot be stored or transported and has to be

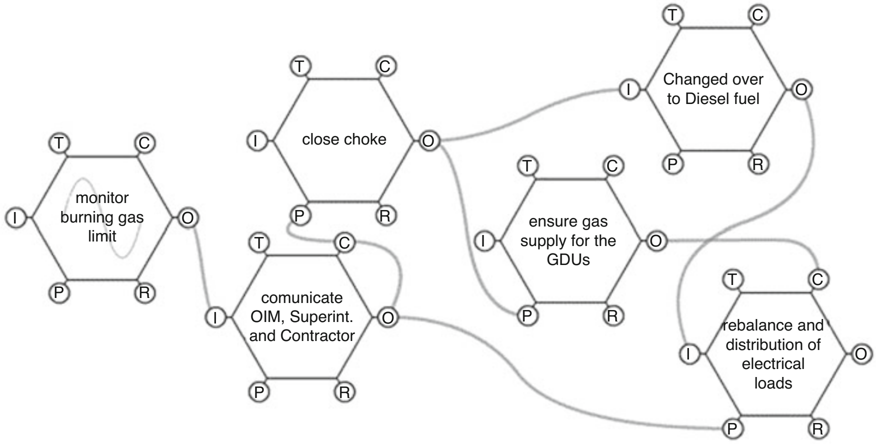

Fig. 3.4 FRAM instantiation of the variability of monitoring burning gas maximum limit

burnt or reinjected. When compression system trips, the contingency plan is to figure out what happened and start the backup system as soon as possible to avoid the reduction of oil production. Initially, the CRO must <monitor burning gas limit> avoiding exceeding environmental regulations. He also must <communicate with OIM, the production superintendent, and the contractor about the situation> so they can draw directives for the system restore, always trading off production shortage, environmental regulations, and safety. The start/restart of the compression system involves a strict step-by-step sequence evolving different teams and cannot be shorted out. When the decision is to keep things slow and safe, the intake valves from the Well (choke) must be roughly closed <close choke>. This action may interfere with the gas supply for the Gas Turbine Generators (GTGs) that are the source of electrical power for the FPSO. When enough gas cannot be supplied <ensure gas supply for the GDUs>, one or both GTGs may be <changed over to Diesel fuel>, requiring a <rebalance and distribution of electrical loads>.

3.5.2.2 Second Instantiation

Figure 3.5 illustrates the FRAM instantiation of the impact of sensors and equipment malfunctions in the gas system startup.

Equipment malfunction is inherent to the environment of FPSOs due to the sea breeze and the operating conditions. One of the attributions of the CRO in parallel with the automated system is to <protect GDU[1] integrity>. When any high/low sensor indicates abnormal conditions, CRO must <evaluate high/low-pressure

[1] GDU: Gas Dehydration Unit. Is the unit responsible for removing moisture from incoming gas so it can be used as fuel by the GTGs.

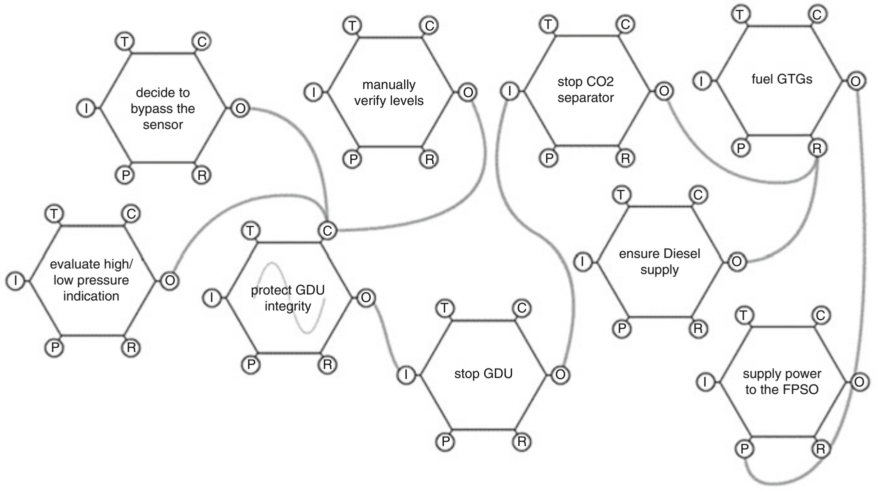

Fig. 3.5 FRAM instantiation of the impact of sensors and equipment malfunctions

indication> to ensure that the situation is happening. He must <decide to bypass the sensor> and request the area operator to <manually verify levels>. In case of a dangerous situation for the GDU he must <stop GDU> leading to <stop CO2 separator>. Without the gas supplied from the CO2 separator, the GTG fuel <fuel GTGs> must be changed over to Diesel <ensure Diesel supply> and electrical loads must be balanced to <supply power to the FPSO>. The FRAM instantiation shows part of the gas system operation regarding a possible malfunction in a critical component (i.e. GDU).

3.5.2.3 Third Instantiation

Figure 3.6 illustrates an instantiation of the variabilities in readings during the gas system startup operation.

Compression system startup/restart is not an entirely autonomous operation, mainly because it is not possible to ensure hardware integrity only by remote sensors and actuators. Among several activities concerning the start of a compressor, some pre-conditions assured by area operators are <check the pressure and flow readings> to guarantee that sensors are sending the correct information to CRO, <read chemical composition readings> to verify if chemical processes are being correctly applied to the incoming gas, and <purge main motor> to avoid the presence of oxygen or oil that can cause an explosion inside the main motor of the compressor. All pre-conditions met, the CRO can <start the compressor>.

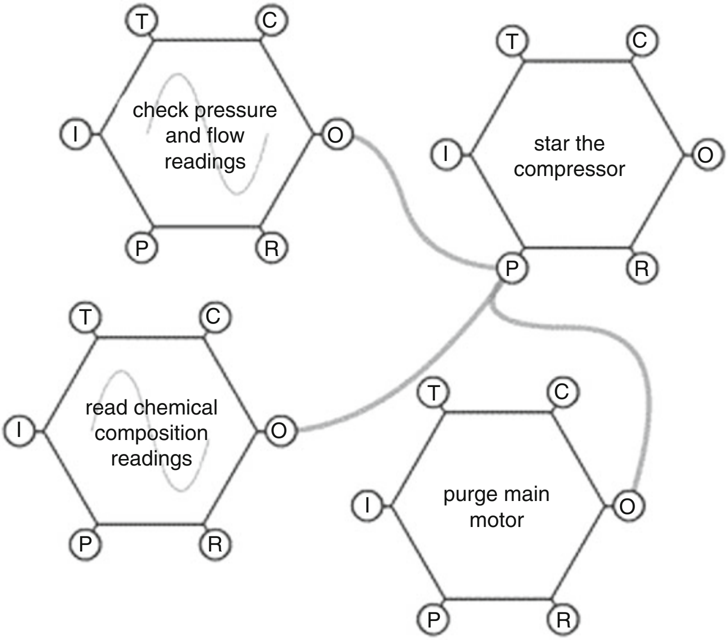

Fig. 3.6 FRAM instantiation of variabilities in readings during the gas systems startup

3.6 Discussion

The oil and gas industry has a fast pace of innovation with the increasing use of automated technologies and digital data in operations. Major oil and gas companies currently have digital transformation programmes, and smart technologies and fields have been scientifically investigated and engineered for almost 20 years (Carvajal et al., 2017). According to Redutskiy (2017), the motivations for smart solutions in oil and gas are typical: the need for decision support in drilling and reservoir management, production optimisation, monitoring operability and integrity of equipment and tools, communication for remote support of, or even entirely remote, operations, and information management.

BOP Running and Land-out and HP Compressor Startup operations illustrate different dynamic relations in complex socio-technical systems, where essentially operators interact with technologies and may experience unexpected or undesired events emerging from these interactions. Systems variabilities are absorbed by resilient capabilities that can be comprehended in three different behaviours: disarming, recovering, and adapting. Disarming is understood as the early control of unwanted behaviour in the system. Recovery is the behaviour that arises when the desired performance zone is violated, and the system can adjust its performance to return to the desired performance zone. Adaptation occurs when the desired performance zone of the system is violated, and it is not possible to restore previous parameters. Thus, the system works in a new normality zone of performance. In this sense, resilience appears to be locally placed, bringing the discussion on how remoteness and digital transformation can sustain the resilient capabilities of systems despite its movement to integrated operations. Some challenges, then, arises when it comes to integrating digital transformation and support resilience in these systems.

Challenge 1: Provide Support for Coordination Demands
Integrated operations demand coordination among several agents, including some specific types of automation. Since automated systems have some degree of control and authority over particular processes (e.g. technological functions illustrated in our FRAM instantiations), they also have to be considered in the joint activity. The modelling of BOP Running and Land-out and HP Compressor Startup using FRAM show multiple functions demanding interpredictability, common ground, and directability (Klein et al., 2005). Interpredictability refers to the capacity of agents to predict each other's behaviour and adjust according to it; common ground relates to the shared understanding of agents of what is going on and what should be happening next, then adjust their behaviour according to it; directability is the capacity of an agent to give and receive commands from another agent.

In the instantiations of BOP Running and Land-out, it was possible to verify that the performance of some functions is susceptible to environmental variability (in this case, ocean condition), demanding constant monitoring, adjustments, and coordination among multiple agents. Perrow (1984) argues that the environment acts as a source of complex interactions, as it can impact an operation in a circumstantial and non-controllable way, limiting the knowledge of the entire system. In FRAM terms, it can be classified as an exogenous type of variability (Hollnagel, 2012). Coordination support resilience since it allows agents to operate in an integrated manner to best adjust behaviours according to the situation (Henriqson et al., 2011).

Digital transformation, in this sense, should support coordination demands of the operations in a way the entire choreography of operations benefits from it. Digital transformation initiatives should look at mechanisms for appropriately signalling functions and agents status and changes in the phases of the operations, as well as should reduce agents' coordination efforts.

Challenge 2: Provide Support for Adequate Human Supervision of Automated Functions
Some instantiations portrayed endogenous variabilities due to technological functions. The introduction of these sophisticated technologies has led to an increase in the complexity of the systems, especially those that employ digital technology (Leveson, 2011). Given this scenario of integrated operations, some concerns and drawbacks can be pointed out. Remoteness controls dissociate human operators from the process they are controlling; thus, the activity becomes more symbolic without direct physical input. Besnard (2017) argues that little feedback about the system state and the indirect data presented by some parameters requires an operator's accurate mental representation of the system.

This drawback can be seen in instantiations of gas system startups. Although CCR is not located onshore, inside FPSO, CRO interacts with a digital interface isolated from the plant. To overcome barriers to the mental representation and common ground, area operators also play the role of "human-based sensors and probes" to provide more sensible and tactile data to CRO via radio communications. In the same way, during BOP running lower and land-out operations, in loco, visual checks of pressure lines are constantly made by the subsea team. Even though cameras are available to monitor, they cannot capture the same detail as a person in the place can. In resilience terms, monitoring is not just about making sure that systems parameters are meeting design criteria for proper functioning but interpreting the signs of possible upcoming problems (Lundberg & Johansson, 2015). These two instantiations depict ways of accessing more accurate information based on human expertise and, thus, provide a better view of the system state.

Digital transformation, therefore, should provide support for human supervision. Cockpit automation in aviation has proved that the best direction is the design of human-machine systems rather than the pure attempt of complete human substitution by technologies. Operators' expertise is a tremendous resource for system resilience since they can use knowledge repertory to integrate complex (and sometimes imprecise) data and come up with smart and novel solutions (Klein, 1999).

Challenge 3: Reduce System Opacity
Another concern related to remoteness control, but mainly with automation, is the indirect control provided by an interface, which can increase the opacity of a system and it makes more difficult for the operator to follow the process steps (Ferreira & Cañas, 2019) and facilitate automation surprises (Sarter et al., 1997).

The instantiation of the DP system portrayed the side effects of interface opacity, which DPO needed to assume the manual control immediately due to the degradation of the automatic positioning determined by an inaccurate referencing system. In this case, the automation level is higher on the rationale of management by exception (Endsley, 2017) because the DP system evaluates options, selects best, and carries out, a human operator can override if necessary. However, Hogenboom et al. (2020) claim that the opacity of decision criteria of the DP system leaves the DPO out-of-the-loop and when interventions are required. According to with authors, in this case, the sudden workload increases from low (monitor and supervise) to high (make sense and intervene) make DPO actions more error-prone. From the resilience engineering point of view monitoring system state is compromised due to opacity; thus, disarming unwanted behaviour is also compromised. To return to the desired performance state, a recovery override action of DPO is required.

Initiatives of digital transformation should, consequently, consider and assess the risks of increasing opacity in critical functions. Opacity is not only the result of operating complexities behind an interface of control. It also can emerge in the form of insufficient or overload data (Hollnagel & Woods, 2005).

Challenge 4: Provide Support for Adaptations
Another automation drawback is its inability to make decisions or judgments outside a predetermined algorithm (Hogenboom et al., 2020; Parasuraman & Wickens, 2008). Running lower and landing-out a BOP is an activity at the mercy of ocean conditions because underwater currents deform the riser column profile and change the depth reached in a quite unpredictable way. In this case, adaptations are required in the riser column to avoid downtime and keep the system working in a new performance zone. Adaptive capability relies heavily on the availability of resources, time, and accumulated expertise among decision-makers and operators (Lundberg & Johansson, 2015; Woods & Branlat, 2016). This operation illustrates a characteristic where a high level of automation is unlikely. Automated systems operate as intended for a range of situations it is designed, but there is no technology (today) that copes better with variability and uncertainty than human operators (Ferreira & Cañas, 2019). As oil and gas socio-technical systems are complex, among other things, because of the residual level of uncertainties and risks in operations, providing the system with the appropriate conditions for adaptations should be considered in any digital transformation process.

Challenge 5: Provide Support for Operators Non-Technical Skills
The diversity of situations that arise on an oil platform because of a hostile operating environment gives rise to variability in performance. Due to non-technical skills like situational assessment and decision-making, human performance often plays a decisive role in reestablishing normal operation when the systems' variability arises (França et al., 2020). Given the restricted rationality of the technical system that only performs what it was planned and programmed for, the management of the variability by the human system is essential since it manages to deviate from what is formally prescribed.

All six FRAM instantiations presented bring elements of the necessity of manual/local interventions on highly complex equipment and machinery. The development of such systems must assess those kinds of situations, looking forward to creating redundant and robust processes that can guarantee continuous operations without pushing safety barriers to their limits. Thus, interventions of digital transformation should consider the non-technical skills mobilised by works to monitor and intervene in the operation whenever necessary.

3.7 Conclusion

In the context of this study, resilience can be defined as a dynamic capability to disarm, recover, and adapt in the face of expected and unexpected events with unintended consequences. Capability here is defined as the potential to mobilise knowledge, skills, and resources to accomplish something. Dynamic because such capacity is defined as something that a system does and not something that a system has. A system may have the potential to be resilient, but its resilience is seen in the way it faces the variability and challenges of work, i.e. in the dynamics of disarming, recovery, and adaptation. Therefore, resilience can only be observed, in this case, in the behaviour manifested by the system in relation to unwanted events, whether they are expected or not.

There is not a perfect match between the work-as-imagined and work-as-done, and the success of the system depends on how workers adjust procedures to the local demands. These adjustments, based on expertise acquired through years of work, are translated into practices by people taking notes during certain stages of operation and observing the activity in different locations. The instantiations demonstrated the importance of the operators in making decisions when organising responses for disarming and recovery, which is not programmed and expected by the technical system. This adaptability based on creativity cannot be easily implemented on machines and algorithms. For this reason, future studies of variability in complex socio-technical systems are necessary to support digital transformation and large-scale use of automation appropriately.

FRAM modelling provides interesting support for mapping and understanding functions and teams that must work in an integrated manner. System variability may emerge from internal variabilities in functions as well as from inadequate coordination among them. Future studies should explore the design of methods and tools to address the five challenges for resilience in digital transformation. Likewise, those challenges could be interpreted as guidelines for supporting digital transformation initiatives.

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Chapter 4
Relational Capital and Organisational Resilience

Florinda Matos, Graciele Tonial, Maria Monteiro, Paulo Maurício Selig, and Leif Edvinsson

Abstract In the current context, marked by the challenges of the digital transformation, the climate emergency, the risks of the Covid-19 pandemic and the economic and health crisis, resilience emerged as a concept explaining how societies, systems, and subsystems can respond to shocks and better manage the inherent risks that are constantly changing. With the digital transformation and the increasing use of the internet by organisations, relational capital has emerged as one of the components of intellectual capital with greater relevance for the resilience and agility of organisations. Through the most recent literature review, this study explores the relationship between relational capital and firms' resilience indicators. The results provide empirical evidence for the positive relationship between the two concepts and present the basis for developing an auditing framework of organisational resilience.

Keywords Organisational resilience · Relational capital · Indicators

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4.1 Introduction

The coronavirus pandemic (COVID-19) started a revolution in business models. Companies, in all sectors, have been forced to adapt their organisational processes, people management, customer, and supply chain management and even their interaction with the application of public policies. This challenge is indicative of new times (Sneader & Singhal, 2020).

Large, medium, and small organisations have gone to great lengths to find solutions, optimise production and create alliances with other organisations operating in the same sector to overcome emerging challenges together, and most of these initiatives have had a positive impact (Mariano, 2021).

The pandemic appears to have changed, mainly how consumers shop and how supply chains and value chains are organised. In this scenario, the most resilient companies, driven by the accelerated growth of digital transformation, were forced to gain elasticity, re-adapt, reinvent themselves, become agile, and develop new characteristics that seem to make them stronger (Verhoef et al., 2021).

The literature and empirical observation seem to indicate a relationship between the development of companies' relational capital (RC) and their resilience, as it points Walecka (2021). That is, companies with better performances in relational capital have a better capacity to adapt to contexts of crisis and uncertainty in what we currently live. Thus, it is clear that companies establish relationships seeking to minimise risks. Through cooperation with unknown partners, they consciously create their relational capital.

Bolisani and Bratianu (2017) and Keszey (2018) note that to respond to hyper turbulent environments, organisations cultivate a knowledge ecosystem that promotes opportunities for knowledge exchange among employees and allows dynamic knowledge exchange activities to occur and evolve as environmental circumstances so require.

Considering this context, García and Bounfour (2014) report a growing body of empirical evidence that proves the contribution of the RC as a knowledge asset capable of boosting the company's capacities to intensify the absorption of intangible resources. In the context of external relations, Relational Capital is identified as a research gap, as pointed out by Buenechea-Elberdin et al. (2018).

In this sense, Venugopalan et al. (2018) recommend that managers develop RC indicators based on the nature of their businesses. To this end, they suggest that time and effort should be invested in nurturing and maintaining relationships with its internal and external audiences. This practice should be seen as an organisational strategy of considerable importance in a knowledge-based economy.

Research suggests a positive linear and relationship between RC and resilience; see, for example Polyviou et al. (2019), Teo et al. (2017) and Walecka (2021). The authors argue that CR results in superior access to resources and information maintained by the relationships between organisations. At the same time, resilience is associated with improved organisational capabilities to survive, adapt, and grow when faced with environments of change, uncertainty, and extreme crises. However, gaps arise in the understanding of how the RC can facilitate the capacity for organisational resilience.

In this sense, this chapter's primary objective is to understand how the development of relational capital influences organisational resilience in times of crisis. Besides, it is intended to identify the determining factors in these resilience processes and present the basis for developing a framework that allows auditing organisational resilience.

Our research question seeks to answer how the factors of the RC can be facilitators of the capacities of organisational resilience. This initial study is exploratory in nature is based on the analysis of the state of the art of literature of relational capital and the literature of organisational resilience, completed by the literature search that relates the two concepts.

4.2 Methodology

To achieve the objectives of this article, exploratory research strategies were used in the literature. According to Creswell (2010), this type of research aims to explain and expand the understanding of the causes and consequences of this phenomenon. The exploratory strategy is especially advantageous for studies that aim to build an exploratory framework on little-explored topics.

Through search and analysis of the papers for this study, the authors intend to collect the current research that relates relational capital with resilience to identify and understand the overall landscape in this field of study.

Data were collected through a literature review carried out in the international databases Scopus, Web of Science and Ebsco. Time limits were not considered to include this review as many studies as possible.

A structured keyword search was the basis for the search for articles for this research. The searched keywords on these databases were "relational capital" and "organisational resilience."

The identified articles were analysed qualitatively, using the content analysis method, with the recurrence of themes. The indicators that characterise or form the RC and organisational resilience were identified and delimited. These exploratory findings were analysed based on the assumption that using relatively systematic procedures, hypotheses of relationships relevant to the phenomenon proposed in this research could be identified.

In this sense, indicators incorporated in the concepts of RC and organisational resilience were gathered. After linking these topics, a framework was proposed to serve as a basis for expanding studies on the theme.

4.3 Literature Review

This section presents the concepts and indicators identified through articles of the international databases Scopus, Web of science and Ebsco.

Relational Capital Concepts Relational Capital (RC) is understood as an intangible resource of the organisation capable of generating knowledge from its relations with its strategic partners. Stewart (1998) points out that the RC is based on the idea that companies are not an isolated system but belong to an interconnected system, dependent on their relationship with the external environment (Knight, 1999).

However, as Bontis (1996) proposed, initially, the RC construct was used to identify issues related only to the client's capital value. Academic and empirical contributions advance this understanding and begin to recognise the intangible value of the relationships that a company maintains beyond customers and begin to consider relationships as partnerships and strategic alliances, as advocated by Stewart (1998), and as the assets of the market, which is pointed out by Brooking (1996). In this sense, Stewart (1998) considers RC to be a valuable intangible asset for the organisation, as it refers to the long-lasting relationships of companies with their strategic partners, capable of creating value for the company. This value can be measured from the value of the strategic alliances established, collaborative relationships, business partnerships, joint ventures and relationships with customers, employees, suppliers, and associations.

Edvinsson and Malone (1997) corroborate with the authors and affirm that the RC deals with the organisation's internal and external relations with employees, customers, suppliers, universities, associations, unions, strategic alliances, collaborative relationships, competitors, and partnerships capable of expanding the company's market share.

One of the pioneers in explaining the importance of relational capital was Leif Edvinsson. As the corporate director at Skandia AFS, this author explained the concept of intellectual capital using a metaphor. The author compares a company to a fruit tree in which the roots that provide long-term sustainability are intellectual capital, and the fruits are financial results. According to the author, it must have qualified human capital and relational capital to satisfy customers for a company to develop good products and services. Relational capital contains relationships with customers, suppliers, shareholders, or partners (Edvinsson, 1997, 2002; Edvinsson & Malone, 1997).

In 2013, on the occasion of reflections from 21 years of IC practice and theory, Edvinsson reinforced the idea of the importance of relational capital by referring that "The critical question became how to build a bridge between brains inside the organisation, known as human capital, and brains outside, known as relational capital." (Edvinsson, 2013, p. 168). For the author, the main challenge is "understanding and development of the value of networks" (Edvinsson, 2013, p. 168) because it is in the networks that the company's adaptability lies. The author thus makes an approximation between the concept of relational capital and resilience.

More recently, the author states that in a context dominated by artificial intelligence, the core of intellectual capital appears to be in the “relational capital dimensions, the in-between space of connectivity, and contactivity” (Ordóñez de Pablos & Edvinsson, 2020, p. 295). Intellectual capital is often the primary driver of an organisation’s success and survival, and therefore relational capital as a source of connectivity and innovation becomes a crucial capital (Warkentin et al., 2021).

Similarly, Welbourne and Pardo-del-Val (2008) find that companies with high-performance levels can negotiate with other actors and develop collaboration agreements, placing a high value on RC. The authors also note that organisational performance improves when the RC configuration is adapted to change and resource needs, so the RC impacts organisational adaptability in turbulent scenarios.

Thus, it is possible to analyse that the amount of knowledge acquired by a company depends on RC factors. As mentioned by Liu et al. (2010), the amount of knowledge acquired by a company depends on three critical dimensions of RC: the quality of the relationship in terms of the trust, the level of transparency between the firm and partners, and the partner’s level of interaction. Buenechea-Elberdin et al. (2018) corroborate this idea and understand that the RC can be understood by internal relations, which is knowledge, embedded and available to the company through the webs of relations between its members; and external relations, which includes cutting-edge knowledge and resources that come from the company’s external relations, is seen as connections with customers, suppliers, partners and the local community.

Still, Ho et al. (2019) note that companies that strengthen their RC through frequent interaction with their partners, mutual trust, and mutual commitment reduce the ambiguity of knowledge, which helps them to enhance knowledge capabilities and resources.

Walecka (2021) notes that establishing cooperation with different groups of stakeholders and creating RC in a company is an increasingly relevant process for reducing the uncertainty of economic activities. In this sense, the ability to create economic relationships and establish alliances seems to increase the organisation’s flexibility, which significantly increases its competitiveness and determines its resilience in times of crisis.

However, as demonstrated (e.g. Matos et al., 2020; Osinski et al., 2017), the management of intellectual capital presupposes the integration between the various components of this intangible asset (human capital, structural capital, and relational capital), that is, RC seems to have a significant impact on organisations’ resilience, but per se it just should not be enough for an organisation to be resilient.

Relational Capital Indicators Seminal studies such as Roos and Roos (1997), Stewart (1998) and Sveiby (1998) point to the RC as one of the components of the intellectual capital, understood through the internal and external relations that the organisation establishes with its employees, customers, consumers, and with suppliers.

Knight’s (1999) theoretical perspective analyses the RC based on strategic alliances, collaborative relationships between companies and partnerships that companies establish with the community, associations, and universities, namely, its stakeholders.

Capello and Faggian (2005) pointed out the external factors of the RC for the overflow of knowledge, which refers to the positive externalities that companies receive in terms of knowledge of the environment in which they operate. The RC is characterised by the organisation's proximity to its stakeholders, the interaction and shared common values, explicit cooperation with its suppliers and customers, and the public and private partnerships with its environment.

Also, Rodrigues et al. (2009) analyse the RC as a construct capable of measuring the value generated by the organisation's relations with its customers, suppliers, alliances, shareholders, external agents, industrial and governmental associations and stakeholders. Thus, it is understood that factors such as collaboration networks with customers, suppliers, collaborative networks with competitors, knowledge institutions such as universities, the R&D partnerships enable the highest performance and the ability to innovate in the organisation.

Lu and Wang (2012) consider that interfirm cooperation has gained importance in the relationships between buyers, suppliers, and business partners since proximity between companies can be regarded as a strategic alternative that allows organisations to combine valuable resources and knowledge to achieve superior performance long-term. According to the authors, factors related to trust, cooperation, and the intense relationship between networked companies allow companies to rationalise their management activities and generate a competitive advantage.

García and Bounfour (2014) analysed the RC based on cooperation between companies as a fundamental resource for innovation in 5813 companies from 13 countries in Europe. The findings corroborate that firm's cooperative relationship with its requirements in innovation activities and the relationship developed with other types of partners such as organisations in a conglomerate, joint ventures, customers, universities, consultants, or government institutions, and participation in programs with the government leverage as a resource for firms.

For Engelman et al. (2016), the ability to collaborate, to diagnose and solve problems, sharing information, interact and exchange employee ideas with people from different areas of the company, such as partnerships with customers, suppliers, alliance partners, to develop new solutions, generates the application of knowledge from one area of the company to problems and opportunities that arise in another area and make it possible to expand organisations' innovative resources, in turbulent environments such as developing countries like Brazil.

Research by Yoo et al. (2016) also confirms that RC elevated by factors such as good relationships of trust with alliance partners—a process of communication and information sharing between strengthened alliance partners and companies' commitment—enables an improvement in the company's performance.

Andreeva and Garanina (2016) and Buenechea-Elberdin et al. (2018) consider indicators such as the company's internal relations with the R&D, marketing and production departments; the frequent collaboration of employees to solve problems; internal cooperation; the company's relations with external stakeholders, such as customers, suppliers and partners; and the frequency of the company's collaboration and its external stakeholders as factors of the RC that enable the company to perform at a higher level.

However, as proposed by Ho et al. (2019), it is observed that the RC is analysed as a multidimensional relative construct to a sequence of positive interactions between companies in a state of cooperation. The authors use measures that analyse interaction with the partner, mutual trust and reciprocal commitment.

When analysing the impact of the RC as a factor that enhances the capacity for organisational resilience in cases of crises, Walecka (2021) considering the following criteria: the relevant market information of a particular group of investigated parties; limited bidding for a specific group and prepared matches; the reduced influence of a certain group of stakeholders on the quality of the company's products and processes; the long-term cooperation released; the trust by a group of stakeholders; and the benefits of cooperation. To the authors, the research findings prove that the high RC value allows conditions for building organisational resilience in the face of a crisis.

Through this theoretical and exploratory review, recurrent indicators were identified that analyse the RC as a factor capable of leveraging organisational resources such as performance, innovation, and resilience. The principal factors identified are (1) The quality of the companies' relationships with their stakeholders (2) The strategy and benefits of long-term cooperation between companies with their customers and suppliers (3) The collaboration between organisations to achieve common goals (4) The trust created with the interested groups (5) the frequency of communication between companies and stakeholders to share information and knowledge about the sector.

Resilience Concepts Through the most recent literature review, research on resilience concepts was carried out that would allow us to identify the factors that make organisations more resilient.

Resilience, seen as the capacity for people, organisations, and countries to adapt quickly to new environments has been presented with different perspectives. The most common being the following: (a) Disaster Resilience (e.g. Klein et al., 2004; Manyena, 2006; Gallopin, 2006; Alexander, 2013; Davoudi et al., 2012; IOM (Institute of Medicine), 2015); (b) Infrastructure Resilience (e.g. Omer et al., 2009; Jackson & Ferris, 2013; Chang et al., 2014); (c) Social and Community Resilience (e.g. Tobin, 1999; Pelling & High, 2005; Cutter et al., 2008; Norris et al., 2008; ARUP, 2014; Ross, 2013); (d) Ecological resilience (e.g. Folke, 2006; Curtin & Parker, 2014; Pickett et al., 2014); (e) Economic Resilience (e.g. Rose, 1999; Hallegatte, 2014); (f) Psychological Resilience (e.g. Bonanno, 2004; Campbell-Sills et al., 2009; Mclarnon & Rothstein, 2013); (g) Organisational Resilience (e.g. Coutu, 2002; Hamel & Välikangas, 2003; Cameron et al., 2005; Bhamra et al., 2011; Demmer et al., 2011; Välikangas & Romme, 2013; Stark, 2014; Weick, 2015).

"The ability of a system, community or society to pursue its social, ecological and economic development objectives, while managing its disaster risk over time in a mutually reinforcing way" (Keating et al., 2017).

Infrastructure resilience is the ability to withstand, adapt to changing conditions, and recover positively from shocks and stresses. Resilient infrastructure will therefore be able to continue to provide essential services due to its ability to withstand, adapt and recover positively from whatever shocks and stresses it may face now and in the future (The Resilient Shift, n.d.).

Community resilience can be defined as the absence of illness, as the opposite of vulnerability, as a static and unchanging element, or in a circular way as both a cause and an outcome (Ntontis et al., 2019).

Social-ecological resilience generally is the capacity to continue functioning despite stresses or shocks (Ifejika Speranza et al., 2018).

Economic resilience is described by The National Association of Counties (NACO) as a "community's ability to foresee, adapt to, and leverage changing conditions to their advantage" (Georgia Tech, n.d.). Economic resilience is usually measured in local or regional dimensions. Regional economic resilience can be described as the ability of a state's regions to cope with changes in the nature of shocks and disruptions, regardless of their nature (economic, disasters, environment, health), and to use these events to continue their development (Oprea et al., 2020).

Psychological resilience is defined by Sisto et al. (2019) as the ability to maintain the persistence of one's orientation towards existential purposes. It constitutes a transversal attitude that can be understood as the ability to overcome the difficulties experienced in the different areas of one's life with perseverance and a good awareness of oneself and one's own internal coherence by activating a personal growth project.

To Ingram and Głód (2018), organisational resilience is an ambidextrous dynamic capability that allows the firm to take competitive advantage by rapidly and efficiently coping with adversity.

Furthermore, Ortiz-de-Mandojana and Bansal (2015) treat organisational resilience as the firms' ability to anticipate, avoid, and adjust to cope positively with surprising situations and continuously improve the firms' viability.

Bearing in mind that organisations are made up of people with common goals, it is underlying that the resilience of organisations depends on the resilience of the people that constitute them and, therefore, the management of intellectual capital and each of its components (namely human capital, capital structural and relational capital) will come up with a possible correlation with the capacity for organisational resilience.

This chapter focuses on the relationship between relational capital and organisational resilience, which is a very broad concept, including strategy, adaptation, culture, risk, and learning organisation. The richness of this concept and its importance have led the authors to develop composite indicators or other frameworks to assess organisational resilience. There has also been specialisation in different areas, sectors, phases of the production process, steps of management, etc. (e.g. specialisation in SMEs, in supply chains and value chains, in the workplace, in the analysis of professions).

As demonstrated, the literature presents a diversity of studies related to the issue of resilience that reflects the lack of consensus that persists today in defining the concept.

The concepts presented below focus on organisational resilience and result from a systematic review of the literature whose main objective is to understand how organisational resilience relates to relational capital.

Organisational Resilience According to Hillmann and Guenther (2020), organisational resilience can be defined as a capacity, competence, characteristic, result, process, behaviour, strategy, type of performance, or combination.

In contrast, multiple authors criticise the idea that capacity and competence are synonymous. The resilience literature, however, is unclear about what it means to have resilience and resilience competence. These concepts are often used interchangeably. Lengnick-Hall et al. (2011) specify that having a resilience capacity is not equal to having a resilience competence. Richtnér and Löfsten (2014) elaborate that having a capacity means having both the skill and competence. When resilience competence is transformed into action, resilience becomes an organisational capacity (Hillmann & Guenther, 2020).

For Hillmann and Guenther (2020), organisations will only be able to increase their resilience if there is clarity in the concept and the variables that determine it to evaluate, develop, and improve continuously over time.

According to the British Standard 65,000, organisational resilience is defined as "the ability of an organisation to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper." (Denyer, 2017). Here, the words "and thrive" really matter. Organisational resilience goes beyond survival towards a more holistic view of health and business success. A resilient organisation is Darwinian in the sense that it adapts to a changing environment to remain fit for its purpose (Kerr, 2015).

Another definition presents organisational resilience as a continuous process of benchmarking, improvement and reassessment. It is an organisation's ability to anticipate, prepare, respond, and adapt to incremental changes and sudden disruptions to survive and thrive (The British Standards Institution, 2018).

Kahn et al. (2018) are based on the definition of Sutcliffe and Vogus (2003) and claim that organisational resilience can also be defined as the organisation's ability to absorb tension and preserve or improve its functioning, despite the presence of adversity.

Over the years, several articles have been published on how and why companies should develop a strategy to build their organisational resilience to protect themselves from the growing threats to the business. However, organisational resilience is based on a much broader view of resilience as an enabling factor for organisations, allowing them to perform robustly in the long term (Kerr, 2015).

In 2017, the International Organisation for Standardisation published a new standard that provides guidance for increasing the organisational resilience of organisations of any type or dimension, which is not specific to any industry or sector and can be applied throughout the life of an organisation. This international standard 22316 (International Standards Office, 2017) defines organisational resilience as: “the ability of an organisation to absorb and adapt in a changing environment.” It results from a long development process and represents the global consensus on the concept of organisational resilience (BCI, 2017).

ISO 22316: 2017 does not promote uniformity in organisations’ approach. As these are distinct, the specific objectives and initiatives are adapted to meet the particular needs of each organisation (BCI, 2017).

Indicators of Organisational Resilience According to the literature, the six main indicators of resilience were identified:

The Strategy. Organisational resilience is not a defensive strategy but a positive and forward-looking “strategic enabler” that allows CEOs to take risks measured with confidence. Robust and resilient organisations are flexible and proactive—seeing, anticipating, creating, and taking advantage of new opportunities—to ultimately stand the test of time (Kerr, 2015).

An organisation’s resilience can be a confidence indicator that benefits the company’s reputation, facilitates external investors’ decision, and supports the organisation’s values (Kerr, 2015).

The Culture. Organisational resilience encompasses, but also transcends, the operational aspects of a company. It is based on an organisation’s values, behaviours, culture, and ethos. It is the leaders of an organisation, especially CEOs, who drive these factors, but to make a real cultural difference, the message must circulate from top to bottom and bottom to top. It is also a condition of success, and it is even a mandatory requirement that all employees of the organisation are willing to integrate the message voluntarily (Kerr, 2015).

The Organisational Learning. The writer and philosopher Aldous Huxley said: “Experience is not what happens to a man; it is what a man does with what happens to him.” Likewise, resilience is not what happens with an organisation; it is what the organisation does with what happens to it (Kerr, 2015).

The most resilient organisations are eager to learn from their own experience and that of other organisations to minimise problems, seize opportunities, seek to invest in new areas, introduce innovative products and processes, or penetrate new and unknown markets (Kerr, 2015).

A resilient organisation is adaptable, agile, robust, and competitive, taking advantage of experience and embracing the opportunity to pass the test of time (Kerr, 2015).

Organisational resilience implies adopting best practices—incorporating competence and capacity in all aspects of the organisation—to provide continuous business improvement (Kerr, 2015).

The Dynamism and Statism. Organisational resilience can be divided into dynamic resilience and static resilience (Annarelli and Nonino, 2016). Dynamic resilience is based on dynamic resources that allow organisations to manage unexpected threats and risks, while static resilience deals with strategic resilience initiatives based on the management of internal and external resources (Annarelli & Nonino, 2016; Jia, 2018).

Amore et al. (2018) also argue that static resilience and dynamic resilience coexist with the views of proactive resilience and reactive resilience. According to Somers (2009), reactive resilience refers to the organisation's ability to return to its normal state without incurring serious damage or loss, while proactive resilience refers to deliberate efforts that increase the ability to deal with threats potential (Jia, 2018; Lovins & Lovins, 1982).

Leadership. The literature on leadership and its outcomes can be studied from different perspectives (Asrar-ul-Haq & Anwar, 2018). Frequently, the definition of leadership is related to the trait, ability, skill, behaviour, and relationship that shows that the leadership field of study rushed from one fad to another (Yukl, 2013). The impact of leadership on business and organisational management has been recognised as a significant factor that could make a difference in organisational performance (Al Amiri et al., 2020).

Harland et al. (2005) theorised on a link between leadership and resilience. These authors stated that developing the capacity for resilience is a vital component of effective leadership. Wan Sulaiman et al. (2012) found significant correlations between leadership and resilience, namely the higher the skills of leadership, the higher the ability to be resilient and to overcome challenges.

According to British Standards Institution (ISO, 2017), leadership is perceived as both important and relative strength in terms of resilience. Strong leaders promote subordinates' intrinsic motivation, show concern for their needs, focus on emotional aspects, care about employee needs, provide social support and furnish work support to broaden their individual responsibilities for assuming greater challenges. Therefore, strong leadership enhances work engagement (Tau et al., 2018).

Furthermore, highly resilient individuals cope more successfully with stress and negative events and therefore have high levels of positive affect, and employees/individuals with high positive affect are more inclined to be engaged with their work (Wang et al., 2017).

Research has shown that leaders need to be resilient in order to lead their teams. According to Jackson and Daly (2011), resilient leaders not only have the ability to survive in difficulty and adversity but are able to display behaviour that will enhance subordinates' ability to thrive. In consequence, it is clear that higher leadership qualities are related to higher resilience levels. In fact, Moran and Tame (2012) confirmed that for organisations to adapt, individuals must work towards a resilient culture.

Adaptive Capacity. Several authors argue that adaptive capacity is a significant factor in characterising vulnerability and may be defined as "the extent to which a system can modify its circumstances to move to a less vulnerable condition" (Dalziell & Mcmanus, 2008; Luers et al., 2003).

Adaptive capacity reflects the ability of the system to respond to changes in its external environment and recover from damage to internal structures within the system that affect its ability to achieve its purpose (Dalziell & Mcmanus, 2008). Recovery is closely linked to the time taken by the organisation to intervene, i.e. whether the organisation intervened pre-event or post-event. Thus, it is essential to characterise two types of resilience: proactive resilience or reactive resilience.

Proactive organisational resilience identifies potential risks and takes proactive steps to ensure an organisation will survive and thrive in an adverse situation in the future (Longstaff, 2005; Somers, 2009).

According to Lengnick-Hall et al. (2011), reactive organisational resilience is the capability to effectively and efficiently respond to external disruptions and quickly recover to an organisation's pre-impact state after experiencing extreme external impacts. In addition, reactive organisational resilience is closely related to operational losses and time of reaction and recovery (Bruneau & Reinhorn, 2007).

As Jia et al. (2020) noted, time of reaction and recovery refers to the required time for initial reactions to disruptions based on their business continuity plan and restoration of disrupted functions through their recovery plans.

4.4 Relationship Between Relational Capital and Organisational Resilience: A Conceptual Framework

For Johnson et al. (2013), factors of the CR, such as trust and cooperation, promote the construction of information sharing structures in companies established in networks, thus emphasising the importance of formal and informal network ties. The research confirms that these factors are valuable resources and contribute to the training capacities of organisational resilience.

Polyviou et al. (2019), when analysing the resources that allow small and medium-sized companies to become resilient, concluded that the relationships established between employees and/or groups within a network create cohesion and facilitate the search for collective goals, being beneficial for companies, as it facilitates the acquisition of tacit knowledge and access to resources for the exchange of knowledge and collaboration. Thus, it is concluded that these organisational relationships develop resources that enhance resilience capacities, mitigating risks or helping organisations to recover from periods of crisis.

The research by Yoo et al. (2016) complements that the RC generates close interaction between alliance partners and provides an effective channel for organisational learning, for accumulation and sharing knowledge, creating a better performance for the companies and their strategic alliance partners. Consequently, the companies inserted in a dynamic and volatile environment, which have a strong Relational Capital structure, can contribute to the achievement of more fruitful organisational results, directing efforts to expand the resilient capacities of organisations.

Walecka's research (2021) confirms that the high level of RC contributes to building resilience. The research identified in companies from different sectors, that factors such as long-term cooperation, trust between groups and stakeholders, and the relationships established with stakeholders, namely, the indicators that form the well-developed relational capital of a company allow not only protecting the

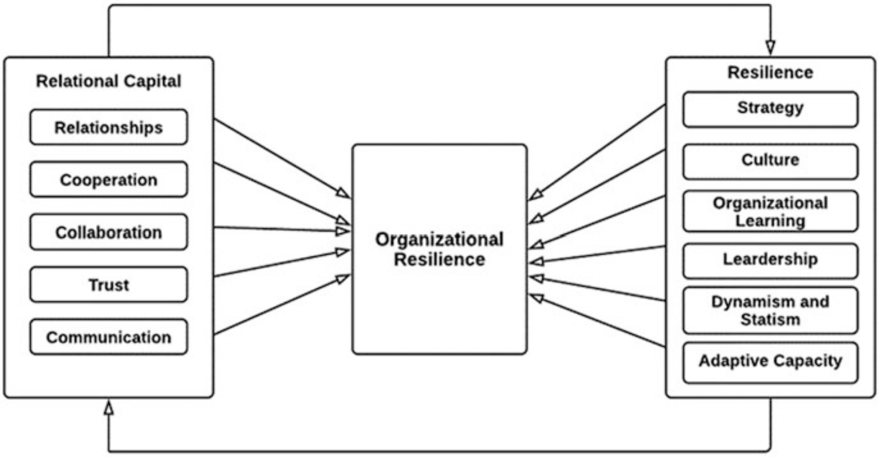

Fig. 4.1 Framework conceptual between relational capital and resilience. Source: The authors (2021)

company against the crisis but also overcoming it, developing resilient capacities. These findings contribute to the proposal of this research.

In consequence, it is relevant to broaden the understanding of the CR through the frequency and quality of the relations established by the company with its stakeholders, by the strategies and benefits of long-term cooperation between companies with their customers and suppliers and by the intensity and frequency of collaboration for achieving common goals; for the trust established with the interested groups, and for the frequency of communication established with the stakeholders to share information and knowledge about the sector. These factors of organisational resilience allow companies to benefit from the knowledge base available in interorganisational relationships, which stimulates the development of capacities, such as adaptive capacity, organisational learning, leadership, the culture of sharing (Fig. 4.1).

The conceptual model above shows that the indicators of the development of relational capital are complementary and jointly contribute to organisational resilience. Likewise, resilience indicators, acting together, provide organisations with adaptive capacities that make them more agile and resilient. Although the conceptual framework tries to give an image of the indicators independently, this independence does not exist. The imbalance between indicators inevitably affects the capacity for resilience (e.g. between culture and leadership or between trust and communication).

On the other hand, the results of this research indicate that resilience and relational capital influence each other. This means that, predictably, there is a relationship between resilience and relational capital, as specified in the objective of this research. Demonstrating this relationship, in empirical terms, is, therefore, one of the challenges of future research.

4.5 Conclusion and Future Work

This exploratory research sought to identify the CR factors that enhance the capacity for organisational resilience and the link between relational capital and organisational resilience, using a literature review.

The results of this paper corroborate the understanding that a high level of RC enables organisations to face turbulent periods and crises in companies and to strengthen organisational resilience capacities. Factors such as relationships, cooperation, collaboration, trust, and communication, which organisations build with their stakeholders, were identified as essential for the RC to develop.

The relationship established between the resilience indicators, namely the type of strategy, the organisational culture, the organisational learning, the leadership, the dynamism and statism balance and the adaptive capacity, also emerged as conditioning indicators of the resilience capacity. The theoretical discussion of the association of the relational capital and resilience binomial is a contribution to the literature and supports the evidence that the two topics influence each other and contribute to reinforce organisational resilience.

Additionally. the results of this study provide theoretical implications that allow advances in research regarding the topics of Relational Capital and Resilience, allowing to fill in the gaps that highlight the antecedent factors of these constructs. The understanding and familiarity with these factors of organisational resilience are particularly relevant for managers of companies operating in an emerging economy and in a dynamic, complex and high technological mobility environment, who exploit the intangible resources of the RC as a strategy to mitigate crises.

The limitations of this study drive future research that can use the other dimensions of the IC, such as structural capital and human capital, as measures to analyse the resilience capacity.

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Chapter 5
Organisational Resilience in the Digital Age: Management Strategies and Practices

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Abstract The current changes in the labour market, induced by technological advances, have required several adaptations from organisations, generating recurring transformations. Employees and professionals are required to have new skills and qualifications. In turn, from organisations, these changes require adaptations in various perspectives, from their structure to their culture and even to their strategies. In this context, resilience is a key factor for this organisational system to adapt so that it can sustain its operations under these new, more complex and uncertain performance constraints. To understand how resilience can contribute to the sustainable adaptation of organisations, this article explores management practices that enhance resilience in the context of digital transformation. Thus, through an exploratory analysis based on previous studies, the main practices and strategies that enable organisations to leverage their intellectual capital in the intrinsic aspects of resilience and the formidable context of today's digital transformation have been identified. The main results point to invest in resources that enhance each of the structures of Intellectual Capital, such as training, relationships with stakeholders and applied technologies, with a view to strengthening

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organisational resilience, given the challenges imposed by the digital transformation of today's society.

Keywords Organizational resilience · Digital transformation · Management practices · Intellectual capital

5.1 Introduction

Technology is at the centre of many business transformations, and its voracious development has accelerated the pace of these changes. Also known as the Digital Era, the digital economy is not only related to forms of communication, but it also concerns changes in competitiveness, consumption and the functioning of the market. For this reason, new business models are being created to adapt and become competitive (Holbeche, 2018; Lambin, 2014).

The rapid changes and complex scenarios, defined by ambiguity and unpredictability, require organisations to become resilient, thus seeking to respond to the disruptive changes we face today. It is in this context that organisational resilience is inserted, the organisation's ability to implement different forms of strategic agility, to respond effectively to changing conditions (Holbeche, 2018).

Many of these changes come from the explosive growth of the Internet, as digital technology has a great impact on how markets work. Work models and economic sectors are being transformed exponentially by the effects and the use of technologies. With the development of the digital economy, multiple stakeholders become part of the same system, creating environments of greater complexity (Holbeche, 2018; Lambin, 2014; Snowden, 2002).

Complex systems, according to Snowden (2002), are characterised by environments of many possibilities, where multiple agents are in interaction. The situation is coherent, orderly, but it only makes sense when looked back at. This pattern is logical, coherent, but it is just one more pattern among others that could have arisen with the same, predictable logic. In other words, there are coherent cause and effect relationships, but they are no longer predictable; today, they are both complex and uncertain.

How organisations deal with the variability of their context depends on how they understand it, monitor and address existing risks. The way they adapt to the non-prescribed and routine environment allows them to develop their resilience. (Gibson & Tarrant, 2010). In this context, organisational resilience supports the resolution of complex problems through its capacities to anticipate, respond, monitor and learn (Hollnagel, 2010).

Also, for strategic returns through technologies, it is necessary to build the organisational capacity to respond to the needs imbricated to it. Changes are required both in the organisation's culture and in its process (Holbeche, 2018).

In this way, this exploratory article presents the management strategies identified in studies that address the impact of digital transformation to support organisations and their managers in the direction of decision-making, considering aspects that enable greater conditions for adaptation in these organisations and, thus, increased resiliency. To this end, this article will be analysed from the perspective of Intellectual Capital (IC) and the conceptual dimensions that support it.

5.2 Intellectual Capital and Its Dimensions

The term Intellectual Capital (IC) is used extensively (Petty & Guthrie, 2000), and there are many definitions for its conceptualisation (Ferenhof et al., 2015). According to Edvinsson and Sullivan (1996), Intellectual Capital is determined by the organised knowledge that organisations use for some purpose. In other words, IC is the knowledge that can be transformed into value. However, the increase in organisational value does not occur purely through the expansion of knowledge stocks but rather through the capacity to foster Intellectual Capital.

For Sveiby (1997, 2001), IC is composed of the combination of intangible assets, which generate growth, efficiency, renewal and organisational stability. The value of these resources increases as the knowledge pertaining to them is shared. In other words, IC enables the creation of value for organisations through the use of their knowledge (Petty & Guthrie, 2000).

Corroborating, Stewart (1997) understands that the knowledge that makes up IC is that which turns the raw material into something valuable for the organisation. Information and knowledge that are not involved in creating value are not part of the organisation's Intellectual Capital. Thus, according to the same author, IC is information, knowledge, intellectual property and experience that can be used to generate wealth for organisations.

In addition to creating value, according to Edvinsson and Malone (1998), IC enables organisations to remain competitive in the market, thus generating sustainability. However, it is necessary to identify the roots of this value and the dynamic factors behind it, which are hidden. For the authors, IC also has organisational knowledge as its source.

Intellectual Capital has its dimensions which, according to Stewart (1997), are: Human, Structural and Customer Capital. For him, all organisations have these three capitals, but the emphasis given to each one is specific to each organisation. However, in the study by Ferenhof et al. (2015), the authors identified 83 different models to identify the dimensions of Intellectual Capital. However, this research identified that the three main dimensions of the IC are: Human Capital (HC), Structural Capital (SC) and Relational Capital (RC), the latter linked to Clients, corroborating with Stewart (1997) and other seminal authors in approach to this theme (as Sveiby, 1997; Edvinsson & Malone, 1998; Bontis, 1998).

Human Capital (HC) is characterised by the organisation's human resources (Petty & Guthrie, 2000). Edvinsson and Malone (1996) understand HC as the skills, personal characteristics and education of employees. Bontis (1998), Sveiby (2001), and Petty and Guthrie (2000) complement by stating that people's tacit knowledge contributes to the organisation's HC structures, in addition to individual experiences, such as know-how, entrepreneurial spirit, power of innovation, creativity and proactive skills. According to Sveiby (2001), Human Capital is a primary intangible resource, as it is composed of fundamental agents in the business. All tangible goods and products, as well as their intangible relationships, are the result of people's actions.

In turn, Structural Capital (SC) is the organisational capacity and its infrastructure, which supports employee productivity. It concerns all internal resources that remain when people leave (Edvinsson & Malone, 1998). These are "non-human" knowledge structures. These intangible structures (such as better processes) are developed when employees direct their skills to the organisation's internal issues, creating value for them (Sveiby, 2001). The SC is composed of the knowledge incorporated in the organisation's routines, in its strategy, in the manuals, in the supply networks, databases, work distribution and organisation chart, for example (Bontis et al., 2000; Petty & Guthrie, 2000).

Finally, Relational Capital (RC) refers to external organisational relationships, such as relationships with customers, stakeholders, suppliers and strategic partners, which generate value for the organisation (Edvinsson & Malone, 1998; Roos et al., 1997). The loyalty of consumers and customers, trust and commitment to and from suppliers, alliances with trusted partners, favourable contracts, the organisation's reputation in the community in which it operates (Knight, 1999; Petty & Guthrie, 2000), and other characteristics related to external partners are all part of the RC.

The management of Intellectual Capital, according to Wiig (1997), occurs through the construction and management of intangible assets from perspectives and management strategies of the organisation itself. Matos (2013) notes that IC management is a factor that influences organisations' competitive advantage, as it is a key element of the knowledge economy. In this sense, Kianto et al. (2013) consider that the main indicators of intangible value are seen in terms of human and structural resources and relationship networks. Thus, IC management must take place based on strategies that better leverage these resources.

Therefore, the adoption of management practices is an opportunity to improve the organisation's position in the market (Stefano et al., 2014). The training of employees, investment in education, the development of individual tacit knowledge, skills, creativity and innovation of employees (Edvinsson & Malone, 1998; Kianto et al., 2013; Matos & Lopes, 2008; Stewart, 1998; Sullivan, 1998) are examples of practices related to the development of Human Capital.

Management practices involving the SC can be carried out through the creation of a database, knowledge sharing, the management of organisational culture, intellectual property, organisational processes and tools that transform individual knowledge into organisational assets (Edvinsson & Malone, 1998; Kianto et al., 2013; Matos & Lopes, 2008; Stewart, 1998; Sullivan, 1998; Swart, 2006). Finally, customer prospecting, external relations, the development of organisational and individual relationships and partnerships are strategies for managing the RC (Edvinsson & Malone, 1998; Kianto et al., 2013; Matos & Lopes, 2008).

In the next section, aspects related to Organizational Resilience and its relationship with the Digital Age will be presented.

5.3 Organisational Resilience in the Digital Age

According to Gibson and Tarrant (2010), organisational resilience can be observed after an unexpected situation, which emerged in response to major changes. It is not a management, process or predictive measurement system. For this reason, it is not a fixed resource. It changes in response to the changing environment, increasing and decreasing as the context changes.

Organisational resilience is considered as an organisation's capacity that allows it to adjust its internal functioning before, during or after changes (Hollnagel, 2010, p. 1). Also, organisational resilience exists in varying conditions, alternating from low conditions (vulnerable system) to high resilience (resilient system). This spectrum varies not only from organisation to organisation, but can be observed within a single location, depending on the period and/or the type of event. In this way, resilience is based on risk management, which can be developed through risk assessment, monitoring and communication. The more the system invests in increasing its resilience, the greater the maturity of its resilience capabilities (Gibson & Tarrant, 2010).

Nevertheless, according to the authors, resilience can be built through two important organisational characteristics, which help to face adversity and uncertainty. They are (1) Leadership, through the training of employees, generating trust, commitment and strategic direction for understanding risk; and (2) Organizational Values, where it is necessary to create common purposes, generating commitment, trust and internal alignment. From these two capabilities, a specific culture emerges, which allows the organisation to understand and be sensitive to internal and external changes.

Quinlan et al. (2016) state that the efforts that Sciences made to apply resilience stimulated its evaluation and measurement, giving rise to different methods and metrics for that. Thus, the application and measurement of resilience in different fields are varied, and, according to the authors, the interest in its measurement has increased.

The digital age, in turn, is disruptive (Holbeche, 2018). For the author, digitisation, artificial intelligence, automation, the Internet of Things, robotics, Big Data, and other forms that characterise it have driven great and profound changes. Business, sectors and work practices are being transformed by both the use and the effect of technology. It is in this context that the need for permanent adaptation requires organisations to implement resilient capacities.

For Butler (2018), the arrival of social media accelerated the pace of organisations, requiring them to adopt an innovative, dynamic and proactive approach to risk management in their operations. In this case, resilience must go beyond the organisation's ability to return to its previous status of the change. Risks and impacts must be seen as opportunities for adaptation and evolution in the face of advanced cyber threats, hyper-competitive environments and connected networks. Thus, resilient organisations must increase collaboration and cooperation, both vertically and horizontally, internally and externally.

Also, the accumulated experience of organisations in situations prior to the crisis contributes a lot to the effectiveness of their resilience. This accumulation of experience and the knowledge generated are crucial elements to face new crises (Rapaccini et al., 2020). In addition, adding new practices and strategies should contribute to increasing their resilience.

In the next section, studies that contemplate these practical strategies and contribute to coping with unexpected situations to enhance organisational resilience will be presented.

5.4 Management Practices for Organisational Resilience

To identify management practices that enable organisations to increase their resilience capacity, previous studies, strategies and resources that point to the adaptation of organisations, taking into account the scenario of digital transformation was sought out.

Considering the impacts related to digital transformation for business systems, some authors present the need to integrate risk management processes with resilience management (Annarelli et al., 2020; Papagiannidis et al., 2020). Papagiannidis et al. (2020) state that organisational risk management should be done through the registration and elucidation of possible risks and their classification. With this, a diagnosis and analysis of the impact can help in the identification of critical sectors of the organisation, be they employees, infrastructure and data, external relationships and business processes. These assessments enable the organisation to prioritise decisions and investments based on roles and tasks rather than hierarchy.

For the authors, risk management should be extended to the organisation's Information Technology (IT) area. Annarelli et al. (2020) complement, suggesting the expansion of the vision under the context of organisational resilience for resilient cyber systems. In this case, in hyper and interconnected digital environments, cyber resilience is a continuous condition for maintaining competitive advantage and dealing with constant vulnerabilities and cyber threats. According to the authors, the main strategies for aligning management actions and practices to increase the resilience of cybersecurity take place through permanent training and artificial intelligence.

In this sense, it is very important to invest in employee and machine learning. These strategies, especially training, make it possible to develop better employee awareness and prevent behaviours that encourage error. In addition, the system will have better conditions to be resilient through organisational learning. It is through the safety culture, incorporated, disseminated and institutionalised in the organisation, that its resilient capacity will increase. Another strategy to increase the resilience of the digital structure can be through the expansion of this structure and the agile response in the face of unexpected situations (Papagiannidis et al., 2020).

Rapid changes have an impact not only on organisational structures but also on people's skills and knowledge, requiring greater proactivity from both the individual and the organisation to assume greater responsibilities. As a result, greater capacity for adaptation and regulation of development itself is needed (Morris & König, 2020). Thus, as considered by Annarelli et al. (2020), other authors indicate that organisations should promote constant training, considering new technologies and the emerging scenario (Bode et al., 2019; Morris & König, 2020).

However, these skills must focus not only on improving the technical knowledge and cognitive skills of their workers. It is necessary to invest and focus on their non-cognitive skills, that is, on the beliefs, values, attitudes, behaviours and the employees' own subjectivity (Bode et al., 2019).

Personal identity, which is related to the points mentioned above, is one of the aspects of promoting resilience, according to a study by Daou et al. (2019). According to the authors, the characteristics of flexibility, optimism, strength, hope, acceptance and even religious beliefs stand out. All of these characteristics enable people to find solutions that help organisations survive in difficult situations.

In the context of Small and Medium Enterprises (SMEs), Chonsawat and Sopadang (2020) define some essential indicators for the readiness and decision-making of organisations in this emerging socio-economic environment. In this study, organisational resilience is considered a fundamental dimension for the insertion of SMEs in the digital context. This dimension is characterised by the organisation's flexibility, operation and strategy for its integration. Here, resilience is understood as a skill in terms of organisational cooperation and its stakeholders. It takes place through communication between an interdisciplinary department and employees.

Therefore, the aspects that link SMEs and resilience are: (I) the business model: this being the digital business model; (II) business strategy: competitive, long-term business strategies and plans; (III) digital transformation in the organisation: digital design for the creation of product marketing; (IV) leadership: raising awareness of leaders about the scenarios and influence of people; (V) organisational structure: with environmental and cultural aspects of openness and flexibility; and (VI) supply chain management: co-creation of value with internal and external stakeholders.

Regarding leadership, Teo et al. (2017) had already pointed to its role as a resource for the organisation's resilience. According to the authors, leaders can activate resilience by building relationships permeated by the trust. It is through these connections that leaders communicate to build a collective sense in the group, promoting positive relationships between people. Thus, the organisation's resilience is strengthened by the group's social, cognitive and emotional resources.

Likewise, some authors have already pointed to communication networks, social connections and interpersonal relationships as essential factors to activate organisational resilience (Doerfel et al., 2010; Powley, 2009). That is, as stated by Teo et al. (2017), relational and social connections are a source of resilience and progress dynamically throughout crises.

Regarding specific operations and supply chain management, Belhadi et al. (2021) claim that the resilience of organisations in these processes and their performance have become increasingly important for business, considering the increase in crises in recent years. For them, the use of Artificial Intelligence as a strategic resource proves to be a factor of success to improve this area and even the sector. In the current scenario, these processes are increasingly dynamic, considering business environments and technological changes.

Thus, organisations must exploit their information processing capabilities to manage their risks. Likewise, Rapaccini et al. (2020) and Fonseca and Azevedo (2020) indicate that accelerating the digital transformation at all ends is a strategy to improve the resilience of operations. That is, it is necessary to adopt organisational, management and technology policies and practices to digitise processes and have greater visibility of the organisation as a whole.

In these aspects, technology is one of the fundamental components, but not the only one, in the strategy to support resilience. It is up to organisations to be prepared to take advantage of all the human potential behind the technology. For this, it is important to develop the leadership processes and support management, create clear and well-defined roles, detail the competence needs (mainly in relation to technology), and ensure the development and education of employees (Centobelli et al., 2020).

In addition, Papagiannidis et al. (2020) affirm the importance of the presence of management in decision-making in the face of unexpected or disturbing situations. According to the authors, this presence can be fundamentally important to ensure that decisions are not made under a scenario of great stress, which could lead to errors and shortcuts.

In this way, considering the sustainability not only of the organisation but of the others that operate in its system helps to maintain its resilience. When considering suppliers, customers, stakeholders and other external agents, the organisation strengthens its relationships, which can have a positive effect in the face of uncertain scenarios (Papagiannidis et al., 2020). Strengthening the organisation's Relational Capital can be a strategic and highly recommended action to increase the speed of a resilient response.

Considering this idea, Rapaccini et al. (2020) state that, in addition to digitalisation in business aspects, servitisation can increase resilience, considering future crises. This, referring to the change from a business model centred on the product to a model oriented to the product-service, added or not to the product, facilitating the creation of value for the customer. In other words, servitisation, digital or not, can be considered a proactive and positive strategy for accelerating responses to crises.

Although the authors have no empirical evidence that this strategy can be generalised to any type of crisis, the study showed that enhancing the relationship with customers is an effective survival strategy in pandemic situations. Resilience is strengthened through the redundancy and elasticity of the IT infrastructure and Human Capital, both capable of managing interruptions through technical knowledge and customer relations.

Table 5.1 Digital age: management practices and strategies for strengthening organisational resilience

Human capital (HC)	• Training (development of technical knowledge, behavioural and response skills and non-cognitive skills) • Leadership development • Personal characteristics of flexibility, optimism, hope and acceptance • Personal beliefs that enhance the employee's strength and hope • Communication networks
Structural capital (SC)	• Risk management (impact analysis, registration, clarification and classification) • Use of artificial intelligence in the processes • "Agile" responses to unexpected situations • Development of a digital business model • Development of a business model centred on service ("servitisation") • Development of a competitive and long-term business strategy and plan • Digital internal design • Development of a culture of openness; a culture of flexibility; a safety culture • Digitisation of processes • Redundancy and elasticity of IT systems
Relational capital (RC)	• "Agile" supply chain management • Co-creation of value with external and internal stakeholders • Strengthening of relations with the market • Development of relationships of trust and collective sense, by leadership • Communication networks • Social connections • Interpersonal relationships

To link Intellectual Capital with management strategies and practices to strengthen organisational resilience, these were grouped and divided according to the three main dimensions of IC. Table 5.1 identifies each of them, as presented by the various authors referenced above.

5.5 Conclusions and Practical Guidelines

As presented in this brief theoretical review, and in the aspects addressed by recent studies, the elements that enhance and induce the transformations of the digital economy (e.g. big data, machine learning, Internet of things, artificial intelligence) are many of the resources that organisations themselves already have and can contribute to creating new strategies for better adaptation. These same technology resources can also be invested in their management processes, so that they can support decision-making in a more conscious and more systemic way. According to Papagiannidis et al. (2020), when considering the COVID-19 pandemic, what helped the response capacity of many organisations, were the elements of digital transformation that were already available and in progress.

In this sense, it is evident the use of technology (artificial intelligence, for example) as a permanent support resource for organisational learning. Artificial intelligence itself, when used as an input to identify the strategic elements of the external and internal environment, can be a resource adapted to work processes to create new strategies and processes for businesses, which generate better adaptations to the market.

Also, practices that develop new skills and knowledge needed by professionals are of paramount importance to respond to the rapid changes required in the current context. Thus, investing in training that develops non-technical and behavioural skills is as relevant as technical development skills. Together with these, preparing professionals on a permanent basis so that they can be trained in new technologies is proving to be a very important and highly sustainable action for organisations.

As presented in some studies, risk management is a fundamental practice to ensure that organisations face up to imminent threats, whether they are known or unknown. Gibson and Tarrant (2010) have already shown its importance as a device to guarantee organisational resilience.

Much research has been focused on the supply chain as an organisational area—or even the sector—as being one of the major impacted in the face of technological changes and even the pandemic of the years 2020/21. The COVID-19 crisis exposed the fragility, vulnerability and low resilience of this area, suggesting that organisations need more resilience skills (Fonseca & Azevedo, 2020).

However, it is necessary to consider all spheres of the organisation and increase the resilience of all areas in an organic and systemic way to guarantee its continuity. Finding creative and technological solutions for new operational processes is of paramount importance to maintain the sustainability of businesses inserted in the digital context (Papagiannidis et al., 2020).

In this way, the importance of strengthening Intellectual Capital to ensure better resilient responses is perceived. Actions that consolidate each of its dimensions are shown to be important allies for quick and assertive responses. For Human Capital, practices for developing skills and the knowledge of employees and strengthening teams' management may reflect an appropriate path to be followed. With regard to Relational Capital, strengthening relationships between customers, suppliers and stakeholders can support early decision-making. And, finally, investing in technology and process structures, that is, in Structural Capital, can also consolidate an effective strategy to support organisational resilience.

In this research, it was identified that most of the practices that generate better resilience resources are aimed at strengthening, adapting and improving Structural Capital. With this, it was identified that reinforcing the intangible structures of the organisation, so that the response resources are also available in the knowledge intrinsic to its own infrastructure may enhance the capacities of organisational resilience.

It is important to note that the context of this study permeates the digital age and all its inherent challenges. In this scenario, the aspects related to SC were more evident. However, it is possible that in other contexts that mobilise the resilient capacities of the organisation, more robust elements of Human Capital or Relational Capital are required because, according to Daou et al. (2019), all elements of Intellectual Capital contribute to the capacities of the resilience of an organisation.

It is worth emphasising the importance of prioritising the most relevant and impacting factors. As resources are scarce, efforts need to be made for those with the greatest impact and relevance. Therefore, it is necessary to consider multicriteria for decision-making. That is, it is important to analyse the context to carry out a priority analysis for the development of such practices and strategies.

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Chapter 6
Framework for the Analysis of Resilient Performance Conditionings in Integrated Operations of the Oil and Gas Industry

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Abstract Complexity and instability are elements present in the oil and gas industry, making it challenging to predict and deal with all elements and situations that may affect the safety of its operations. Thus, it is essential to classify and analyse the factors that condition resilient performance to promote assertive interventions and increase the resilience potential in this sector. This chapter presents a framework that operationalises the analysis of the factors that condition resilience through methods and techniques of knowledge engineering and resilience engineering. The framework consists of a knowledge model that represents elements that condition resilient performance and data science tools to enable handling and analysing workers' perceptions and supporting the analysis of safety events. Through an interdisciplinary approach, the framework was established involving an integrative review of the literature and the contribution of experts from several areas for defining the analysis model. Knowledge engineering methods and techniques were used to enable data analysis on integrated operations of companies in the oil and gas sector, thus allowing a systemic view on the conditionings of resilient performance in the

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companies that participated in the study. As main results, a new generation of tools for data processing and support for the analysis of factors that influence the potential for resilience and a holistic view of latent factors for promoting resilience are highlighted.

Keywords Resilience · Human factors · Resilience assessment · Knowledge engineering · Resilience engineering

6.1 Introduction

Complex socio-technical systems, such as oil and gas operations, are resistant to Cartesian analysis since they are open, difficult to detail, and even to delimit. Their characteristics force us to accept the possibility of never being able to predict potential states and results that may emerge from them since they always operate with residual risks and uncertainties (Lundberg & Johansson, 2015). A system becomes complex as the number of agents involved increases, and their behaviour becomes non-linear. Hence, it is no longer possible to fully anticipate its conduct based on the individual behaviour of these agents (McManus, 2008).

It is common to assign organisations' complexity to their internal and external environments. The first reflects the organisational supports and technologies, while the second comprises suppliers, competitors, markets, etc. (McManus, 2008). The systemic perspective, which sees organisations as living organisms, where stability is dynamically emerging instead of structurally intrinsic, suggests that safety is what the system does and not something it possesses (Dekker et al., 2008). Hence, there is a growing interest in Human Factors as an interdisciplinary research field, which addresses the interactive relationship between humans, works, and artefacts, and on the study of the systemic elements that condition human performance, with a focus on efficiency and accident prevention (Sheridan, 2008).

In sectors such as oil and gas, where eventual accidents are critical for their potential human, social, environmental, and economic damage, human factors deserve special attention, as they are essential for risk management and safety. It has important implications, as on the common practice of investigating accidents in retrospect. In systemic theory, any rules that could be formulated would list possibilities, never certainties. Therefore, the usefulness of retrospective analysis of events is limited. In a living and complex system, future possibilities are not determined by the past—the science of linear equilibrium does not apply, nor does the Newtonian symmetry between past and future (Dekker et al., 2008; Rasmussen, 1997).

Dekker et al. (2008) state that, under the systemic view, accidents result from the complexity of people's activities in an organisational and technical context. These activities typically focus on accident prevention but also have other goals, such as yield, efficiency, and cost control, which can cause conflicts, always under the pressure of limited resources (time, money, people). Accidents, then, emerge from a confluence of conditions and events that are normally associated with the search for success but, in this combination, can cause failures.

The fast pace of technological change has brought uncertainties to safety systems, making them even more complex. Accidents can occur from the complicated and non-linear interaction among many operational subcomponents considered reliable. When physical disruptions are not identified, suspicions tend to fall on those who operate the systems (Dekker et al., 2008; Woods & Hollnagel, 2006). For this reason, traditional methods of safety engineering, based on prediction and decomposition, demand alternatives since these characteristics are no longer common in today's complex socio-technical systems (Lundberg & Johansson, 2015).

Therefore, Resilience Engineering (RE) is an alternative approach for the design and assessment of the response capabilities of complex systems amidst the need to preserve safety in the face of pressures for increased productivity and profit (Nemeth & Hollnagel, 2014). RE seeks a new perspective for human factors' approach, involving analysis of the interactive relationship between humans, works, and artefacts, from the system's design stage to its operation and control. The RE perspective on human factors also seeks to examine human performance, working conditions, technological, physiological, psychological, sociological, and managerial factors, as well as the dynamics of systems under financial, operational, and risk constraints, considering not only the absence of negative aspects but the presence of positive ones (Hollnagel, 2014).

However, despite a significant progress in the last decades, these disciplines lack reference models that allow a roadmap for analysing human factors and the resilience potential in complex socio-technical systems (Nemeth & Hollnagel, 2014). Current models, such as the Resilience Assessment Grid (Hollnagel et al., 2015), Training for Operational Resilience Capabilities (Grøtan & Paltrinieri, 2016), and the Resilience Measurement Index (Petit et al., 2013a, b) have gaps, when we consider the integration between systemic factors that determine human performance, and constructs related to resilient performance (Patriarca & Bergström, 2017).

The study of the relationship between human factors, resilience potential, and safety events continues to arouse interest in academia and in different industrial sectors (Katsakiori et al., 2009; Salmon et al., 2012). Hence, there are two elements that make up a research challenge: (1) how to qualify the human factors that condition resilient performance?; and (2) how to analyse these factors' conditions in order to direct actions and investments assertively for promoting safety?

Based on an approach that involves concepts and methods of various disciplines, in this chapter, we present a framework for supporting the analysis of human factors that condition resilient performance. The proposed framework enables a systemic look at factors linked to individuals, work, and the organisational level, in order to support decision-making and guide actions that may affect the resilience potential and mitigate risks and accidents in the oil and gas sector, as well as in other high-risk industries.

The chapter presents the human factors, from the perspective of safety and resilience, the research strategy, and the framework set to support the analysis of resilience and human factors in integrated operations in the oil industry and gas; finally, it discusses the results and conclusions of the research.

6.2 Human Factors Under the Perspective of Safety and Resilience

The first mentions to the term resilience go back to studies carried out in ecology, for naming the persistence of relationships within a system (Holling, 1973); in exact sciences, on the study of materials' resistance; and in human sciences, in psychology, regarding the analysis of people's repertoires used for overcoming difficulties (Ayyub, 2015; Benetti & Crepaldi, 2012).

In this study, we are interested in explaining what resilience means for organisations, especially those considered complex socio-technical systems. For this purpose, we rely mainly on the definitions of organisational resilience proposed by Dekker et al. (2008) and Hollnagel (2012). These authors address resilience as the ability to accommodate changes, conflicts, and disorders without resulting in severe damage or catastrophic failure. A resilient organisation, in their view, does not seek stability, but instead sustainability, by reducing negative elements (incidents, errors, violations) and identifying and improving the positive capacities of people and organisations, which allow them to adapt effectively and safely under pressure. They treat resilience as the intrinsic ability of a system to adjust its functioning in the presence of a disorder and unexpected changes. Thus, resilience allows organisations to manage disruptive challenges (Durodié, 2003), but it is not a static condition and can vary over time depending on the nature and consequences of a particular crisis (McManus, 2008).

As early as 1996, Rasmussen presented the basis for a new approach to safety in complex socio-technical systems, based on Resilience Engineering (ER). He recalled that a common approach to modelling socio-technical systems was to decompose them into separately shaped elements. Traditionally, systems were modelled by the decomposition of their structural elements, while the dynamics of the systems' behaviours and their actors were shaped by the decomposition of the behavioural flow into events. Under these approaches, activities were broken down into tasks and tasks into decisions, actions, and errors.

In practically all working situations, even in highly complex socio-technical systems, workers are free to choose the means and times they consider appropriate for action, so that they almost never follow the rules, laws, and instructions strictly. Therefore, work objectives, task instructions, and operational standards could not be used, by themselves, as a reference for behavioural judgments (Rasmussen, 1997). One implication, in the current context, is that, after an accident, it is usually easy to find someone involved in the dynamic flow of events who has violated a formal rule by following established practices. This person would probably be punished, and human error would be ascribed as the cause of the accident (Rasmussen, 1997; Woods & Hollnagel, 2006).

In safety events, operational decisions under high pressure, high stakes and dynamic circumstances are usually not made after a complete rational analysis of the situation. Researchers on Naturalistic Decision-Making have proved that these decisions are based on the information necessary to make sense of available courses of actions in those contexts (e.g. Klein, 2015). It is difficult to identify decisions separately; therefore, the study of decision-making cannot be dissociated from a simultaneous study of the social context and the value system where it takes place and the dynamic work process that it intends to control (Rasmussen, 1997; Salmon et al., 2012).

RE represents this new way of thinking about safety. It is a discipline that challenges the false assumption that safety should be defined as the absence of something, because the systems are already safe. It seeks ways to improve the ability of organisations to create robust yet flexible processes, monitor and review risk models, and use resources proactively in the face of interruptions and economic pressures and on the production level (Dekker et al., 2008; Hollnagel, 2014).

RE seeks to understand how resilience manifests itself in different contexts; based on that, and it develops project principles and practices that create favourable conditions for the resilience of complex socio-technical systems, such as the operations of the oil and gas sector. In addition, it provides useful tools for measuring resilience, since it helps organisations to show progress in their efforts to become more resilient by using quantitative measures (Stephenson, 2010).

There is a growing understanding that works accidents and incidents, beyond unintended or individual phenomena, result from social and organisational factors (Hovden & Albrechtsen, 2010). The complexity of variables that interact in the events requires understanding the dynamics of social relationships (Areosa & Dwyer, 2010), and this reality affects people's actions; thus, a possible answer would be the establishment of a trusting environment to neutralise this feeling (Fischer & Novelli, 2008). Looking at these dimensions makes us understand that quality of life and the concepts of health, environment, management, and safety are associated with each other and are social and multifactor constructions.

Among the human factors that contribute (positively or negatively) to the resilience potential and to safety events, we mention the historical contribution of the studies by Edwards (1988), Hawkins and Orlady (2007), Turner and Pidgeon (1997), and Reason (1990). Edwards (1988) presented, as the basis of his software-hardware-environment-liveware (SHEL) model, individual factors (those related to the competencies and physiological and psychological conditions of workers), related to the work (those related to equipment, rules, and procedures), and environmental (internal and environmental conditions that may affect work). Hawkins and Orlady (2007) extended Edwards' proposal to include the relationships among individuals, composing his software-hardware-environment-liveware-liveware (SHELL) model. With the 'man-made disaster' theory proposed by Turner (1997), and the 'Swiss cheese' model by Reason (1990), management perspectives and organisational factors have come to be considered. Such studies were the basis for the development of different methods for analysing safety events; in the last decade, methods based on systemic analysis, which recognise events as accidents resulting from uncontrolled interactions of the system, have been emphasised.

Among the studies developed from the systemic approach, the HFACS method (Wiegmann & Shappell, 2003) stands out. It establishes a taxonomy of factors based on the analysis of accidents recorded in the aviation industry, according to Reason's model, noting that active failures are the result of latent failures involving complex relationships of different factors. Rasmussen and Svedung sought to incorporate in the Accimap Method ways of identifying factors related to multiple socio-technical levels (regulation, organisation, work environment) and the dynamic interrelationships between individual factors and the various factors of the socio-technical levels, in order to support accident analysis (Rasmussen, 1997; Rasmussen & Svedung, 2000; Svedung & Rasmussen, 2002).

Several studies describe the use of these methods in health, construction, and aviation sectors, showing the extensions/changes of the categories originally defined in order to meet the specific analysis demands in these sectors or to explain the factors for applying them to specific areas (Hulme et al., 2019; Theophilus et al., 2017; Waterson et al., 2017). Therefore, one of the challenges of this chapter is to detect the human factors that condition resilient performance in integrated operations of the oil and gas sector. Integrated operations in this sector involve multiple arrangements of individual and organisational skills distributed between onshore and offshore units.

The proposed approach comprises different factors described in the literature that can affect the system's capacity for resilient performance (Henriqson et al., 2018). The different views on human factors and resilience summarised from the literature were examined by a team of 30 researchers from areas such as resilience engineering, sociology, social service, environmental management, engineering, and knowledge management, in addition to experts from the oil and gas industry. As a result, a comprehensive model was defined, which unfolds human factors into constructs and associated factors. We represented the model through a domain ontology (Studer et al., 1998) in order to explain the factors and facilitate their use in knowledge systems (Schreiber et al., 1999) that make up the proposed framework.

To examine the factors that condition resilient performance, the framework also incorporates a data processing system with the perceptions of workers and leaders, in addition to data associated with safety events. For that matter, knowledge engineering provides different methods and techniques to support knowledge creation and the representation of human factors by knowledge models in order to analyse complex systems, operationalise data treatment, and the development of knowledge systems (Schreiber et al., 1999). Thus, based on similar efforts in the areas of social sciences and resilience engineering, the knowledge engineering approach used for structuring this framework allows establishing a knowledge model that expresses human factors and enables data collection, handling, and analysis on the human factors that condition resilient performance. It also supports decision-making and the establishment of actions that strengthen safety in the oil and gas sector. In the next section, we describe the structuring approach of the various elements of the proposed framework.

6.3 Research Methods

There were two goals for creating the framework. One was to enable the qualification and evaluation of the factors that condition resilient performance in integrated operations. The second was to operationalise data collection and organisation, in addition to knowledge creation on the elements that condition resilient performance, to allow the analysis of the resilience potential in integrated operations of the oil and gas industry.

We used the methodology Design Science Research (DSR) to guide the framework creation. This approach defines the basis for the development of multidisciplinary research, oriented to relevant complex problems, which takes into account the context where the results are applied (Burgoyne & James, 2006; Lacerda et al., 2013). For Kuechler and Vaishnavi (2008), DSR gathers a set of analytical techniques that allow the development of research in several areas, especially in engineering, seeking to characterise and establish appropriate research methods with greater accuracy in conducting the research (Lacerda et al., 2013). DSR is a rigorous process of designing artefacts to solve problems, assessing what was designed or what works, and communicating the results achieved (Çağdaş & Stubkjær, 2011).

The DSR approach has different stages. In this study, we adopted the steps indicated by (Peffers et al., 2006), which involve: (1) identification of the problem and motivation; (2) definition of the solution's objectives; (3) project and development; (4) demonstration; (5) evaluation; and (6) communication.

Following DSR guidelines, steps 1 and 2 address the identification of needs and the solution's objectives. We carried out this stage by using the modelling techniques of organisational context, proposed by the knowledge engineering methodology CommonKADS (Schreiber et al., 1999). It comprised the survey of needs and opportunities for the consolidation of a program of human factors associated with safety management, in operations such as drilling, completion of new wells, extraction, and production of oil and natural gas. We developed the study with seven companies, among contracting and chartering firms, and the survey collected information on companies' operations, testimonies from managers, and data on safety management procedures. In addition, we looked for laws, norms, and other documents to contextualise the environment and serve as a source of reference material in the process of building the research instruments. As a general goal, the framework should enable the monitoring and analysis of the factors that condition resilient performance, based on the perceptions of operation teams and on data produced in the operations, such as safety events.

Step 3 comprised different research and development fronts. With regard to building the model for representation and analysis of human factors, the project stage started with the search for models of reference and definition of factors, dimensions, and analysis criteria to compose the framework's analysis model. To this end, we conducted an exploratory literature review by using descriptors such as 'Resilience Measurement OR Resilience Assessment OR Resilience Management

OR Resilience Evaluation' in SCOPUS and Web of Science databases. We also considered studies on human factors and resilience done by associations or organisations focused on the study of safety promotion actions in high-risk industries (such as IOGP[1], ERA[2], ARGONNE[3] and IAEA[4]). Because of the exploratory review, we established an initial version of the analysis model, gathering a set of human factors that potentially condition resilient performance, according to the literature and empirical studies found in the review.

After creating the initial version of the model, we carried out-group dynamics to check and assess the model, which gathered experts in the areas of sociology, social service, resilience engineering, engineering and knowledge management and the environment, in addition to representatives of the companies involved in the study. The model was reviewed in coproduction workshops, according to the following stages:

1. Review of the factors, by different teams of experts, regarding their level of coverage and adequacy in meeting the demands defined in the project for analysis and research.
2. Review of the observations and adjustments proposed by the distinct teams of experts; and.
3. Consolidation of the proposed changes and final group evaluation.

Due to the coproduction workshops, a new version of the model was established, comprising 10 human factors and 126 associated factors that potentially condition resilient performance and are present in the operations of the companies that participated in the initial study. These steps represent one of the most critical points of the framework since they provided the structure that guided the whole process of data collection and organisation.

The established model is a central element of the framework. We represented the framework's analysis elements through a domain ontology (Schreiber et al., 1999), which describes the factors that condition resilient performance through the SKOS[5] model. The strategy for organising the factors in the ontology facilitates the creation of different elements and hierarchies of analysis, enabling the exploitation of the factors by using, for example the taxonomy defined in the HFACS (Wiegmann & Shappell, 2003) or the socio-technical levels of the Accimap (Rasmussen & Svedung, 2000).

Also, according to DSR's step 3, we determined the requirements and designed the information and knowledge systems responsible for collecting, handling, and analysing data from the integrated operations of the companies that participate in the study, which we describe in the next section. Such systems were used to process

[1] https://www.iogp.org/
[2] https://www.era.europa.eu/
[3] https://www.anl.gov/
[4] https://www.iaea.org/
[5] https://www.w3.org/2004/02/skos/

quantitative and qualitative data on the perceptions of operations' teams, collected through surveys, interviews, and storytelling sessions, and through focus groups formed by the research & development project team.

Different analytical outputs were established in order to demonstrate and evaluate the framework, according to DSR's steps 4 and 5. The analytical approach applied involves the production of indicators from data collected on the operations of the companies involved in the case study and the analysis of investigation reports on accidents related to the oil and gas industry that occurred in Brazil.

Stage 6 regards bibliographic production and knowledge transfer actions to the companies involved in the project. The next section describes the projected modules and the results of the framework's application on data collected at companies of the oil and gas sector involved in the study.

6.4 Presentation of the Framework Modules

A framework is an artefact that explains, graphically or descriptively, the main issues to study, that is, the key factors, constructs, or variables in a study field. In addition, a framework identifies the objects or study issues, the way these elements are interrelated, and the mechanisms for that to happen (Nascimento, 2018).

The Framework for Analysis of Resilient Performance Conditionings was established to enable a broad and in-depth analysis of the factors that condition resilient performance in order to facilitate the identification of strengths and weaknesses that deserve attention for future interventions in the system.

As shown in Fig. 6.1, the framework modules were defined to support activities of collection, processing, and analysis of workers' perceptions and safety events. These modules make up the framework:

1. As a knowledge model used to represent human factors. The model has the flexibility to provide different views on human factors and allows different types of analysis on the factors that condition resilient performance.
2. As an information and knowledge system to handle and analyse the perceptions of the teams involved in the operations of companies in the oil and gas sector.
3. As a knowledge system to support the identification and analysis of latent and active safety events.

We describe the framework modules in the next sections.

6.4.1 *Organisation Model*

The central element of the analysis model is the construct Resilience Performance Conditionings. This second-order construct takes into account several elements of a socio-technical system relevant for each combination of work situations. They are

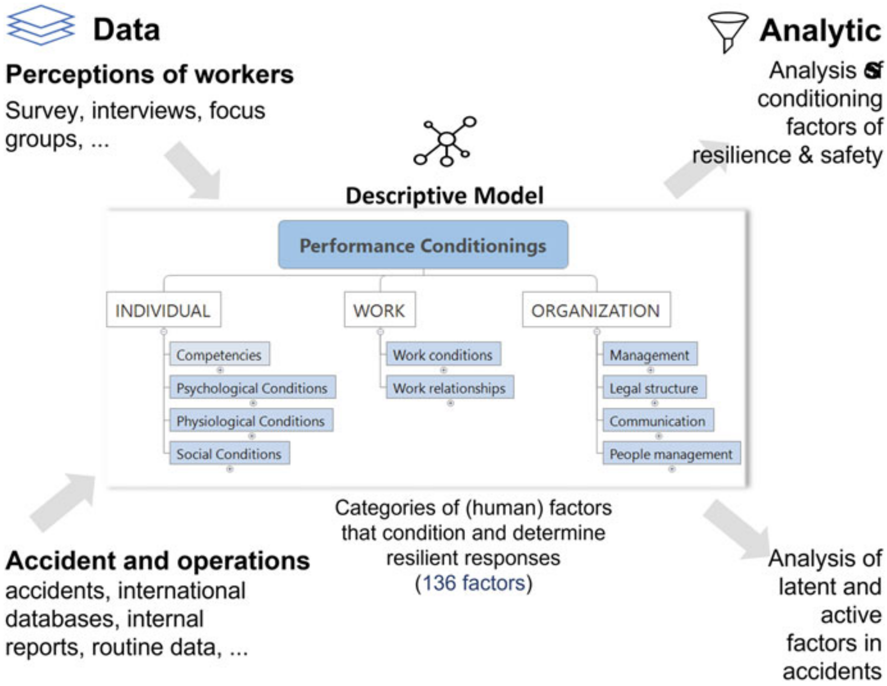

Fig. 6.1 Identification of the elements and the framework modules

more stable factors, derived from the system's status quo, whose presence (to a greater or lesser degree) or absence condition resilient answers in unexpected events (Henriqson et al., 2018). They are the results of the work project, of technology, of the environment, and the expression of more complex socialisation processes, created over time and exhibited in a systemic (broad), systematic (regular), and symptomatic (present) way.

This construct is detailed through a set of human factors identified by a literature review and analysis of studies on human factors and resilience conducted by associations or organisations focused on actions to promote safety in high-risk industries. The factors identified in the literature were initially ranked according to the SHELL model (Hawkins, 1984), around the perspectives of Software, Hardware, Environment, and Liveware-Liveware. Later, the factors underwent review sessions with experts in the areas of sociology, social service, resilience engineering, engineering and knowledge management, and environment, in addition to representatives of the companies in the oil and gas sector involved in the study.

The structuring of the framework's analysis model presents the factors that may interfere with human performance. It incorporates those linked to the individual level (workers' skills, psychological, physiological, and social conditions); to work organisation (workload, internal conditions, rules, procedures, and technologies, among others); and to organisational and exogenous aspects (policies related to people's

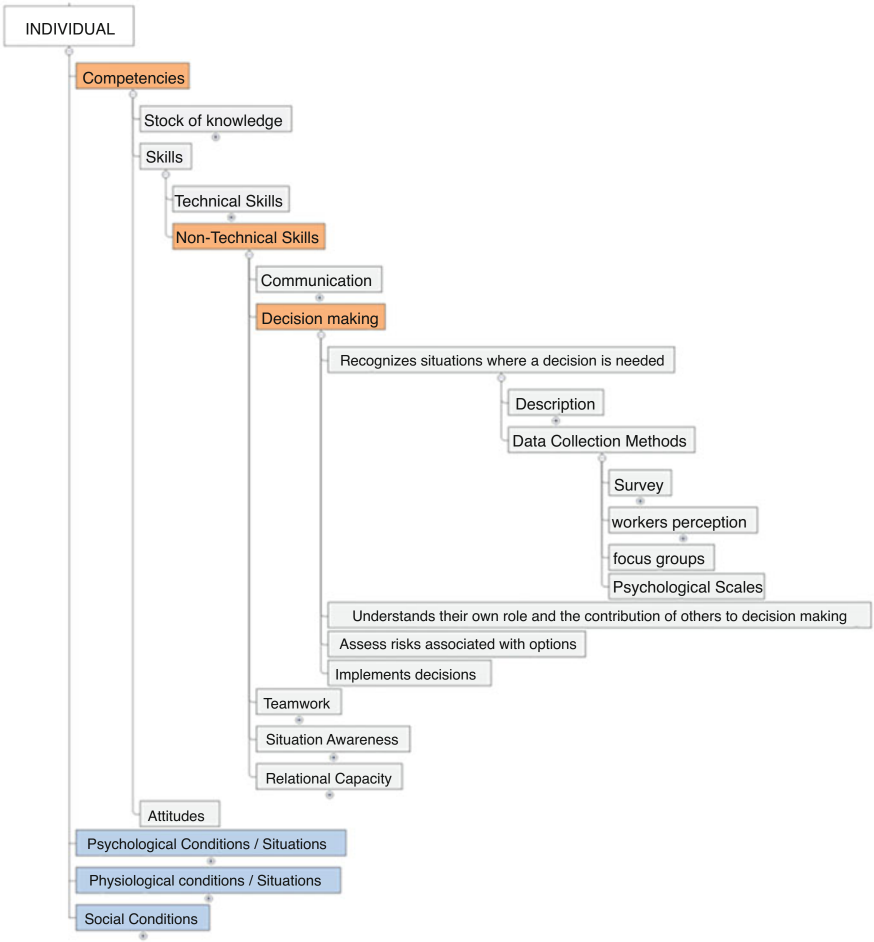

Fig. 6.2 Example of factors related to the Individual dimension of the model

management, contractual relations, safety culture, safety management, and regulation, among others). The model gathers 136 associated factors, grouped into 10 general factors, and organised into three first-order constructs (Individual, Work, and Organization). The main factors are broken down into up to four levels of associated factors, which qualify the model factors and provide an operational description to guide their observation in the work environment.

In order to show the model's structure, Fig. 6.2 presents the breakdown of the factors associated with the 'Non-Technical Skills' factor, highlighting the associated factors 'Decision-Making' and 'Recognises situations where a decision is needed', factors that were based on IOGP (2018). The model describes each associated factor, and data collection methods suitable to guide the observation and analysis by different instruments are identified and explored in the framework's collection strategy.

To facilitate the interpretation of the factors and apply the model to knowledge systems, we represented it by a domain ontology (Schreiber et al., 1999), which describes the factors through the SKOS model. The strategy of organising the factors in ontology facilitates the creation of different aspects and hierarchies of analysis, allowing, for example the exploitation of the factors through the taxonomy established in the HFACS (Wiegmann & Shappell, 2003) or the socio-technical levels of the Accimap (Rasmussen & Svedung, 2000).

Each factor in the model is represented by a set of properties and relationships to enable data processing from potential information sources, on the perceptions of workers and on safety events. The relationships between the factors are expressed in ontology through specialisation/generalisation relationships, such as *is-a*, or *is-a-special-kind-of*, resulting in a hierarchical order of concepts. Such relationships are supported in the SKOS model through the properties *broader* and *narrower*, allowing, for example the association between the factors 'Situational Awareness' and 'Decision-Making' with the 'Non-Technical Skills' factor. Ontology also allows the characterisation of the model's factors to facilitate data mining, such as transcripts of workers' interviews, reports of focus groups, and reports on safety events. Therefore, for each factor, we established *associated terms, classification heuristics*, and *text excerpts*. We address such model properties in Sect. 6.5, where we present the results of the model's application for the analysis of accident investigation reports.

6.4.2 Analysis of Workers Perception of Resilient Performance Conditionings

In order to test the framework, we collected data on companies in the oil and gas industry with integrated operations involving seven contracting and/or chartering firms. For that matter, we collected data through a workers' survey, with questions regarding the model's factors, to capture the interviewees' perception of the operations in which they participated. The team of sociology researchers defined the survey items for seizing the level of agreement of the teams involved in drilling operations and completion of wells, and in the extraction and production of oil and gas, with statements on the level of development of each factor associated with their work environment. Other qualitative data were collected by different teams involved in the research, through focus groups, interviews, documentary analysis, and the analysis of the variability of specific operations prioritised by companies' managers that used the framework.

The framework model facilitated the organisation of the data collection process, indicating the responsibilities and complementarity of the collection instruments of the different groups of researchers involved in the study. In addition, the organisation of the factors in the model, in a hierarchical structure, by grouping the associated factors with the main factors and the constructs, allowed the creation of aggregated indicators and indices on the conditions of human factors, according to the perception of the teams involved with the survey.

The calculation of the framework index was adapted from the critical infrastructure resilience index, RMI (Petit et al., 2013a, b). RMI's main objective is to measure the capacity of an infrastructure to reduce the magnitude and/or duration of the impacts of disturbing events regarding the items related to risk management, answers to disasters, and keeping the continuity of activities. Among the main benefits of adapting RMI are: (1) the flexibility and simplicity of metrics and indicators' calculations; (2) the tree structure of the factors that integrate the framework, which allows incorporating and removing new factors from the structure; and (3) the possibility to carry out 'simulations' with the framework or part of it, by changing the factors' weightings.

The final index of the second-order construct Performance Conditionings is based on the aggregation of the first-order constructs (Individual, Work, and Organization) equally weighted; that is, we considered the same relative importance for the three subfactors, as described below:

Index (Performance Conditionings) = Sum (Wi * Ui), where Wi is the relative importance of the utility (weight) of factor i, and Ui is the index value of factor i. Factor i is the factor of the next level to the factor we are calculating.

$$\begin{gathered}\text{Index}(\text{Performance Conditionings}) = 0.33 * \text{Index}(\text{Individual}) \\ + 0.33 * \text{Index}(\text{Work}) + 0.33 * \text{Index}(\text{Organization}).\end{gathered}$$

The calculation of the indices of the factors of the next level of Performance Conditionings follows the same reasoning. For example the calculation of the index of the 'Individual' construct is based on the weighted sum of the factors of the immediately lower level, as follows:

$$\begin{gathered}\text{Index}(\text{Individual}) = 0.25 * \text{Index}(\text{Competence}) + \\ 0.25 * \text{Index}(\text{Psychological conditions/situations}) + \\ 0.25 * \text{Index}(\text{Physiological conditions/situations}) + \\ 0.25 * \text{Index}(\text{Social conditions});\end{gathered}$$

By the same reasoning, and using the examples of Fig. 6.2, we have:

$$\begin{gathered}\text{Index}(\text{Competence}) = 0.33 * \text{Index}(\text{Stock of knowledge}) + \\ 0.33 * \text{Index}(\text{Skills}) + 0.33 * \text{Index}(\text{Attitudes});\end{gathered}$$

The calculation of the indices of the factors follows the same reason, until the last level, where the value of the factor that is the last level of the tree is given by the survey with the workers, focus groups, or else.

$$\text{Index}(\text{Skills}) = 0.50 * \text{Index}(\text{Technical Skills}) + \\ 0.50 * \text{Index}(\text{Non-technical Skills});$$

Continuing with the factors' tree of Fig. 6.2:

$$\text{Index}(\text{Non-technical Skills}) = 0.20 * \text{Index}(\text{Communication}) + \\ 0.20 * \text{Index}(\text{Decision-Making}) + \\ 0.20 * \text{Index}(\text{Teamwork}) + \\ 0.20 * \text{Index}(\text{Situation Awareness}) + \\ 0.20 * \text{Index}(\text{Relational Capacity});$$

Finally:

$$\text{Index}(\text{Decision-Making}) = 0.25 * \text{Index} \\ (\text{Awareness of the need for decision-making}) + 0.25 * \text{Index} \\ (\text{Recognition of their role and contribution of others in decision-making}) \\ + 0.25 * \text{Index}\ (\text{Risk analysis in decision-making}) \\ + 0.25 * \text{Index}(\text{Implementation of the decision})$$

In the case of the Index (Awareness of the need for decision-making), we are at the last level of the factors' tree. Therefore, the index value is the 'value of the collected item'.

The structure that represents the factors allows organising them by using different hierarchies and relationships between factors and constructs. This relationship structure provides great flexibility to the model by the incorporation of new factors or the inclusion and removal of levels of grouping. This facilitates the organisation of the factors according to different analysis perspectives, which helps factors' integration and their measurements with other performance evaluation systems, also providing the qualification of weights and goals for individual factors or for groups of factors. Such weights and goals can direct the organisations' interventions and projects towards the teams' perceptions and other sources of information, which highlight the conditions that affect human performance and safety. The strategy for evaluating the conditions of the factors can follow the interests declared in each company's strategy, seeking to involve different actors in efforts that are in line with the safety management strategy defined by the organisations (Portulhak et al., 2016).

The indicators defined in the analysis model try to synthesise the factors' scores, enabling the stratification of the level of resilient performance conditionings in the participating companies' operations for the Individual, Work, and Organisation dimensions. Indicators are presented in a knowledge system through a set of dashboards, which gather summaries of the qualitative analyses carried out for each factor. Figure 6.3 shows the first screen of the knowledge system, where we

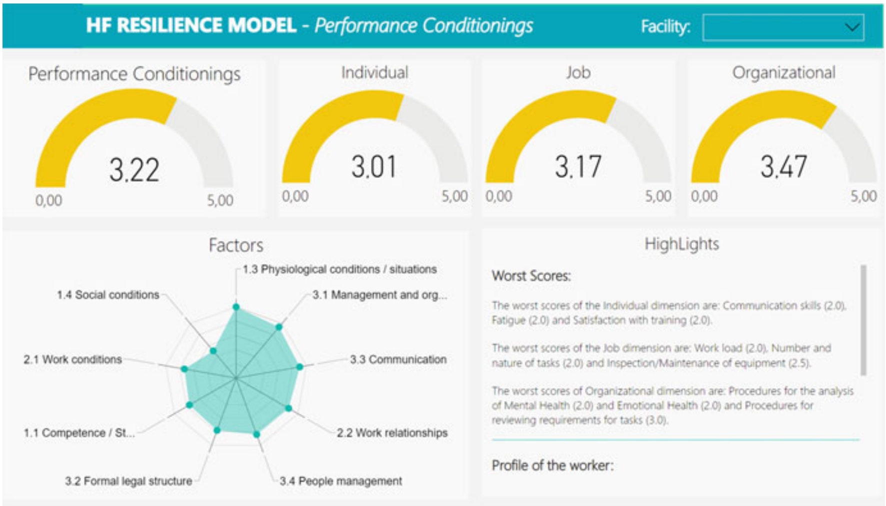

Fig. 6.3 Illustration of the presentation of general indicators associated with model factors in the decision support system prototype

can choose one of the platforms addressed in data collection. Below, there is the estimated score for the Individual, Work, and Organisation constructs, in addition to the general index of the Performance Conditionings construct. There is also the estimated score for each model factor and a table of highlights, with the associated factors with the worst scores and a qualitative profile of the workers in each platform. We recharacterised the data due to the secrecy of the information generated in the study regarding the companies involved.

Figure 6.3 shows the initial screen of the prototype.

The dashboards allow visualisation by offshore platform of the scores assigned to the constructs and the drill down to the last level of the factors associated with each construct of the model. In Fig. 6.4, the system shows the calculation of the factors that correspond to the selected construct (in the example, Individual). In the table on the right, the user can drill down to the level of detail of his/her interest. In the example, we see details of the factors associated with non-technical skills, with emphasis on the factors associated with the communication.

Information and qualitative analyses produced by researchers and analysts were associated with each factor of the model, enabling the presentation of additional information to the scores. Specific dashboards, such as the one in Fig. 6.5, present highlights associated with each factor in order to guide the interpretation of the achieved scores, thus indicating the reasoning followed for measuring the associated factors, as shown in Fig. 6.5. Among the qualitative information, we tried to add processed information on safety events. To this end, we describe in the next section the mining approach for accident investigation reports, using the model's factors.

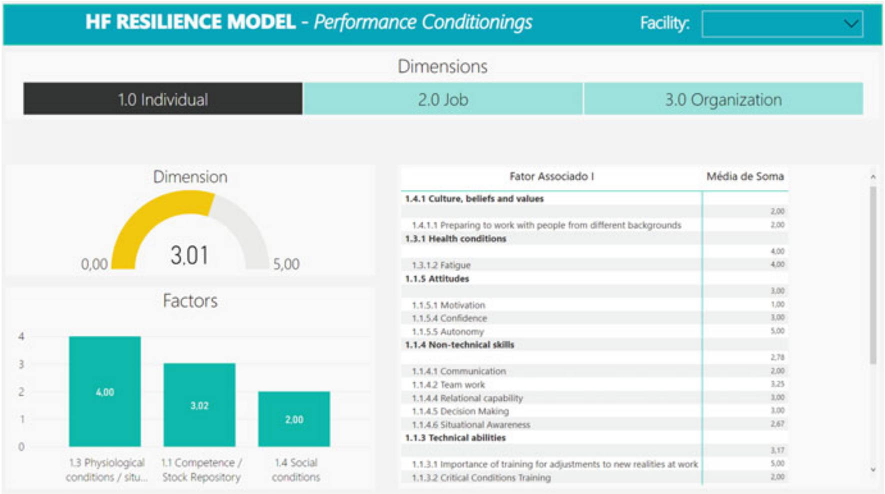

Fig. 6.4 Illustration of the drill down resource and analysis of associated factors

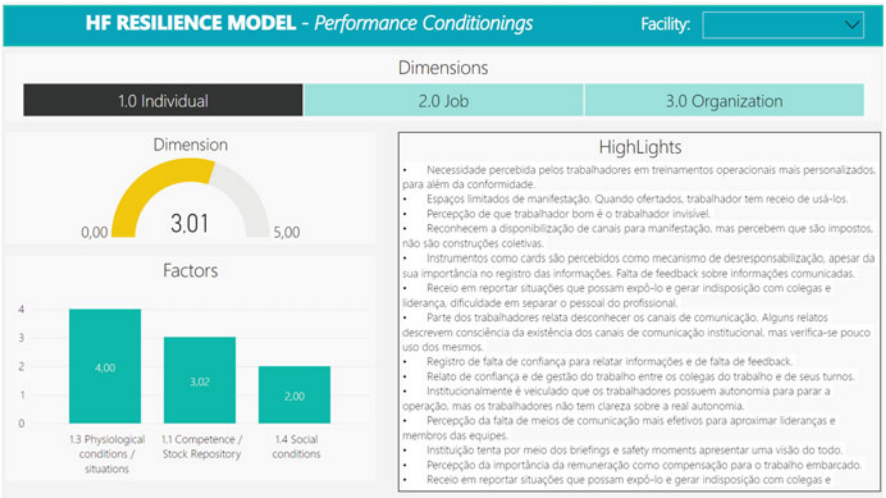

Fig. 6.5 Illustration of the presentation strategy of the highlights associated with the model factors

6.4.3 Analysis of the Conditioning Factors of Resilient Performance from Reports and Data on Accident Investigation

The framework model facilitates the analysis of the factors that condition resilient performance from different data sources. Important information about accidents, incidents, occupational health records, among others, is usually found in documents but dispersed among thousands of paragraphs of little value to decision-makers, making it difficult to search, sort, analyse, and extract knowledge on human factors. In accident investigation reports, for example the qualification of latent factors in accidents is of paramount importance for understanding the need for improvement in the system in order to make it safer.

The framework module on 'safety events analyses consists of a knowledge system that applies text mining techniques and natural language processing. Text mining is a synonym for 'knowledge discovery in texts' (Benoit et al., 2018). These texts can be e-mails; files in different formats (pdf, doc, txt); web pages; text fields in databases; electronic texts scanned from paper, etc. (Morais & Ambrósio, 2007). The main contributions in this area, not limited to these, are selection of documents, classification of documents, and qualification of documents.

There are several techniques and methods that can be used in text mining, and their choice will depend on the purpose of the textual analysis. The choice of a semantic analysis consists of the application of techniques that evaluate the sequence of terms in the context of the texts. These techniques require morphological knowledge (structure, shape, and inflexions of words); syntactic (word lists (tokens), terms, and sequences), semantic (meaning independent of the context); pragmatic (context-dependent meaning); of the speech (network of meanings); and of the world (general knowledge of the field).

Statistical analysis, on the other hand, analyses the importance of a term by the number of times it appears in the text. This process involves statistical learning from data, which normally includes the following steps: (1) data coding: analysis made by expert indications combined with objective analysis criteria; (2) data estimation: search for a suitable model of an estimation method; and (3) document representation models, also known as 'bag-of-words' (Morais & Ambrósio, 2007).

In this application, we used statistical and semantic techniques. As shown in Fig. 6.6, the initial stage of document analysis involves the application of terms and heuristics associated with ontology to the factors for finding fragments in the documents. Then, we apply ontology to the process of fragment classification by analysing the closer factors, considering the properties' information and the relationships between the ontology factors. This process of analysis and classification is based on (Nagarajan et al., 2007) and Allahyari et al. (2014).

The process of document analysis allows accounting for the frequency of occurrence of the factors in the analysed contents, as shown in Fig. 6.7. The analysis involving the processing of the documents' main characteristics and the correlation analysis between the factors are a possibility for complementing the analyses.

From the experiments carried out, it was possible to verify the feasibility of applying the framework to support the analysis of accident investigation reports.

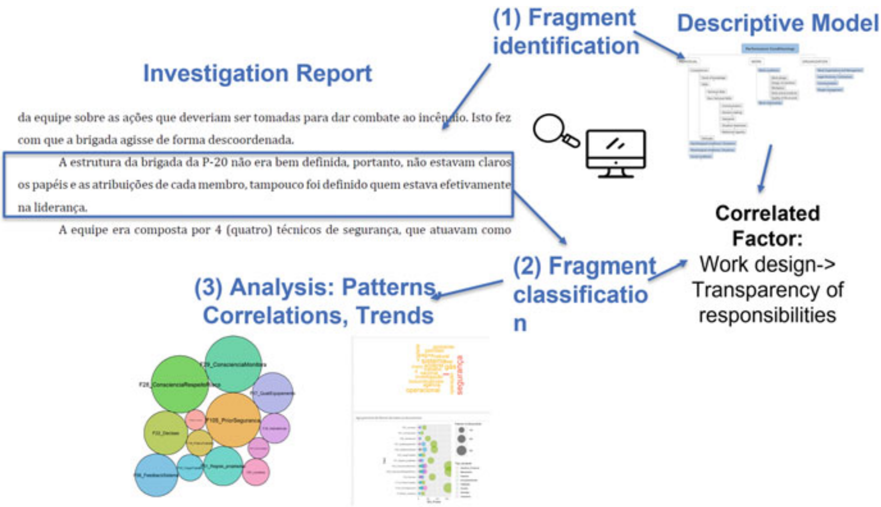

Fig. 6.6 Identification of method steps for identifying human factors in accident investigation reports

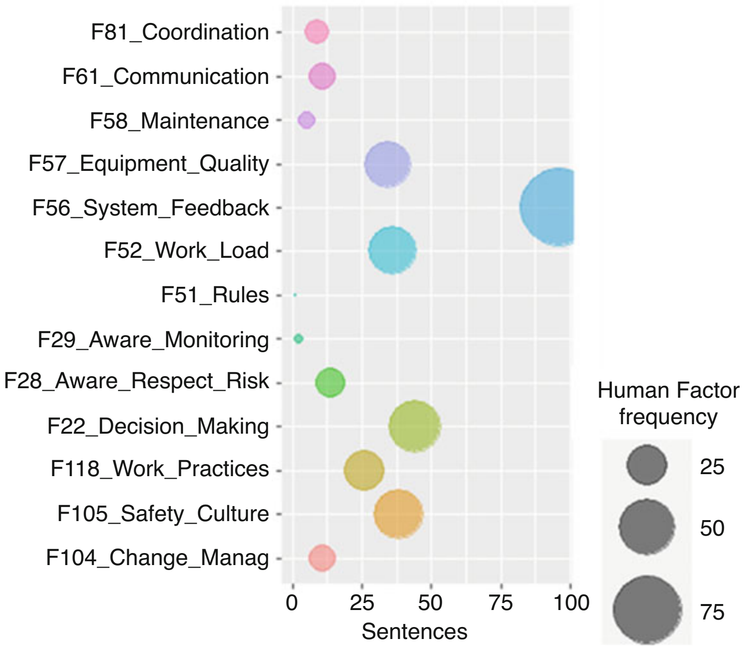

Fig. 6.7 Example of factors identified in an accident investigation report

6.5 Conclusions

This chapter presents the results of interdisciplinary research that gathered experts in different knowledge areas. It involved the creation of a framework for the continuous analysis of the elements that condition resilient performance in complex and high-risk operations, such as integrated operations in the oil and gas industry.

Building the framework involved, initially, the identification of the factors that condition resilient performance, which involved the analysis of models and frameworks used in different industries and a systematic search of the literature. As a result, we established the framework analysis model, with 136 factors, distributed among 10 general factors and 3 first-order constructs. The comprehensive list of factors and the flexibility of factors' organisation into categories or hierarchies allows using the model in different methods of analysis of safety events, like Accimap and HFACS.

In order to demonstrate the framework's applicability, we used data collected by members of an interdisciplinary research project developed together with several companies operating in the oil and gas sector. We used the data to feed the framework and support the creation of indicators and analyses through knowledge systems, which brought a wide view on the factors that condition resilient performance.

The indicators and information produced by knowledge systems enabled cross-checking information from different sources with the participating companies in the oil and gas sector. This new organisation of information led to a holistic view of the conditions found in those companies and helped an interdisciplinary analysis of the issues to be addressed by interventions that facilitate the strengthening of resilience and safety in the integrated operations of those companies.

The text mining approach used to support the analysis of accident investigation reports made it possible to identify a list of latent factors similar to those found through a manual analysis by experts. The approach is being refined to advance into machine learning techniques for an additional classification of relevant sentences in the documents based on excerpts classified by human experts. This approach will complement the current analysis made through ontologies, making it possible to classify excerpts without an explicit mention of ontology terms or concepts in the future.

The framework gathers abstract elements that represent the relationships in complex socio-technical systems, being a device for potential support in resilience management. Future studies involve expanding the factors that make up the model, to enable the analysis of those that determine the resilience potential and apply them for studying the system's behaviour in action. We also intend to examine alternatives for data collection in order to feed the knowledge systems.

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Chapter 7
Relating National Intellectual Capital with Resilience, Reliability, Sustainability, and Reputation of Countries

Valter Vairinhos, Florinda Matos, and Ana Josefa Matos

Abstract Resilience has been associated with the development of competences in many areas and is considered a determining factor in situations that involve major challenges. In recent years, with the emergence of sustainability issues, particularly the climate issue, resilience has been associated with countries' sustainability. Furthermore, many resilience attributes seem to be founded and reinforced through intellectual capital components. Nowadays, resilience has become one of the most used words by decision-makers in all areas of society. Economic and social crises have forced countries to face numerous challenges that have tested their decision-making capacity and adaptation in a short period and a turbulent context. However, it appears that some countries have more agility than others in these processes of response and adaptation. This chapter aims to explore, at a national level, the possible relation between the concepts of Intellectual Capital, Resilience, Reliability, Sustainability, and Reputation. The research is supported by a data-driven approach, oriented by a path analysis model. This study contributes to the literature on resilience, and it can serve as a support to decision-makers, allowing to identify the determinants of resilience in terms of the management of intellectual capital, sustainability, and countries' reputation.

Keywords National intellectual capital · Resilience · Sustainability · Reliability

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7.1 Introduction

7.1.1 Resilience

Resilience is a word that derives from the Latin "resiliens" and that means "to recover quickly". According to the Cambridge dictionary, the resilience[1] is: "the ability of a substance to return to its usual shape after being bent, stretched, or pressed"; "the ability to be happy, successful, etc."; or, in a business context, "the quality of being able to return quickly to a previous good condition after problems".

There are numerous definitions of resilience that have been proposed, some of quantitative nature, others of a more qualitative nature, covering several disciplines (Hosseini et al., 2016), and there is no general concept accepted by the scientific community and by society in general. Thus, for example, there are definitions associated with Disaster Resilience (e.g. Alexander, 2013), Psychological Resilience (e.g. Avey et al., 2009), Ecological Resilience (e.g. Adger, 2000), Economic Resilience (e.g. Park et al., 2011), Organisational Resilience (e.g. Bhamra et al., 2011), Systems Resilience (e.g. Vugrin et al., 2010), Social and Community Resilience (e.g. Aldrich, 2011), amongst others.

Since the focus of the present study is country resilience, the adopted definition was from the United Nations' Vulnerability-Resilience Country Profile: "Resilience is the ability or capacity of a country or a population to withstand, adapt to, or recover from, exposure to the negative effects of shocks, and is often embedded within the concept of vulnerability". The concept presented in Kammouh et al. (2017)—"a resilience index refers to the ability of a community—a country for example—to recover and attain its original functional state"—was also considered.

7.1.2 Intellectual Capital and Sustainability

Intellectual capital has been linked to sustainability, being evident that the most sustainable countries are also those that seem to better manage their intellectual capital (e.g. Vairinhos et al. (2019)). Thus, in this section, the definitions of the two concepts will be presented.

Several models and methodologies for analysing intellectual capital present a macro perspective, focusing on countries. However, there is no consensus on the most appropriate for each study. Some models have a macro perspective derived from business models (e.g. Lin & Edvinsson, 2011; Navarro et al., 2011); others have a more focused view on analysing competitiveness (e.g. Atkinson, 2002; Ståhle & Bounfour, 2008).

[1] https://dictionary.cambridge.org/pt/dicionario/ingles/resilience

Following previous research carried out by the authors of this chapter, intellectual capital is understood as an intangible, renewable, and manageable asset, available at micro-level (individuals and organisations) and macro-level (cities, regions, and countries), that can be managed to create sustainable wealth (Matos et al., 2019). This research methodology for analysing intellectual capital is the methodology proposed by Lin and Edvinsson (2011) in their analysis of 40 countries.

For the sustainability concept, the authors of this chapter choose to consider the United Nations' concept, formulated in the Brundtland Report (WCED, 1987): "meeting the needs of the present without compromising the ability of future generations to meet their own needs".

7.1.3 Reliability

The concept of reliability has emerged from engineering to model, using probabilities, the occurrence of machine failures, often appearing as synonymous with systems resilience (Youn et al., 2011). For these systems, reliability is essential to avoid disruption (Hosseini et al., 2016). These authors considered reliability as a dimension of resilience.

Bensoussan (2005) proposes a reliability index and considers that this index is a valuable indicator to compute failure probability.

For Youn et al. (2011), resilience is the sum of reliability and restoration (defined by the authors as the degree of reliability recovery). Therefore, there seems to be a positive correlation between resilience and reliability for these and other authors.

In this work, country reliability is associated with the concept of country frailty, leading to the occurrence of country failures and failed countries. This means that countries with high frailty index are countries with low reliability.

The frailty index used to represent country reliability/fragility in this work is published by the United States' think tank "The Fund for Peace".[2]

7.1.4 Country Reputation

According to Matos et al. (2015), the way countries deal with their intellectual capital management is a decisive factor for their reputation, leading to the "country branding" concept. To the same authors, countries with a better reputation attract more investment and more qualified people, get better interest rates on loans, and become more innovative and competitive, allowing them to create more wealth and improve their citizens' well-being.

[2] "The Fragile States Index"—https://fragilestatesindex.org/

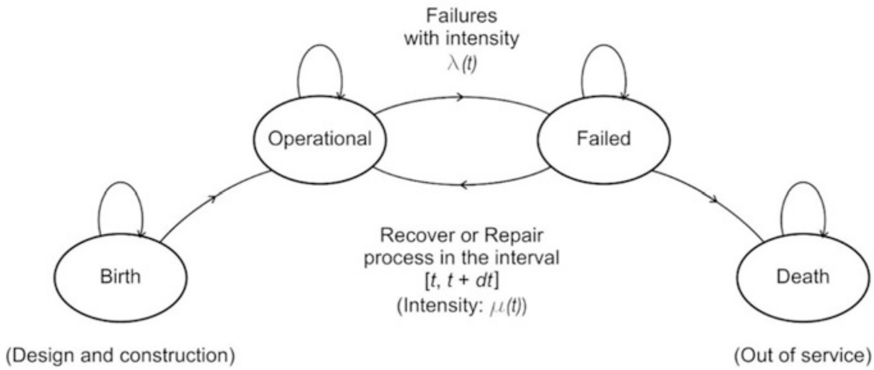

Fig. 7.1 Dynamics of a generic system: states and state transitions during a small time interval [t, t + dt], dt representing a small duration

There are several country indexes, such as the "Country Brand Ranking" (Bloom Consulting, 2020), the "FutureBrand Country Index" (FutureBrand, 2019), and the "Good Country Index" (Anholt, 2007; Anholt & Govers, 2014).

In this work, country reputation is measured by the "Good Country Index", created by Anholt and Govers (2014).

7.1.5 A Systemic View

All natural and artificial systems, a country, for example, have a life cycle that runs between its birth and death. Along its lifetime, there are common elements of behaviour expressed by terms such as state, condition, degradation, failure, illness, health, reliability, resilience, recovery, according to that system's nature and domain. Figure 7.1 is useful to describe visually the relationships between those concepts, applicable to the evolution and running of a large class of systems such as biological, mechanical, electromechanical, software, organisational, political, social, moral, enterprises, and other organisational systems, including countries. In this paper, the specific system that is under scrutiny is the "country" (Butler et al., 2017; Casal-Campos et al., 2015; Connor & Davidson, 2003; Doorn et al., 2019; Gasser et al., 2019; Wang et al., 2017).

As shown in Fig. 7.1, once created ("birth"), the system evolves between two main states, besides "birth" and "death": "operational" and "failed". The transition between the states "operational" and "failed" results from the occurrence of failures in the context of degradation processes and is frequently characterised by a parameter (constant or variable with system age) called failure intensity (λ failures by time unit). The occurrence of failures, their frequency or probability and their relations with a specific degradation process is covered by a specific mathematical model called "Reliability".

When the system fails, being incapable to operate or fulfil its intended function, a process that restores it to an operating state or condition occurs and this process, depending on the nature of system, can be named "failures repair", "recovery process", "disease cure", "restoration", amongst others. The speed with which the failed system is restored to an operating condition is frequently characterised or described by a numerical parameter or mathematical model $\mu(t)$ expressed as a function of system age t. Resilience is an intrinsic feature of the system that explains the speed and conditions that characterise the returning of a system to its functional or operational condition after a failure, avoiding "final death" or "scrapping".

Thinking of a very small time duration dt, the possible system state transitions during a time interval beginning at t and ending at t + dt are: (1) Starting from an initially operating, the system remains operational during the interval [t, t + dt]; (2) Starting from an operating system, the system fails during the interval [t, t + dt]; (3) Starting from a failed state, the system stays in a "failing" state during the interval [t, t + dt]; (4) Starting from a failed state, the system recovers during the interval [t, t + dt].

As easily inferred from examining Fig. 7.1, Reliability (a system's propensity to fail) is closely related to recovery from a failure or catastrophic event and the associated characteristic "Resilience". From a highly reliable system, short periods of "failed" states are expected, meaning that its propensity to return to an operational state should be high (resilience). However, this does not mean that "Resilience" and "Reliability" are the same thing: both are system intrinsic properties but explaining distinct behaviours of the system's reaction to "shocks". A resilient system avoids failures, fails with lesser severe consequences and, when in a "failed" state, it recovers faster.

For an economic or social system, sustainability is its capability to endure failures without being destroyed by the "shocks" resulting from its environment, own behaviour, climate, or pandemics, for instance, through a large period of time in the future. This means that "Sustainability", for systems in which the concept makes sense or is relevant, is related with "Reliability/Fragility"—propensity to suffer failures—and "Resilience"—propensity to recover rapidly from failures (Redman, 2014; Sachs et al., 2020; Sharma et al., 2018).

When the systems under consideration—such as companies, organisations, economic, social, ideologic, and political systems—incorporate or integrate into its structure, as components, human beings allowed to decide based on experience, innovation, and the knowledge created, it is legitimate to wonder about the effects of this knowledge and of intellectual capital on the sustainability, reliability, and resilience of such systems (Kammouh et al., 2017; Pouikli et al., 2020).

Specifically, for a country, seen as a political, economic, social, and human system, organised on a specific territorial base, all the above concepts are relevant. Nations are living beings subject to "birth" and "death" (lifetime), with economic, moral, social, and territorial systems, subject to deteriorating (or development) processes, that can suffer failures (economic crisis, health crisis, moral and political crisis) from which they recover with minor or greater speed and with consequences for the nation's future resilience, reliability, and sustainability.

A country learns from its experience, and this experience expressed as Knowledge and Intellectual Capital applied to management and other tasks (scientific, technical, organisational), modifies the conditions that allow the country to endure successfully future “shocks” or crisis, meaning that National Intellectual Capital has a strong influence on Sustainability.

This work aims to discover, using a data-driven approach, at country level, empirical evidence of relations between the concepts of National Intellectual Capital (NIC), National Reliability (REL), National Resilience (RESI), National Sustainability (SUST), and National Reputation (REPUT) and build a Path Model that explains REPUT as a consequence of the other variables and its mutual believed influences.

The following sections are structured as follows: Section 7.2 describes the data and methods used, Section 7.3 explains the data analysis, and Section 7.4 presents a synthesis of the findings.

7.2 Data and Methods

The data set used consists of 56 rows and 34 columns—corresponding to observations of 56 countries for which there is available data about the following blocks of variables: National Intellectual Capital (NIC), Reliability (REL), Resilience (RESI), Sustainability (SUST), and Reputation (REPUT). Table 7.1 displays, for each one of the 34 indicators (columns), its number, symbol, and meaning, as well as the block of variables to which it belongs.

The data associated with NIC block of variables was obtained from the 2014 National Intangible Capital performance of 59 countries as measured by the ELSS (Edvinsson–Lin–Ståhle–Ståhle) methodology for measuring stock of national intangible capital, economic impacts, and efficiency of National Intangible Capital[3] (Ståhle et al., 2015). From this data, the NIC indicator NIC_M2 was created, in which small values of NIC_M2 correspond to small values of NIC and large values of NIC_M2 correspond to countries with large values of NIC.

For the REL block of variables, the “Fragile States Index”[4] published by “The Fund for Peace” was considered. This source presents data about country fragility and for the years 2016 to 2020, a table with several indicators[5] was published. In this work, Country Fragility Indicators are assumed as contributing for a general country propensity to fail in one or more of its intended national functions, such as economic heath, defence, education, etc., meaning that a country with large Fragility is a country with small reliability and a country with small Fragility is a country with large reliability. Therefore, each one of the 12 indicators of this index is represented

[3] https://en.wikipedia.org/wiki/National_Intangible_Capital

[4] “The Fragile States Index”—https://fragilestatesindex.org/

[5] https://fragilestatesindex.org/indicators/

Table 7.1 The number, symbol, meaning, and block of variables associated with each one of the 34 indicators used in the data analysis

Number	Symbol	Meaning	Block
1	Country	Name of the country	–
2	NIC_M2	National Intellectual Capital	NIC
3	REL_M1	Security apparatus	REL
4	REL_M2	Factionalised elites	REL
5	REL_M3	Group grievance	REL
6	REL_M4	Economy	REL
7	REL_M5	Economic inequality	REL
8	REL_M6	Human flight and brain drain	REL
9	REL_M7	State legitimacy	REL
10	REL_M8	Public services	REL
11	REL_M9	Human rights	REL
12	REL_M10	Demographic pressures	REL
13	REL_M11	Refugees and IDPs	REL
14	REL_M12	External intervention	REL
15	RESI_M5	Productivity	RESI
16	RESI_M6	Political risk	RESI
17	RESI_M7	Oil intensity	RESI
18	RESI_M8	Urbanisation rate	RESI
19	RESI_M11	Exposure to natural hazard	RESI
20	RESI_M12	Natural hazard risk quality	RESI
21	RESI_M13	Fire risk quality	RESI
22	RESI_M14	Inherent cyber risk	RESI
23	RESI_M17	Control of corruption	RESI
24	RESI_M18	Quality of infrastructure	RESI
25	RESI_M19	Corporate governance	RESI
26	RESI_M20	Supply chain visibility	RESI
27	SUST_M2	Sustainability indicator	SUST
28	REPUT_M2	Science and technology	REPUT
29	REPUT_M3	Culture	REPUT
30	REPUT_M4	International peace and security	REPUT
31	REPUT_M5	World order	REPUT
32	REPUT_M6	Planet and climate	REPUT
33	REPUT_M7	Prosperity and equality	REPUT
34	REPUT_M8	Health and well-being	REPUT

in Table 7.1 as follows: REL_M[NUMBER] (for example, the REL_M1 indicator represents the "Security Apparatus", the REL_M2 indicator represents "Factionalized Elites" and so on).

The data for the RESI block of variables was obtained from the "FM Global Resilience Index"[6] published by FMGlobal. This index includes several indicators,

[6] https://www.fmglobal.com/research-and-resources/tools-and-resources/resilienceindex

such as “Productivity”, “Political Risk”, “Natural Hazard Exposure”, “Control of Corruption”, amongst others, and each indicator is represented in Table 7.1 as RESI_M[Number], in which higher scores represent better resilience levels.

For the SUST block of variables, data was obtained from the “Sustainable Development Goals Index”[7] presented in the “Sustainable Development Report” prepared by the Sustainable Development Solutions Network and the Bertelsmann Stiftung (Sachs et al., 2019). In this index, larger scores correspond to countries such as Denmark (85.2), Sweden (85), or Finland (82.8), all considered very sustainable countries, and the smaller scores correspond to countries such as Chad (42.8) or Central African Republic (39.1), not so sustainable countries. Therefore, for the indicator SUST_M2, the larger the country’s score, the better is its sustainability level.

The data associated with the REPUT block of variables was obtained from the “Good Country Index”,[8] developed by Simon Anholt. This index ranks countries based on seven indicators, measuring how much each of the 163 countries on the list contributes to the planet and the human race through their policies and behaviours. From these categories, the REPUT indicators were created, being represented in Table 7.1 as follows: REPUT_M[Number] (for example, the REPUT_M2 indicator represents the “Science and Technology”, the REPUT_M4 indicator represents “International Peace and Security” and so on). The lower the scores for these indicators for a certain country, the higher the country’s reputation.

In the introductory section of this work, some informal hypothesis about relationships between Intellectual Capital, Reliability/Fragility, Resilience, and Sustainability at the country level were identified. Those hypotheses were formulated based only in the generic meaning of those concepts. In the following sections, an attempt to support with empirical evidence those hypotheses is presented. For that, a multivariate descriptive graphical data analysis was used to detect empirical evidence of dependence or influence relations between those variables.

The data was organised in a data set with the structure shown in Table 7.2. This table with 56 rows (countries) and 34 columns (manifest variables)—is the input for all data analysis performed in this chapter.

Cronbach alpha and principal component analysis were used to decide if the relevant blocks of observed variables could possibly be replaced with single indicators or if, subjacent to some of those groups, single latent variables could be assumed to exist, explaining the observed indicators values from those blocks.

As an intermediate step, multiple regression analysis was employed to relate empirically rough estimators (the means of corresponding blocks of indicators) for those theoretical and unobservable latent variables. Subsequently, a path analysis model was formulated, aiming to find empirical support for some believed influence relations between those latent variables and model the perception that Country Reputation was directly influenced by those latent variables. This model was

[7] https://sdgindex.org/

[8] https://www.goodcountry.org/

Table 7.2 Each column contains an indicator (manifest variable) of the latent variable correspondent to that block

	NIC block	REL block			RESI block			SUST block	REPUT block		
Country number	NIC_M2	REL_M1	...	REL_M12	RESI_M5	...	RESI_M20	SUST_M2	REPUT_M2	...	REPUT_M8
1	8.98	3.80	...	1.30	48.5	...	90.2	76.43	38	...	3
2	.	.	...	.	.	...	.	.	.	...	.
...	...	...	...	...	...	...	...	...	...	...	...
I	.	.	...	.	.	...	.	.	.	...	.
...	...	...	...	...	...	...	...	...	...	...	...
56	3.72	6.07	...	4.30	9.70	...	56.4	65.3	160	...	84

estimated using partial least squares (PLS) (Tenenhaus et al., 2005). Computations were made using the R Language packages "stat"[9] and "semPLS".[10] Biplots were drawn using the software BiplotsPMD (Vairinhos, 2003) and auxiliary calculations and pictures were built in Microsoft Excel.

7.3 Data Analysis

7.3.1 Relating Groups of Indicators

In what follows, biplots are used to relate the observed values of indicators in each block.

The main objective is to discover empirical evidence supporting the assumed associations and influences between latent variables. For that, observed values of indicators in each block are used. In the biplots, points represent countries, also identified by their names, and variables are represented by red vectors with origin in the centre of the biplot. The centre of each biplot represents the average of all those variables. The distance between countries represents dissimilarities, and the angles between variables mean correlations: nearby countries have similar behaviours, and countries far apart display distinct behaviours. Variables with small angles are highly positively correlated. Angles near 90° mean "near independence" and angles greater than 90° represent negative correlations (Gabriel, 1971; Galindo-Vilardón, 1986; Vairinhos, 2003; Vairinhos & Galindo-Vilardón, 2004).

Figure 7.2 represents the relations between the 12 reliability/fragility indicators (REL_M1 to REL_M12) and the NIC indicator (represented by NIC_M2), where the mean values of resilience (mRESI), sustainability (SUST_M2), reliability (mREL), and reputation (mREPUT) are also displayed.

The figure shows that REL indicators, considering the indicator meanings presented in Table 7.1, form the following clusters (from top to bottom):

- Group 1: REL_M4 (Economy), REL_M11 (Refugees and IDPs), REL_M12 (External Intervention).
- Group 2: Containing just REL_M6 (Human Flight and Brain Drain). The countries that contribute mainly for this indicator are Jordan, Ukraine, South Africa, Colombia, and Israel. It is also important to note also that this indicator is colinear with the NIC_M2 indicators, but corresponds to smaller values of NIC_M2, meaning that smaller values of NIC are intrinsically associated with Human Flight and Brain Drain, strongly suggesting that high scores of Human Flight and Brain Drain cause a reduction on Intellectual Capital.

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[9] https://cran.r-project.org/web/packages/STAT/index.html

[10] https://cran.r-project.org/web/packages/semPLS/index.html

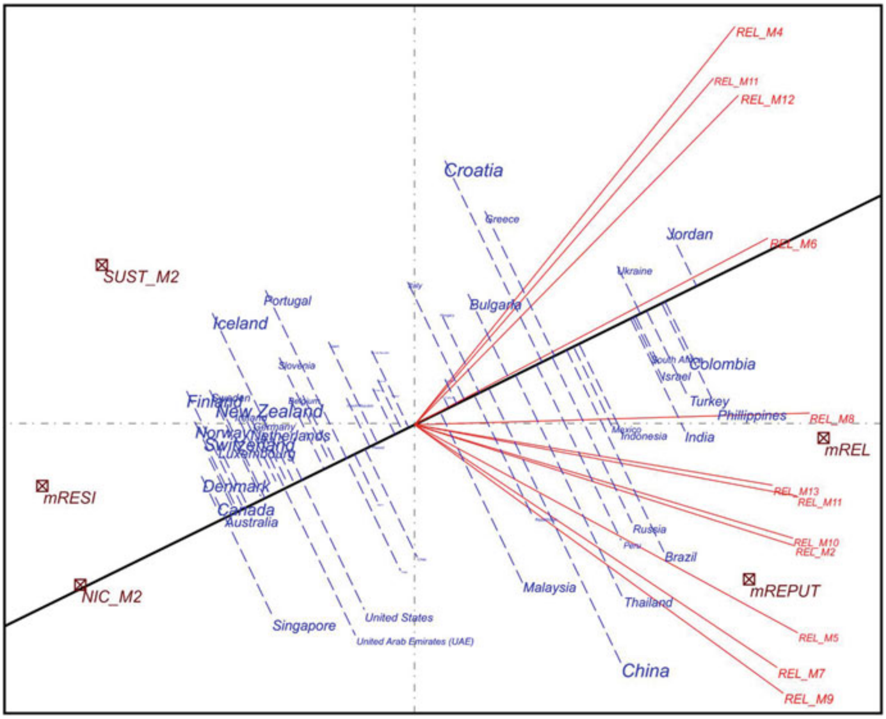

Fig. 7.2 Biplot for the 12 reliability/fragility indicators in relation to NIC_M2 and the mean values of resilience (mRESI), sustainability (SUST_M2), reliability (mREL), and reputation (mREPUT)

- Group 3: Formed by just one indicator—REL_M8 (Public Services). This indicator seems to be a good synthesis of the set of 12 REL indicators, given the small angle it makes with mREL, the mean of those REL indicators.
- Group 4: Containing the indicators REL_M3 (Group Grievance), REL_M1 (Security Apparatus), REL_M2 (Factionalised Elites), and REL_M10 (Demographic Pressures).
- Group 5: Formed by the indicators REL_M5 (Economic Inequality), REL_M7 (State Legitimacy), and REL_M9 (Human Rights). This group of indicators is intimately associated with the following countries: Malaysia, Peru, China, Brazil, Russia, and Thailand.

This biplot also clearly shows that larger values (above the mean) of Sustainability (represented by SUST_M2), Resilience (represented by mRESI), and National Intellectual Capital (NIC_M2), all on the left side of biplot, correspond to countries such as the United States, Singapore, Sweden, Denmark, Japan, Netherlands, amongst others (Vairinhos & Galindo-Vilardón, 2004).

The right side of the biplot of Fig. 7.2 shows countries where reliability/fragility indicators (REL) have values above the mean, corresponding to high propensity to

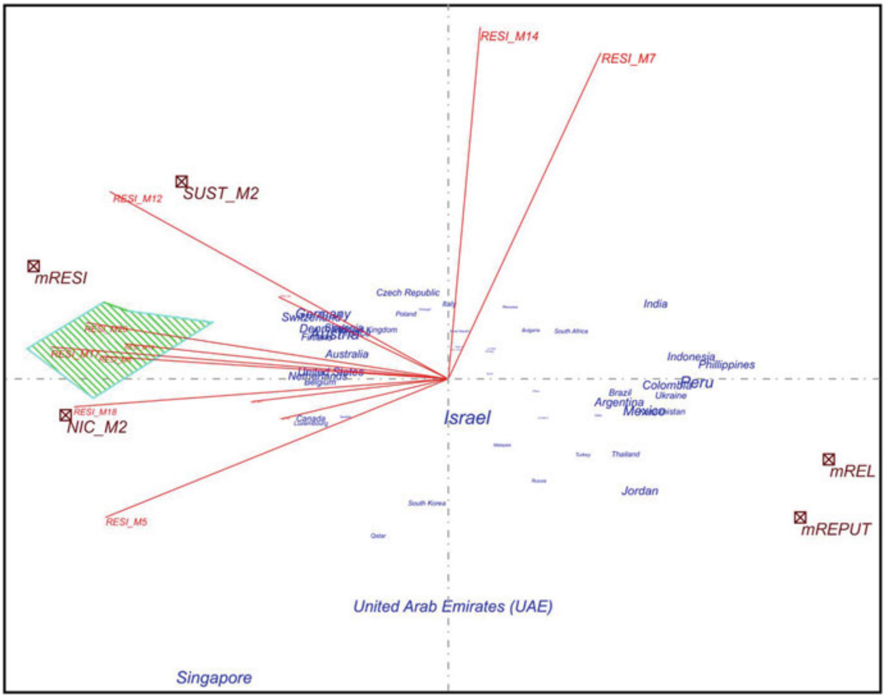

Fig. 7.3 Biplot for the 12 resilience indicators in relation to NIC_M2 and the mean values of reliability/fragility (mREL), sustainability (SUST_M2), reliability (mREL), and reputation (mREPUT)

fail and being also associated with poor reputation (mREPUT) and higher values in the indicators of Group 5 (Economic Inequality, State Legitimacy, and Human Rights).

Figure 7.3 was built with 12 resilience indicators (RESI_M5 to RESI_20), relating the concept of resilience with National Intellectual Capital (NIC_M2), Sustainability (SUST_M2), Reputation (mREPUT), and Reliability/Fragility (mREL).

This figure shows, distinctly, the same macrostructure already noted in Fig. 7.2. On the left side, the values are above average for Resilience, Sustainability, and National Intellectual Capital and, on the right side, the values of Reliability/Fragility and Reputation are below average. It is possible to observe that there is a clear association—positive correlation—between National Intellectual Capital (NIC_M2), Sustainability (SUST_M2), and Resilience (mRESI) on one side and, on the other side, between Reliability/Fragility (mREL) and Reputation (mREPUT).

7.3.2 Unidimensionality of Groups of Indicators

As already noted, except for National Intellectual Capital and Sustainability, both with just one indicator (NIC_M2 and SUST_M2), the other indicators are grouped in blocks of variables: REL (Reliability/Fragility, with 12 indicators), RESI (Resilience, also with 12 indicators), and REPUT (Reputation, with 7 indicators).

Note that blocks NIC and SUST are not presented in Table 7.3 because in those blocks, just one indicator is considered (NIC_M2 and SUST_M2).

Table 7.3 shows the Cronbach α for each block of variables, the percent variance explained by the first and second principal components and its quotient in the last column. Since those quotients are much greater than 1, this suggests that the 3 blocks are, each one, well represented by just one single latent variable whose values explain the observed values of the indicators (Tenenhaus et al., 2005).

For NIC and SUST, with just one indicator each (NIC_M2 and SUST_M2), it can be assumed that two specific latent variables explain the observed scores.

7.3.3 Evidence of Dependencies Between Blocks of Variables

The study of biplots in Figs. 7.2 and 7.3 has already revealed interesting associations between groups of variables representing Reliability/Fragility, Resilience, Sustainability, National Intellectual Capital, and Reputation. Furthermore, Table 7.3 shows evidence that subjacent to the three blocks, exist non-observable latent variables that explain the observed values of the indicators. The following section will present the estimation of those latent variables using PLS estimation.

However, as an intermediate step, it is relevant to replace those formal estimations with rough approximations obtained averaging the values of the indicators in the blocks REL, RESI, and REPUT. This approach is justified by the evidence of unidimensionality of those three blocks of variables, as shown in the previous section. These rough approximations will be named mREL, mRESI, and mREPUT and will be now possible to calculate the correlations between the five variables NIC_M2, SUST_M2, mREL, mRESI, and mREPUT. These correlations represent rough estimations of correlations between the corresponding five latent variables.

Table 7.4 shows the correlations between these variables. As expected from the visual study of biplots in Figs. 7.2 and 7.3, correlations between all these variables are large (small angles), suggesting that, between the latent correspondents of these rough estimates, similar relations exist, showing that it makes sense to express its mutual relations by linear regressions.

Table 7.3 Indicators of unidimensionality for REL, RESI, and REPUT

Group	Cronbach α	% Variance 1st PC	% Variance 2nd PC	1st/2nd
REL	0.95	6.83	0.73	9.4
RESI	0.81	5.27	1.83	2.9
REPUT	0.70	2.94	1.13	2.6

Table 7.4 Correlations between the Variables NIC_M2, SUST_M2, mREL, mRESI, and mREPUT

	NIC_M2	mREL	mRESI	SUST_M2	mREPUT
NIC_M2	1.00				
mREL	−0.76	1.00			
mRESI	0.82	−0.88	1.00		
SUST_M2	0.53	−0.72	0.68	1.00	
mREPUT	−0.69	0.77	−0.82	−0.69	1.00

Table 7.5 Multiple regression expressing mREPUT in function of NIC_M2, SUST_M2, mREL, and mRESI

	Coefficients	Standard error	*t* Stat	*p*-value	Lower 95%	Upper 95%
Intercept	225.87	52.65	4.29	**0.00**	120.17	331.56
NIC_M2	−1.09	2.29	−0.47	0.64	−5.69	3.52
mREL	1.23	2.72	0.45	0.65	−4.23	6.69
mRESI	−1.53	0.54	−2.85	**0.01**	−2.60	−0.45
SUST_M2	−1.10	0.53	−2.07	**0.04**	−2.16	−0.03

The contents of Table 7.5 show that it is possible to express Country Reputation (mREPUT) as a linear function of the other variables (NIC_M2, mREL, mRESI, SUST_M2), using multiple regression with $R^2 = 0.84$. The *p*-values in bold show that the only significant coefficients at level 0.01 are Intercept (225.87), mRESI (−1.53) and SUST_M2 (−1.10).

As shown in Table 7.5, only mRESI and SUST_M2 have significant coefficients, leading to the following final expression:

$$\text{mREPUT} = 225.87 - 1.53 \times \text{mRESIL} - 1.1 \times \text{SUST\_M2} + \text{RESIDUAL}$$

7.3.4 *Path Modelling*

The findings obtained from descriptive statistics are consistent with the idea that the blocks (NIC, REL, RESI, SUST and REPUT) of 34 indicators, presented in Table 7.1, have subjacent five latent variables (lNIC, lREL, lRESI, lSUST and lREPUT) and that these latent variables have strong mutual correlations, suggesting linear relations between them. However, more than mutual linear relations, it is believed that some influence and causal relations make sense. Let us name, in what follows, those latent variables by lNIC, lREL, lRESI, lSUST, lREPUT, the "l" prefixing the labels meaning "latent".

Using literature (for example, Casal-Campos et al., 2015; Moloney, 2020), personal beliefs and experience, an initial and tentative structural model relating the identified latent variables is presented in Fig. 7.4. After estimation of this initial model using the R package "semPLS" and bootstrapping the results, using

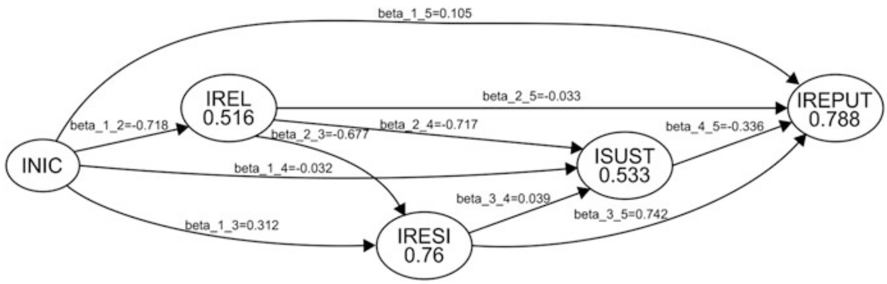

Fig. 7.4 Structural Initial Model

Table 7.6 Structural Model Specifications

Edge number	Initial model	Final model
1	lNIC → lREL	lNIC → lREL
2	lNIC → lRESI	lNIC → lRESI
3	lNIC → lREPUT	N/S
4	lNIC → lSUST	N/S
5	lREL → lRESI	lREL → lRESI
6	lREL → lREPUT	N/S
7	lREL → lSUST	lREL → lSUST
8	lSUST → lREPUT	lSUST → lREPUT
9	lRESI → lREPUT	lRESI → lREPUT
10	lRESI → lSUST	N/S

Fig. 7.5 Structural Final Model

500 pseudo samples, the edges lNIC → lSUST, lRESI → lSUST, lNIC → lREPUT and lREL → lREPUT were found not significant using the 95% bootstrap confidence intervals.

The resulting final structural model is presented in the last column of Table 7.6 and is plotted in Fig. 7.5.

Figures 7.4, 7.5, and 7.6 were obtained with the R package "Rgraphviz".[11] Figures 7.4 and 7.5, in addition to the nodes and edges also present the estimates

[11] http://www.bioconductor.org/packages/release/bioc/html/Rgraphviz.html

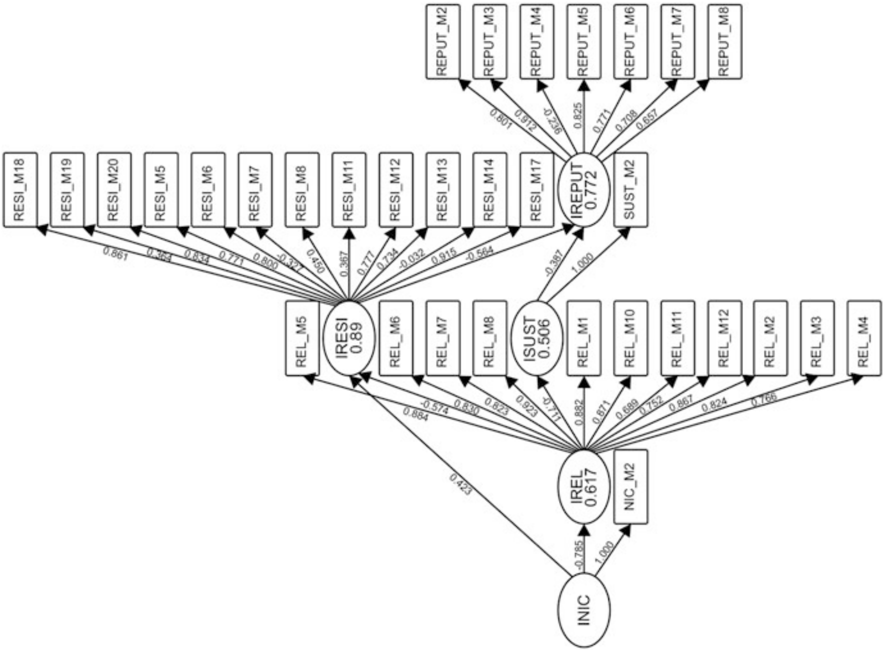

Fig. 7.6 Complete Path Diagram, including both the Structural Model and the Measurement Model

of path coefficients. Inside the ellipses representing latent variables, the R^2 values associated to its estimation are shown.

Examining Table 7.6 and Figs. 7.4 and 7.5, it can be seen—contradicting expectations—that NIC (National Intellectual Capital) has no direct influence on SUST (Sustainability), only an indirect influence based on the available data. This indirect influence of NIC on SUST can be explained from the direct and strong influence of NIC on REL (Reliability/Fragility)—recall that in biplots of Figs. 7.2 and 7.3, large values of NIC are associated to large REL scores and small NIC values are associated with higher observed values of fragility indicators, pointing at a slow future development of NIC for the affected countries, thus influencing indirectly those countries sustainability.

Another unexpected absence is the influence of RESI (Resilience) on SUST (Sustainability) (edge lRESI → lSUST is considered non-significant), given its frequent explicit presence in literature (for example, Moloney, 2020). In this case, data does not support the direct influence or any indirect influence of RESI on SUST. A possible interpretation for this may be found in the meaning of resilience. This concept is associated with speed of recovery from failures, not to its occurrence. After failing, highly resilient countries recover with higher speed, but this does not mean that the country will avoid fatal failures in the future.

The possible direct influence of NIC (National Intellectual Capital) on REPUT (Reputation) is also considered non-significant but this influence exists mediated by

Table 7.7 Goodness of Fit of the Structural Final Model

Latent variable	Communality	R^2	Dillon Goldstein
lNIC	–	–	–
lREL	0.69	0.61	0.96
lRESI	0.44	0.89	0.86
lSUST	–	0.50	–
lREPUT	0.53	0.76	0.86

lREL or lRESI, both directly influenced by lNIC. This makes sense because reductions in scores of Reliability/Fragility indicators, such as Human Rights, Group Grievance or State Legitimacy, are associated with gains in National Intellectual Capital as manifested in Fig. 7.2. In the same way, Resilience indicators, such as Control of Corruption, Productivity, Quality of Infrastructure, increase when National Intellectual Capital increases.

Finally, the direct influence lREL → lREPUT is also non-significant but remains through indirect influence, mediated by lSUST and lRESI.

Figure 7.6 shows the complete final model, including the structural and the measurement models together with the estimation results obtained with R package “semPLS”, both for path coefficients and outer weights relating latent variables and manifest variables. For each latent variable, the corresponding manifests are the indicators listed in Table 7.1 for the specific block of variables.

Table 7.7 shows the values of usual performance and quality indicators of goodness of fit for structural models (Vinzi et al., 2010).

From Table 7.7, it is possible to calculate the goodness of fit for this model, which corresponds to 0.62, being an acceptable value (Tenenhaus et al., 2005; Vinzi et al., 2010).

$$\begin{aligned}\text{Goodness of Fit} &= \left(\text{Mean}(\text{Communality}) \times \text{Mean}\left(R^2\right)\right)^{1/2} = (0.55 \times 0.69)^{1/2} \\ &= 0.62\end{aligned}$$

Using the latent variables estimated scores supplied by “semPLS” package (Monecke & Leisch, 2012) and forming a rectangular array of 56 rows (corresponding to each of the 56 countries) and five latent variables, the biplot represented in Fig. 7.7 was created. This biplot summarises what has been said previously, displaying both latent variables and countries in positions that account for the global results obtained from the estimation of the final model.

Figure 7.8 displays a tree obtained from a cluster analysis (dissimilarities: Euclidean distance, Ward method for aggregation criterium), applied to the same data used to generate Fig. 7.7, showing the 56 countries proximities and the resulting clusters.

Cutting the tree at height = 5, four clusters of countries are identified (from top to bottom):

- First Cluster: From Indonesia to Brazil
- Second Cluster: From Greece to Croatia

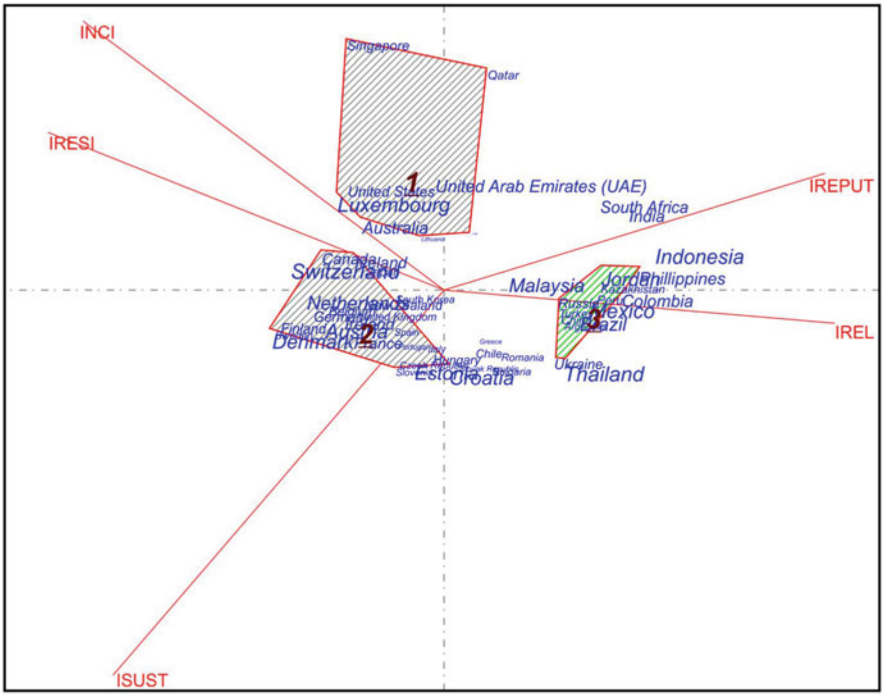

Fig. 7.7 Biplot built with the latent variables PLS estimated scores

- Third Cluster: From Sweden to Austria
- Fourth Cluster: From Israel to Australia

These clusters are also highlighted in Fig. 7.7 (shaded zones).

7.4 Conclusions and Future Work

This chapter presents data-driven research aiming to detect relations between the concepts of National Intellectual Capital, Reliability/Fragility, Resilience, Sustainability, and Reputation. This research was based on open data easily accessible to all.

National Intellectual Capital (NIC), Country Resilience (RESI), Country Reliability (REL), expressed by Fragility, Country Sustainability (SUST), and Country Reputation (REPUT) are modelled in this work by latent variables with observable indicators recorded by international organisations. Table 7.3 presents empirical evidence that these latent variables—roughly estimated by the observational means of its indicators' blocks—are mutually related by linear relations, as suggested by the large absolute values of its sampling Pearson correlations.

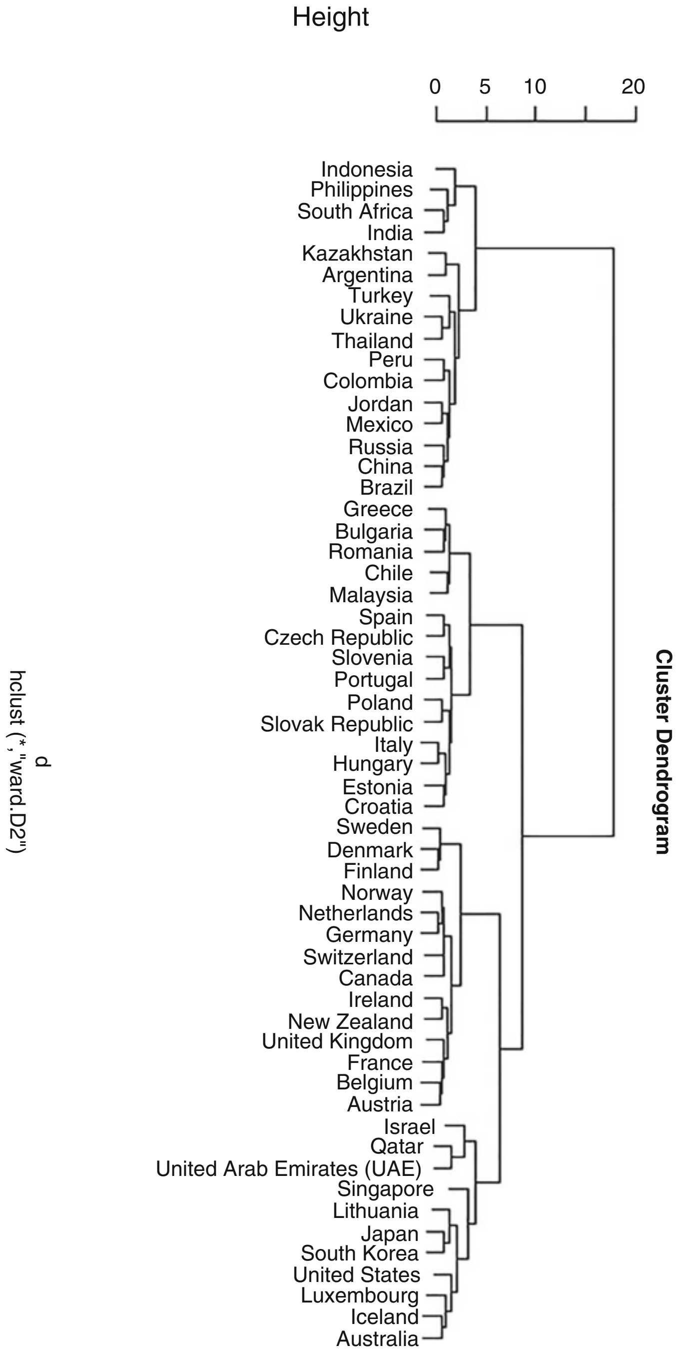

Fig. 7.8 Clusters of countries, built from the coordinates of the biplot of Fig. 7.7

In addition to dependence relations, influence and causal relations were also researched using a path analysis methodology, the main results being concisely summarised by Fig. 7.5. This figure shows that NIC directly influences Reliability/Fragility and Resilience. On the other hand, Country Reputation (REPUT) is directly influenced by Resilience (RESI) and Sustainability (SUST) but only indirectly by NIC and REL. This is coherent with the results of regression analysis shown in Table 7.5.

Contrary to what would be expected from some literature, no significant evidence was detected supporting direct influences from NIC on REPUT, NIC on SUST, and RESI on SUST. However, more research is needed to clarify these aspects.

This means that REL (Country Reliability, expressed by Fragility) and RESI (Country Resilience) act as mediators between National Intellectual Capital (NIC) and Country Reputation (REPUT). REPUT is the country image that is built and emerges as a consequence of temporal changes in the REL and RESI indicators due to NIC development.

This can be interpreted as meaning that each NIC development level produces specific changes on indicators of Fragility—such as Security Apparatus, Factionalized Elites, Group Grievance, Economic Equality, Human Rights, Public Service—and RESI—such as Productivity, Political Risk, Urbanisation Risk, and Inherent Cyber Risk.

These findings may have methodological value in future decision processes relevant for strategic and mid-term planning in policies formulation.

In view of the conclusions and research clues raised by this research, future research should be carried out with the aim of proving the results presented in this research.

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Part II
Applications, Technologies and Digital Tools

Chapter 8
Towards Sustainable Smart City via Resilient Internet of Things

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Abstract Every day, 2.5 quintillion bytes of data are generated which is an unimaginable figure to human beings and even machine. To achieve the global smart city vision, automation, resilience, and sustainable development are crucial elements. This chapter focuses on resilient Internet of Things that links individuals and sensing devices which forms the foundation of data collection and provides ground truth of information. With the tremendous growth of primary data volumes and diversity in every domain, they have played an ever more crucial role in enabling researchers and enterprises to formulate processing and analysis methods to extract latent information from multiple data resources and to leverage a broad range of data management and analytics platforms. We have been witnessed the successful technology story of artificial intelligence in various applications. However, resilient and sustainable development has not yet fully integrated into artificial intelligence applications. It requires automated update and improvement of trained machine learning model with the ever-increasing data. This chapter is organised as follows. Firstly, a systematic

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review of the existing works of resilience and sustainability for smart city is presented. This is followed by a comparison of IoT solutions in software and hardware perspective. Various future research directions and conceptual study of smart city application are discussed.

Keywords Automation · Artificial intelligence · Incremental learning · Internet of things · Resilience · Smart city · Sustainable development

8.1 Introduction

People may have thought smart city is a buzzword because smart is only a general description. Indeed, it is a global vision of the United Nations that countries around the World have shared 17 sustainable development goals (SDGs) and 169 targets to make extensive improvement in the following key areas, including but not limited to sustainable cities and communities, affordable and clean energy, clean water and sanitation, quality education, as well as good health and well-being (Transforming Our World: The 2030 Agenda for Sustainable Development, 2015). Resilience as the adaptation to address new change, often classified as challenge, is a prerequisite to achieve the SDG (HLPF 2020 Session: Protecting the Planet and Building Resilience, 2020). One of the key examples is the COVID-19 pandemic that has influenced the society since December 2019. However, there is limited discussion to apply resilience in smart city based on the systematic review, which will be presented in Sect. 8.2. It is desired to promote the concept in this decade to contribute to SDGs.

Internet of Things (IoT) is a network of physical objects that are embedded with sensing devices, software, hardware, and artificial intelligence techniques for data collection, exchange, and analysis between devices and systems over the Internet (Chaudhary et al., 2021; Nižetić et al., 2020; Plageras et al., 2018). It is one of the most promising solutions in today's digital era, where data and innovation make our cities smarter. The focus of the chapter is to enable resilience and sustainability in IoT network to address challenges in smart city.

The contributions of this chapter are: (1) systematic review of resilience and sustainability for smart city; (2) comparison of IoT solutions in software and hardware perspective; and (3) various future research directions and conceptual study of smart city application.

The chapter is organised as follows. Section 8.2 shares the systematic review of the existing works. The comparison across various IoT solutions is presented in Sect. 8.3. Future research directions and conceptual study of deep incremental learning are discussed in Sect. 8.4. At last, a conclusion is drawn.

8.2 Systematic Review of Resilience and Sustainability for Smart City

In this section, we are going to shortlist the relevant works in the topics of resilience and sustainability for smart city, based on the search strategy and data extraction. Results are presented with basic study characteristics and highlighted in four key research topics.

8.2.1 Search Strategy

Based on the advanced search in Web of Science, we have made three queries up to the date of 12 January 2021: (1) TS = (((sustainable OR sustainability) OR (resilience OR resilient)) AND (smart city OR smart cities)); (2) TS = ((sustainable OR sustainability) AND (smart city OR smart cities)); and (3) TS = ((resilience OR resilient) AND (smart city OR smart cities)). The field tag TS is equivalent to the inclusion of contents in the abstract, title, and/or keywords of the research articles.

8.2.2 Data Extraction

All authors read the title, abstract, and keywords to confirm the relevance of research articles. Then, articles are excluded on the basis of (1) Document type: Editorial material; (2) Languages: Non-English articles; and (3) Web of Science index: Non-social sciences citation index (non-SSCI) or non-science citation index expanded (non-SCIE).

8.2.3 Results

The initial search reveals that 1699 articles, 132 articles, and 152 articles have applied the concept of sustainability for smart city, the concept of resilience, and the concept of sustainability and resilience, for smart city, respectively. These have reflected the research limitation in major works that the crucial element, resilience, has not been fully incorporated in sustainable smart city research. There is room for further study of sustainability and resilience in smart city.

Applying the exclusion criteria (referring to Fig. 8.1), 114 research articles have been included. With the high order of the number of articles, key study characteristics have been reported instead of reporting each of the articles.

Study characteristics. Among 114 articles, 25.4% ($n = 29$), 28.1% ($n = 32$), and 46.5% ($n = 53$) are SCIE, SSCI, and both SCIE- and SSCI-listed articles,

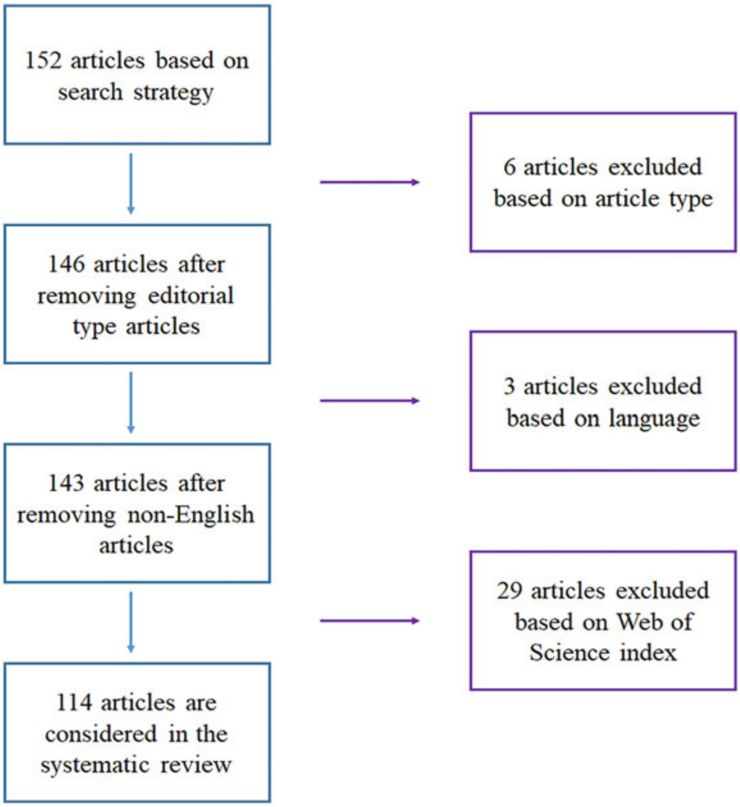

Fig. 8.1 Workflow to identify research articles for systematic review

respectively. These are highly related to the research perspectives towards science and/or social science. The number of publications in each year is 2021 ($n = 1$), 2020 ($n = 34$), 2019 ($n = 29$), 2018 ($n = 20$), 2017 ($n = 12$), 2016 ($n = 11$), 2015 ($n = 3$), 2014 ($n = 1$), and 2011 ($n = 3$). The major reason for the increased attention in this research topic is the agenda of SDGs in 2015 (Transforming Our World: The 2030 agenda for sustainable development, 2015). Figure 8.2 summarises the number of articles ($n = 114$) published in 54 journals. It is worth highlighting that 38 (one-third) of them are in the scope of sustainability, reflecting by the names of the journals.

Research focuses of existing works. We have summarised the research topics of the studied articles. They are categorised into 16 research topics, as shown in Fig. 8.3. For the sake of concise systematic review, only the top 4 research topics, namely (1) promoting the advantages of technologies ($n = 20$); (2) key performance indicators ($n = 18$); (3) water ($n = 15$); and (4) energy ($n = 14$); are discussed in detail. In each category, the top five highly cited articles will be summarised.

Promoting the advantages of technologies. The advent of technologies facilitates the migration of city to smart city. Smart city is a more advanced vision to promote

Fig. 8.2 Distribution of articles in SCIE- and/or SSCI-listed journals

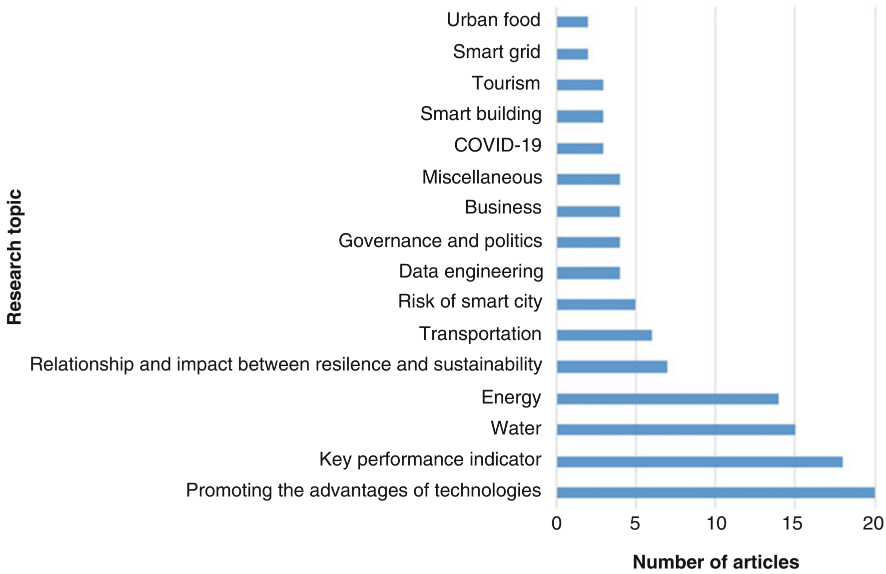

Fig. 8.3 Distribution of the research topics of studied articles

intelligent city, digital city, and information city by integrating information and communication technology (ICT) with other technologies (Transforming Our World: The 2030 Agenda for Sustainable Development, 2015). The technologies aim at promoting the roles of creation and innovation companies, emphasising the urban development based on residents' participation, and improving the economic efficiency of culture and social development. A vigorous planning called master plan, characterised by design guidelines and rules, has been employed to provide a high-level plan before the start of the smart city projects (Delmastro et al., 2016). The master plan is associated with statutory, policy, and strategic documents. Geographic information system was utilised for effective integration between software and hardware as well as information management (displaying, analysing, and capturing). Another idea to enhance the urban systems is the collaborations discovery (Marsal-Llacuna & Segal, 2016). The benefits include the empowerment of processes, enhancement of citizens' involvement, cultural preservation, landscape impact reduction, and the efficiency of the usage of resources.

There are some good practices that have been demonstrated in real-world projects in Brisbane, San Francisco, Amsterdam, Masdar, and Songdo (Yigitcanlar et al., 2019). Technologies must be synergised with community and policy, which have been taken the trade-off into consideration, along with the discussion of the risks to smart city.

However, it has been challenging to consolidate smart city because there are tremendous amounts of potential technologies to address the applications (Chamoso et al., 2018). Therefore, fair key performance indicators should be introduced to evaluate the performance of smart city applications using different technologies. These are going to be discussed in the next subsection.

Key Performance Indicators To evaluate the performance of the technologies and systems, indicators or metrics are necessary for the fair assessment and benchmarking of the solutions (Klopp & Petretta, 2017). Typical indicators include Singapore city biodiversity index, Canadian sustainability index, Sprawl index, Ecological footprint, Climate action in MegaCities, City prosperity index, World's most livable cities, Sustainability index, World's most global cities, Cities of opportunity, Green city index, and Global cities index. There has been an increase in attention to urban underground space (U2S) in recent years. Three indicators, namely developed U2S volume per person, U2S use density, and developed U2S volume, were proposed for the evaluation (Bobylev, 2016). Another researcher argued that the resilience and sustainability in smart city had become a matter of political urgency to measure, record, and take stock of dissensus-driven approaches (Kaika, 2017). Ten smart city examples, including Melbourne, Hong Kong, New York, Washington, London, Vienna, New Songdo, Seoul, Geneva, and Tampere, have been analysed (Anthopoulos, 2017). Smart cities share common characteristics, which mainly focused on city, facilities, and infrastructure planning. As long as the city outperforms in one of the aspects, it could be claimed as smart city. Six strategic principles, adoption of integrated intervention logic, digital transformation, building a strategic framework, combination of community-driven and government-driven approaches, migration towards quadruple-helix collaborative model, and foresee beyond technology, have been proposed in Mora et al. (2019).

Water Water in various forms of drinking water, stormwater, lack, ocean, and drainage, is crucial for human beings and smart city. Three elements namely solid waste infrastructure, waste management system, and sufficient maintenance are important to achieve resilient and sustainable smart city (Koop & van Leeuwen, 2017). The smart cities are water-wise, adaptive, resource-efficient, and wasteful. Wireless based water monitoring system has been investigated (Chen & Han, 2018). The system is comprised of five modules which manage data redistribution, data storage, power supply, data transmission, and data acquisition. The emergent technologies include LoRaWAN, narrowband IoT, LoWPAN, Wavenis, Insteon, Z-Wave, and ZigBee. Typical challenges of water and waste have been summarised based on six cities (Feingold et al., 2018). Governance was concluded as the leading challenge because city agencies possess strong authority. Handling of drainage is important because we do not want to have unclean water. Green infrastructure was proposed to attract living spaces, remove pollution, retain stormwater, and reduce runoff (Zischg et al., 2018). Investigation was made of the influence of placement strategies towards low impact development structures. A simple targeted placement strategy was the best approach. In the work (Giudicianni et al., 2020), a multiscale clustering based adaptive water distribution system was proposed. The network layout was transformed into dynamic district metered areas. Results revealed that water leakage reduction can be reduced by 16%.

Energy Energy has remained as leading research field to reduce global warming. Building is the major contributor of energy consumption and thus various energy-efficient schemes were discussed for smart building (Wachsmuth & Angelo, 2018). For instance, there are leadership in energy and environmental design certification, low-carbon building techniques, optimal design of surface and orientation, etc. In Morimoto (2011), the ecosystem and biodiversity services were discussed to adapt the climate change. Kyoto was taken into consideration as an example. Climate change is getting worsen in recent years (Mi et al., 2019; O'Neill et al., 2020). On the other hand, the possibility of the enhancement of thermal comfort of urban parks was studied (Aram et al., 2019). Analysis revealed that Madrid exhibited cooling effect in hot summer.

A review article has summarised several successful stories for energy reduction via smart grid and IoT (Deakin & Reid, 2018). Non-intrusive load monitoring (NILM) is an important technique to bring total energy consumption of smart meters to individual energy consumption (Chui et al., 2018). Users receive recommendation on how the energy consumption can be reduced. Another review article (Gazzola et al., 2019) concluded that well-established green methods, like sustainability appraisal and environmental assessment, are adopted to examine the green performance of smart city visions. An example is that the remaining useful life of products is important for planning.

8.3 Comparison of IoT Solutions for Smart City

Sensors are the basic components to collect ground truth data. In recent decades, wireless communication has been widely adopted attributable to its advantages in cost, installation, and mobility. In this section, emergent wireless communication protocols are discussed. This is followed by three IoT architectures, from traditional designs to latest cloud-based designs.

8.3.1 Wireless Communication

Four emergent wireless communication protocols, including fifth-generation (5G) and three low power wide area network (LPWAN) based protocols, narrow-band IoT (NB-IoT), Sigfox, and long range (LoRa), will be discussed.

5G. The latest technology standard for broadband cellular networks, 5G, has achieved a significant improvement in bandwidth, latency, and average speed. We have been witnessing more and more successful projects of 5G enabled IoT since 2019. It is estimated that the penetration rate of 5G will reach 90% by 2026 (Forge & Vu, 2020). The basic requirements of 5G include mobility, connection density, long battery lifetime, security, reliability, resilience, very low latency, fine-grained and high scalable networks, and high data rate (Li et al., 2018). The key features of the

Table 8.1 Overview of the characteristics of LoRa, Sigfox, and NB-IoT

	NB-IoT		Sigfox		LoRa	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
License	Cellular licensed		ISM unlicensed		ISM unlicensed	
Spectrum (MHz)	832–862	791–821	868.1–868.3	869.425–869.625	863–870	
Bandwidth (kHz)	180		0.1	0.6	125	
Physical layer	Narrowband		Ultra narrowband		Chirp spreading spectrum	
Scheduling	Network scheduled		Uplink initiated		Uplink initiated	
Transmission power (dBm)	23	35	14	27	14	14–27
Data rate (kbps)	226.7–250		0.1		0.37–27	
Range (km)	35		63		22	

physical layer include a centralised radio access network, device-to-device communication, heterogeneous networks, coordinated multipoint processing, massive multi-input multi-output, and carrier aggregation (Shafique et al., 2020). As a new standard, ensuring security is important to obtain social acceptability. Key agreement scheme, authorisation, and privacy-preserving authentication were discussed in Shin and Kwon (2020). These security features are able to address various types of attacks, including desynchronisation, user collusion, sensor node impersonation, gateway impersonation, user impersonation, stolen verifier, privileged insider, and stolen smart card attack.

LPWAN. The most widely adopted LPWAN-based protocols for IoT are NB-IoT Sigfox, and LoRa. Their characteristics, license, spectrum, bandwidth, PHY, scheduling, transmission power, data rate, and range, have been summarised in Table 8.1 (Lauridsen et al., 2017; Mroue et al., 2018; Vejlgaard et al., 2017).

NB-IoT It is an extension of long-term evolution advanced (LTE-A), customised for IoT. There are three operational modes (1) within the LTE inband carrier by replacing physical resource block(s); (2) within the guard carriers of LTE or universal mobile telecommunications system (UMTS) spectrum; and (3) standalone (Malik et al., 2018). Although some characteristics of NB-IoT follow LTE-A, there are several modifications, including repetition for coverage extension, offset between data transmission and control, random access preamble, and synchronisation sequences.

The overlapping between NB-IoT and LTE-A leads to narrowband interference in devices and base stations. Modelling the narrowband interference has become important to study the characteristics of the interference and thus better to reduce its influence. Typical approaches include compressed sensing theory (Gui et al., 2020) and block sparse Bayesian learning (Liu et al., 2017).

Typical challenges of security in NB-IoT include energy efficiency, single point of failure, availability of services, accounting and authorisation, authentication, integrity, confidentiality, and privacy (Migabo et al., 2020). Various studies have demonstrated the effectiveness of blockchain technology to address the issues of security (Singh et al., 2020; Wang et al., 2020b).

Sigfox It is superior in applications with low data rates. The nature of many real-world applications may not require high-frequency data to produce analysis. Instead, aggregated data (low-frequency data) is sufficient to fulfil the requirement. Differed from NB-IoT, Sigfox takes advantage in interference and collision avoidance. It adopts the diversity mechanism in which each sensor sends data packets on three communication channels randomly (Lavric et al., 2019a, b). This can ensure that each of the transmissions is transmitted in different channels so that the communication performance can be enhanced.

Another key characteristic of Sigfox is that it provides a longer range of data transmission compared with NB-IoT and LoRa. Experimentally, the packet error rate can be maintained at a level of less than 10% at two scenarios, 100 sensors and 360 channels, as well as 1100 sensors and 1920 channels (Lavric et al., 2019a, b). However, Sigfox has experienced several challenges in using beamforming and MIMO because signal processing techniques are needed in physical and medium access control layers (Oliveira et al., 2019).

LoRa. Various long-range protocols have been proposed; among all, LoRa was the firstly launched protocol. Research work has demonstrated the feasibility of mesh network topology in LoRa (Lee & Ke, 2018). The advantage of mesh network is to increase the packet delivery ratio and communication range without the need of introducing gateways (cost reduction). The complete characterisation of the LoRa signal after modulation was investigated (Chiani & Elzanaty, 2019). The key findings were (1) the deviation is less than the occupied bandwidth; and (2) the existing of lines in the spectral domain, possessing a fraction to the overall power.

There are several challenges of LoRa for IoT applications, including (1) severe data packet collision; (2) ineffective control of end devices; and (3) high data latency. Researchers (Piyare et al., 2018) have proposed a high-efficiency on-demand time-division multiple access-based energy-efficient network to address the challenges. Results revealed that the sensing device may last for 3 years using a 1200-mAh battery. The energy-efficient data transmission via LoRa is a key concern when it comes to body sensor network for vital sign monitoring (Shahidul Islam et al., 2019).

8.3.2 IoT Architectures

The full IoT architectures cover four parts, sensing, networking, computing, and applications. In this subsection, three architectures are discussed, being the first the traditional approach, and the latter two are the cloud-based approaches.

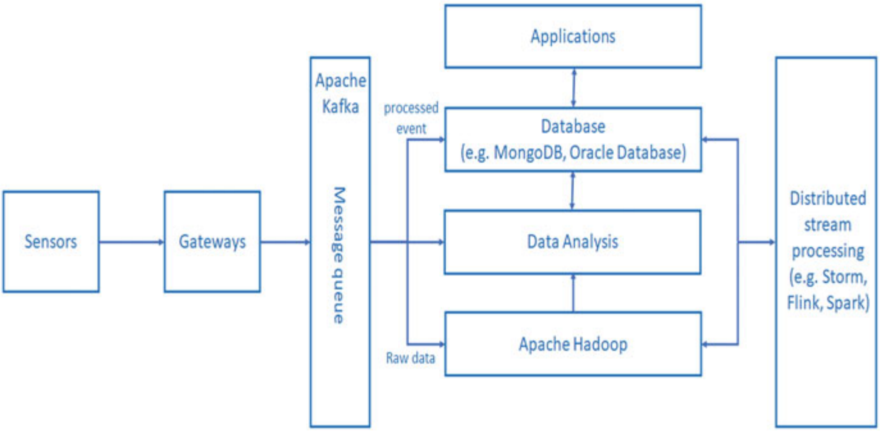

Fig. 8.4 Traditional IoT architecture

Traditional IoT architecture. Figure 8.4 shows the traditional IoT architecture, modified from Chui et al. (2019). It is noted that the description of traditional is related to non-scalable and low-performance computing architectures, which are not applicable to the requirement of resilient and sustainable smart city applications. Owning to the well-known concepts, authors would like to highlight only the roles of Kafka and Hadoop.

Kafka is a stream processing platform which divides data stream (topic) into small pieces (brokers). To prevent data loss when there is failure in data transmission, the topic is reserved in the Kafka log. Studies have suggested the extra brokers could enhance the performance (van Dongen & Van den Poel, 2020). Kafka manages the routing of raw data to Hadoop. Distributed stream processing tools such as Spark, Flick, and Storm materialise batch views from the Hadoop data lake.

Google cloud platform IoT. The recent breakthrough of Google Cloud Platform (GCP) has received much attention in which many companies start migrating the amazon web services (AWS). The architecture, with modification, can be referred to Fig. 8.5 (Google Cloud Platform, 2020). Compared with AWS, GCP offers lower cost for storage and computing power, as well as more support in computational tools, particularly for deep learning. It is worth mentioning that the AI platform can link to various tools like Cloud Bigtable, BigQuery, AutoML, Text-to-Speech, Video AI, Datalab, and Data Studio. Usually, the industries prefer retaining the core of the IoT architecture using AWS, and enhancing the data analytics via GCP, this is named a hybrid cloud a hybrid cloud services (combining GCP and AWS). The research work (Taylor et al., 2018) proposed a generic design of simulation environment for the development of hybrid cloud platform.

Amazon Web Services IoT. AWS is the most widely adopted cloud platform for IoT attributable to its popularity and social acceptability as web services provider. Figure 8.6 shows the general architecture of AWS IoT (AWS IoT, 2020). For the detailed comparison between GCP and AWS, it is suggested to refer to Pierleoni et al. (2019). Indeed, there is no unique solution that fits all applications, as resilient

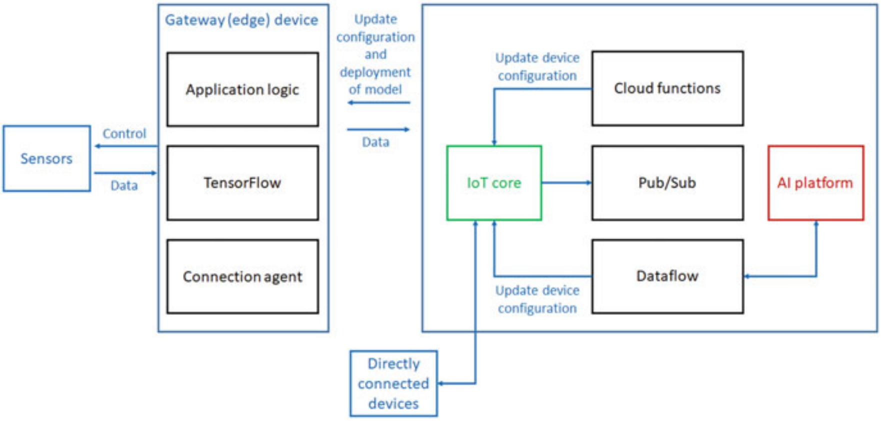

Fig. 8.5 GCP IoT architecture

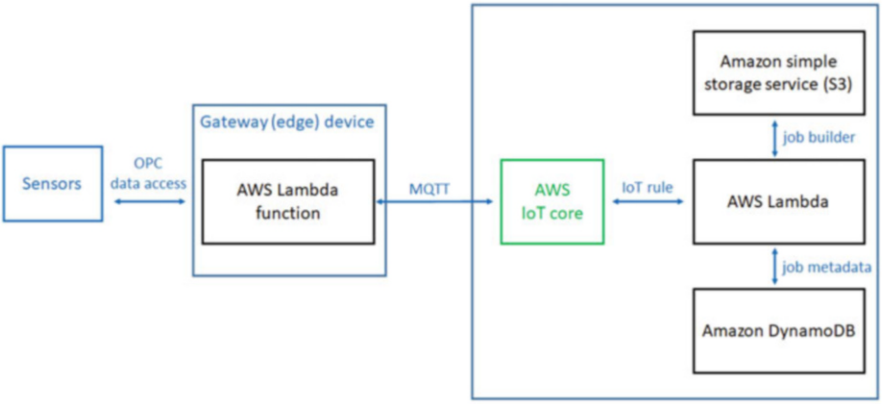

Fig. 8.6 AWS IoT architecture

and sustainable smart city, the vision is to adopt hybrid cloud services that takes advantages in different solutions to yield optimal performance.

Cloud computing offers scalable storage and huge computing power; however, may not fulfil the requirement of low latency and mission critical applications. Edge and fog devices are good alternatives to support data analytics and control locally (Al-Qerem et al., 2020; Wang et al., 2020a). As a result, the most promising solution is edge/fog/cloud-based IoT.

The Best IoT Architecture. There exist many IoT architecture solutions, a common question is how we can implement a best IoT architecture. The answer is no since there is no one solution that fits all applications and requirement, particularly come to an ever-growing standard of sustainable and resilient smart city. As a result, various researchers have reported the adoption of hybrid cloud/fog/edge-based IoT architecture to fulfil the need (Fantacci & Picano, 2020; Mouradian et al., 2020). This ensures the architectures are scalable that allow the inclusion of more resources.

Nevertheless, some of the smart city applications may require huge computational power that drives the need for quantum computing. Here are the recommended readings for linking quantum computing in IoT (Bhatia & Sood, 2020; Lohachab et al., 2020).

8.4 Future Research Directions

The research topic, resilience and sustainability in IoT based smart city, is still young and emerging concept. We look forward to reading more and more research articles in this field. For readers who are interested in contributing research works for smart city, please refer to the following recommended readings that fit to the SDGs. Table 8.2 summarises the recommended readings and topics for SDG 1–17.

Table 8.2 Research directions in SDG 1–17 for resilient and sustainable IoT based smart city

SDG	Name	Work	Research topics
1	No poverty	(Feliciano, 2019)	Crop diversification
2	Zero hunger	(Udmale et al., 2020)	Food security
3	Good health and well-being	(Osingada & Porta, 2020)	COVID-19
4	Quality education	(del Cerro Velázquez & Morales Méndez, 2018)	Augmented reality and mobile devices
5	Gender equality	(Alarcón & Cole, 2019)	Tourism
6	Clean water and sanitation	(Tortajada, 2020)	Recycled wastewater
7	Affordable and clean energy	(Giwa et al., 2017)	Solar energy
8	Decent work and economic growth	(Bastida et al., 2020)	Ecosystem
9	Industry, innovation, and infrastructure	(Kynčlová et al., 2020)	Composite index
10	Reduced inequalities	(Husted & Salazar, 2020)	Income inequality
11	Sustainable cities and communities	(del Cerro Velázquez & Lozano Rivas, 2020)	STEM
12	Responsible consumption and production	(Zhang & Chabay, 2020)	Ecologically and socially sound products and practices
13	Climate action	(Campbell et al., 2018)	Agriculture and food systems
14	Life below water	(Blasiak et al., 2019)	Marine fisheries and healthy oceans
15	Life on land	(Stumpf & Cheshire, 2019)	Tourism
16	Peace, justice, and strong institutions	(Zhou et al., 2017)	Peacebuilding
17	Partnerships for the goals	(Castillo-Villar, 2020)	Cross-sector partnerships

We have conducted a conceptual study of smart city application via deep incremental learning. Deep learning has become the leading approach when accuracy or error rate is dominated criterion compared with computing power. Particularly, this is the vision in smart health applications (Chui et al., 2017). The ever-growing smart city data provides an opportunity for the update (not re-train) and performance enhancement of existing models.

To reduce the training time of model, we firstly adopted the pre-trained model VGG-16 (Simonyan & Zisserman, 2014). It is further updated using the deep convolutional neural network based incremental learning proposed in Roy et al. (2020), with dataset DeepLesion (Yan et al., 2018), which contains more than 32,000 CT images. We divide the dataset into small batches (with batch size of 100 images). The accuracy improvement is 3% after 20 batches, and 5% after 50 batches, respectively. Since this chapter would like to present the feasibility of model enhancement via incremental learning, there are chances to further improve the performance by advanced incremental learning techniques (Sarwar et al., 2019; Yu & Zhao, 2019).

8.5 Conclusion

In this chapter, we have shared a systematic review of the latest development of resilient and sustainable smart city. The results indicated that more than half of the research works focused on the following four categories, promoting the advantages of technologies, key performance indicators, water, and energy. Resilience has become the essential characteristic of smart city to cope with the increasing standard and new requirement. Traditional smart city framework (without resilience) requires fine-tuning and even rework on the framework in order to meet upcoming challenges, as a result, the spending of smart city is high, and may not be affordable in developing countries.

This is followed by three IoT architectures, including both traditional and cloud-based approaches. We have highlighted the hybrid cloud/fog/edge-based IoT architectures will be favourable to fulfil the wide range of needs across numerous smart city applications. This could enable resilience as the IoT architecture can be scaled-up with the increasing volume of data sources and applications. Incremental learning-based deep learning model is briefly studied as conceptual study of medical diagnosis. It has confirmed the feasibility of the performance enhancement of existing models when new data is available. It is worth mentioning that resilient and sustainable smart city is a global vision that everybody should contribute towards the same direction, that drives the 17 SDGs documented by United Nations. At last, 17 topics have been shared as future research directions, linked with 17 SDGs.

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Chapter 9
Digital Ownership Strategies: The Health Care Services Case

Mike Franz Wahl and Susanne Durst

Abstract In the age of digitalisation, good governance and management have become even more important for the resilience of organisations. On the organisational level, resilience is mainly seen as the ability to survive and prosper. The resilient structure is assumed to follow the digital ownership strategy, while changes in strategy lead to changes in the chain of command and thus should be followed by a change in culture. Previous research has stressed that ownership strategy is where corporate governance meets strategic management. Furthermore, it has been argued that this is meaningful only for corporations with concentrated ownership. Claiming that all corporate entities need governing, the authors of this chapter study how resilience can be enhanced in the implementation process of ownership strategies by making use of the opportunities offered by digitalisation. This exploratory research is based on action research involving health care organisations from Estonia. The results presented in this chapter are valuable in several ways. By proposing a digital ownership strategy as a substitute for smart contracts, the study adds a new facet to contract theory. An improved understanding of the needed match between organisational core values and individual values may also enhance organisational resilience and success.

Keywords Concentrated ownership · Health care services · Resilience · Strategic management · Values · Action research

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9.1 Values in Governance, Management, and Ownership Strategy

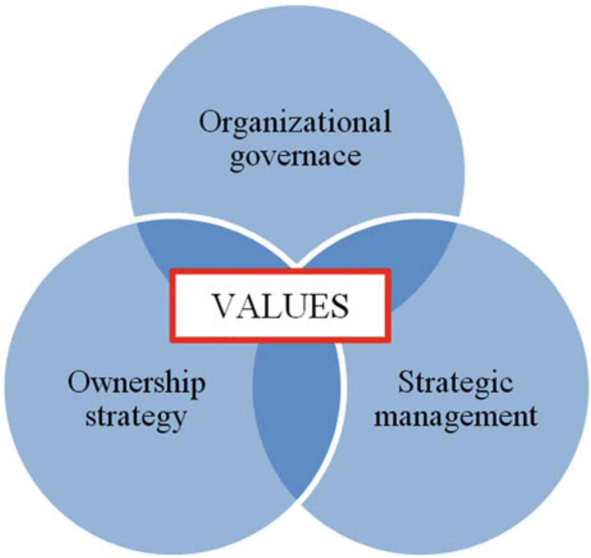
9.1.1 Introduction

Organisational governance is the foundation for an open and participatory society as it deals with policies, rules, processes, and behaviours that affect how power is exercised. It has proven to lead to increased value creation, economic growth, and foster inclusion (Jonsdottir et al., 2020).

Values are vital to understanding what resilience can deliver and for whom. They combine the local context with a broader one, i.e., a macro-scale worldview, and based on that, suggest a beneficial pathway for understanding the emergent resilience metaphor throughout and within policy and planning (Rogers et al., 2020). Hilb (2017) showed that governance is an inclusive process involving various decision and execution bodies both inside and outside the organisation (stakeholders), and the key dimensions of digitalisation are governing digital value creation (who?), enabling digital value creation (why?), amplifying digital value creation (what?), and realising digital value creation (how?). Corporate governance is understood as the thought about the implementation of the owners' will (Wahl, 2012). It is influenced by the national culture (Licht et al., 2005), which in turn underlines the role of values (see Fig. 9.1).

The overarching goal of strategic management is creating and capturing value for all core stakeholders (Freeman, 2010). In the digital age, besides the absence of a common goal in the form of knowledge vision (Banerjee et al., 2018), shortcomings in organisational culture (Prenestini & Lega, 2013), which are mainly reflected as

Fig. 9.1 Values in governance, management, and ownership strategy



value conflicts, have been identified as the main barriers to organisational success (Goran et al., 2017). This hinders not only the formulation of a successful ownership strategy but also its implementation and the achievement of financial and strategic performance goals.

Strategy implementation can be viewed as the total of all activities and choices required for the execution of an ownership strategy. It involves managing, leading, mentoring, and coaching people to use their abilities and skills most effectively and efficiently to achieve the organisational objectives (Wheelen et al., 2017). The behaviours and actions we are seeing in this context are closely related to values. An organisation's success is discussed as a system of functions, and processes are discussed in relationship with the organisation's functions, the main content of procedural analysis is the modelling and improvement of the organisational processes (Gerndorf, 2006; Rüegg-Stürm & Grand, 2021). A change in strategy must be followed by a change in structure, and it must also be supported by organisational culture. The resilient structure follows the digital ownership strategy, changes in strategy lead to changes in the chain of command and should be followed by a change in culture through communication.

A review of different definitions of resilience is not the purpose of this chapter. Therefore we rely pragmatically on the definition given by the International Organization for Standardization (ISO)—organisational resilience is seen as the ability of an organisation to absorb and adapt to a changing environment to enable it to deliver its objectives and to survive and prosper (International Organization for Standardization, 2017). The principles and attributes for organisational resilience are well described and are aimed to enhance organisational resilience for any size and type of organisation. An organisation that has adopted the resilience principles will demonstrate common attributes (shared vision and clarity of purpose, understanding and influencing context, effective and empowered leadership, a culture supportive of organisational resilience, shared information and knowledge, availability of resources, development, and coordination of management disciplines, supporting continual improvement, ability to anticipate and managing change) supported by activities, which guide their utilisation, evaluation, and enhancement (International Organization for Standardization, 2017).

Previous research, including several pilot studies, has highlighted that ownership strategy is where corporate governance meets strategic management, and analysing several firm cases allowed concluding that strategic auditing is a useful tool for developing systemically ownership strategies, which in turn could be a realistic alternative for complete contracts (Wahl, 2015), or even smart contracts. Such a contract is, from a legal point of view, a transactional agreement between two or more parties, subject to absolute trust between the parties. A smart contract is a decentralised programme, and blockchain has become a standard execution platform for it (Bashir, 2018). A smart contract is special in that the code is binding trust with law. Smart contracts are digital contracts bound by "decentralised consensus", which are "tamper-proof" and executed automatically through "self-enforcing" (Cong & Zhiguo, 2019). Smart contracts could have different implementations and not necessarily run on blockchains. However, this technology provides a secure standard decentralised platform for executing such smart contracts (Bashir, 2018). The idea of an ownership strategy is meaningful only for corporations with concentrated ownership. During several board member training activities, it was found that also state-owned enterprises are interesting in this context. As all corporate entities need governing, the next logical step was about digital ownership strategies universal for different kinds of organisations (e.g. state-owned enterprises, private companies, and non-profit organisations), moving from corporate governance to organisational governance.

Although some research has been carried out on strategy development (Grant, 1991), conceptualising ownership strategies (Collin, 2001; Jonsdottir et al., 2020; Luoma, 2011; Wahl, 2015), no studies have been found which explored how to enhance resilience and make use of the opportunities of digitalisation in the implementation process of ownership strategies for organisations.

The chapter proceeds as follows. Section 9.2 reviews theories and evidence relating to organisational governance, strategic management, and ownership strategies focusing on values, will, and resilience. Section 9.3 outlines the research methodology used. An emphasis in this section is put on the attributes of organisational resilience. Finally, Section 9.4 concludes the chapter and offers some future research direction.

9.2 Theoretical Framework: Digital Ownership Strategies for Organisations

9.2.1 Organisational Governance

Corporate governance is built on the idea of a closed, centralised authority, and a clearly defined hierarchy with distinct roles and functions for protecting the interests of those at the pinnacle of that hierarchy—namely, the owners (Fenwick et al., 2019). However, since Laloux (2016), it is clear that one must reinvent organisations and adopt a whole different set of management principles and practices (e.g. trusting employees, believing them to have good intentions, being capable of learning and acting like responsible adults, prize diversity and wholeness, create an environment that invites employees to be present as a whole and complete beings)—self-management rather than a hierarchical structure seems the only logical conclusion. As such, the discourse and practice of corporate governance was an adaptation to, and product of, a world of centralised, hierarchical organisations (Fenwick et al., 2019).

An important application of blockchain could be in organisational governance. The health care industry is already benefiting from blockchain by claims processed faster, simplifying complex operational procedures (Bashir, 2018). Blockchain is a peer-to-peer distributed ledger—it is not centrally controlled in the network, and all participants are directly connected and have access to the complete ledger; that is "cryptographically secure"—it cannot be tampered with or misused; "append only"—it adds a timestamp to the data added to the ledger; immutable—it is almost impossible to change the data once added to the ledger; and "updateable only via consensus"—it is updated only after validation against defined criteria and reaching a consensus among all participants on the network (Bashir, 2018). In business, blockchain is a platform where value is exchanged among peers without the involvement of a trusted intermediary.

In a technology-driven "digital world", many of the largest and most successful businesses now operate and organise as open and inclusive "platforms" (Parker & Van Alstyne, 2018). Such firms leverage networked technologies to facilitate economic exchange, transfer information, connect people, and make predictions. A tension exists between the incentives created by modern corporate governance and the business needs of today's platforms (Fenwick et al., 2019).

Wahl (2015) found that ownership, a relationship between the owner and the business, is still central to organisational governance. Proficient owners and managers are the most important actors in organisational governance and general management. All ownership-related legal-economic, social, and psychological aspects are reflected in owners' behaviours stemming from different economic, political, social, and personal values. The values are woven into our language, thoughts, and behaviour patterns and are based on what is important to us. However, beliefs are assumptions we hold to be right. The most important and right dimensions dictate the owner's behaviour; in other words, the action is taking place only when it is important and right. Unimportant and wrong, unimportant, and right or wrong and important, no action takes place. Organisations or groups of people exhibit consistency in behaviour and beliefs because it is assumed that individuals within them share a similar set of core values (Rogers et al., 2020).

9.2.2 Strategic Management

Strategic management is a set of managerial decisions and actions that determines the long-run performance of an organisation. The performance of healthcare systems and organisations positively consistent with leadership, management practices, manager characteristics, and cultural features that are related to values and administrative approach (Al-Habib, 2020). In the strategic management process, the interrelated activities of internal and external environment scanning and strategy formulation, implementation, and evaluation result in a set of strategies of the organisation. Early efforts ranged from defining strategies as integrated decisions, actions, or plans designed to set and achieve organisational goals to defining a strategy as simply the outcome of the strategy formulation process (Wheelen et al., 2017). In this chapter, strategy is defined as a series of goal-directed plans and activities that match an organisations' structure, culture, and resources with the opportunities and threats in its environment. Enhancing resilience can be a strategic organisational goal and is the outcome of good organisational practice and effectively managing risk; organisations can only be more or than less resilient, there is no absolute measure or definitive goal (Fisher & Law, 2021; International Organization for Standardization, 2017). One thing is to formulate strategies and policies, and the other is to describe clear procedures for implementation. Values are stable because they are transmitted to the next generation through the socialisation process (Dietrich, 2003); however, only the existence of a supportive organisational culture enables the successful implementation of new strategies.

The present and future of values research are imperative to understand how, and for what purposes, resilience is utilised across diverse fields of knowledge and practice (Rogers et al., 2020). Culture functions both as an anchor for resilience and an anvil of pain, hope arises from a sense of moral and social order embodied in the expression of key cultural values like faith, family unity, service, effort, morals, and honour, these values form the bedrock of resilience, drive social aspirations, and underpin self-respect and dignity (Eggerman & Panter-Brick, 2010). Bureaucratic values can affect the ability of agents to adapt to the challenges of crises: Well-entrenched bureaucratic value-sets, relating to efficiency and procedural rationality, have profound consequences for the resilience agenda (Stark, 2014). Traditional cultural values predict resilience and highlight the important role that certain cultural values play in providing strength for overcoming adversity (Consoli & Llamas, 2013). The goal of strategic management should be creating and capturing values, which have been a central concept in the social sciences since its inception (Schwartz, 2017). Our focus hereafter is on organisational- and individual-level values.

Bourne and Jenkins (2013) explained that there are four distinct forms of organisational-level core values—espoused, attributed, shared, and aspirational. The Schwartz (1992) value survey (SVS) is still the most widely used instrument for studying human values, a latent construct that empirically has shown to be moderate to good predictors of group or individual behaviour (Rogers et al., 2020). Values are likely to be universal because they are grounded on one or more of three universal requirements of human existence with which they help to cope, namely, the needs of individuals as biological organisms, requisites of coordinated social interaction, and the survival and welfare needs of groups. What distinguishes one value from another is the type of goal or motivation the value expresses. The value theory defines 10 broad basic values (self-direction, stimulation, hedonism, achievement, power, security, conformity, tradition, benevolence, and universalism). Schwartz fine-tuned his theory in 2012 by adding some broad basic values (self-direction–thought, self-direction–action, stimulation, hedonism, achievement, power–dominance, power–resources, face, security–personal, security–societal, tradition, conformity–rules, conformity–interpersonal, humility, benevolence–dependability, benevolence–caring, universalism–concern, universalism–nature, universalism–tolerance) (Schwartz, 2017).

Stakeholder theory asks managers to articulate the shared sense of the value they create and what brings their core stakeholders together. Stakeholder theory concerns values and beliefs about the appropriate relationships between the individual, the organisation, and the state (Tricker, 2015). Similarly, the "enlightened shareholder value" approach represents an attempt to strike a balance between owners' primacy and stakeholders' interests (Andreadakis, 2011; Pichet, 2011). When trying to explain why owners behave as they do, we often refer to attitudes, beliefs, traits, or norms. However, values are one especially central component of an individual's self and personality, distinct from attitudes, beliefs, norms, and traits. Values are critical motivators of behaviour and attitudes (Schwartz, 2017).

9.2.3 Ownership Strategy

On the organisational level, the owners' will—what owners want—is ideally expressed in the form of an ownership strategy (Wahl, 2015). Enlightened owners should recognise what organisational results they want to have from the organisation in the long run, those results are in the form of diverse individual, social, political, and economic values, and most probably they would succeed in a dynamic environment only if they "seed" those same values. Long-term success means accomplishing the mission, organisational development, requires a consistent knowledge vision and has a digital ownership strategy at heart.

Digital ownership strategy is here defined as an analysis-based smart contract between the ultimate owners, choosing a consensual direction for the whole organisation. A narrow definition of ownership strategies is already given by Delios and Beamish (1999); they are describing the ownership strategy as the choice concerning the degree of ownership (percent equity holding) taken when foreign investment is made. Experience and institutional factors (e.g., quality of corporate governance, enforcement of property rights) are the most important determinants of the ownership strategy (Delios & Beamish, 1999). However, owners are distinctive and may have their agendas—their ownership strategies at the individual level. Therefore, the ownership strategy is also an expression of the owner's will and values. In clarifying what owners want in terms of rights, resources, risks, responsibilities, and returns, we give one clear message from principal to agency instead of several signals, enabling to improve communication both among and between owners, directors, and the management (Luoma, 2011).

Concluding that, if value conflicts are the main barriers to organisational success in the digital age, it could be reasonable to compare individual-level "basic human values" with the declared organisational-level "core values". Values are based on what is most important to us, and therefore must be aligned with core values, i.e., what the organisation stands for, its philosophy, and the reason for existing.

9.3 The Health Care Services Case

9.3.1 Research Methodology, Data Collection and Analysis

The overall aim is to improve general management and organisational performance, making use of the opportunities of digitalisation. Therefore, the following question has been posed: "How to enhance resilience and make use of the opportunities of digitalisation in the implementation process of ownership strategies for organisations?"

Action research is the chosen research strategy for the study, including mixed methods. The research is categorised as an explanatory, cross-sectional, multilevel research study. Action research strategy offers a potential win-win whereby scientific knowledge is expanded while actionable insights from that knowledge also increase (Zhang et al., 2015). A mixed approach has the greatest potential to yield the insights needed both to improve theory development and testing and to improve organisational decision-making.

When comparing individual-level "basic human values" of the two health care strategic management teams with the declared organisational-level "core values" of those health care service organisations and their resilience, we could show how value conflicts influence organisational success and afterwards find ways of mitigating those barriers in using the opportunities of digitalisation in the implementation process of ownership strategies for organisations. A better match of the core values with individual values could improve organisational success.

Healthcare organisations are often characterised by diffuse power, ambiguous goals, and a plurality of actors. However, senior healthcare managers are expected to provide strategic direction and lead their organisations toward their goals and performance targets (Prenestini & Lega, 2013). Most health professionals believe that hospital administration is ineffective (Vlastarakos & Nikolopoulos, 2008); the main reason seems here to be their Hippocratic Oath and *primum non nocere*. Healthcare managers understand that better communication between doctors, nurses, and non-medical educated managers is crucial for a successful performance. Therefore, so far (i.e. between 2016 and 2020), six strategic management team training events for health care managers in Estonia were organised, during which the needed primary data was collected. The didactical considerations of the training relayed on the ideology of the strategic decision-making process (Wheelen et al., 2017) and the strategy implementation through procedural analysis (Gerndorf, 2006; Rüegg-Stürm & Grand, 2021). Basic human values of the health care managers were identified using the Schwartz (1992) Portrait Values Questionnaire (PVQ) (Table 9.1).

PVQ is the short version of the SVS containing 21 structured questions (see Appendix). Secondary data sources used are the organisations' homepages and internal documentation. All this data is made anonymous already before analysis.

Table 9.1 Descriptive summarising statistics

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21
n	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Max	5.00	6.00	5.00	6.00	6.00	5.00	6.00	5.00	6.00	6.00	5.00	4.00	5.00	5.00	6.00	6.00	6.00	5.00	5.00	5.00	6.00
Mean	2.27	4.14	2.92	3.33	2.96	2.33	3.80	2.02	3.59	2.92	2.00	2.04	3.08	2.35	3.53	3.65	3.06	1.84	1.98	2.37	3.88
Stand. dev.	1.04	1.30	1.20	1.47	1.30	1.21	1.31	0.93	1.49	1.47	0.89	0.89	1.13	1.23	1.38	1.31	1.22	0.92	1.09	1.17	1.07
Median	2.00	4.00	3.00	3.00	3.00	2.00	4.00	2.00	3.00	3.00	2.00	2.00	3.00	2.00	4.00	4.00	3.00	2.00	2.00	2.00	4.00

9.3.2 Background Information

The health care services case consists of two organisations in Estonia, North is a non-profit organisation (foundation), and East is a state-owned enterprise (public limited company). The North (2020) is one of the top health care providers in the country. As a regional hospital, it has the highest-level competence to provide specialised medical care. According to its statutes, its goal is to provide high-quality, specialised medical care and ambulance services, to be the learning base of training that precedes and follows the acquiring of health care professionals' qualifications and does healthcare-related study and research work. The hospital consists of seven clinics and 32 specialist centres. Like other European university hospitals, the North offers medical care in all specialist fields other than ophthalmology and obstetrics. In a year, the North gives specialised medical care to ca 144,000 patients, of which over 24,500 are treated on the hospital's 1150 treatment beds. Emergency medicine helps about 84,000 patients in a year.

The East (2020) is dedicated to helping its patients live happy and healthy lives. As a modern hospital, they rely on the world's latest technology and practices. Easts medical fields are divided into seven individual clinics: The Diagnostic Clinic, the Clinic of Internal Medicine, the Eye Clinic, the Women's Clinic, the Surgery Clinic, the Clinic of Medical Rehabilitation, and the Long-term Nursing Clinic. The clinics include centres and departments with a narrower focus on specialities. Medical operations are supported by the administration and services of the hospital. Some strategic information like core values, mission, and vision in the case organisations are demonstrated in Table 9.2.

Core values are the most important elements of the organisational culture, which, together with the beliefs and expectations, either hinder or support the achievement of the formulated strategy. In both cases, they are closely connected with the mission (how?). A challenging vision (direction) should begin with the word "become"; in the given cases, the formulated visions were almost achieved and needed an update.

Table 9.2 Core values and strategies in the studied organisations

	Core values	Mission	Vision
North	Caring attitude Cooperativeness Dedication Openness Professionalism Responsibility	We invest in people's health	To be a recognized and innovative medical centre, a pioneer in Estonian health care
East	Empathy Integrity Openness Security Teamwork	We are a people-centric, innovative hospital that offers the best treatment to each patient and has a positive impact on the health of the Estonian population. Our activities contribute to a sense of social	We want to be the hospital in Tallinn that provides top-level healthcare services and is the go-to choice for patients, partners and employees

Table 9.3 Weighted scores of attributes for organisational resilience

Attributes for organizational resilience		Weight	Rating North	Rating East	Weighted Score North	Weighted Score East
Shared vision and clarity of purpose	RVi	0.20	3	4	0.60	0.80
Understanding and influencing context	RCo	0.05	4	4	0.20	0.20
Effective and empowered leadership	RLe	0.10	3	3	0.30	0.30
A culture supportive of organizational resilience	RCu	0.20	4	4	0.80	0.80
Shared information and knowledge	RKn	0.10	5	5	0.50	0.50
Availability of resources	RRe	0.15	4	3	0.60	0.45
Development and coordination of management disciplines	RMd	0.05	4	4	0.20	0.20
Supporting continual improvement	RIm	0.05	4	3	0.20	0.15
Ability to anticipate and managing change	RCh	0.10	4	3	0.40	0.30
		100%			**3.80**	**3.70**

Although there is no single approach on how to enhance an organisation's resilience, nevertheless, the principles provide the foundation upon which a framework and strategy to achieve an enhanced state of organisational resilience can be developed, implemented, and evaluated (International Organization for Standardization, 2017). However, organisations should consider the following attributes for organisational resilience (Table 9.3).

The authors have composed this table to propose an instrument for evaluating the organisation's resilience. The first step is weighting the attributes because the attributes have not equal importance. In other words, we would say that we are calculating the probability for every attribute. For instance, in our case, we gave higher weight to RVi and RCu; those are subjective expert evaluations. In the second step, we are evaluating the impact of every attribute, this rating on a scale from 1 (low) to 5 (high), and finally, we are calculating the weighted scores. In our case, North (3.80) has a slightly higher weighted score of resilience than the East (3.70). The roles of every attribute are explained in more detail in the following parts.

9.3.3 Shared Vision and Clarity of Purpose (RVi)

Organisational resilience is enhanced by a clearly articulated and understood purpose, vision, and values to provide clarity to decision-making at all levels of the organisation (International Organization for Standardization, 2017).

North's vision is to be a recognised and innovative medical centre and a pioneer in Estonian health care. According to the vision, when it comes to the complexity of medical cases and treatment and diagnostic technologies that are used here, it is comparable to Europe's university hospitals (North, 2020). East's vision says that "We want to be the hospital in Tallinn that provides top-level healthcare services and is the “go-to”-choice for patients, partners, and employees” (East, 2020). North’s mission states that “We invest in people’s health”. East’s mission tells that “We are a people-centric, innovative hospital that offers the best treatment to each patient and has a positive impact on the health of the Estonian population” (East, 2020).

In both cases, the organisations have clearly articulated their vision, purpose, and core values, providing strategic direction, coherence, and clarity for decision-making—policies. The individual goals and objectives are aligned with and committed to the organisation’s purpose, vision, and values. Both organisations monitor and review regularly the suitability of the organisation’s strategies and their alignment with purpose, vision, core values, and objectives. They have recognised the need to reflect on and revise the organisation’s purpose, vision, and core values in response to external and internal changes. Both organisations seek out and promote new and innovative ideas to achieve and develop their resilience and performance.

9.3.4 Understanding and Influencing Context (RCo)

A comprehensive understanding of the organisation’s internal and external environments will help the organisation make more effective strategic decisions about the priorities for resilience (International Organization for Standardization, 2017).

The organisations demonstrate and enhance the ability to think beyond current activities, strategy, and organisational boundaries. Otherwise, we would not have such training workshops at all. For example, for overcoming the scarcity of financial resources, which both organisations see as the main problem, they both are offering medical tourism. They also understand that collaborating and strengthening relationships with relevant interested parties to support the delivery of the organisation’s purpose and vision is crucial.

Both organisations monitor and evaluate the organisation’s context, including interdependencies, political, regulatory environment, and competitor activities under changing circumstances. They also maintain strong relationships with interested parties and foster cooperation at all levels, and collaborate with interested parties that share the organisation’s purpose and vision. North (2020) mentioned the following partners: Tallinn University of Technology, University of Tartu, Tallinn University, Ministry of Social Affairs, National Institute for Health Development, Karolinska University Hospital, Gothenburg University Hospital, Helsinki University Hospital, and Connected Health Cluster.

9.3.5 Effective and Empowered Leadership (RLe)

Organisational resilience is enhanced by leadership that develops and encourages others to lead under a range of conditions and circumstances, including during periods of uncertainty and disruption (International Organization for Standardization, 2017).

It is said that healthcare organisations led by people with medical degrees show better performance than others (Al-Habib, 2020), and the interdisciplinary model, with a manager having both medical and economics degrees and exercising his/her role with flexibility and taking the widest consent of health professionals may improve the very low rates of acceptance and perceived efficacy (Vlastarakos & Nikolopoulos, 2008).

North (2020) is a patient-centred institution committed to professionalism, innovation, and teamwork, hiring over 4800 people—doctors, nurses, caregivers, and specialists—working for the good of patients, more than 500 of them are doctors, and at any given time, 100 medical residents are also based at the hospital. It is chaired by a Master of Jurisprudence and supported by a management board member with a Doctor of Medicine and additionally one Master of Science. East's chairman of the board owns a Doctor of Medicine, and three other management board members have medical degrees.

Both organisations demonstrate effective and empowered leadership throughout the organisation that encourages a culture supportive of resilience, and that can adapt to changing circumstances, and leadership that utilises a diverse set of skills, knowledge, and behaviours (diversity) within the organisation to achieve organisational objectives. The organisations develop trusted and respected leaders who act with integrity and are committed to a sustained focus on organisational resilience. They also encourage the creation and sharing of lessons learned about success and failure and promote the adoption of better practices and empower all levels of the organisation to make decisions that protect and enhance the resilience of the organisation. "We respect our colleagues' work, and even the employees who are not directly involved in the patient's treatment are giving their best to create as favourable conditions as possible for the treatment activity" (North, 2020).

9.3.6 A Culture Supportive of Organisational Resilience (RCu)

A culture that is supportive of organisational resilience demonstrates a commitment to, and the existence of shared beliefs and values, positive attitudes, and behaviour (International Organization for Standardization, 2017).

In both cases, the organisations have determined the beliefs, values, and behaviours within the organisation that define the organisational culture. The chairman of the board of East (2020) states that "Our core values are integrity, empathy, teamwork, and openness, which ensure a sense of security—one of the main expectations people have for a hospital". Patients' needs are always a priority, and integrity, empathy, and cooperation ensure the sense of security that people and society expect from a hospital we want our employees to feel proud of their hospital.

Table 9.4 Individual values mean of health care strategic management teams

Motivational types of values	Characteristics	North	East	Bipolar value dimension	North	East
Benevolence (BE)	helpful, honest, forgiving, loyal, responsible	5.00	3.75			
Universalism (UN)	broadminded, wisdom, social justice, equality, a world at peace, a world of beauty, unity with nature, protecting the environment	4.00	4.43	Self-transcendence	4.50	4.09
Tradition (TR)	humble, accepting my portion in life, devout, respect for tradition, moderate politeness, obedient, self-discipline, honoring parents and elders family security, national security, social order, clean, reciprocation of favors	4.00	4.98			
Conformity (CO)		3.50	4.09			
Security (SE)		3.75	3.76	Conservation	3.75	4.28
Power (PO)	social power, authority, wealth, preserving my public image successful, capable, ambitious, influential	4.00	4.04			
Achievement (AC)		4.75	4.55	Self-enhancement	4.38	4.30
Hedonism (HE)	pleasure, enjoying life, self-indulgence daring, a varied life, an exciting life creativity, freedom, independent, curious, choosing own goals	2.25	4.02			
Stimulation (ST)		3.50	4.37			
Self-Direction (SD)		5.00	4.86	Openness to change	3.58	4.41

North's (2020) core values are dedication and professionalism "We are always focusing on the patient, take every patient's problem seriously and are always ready to give our best; regardless of how complex the patient's health condition is, based on a patient's age, gender, religion, nationality, social situation or other factors". A "core values" caring attitude and responsibility means that, "We think a caring attitude is important in the approach towards patients, colleagues, and ourselves. Core values openness and cooperativeness means "In the name of the patient's better treatment plan, we work together with the patient's loved ones and with different-level health care providers and social service providers".

However, organisations should identify core values and behaviour that enhance organisational resilience and establish criteria that can be applied to assess individual performance (International Organization for Standardization, 2017). Next, we tried to understand how well those declared core values match with the individual values (Table 9.4); as an example, we are using the data collected from the health care strategic management teams.

The calculation shows that North tends to self-transcendence (4.50) where East is more openness to change (4.41) oriented when looking at the bipolar value

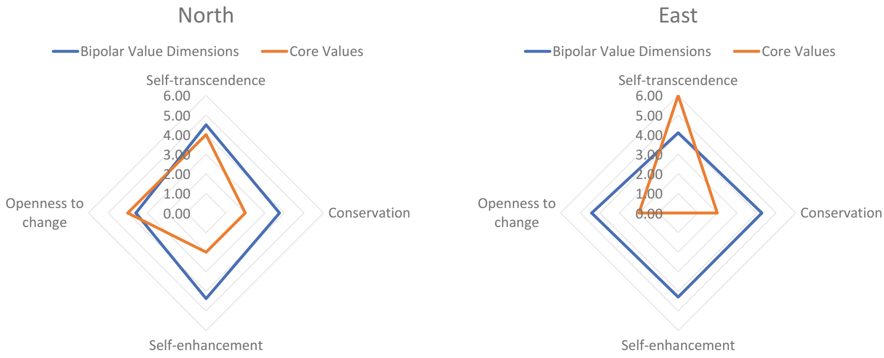


Fig. 9.2 Radar of bipolar value dimensions and core values continuum for North and East

dimension. North has declared the following organisational-level core values: caring attitude (UN), cooperativeness (ST), dedication (TR), openness (ST), professionalism (AC), and responsibility (BE). East has declared empathy (BE), integrity (BE), openness (ST), security (SE), and teamwork (BE). To understand the match of the core values with the individual values, they were brought together (see Fig. 9.2).

When comparing the individual-level basic human values of the health care strategic management teams with the declared organisational-level core values of our pilot study, we can determine that North has a better match than East. North also has a higher weighted score of resilience than East. Those initial results suggest that there may be a link between value conflicts and organisational success. However, with such a small sample size ($n = 51$), caution must be applied, and the findings might not be transferable to all kinds of organisations.

Value conflicts could influence resilience, and our goal is to find ways of mitigating those barriers by using the opportunities of digitalisation in the implementation process of ownership strategies for organisations. It is also important to engage people at all levels to promote the organisation's values and foster creativity and innovation that enhances organisational resilience. Staffing is an important element of strategy implementation; a new strategy usually needs new structures too. However, individual-level values are rigid; an automatic PVQ test for all existing and potential members of the organisation would allow avoiding conflicting core values.

Organisations should empower people to identify and communicate threats and opportunities and to take actions that will benefit the organisation and monitor and review organisational culture to detect any changes that may influence organisational resilience (International Organization for Standardization, 2017). "We support our colleagues and react in situations where there have been shortcomings in the help given to the patient" (North, 2020).

9.3.7 Shared Information and Knowledge (RKn)

Organisational resilience is enhanced when knowledge is widely shared where appropriate and applied, e.g., learning from experience, learning from each other is encouraged, learning is valued, and is drawn from all available sources (International Organization for Standardization, 2017). "To achieve the best results, we choose methods that have been recognised as evidence-based and work together with the patient and their loved ones, as well as with different-level health care providers and social service providers" (North, 2020).

Both organisations ensure that knowledge and information are accessible, understandable, and adequate to support the objectives set by the organisations. Knowledge is transferred efficiently and effectively. It is shared with all members of the organisation to improve decision-making. Knowledge and people are recognised as a critical resource of the organisation, and created, retained, and applied through established systems and procedures. Knowledge is shared promptly with all relevant related parties and applied in organisational learning.

9.3.8 Availability of Resources (RRe)

The organisation should develop and allocate resources, such as people, premises, technology, finance, and information, to address vulnerabilities, providing the ability to adapt to changing circumstances (International Organization for Standardization, 2017).

The organisations take appropriate decisions on resourcing and capacity, diversification, replication, and redundancy to avoid single points of failure and respond to incidents and change, so that core services are maintained at an acceptable, predetermined level. "We use the treatment resources rationally and in the most useful way to the patient and society" (North, 2020).

The organisations select and develop employees with a diverse set of skills, knowledge, and behaviours that can contribute to the organisation's ability to respond and adapt to change. They routinely review the suitability, availability, and allocation of resources, taking account of the impact of any changes in the organisation and its context (International Organization for Standardization, 2017). "We act according to the principle to increase the positive effects of our activity and reduce the negative effects" (North, 2020). In both cases was financial scarcity the main issue to reach strategic goals.

9.3.9 Development and Coordination of Management Disciplines (RMd)

The design, development, and coordination of management disciplines (e.g. governance, health and safety management, quality management, risk management, strategic planning) and their alignment with the organisation's strategic objectives are fundamental to enhancing organisational resilience (International Organization for Standardization, 2017). "In our work, we use evidence-based methods, and our action is based on interdisciplinary and good teamwork, we are open to innovation" (North, 2020).

The organisations demonstrate and enhance the management that disciplines are coordinated so that they individually and collectively contribute to the organisation's purpose and the protection of what it values. "We have been created to bring value by giving our contribution to preserving patients' quality of life and growth via medical treatment and preventive action, as well as being a trainer and designer of health policy" (North, 2020).

The organisations manage the effect of uncertainty on their objectives across management disciplines. "We act in the patient's (and society's) interests and always try to achieve the best possible treatment result for each patient" (North, 2020). The organisations identify and design management disciplines that contribute to the organisation's resilience, and regularly assess how each management discipline contributes to the overall resilience of the organisation, and address weaknesses where these are found. They build flexibility into the management disciplines so that the organisation can absorb and adapt to change, and enhance communication, coordination, and cooperation between the management disciplines of the organisation to build a coherent approach. "To keep up with the times, we are ready to carry out changes in the methods used in our work. In our cooperation with all specialists, we can find and achieve solutions that would be out of reach when acting alone" (North, 2020).

9.3.10 Supporting Continual Improvement (RIm)

Organisational resilience is improved when organisations continually monitor their performance against predetermined criteria to learn and improve from experience and take advantage of opportunities, create, and encourage a culture of continuous improvement across all employees (International Organization for Standardization, 2017).

The organisations demonstrate and enhance a culture of continuous improvement that ensures organisational objectives, strategies, and procedures can be kept relevant and appropriate in supporting the changing needs of the organisation. "We are constantly improving ourselves to keep ourselves informed about the newest technologies, diagnostic and treatment methods and offer the patient the best help possible" (North, 2020).

The organisations demonstrate and enhance a commitment to validate and continually improve organisational resilience activities and capabilities. "The qualitative level of medical work expresses in outstanding efficiency indicators and quality indicators that are comparable with other recognised medical centres, also in good treatment results" (North, 2020). The organisation should implement performance monitoring and evaluation mechanisms to support continual improvement and ensure that performance management criteria are responsive to changes that impact organisational objectives (International Organization for Standardization, 2017).

9.3.11 Ability to Anticipate and Managing Change (RCh)

Organisational resilience is enhanced when an organisation can anticipate, plan, and respond to change: The organisation should demonstrate and enhance the ability to deliver consistently on its commitments under changing circumstances and adapting its operations accordingly. Thus, there should be an ability to absorb and adapt to the impacts of sudden and unexpected incidents, preparation to respond to change, or influence change if necessary (International Organization for Standardization, 2017). "Our activities contribute to a sense of social security in society, which is supported by the professionalism of our staff. Modern evidence-based health services, well-established traditions, and cooperation networks, and an openness and willingness to initiate change" (North, 2020).

The organisation should remain aware of situations that are likely to influence change and adapt it when needed without significant impact on its products and services, e.g., commit to protection, performance, and adaptation but with the ability to shift focus without compromising its vision and core values, and ensure that the management disciplines are sufficiently robust and effective to respond to changes (International Organization for Standardization, 2017). Both organisations remain aware of continuous change, and they have been creative in responding to diverse situations.

9.4 Enhancing Organisational Resilience and Success

In aiming to enhance organisational resilience and success, the current results are valuable in several ways. Firstly, adding a new facet to contract theory by proposing a digital ownership strategy as a substitute for complete contracts. Secondly, by comparing individual-level basic human values with the declared organisational-level core values, we can determine that North has a better match than East, and North also has a higher weighted score of resilience than East. Those initial observations suggest that there may be a link between value conflicts and organisational success. However, with such a small sample size and only Estonian cases, caution must be applied.

Staffing is an important element of strategy implementation; individual-level values are rigid—we cannot change them. However, it would be helpful at least to recognise them; therefore, an automatic PVQ test for all existing and potential members of the organisation would give a chance for avoiding conflicting core values.

There is potential in using data mining tools to facilitate the assessment of factual pronouncements about resilience values in strategic or operational documents, and in public and online media; be they from media outlets, governments, private sector, NGOs, or even individual commentators (Rogers et al., 2020). It is recommended that further ownership research should include evolutionary approaches, and another possible area of future research would be to find out which values are universally supporting resilience.

Appendix: Schwartz Portrait Values Questionnaire (PVQ)

How much like you is this person?

1. very much like me,
2. like me,
3. some-what like me,
4. a little like me,
5. not like me,
6. not like me at all.

Q1: Thinking up new ideas and being creative is important to him. He likes to do things in his own original way.

Q2: It is important to him to be rich. He wants to have a lot of money and expensive things.

Q3: He thinks it is important that every person in the world should be treated equally. He believes everyone should have equal opportunities in life.

Q4: It is important to him to show his abilities. He wants people to admire what he does.

Q5: It is important to him to live in secure surroundings. He avoids anything that might endanger his safety.

Q6: He likes surprises and is always looking for new things to do. He thinks it is important to do lots of different things in life.

Q7: He believes that people should do what they are told. He thinks people should follow rules at all times, even when no-one is watching.

Q8: It is important to him to listen to people who are different from him. Even when he disagrees with them, he still wants to understand them.

Q9: It is important to him to be humble and modest. He tries not to draw attention to himself.

Q10: Having a good time is important to him. He likes to "spoil" himself.

Q11: It is important to him to make his own decisions about what he does. He likes to be free and not depend on others.

Q12: It is very important to him to help the people around him. He wants to care for their well-being.

Q13: Being very successful is important to him. He hopes people will recognise his achievements.

Q14: It is important to him that the government ensures his safety against all threats. He wants the state to be strong so it can defend its citizens.

Q15: He looks for adventures and likes to take risks. He wants to have an exciting life.

Q16: It is important to him always to behave properly. He wants to avoid doing anything people would say is wrong.

Q17: It is important to him to get respect from others. He wants people to do what he says. It is important to him/her to be in charge and tell others what to do. He/She wants people to do what he/she says.

Q18: It is important to him to be loyal to his friends. He wants to devote himself to people close to him.

Q19: He strongly believes that people should care for nature. Looking after the environment is important to him.

Q20: Tradition is important to him. He tries to follow the customs handed down by his religion or his family.

Q21: He seeks every chance he can to have fun. It is important to him to do things that give him pleasure.

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Chapter 10
Framework for Analysing Knowledge Critical to Organisational Resilience Capabilities

Bruna Devens Fraga, Denilson Sell, and Gregorio Varvakis

Abstract In turbulent and constantly changing environments, it is critical for organisations to establish strategies to strengthen their resilience. Although knowledge is recognised as a key resource for resilience capabilities, there is a gap in the literature on strategies for identifying and developing critical knowledge to cope with unexpected. This chapter describes a framework that systematises the identification, assessment, and development of critical knowledge to the capabilities of monitoring, anticipating, and responding to new circumstances. The framework was applied in knowledge-intensive organisations and made it possible to establish an assertive action plan for knowledge management, focusing on strengthening the resilience capacities of the analysed organisations.

Keywords Resilience · Critical knowledge · Knowledge management · Framework

10.1 Introduction

In turbulent environments of constant changes and risks, organisations seek actions and strategies to adapt better and react, thus contributing to the increase of their resilience resources (Hosseini et al., 2016; Sahebjamnia et al., 2015). The potential for organisational resilience can be analysed through four resources: respond, anticipate, monitor, and learn (Hollnagel, 2010).

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It is necessary to understand that complex environments generate uncertainty in the actions of individuals who do not know enough about how to respond to risk and anticipate certain situations and unforeseen events. Neaga (2010) argues that knowledge is crucial to the development of resilient responses and to enable organisations to deal with complexity and risks, making knowledge an intangible asset that is critical to the survival of organisations.

For Apgar (2006), knowledge managed as a resource assists employees in decision-making, transforming unexpected events into moments of learning and growth, configuring a repertoire for understanding the nature of risks. The way the organisation monitors, understands, and addresses risks determines the level of resilience of the organisation in the face of unexpected events (Gibson & Tarrant, 2010).

Knowledge is considered an essential resource in organisations and a relevant factor for mitigating and managing organisational risks (Durst & Wilhelm, 2011; Massingham, 2010). Loss or waste of knowledge can negatively affect organisational resilience capabilities. One way to minimise the possible risks and damages caused by the loss or waste of knowledge is to make it visible (Daghfous et al., 2013; Durst & Wilhelm, 2011; Ermine et al., 2006). In this sense, knowledge management can contribute to the improvement and development of resilience capacities by promoting the sharing of information and knowledge and favouring the preservation of experiences in environments of uncertainty and change (Lundberg & Johansson, 2015).

According to Durst and Ferenhof (2016), knowledge management is a systematic process of applying tools and techniques to identify, analyse and respond to the risks that permeate the performance of organisations through the promotion of knowledge creation, application, and retention organisational. In this way, organisations that perform the proper management of critical knowledge in their value creation process reduce the risk of loss of essential skills and avoid reinventing the know-how of their employees and, consequently, boost the development of skills aimed at organisational resilience. (Durst & Ferenhof, 2016; Hollnagel, 2010). In view of these aspects, identifying, and relating existing knowledge helps organisations to achieve their strategic objectives, in order to reduce their risks and providing support in complex situations of changes and disturbances in their development.

Within the scope of strategies for the promotion of operational safety, resilience engineering presents itself as a contemporary approach and with reports of successful application in different industries (Hollnagel et al., 2006; Righi et al., 2015). Resilience engineering (RE) has its origins in the area of safety management (Safety-I and Safety-II) and fits in the context of complex socio-technical systems. While safety management (Safety-I) focuses on reducing the number of adverse outcomes related to preventing unexpected events, resilience engineering (RE) looks for ways to increase the systems' ability to succeed under changing conditions (Safety-II).

Despite the advances presented by studies in the area of resilience engineering, there is a lack of studies that guide how to identify and analyse knowledge directly related to resilient responses in the face of unexpected events, which qualifies the following problem: how to guide management actions knowledge to promote the creation, sharing, structuring, and dissemination of knowledge that is decisive for resilient responses?

In this context, this chapter presents a framework to identify and analyse critical knowledge for expanding organisational resilience capabilities. While the authors of resilience engineering advance to the measurement of risks and resources relevant to the adequate management of resilience, the present framework focuses on using the mechanisms and capabilities presented by Hollnagel and Woods and deepening the identification of specific knowledge that will direct and leverage the potential for resilience in the organisation. The established framework is illustrated through a case study in a technology-based company.

In the next section, the theoretical foundation is presented, which addresses the theme of organisational resilience capabilities and the mapping of critical knowledge. In the subsequent sections, the methodological procedures are presented, with the description of the steps adopted for the development of the work and the description of the proposed framework. Finally, a discussion is presented about the results obtained in a case study involving a technology-based company and the final considerations of the study.

10.2 Literature Review

The purpose of this section is to present the theoretical foundation that provided support for the construction of the framework. Initially, the theoretical bases regarding the resilience potential and its capabilities will be presented.

10.2.1 Organisational Resilience Capabilities

In order to understand the concept of resilience, this section will present the theoretical bases that constituted the concept and the resilience capacities for this work.

There is no consensus regarding the concept of resilience among the different areas of knowledge, since it has a multidisciplinary perspective, for example management, engineering, ecological, socio-technical, socio-ecological, among others.

It is necessary to understand that a system or organisation cannot be resilient, but it can have the potential for resilient performance and adapt to events through its resources (Hosseini et al., 2016). Thus, resilience is a characteristic of how a system performs, not a quality that the system has or possesses (Hollnagel et al., 2006).

The present framework (Fig. 10.2) uses the base of studies in the field of resilience engineering, which aims to understand the human–machine interaction and works in the context of complex socio-technical environments. These systems can be characterised as being composed of a large number of elements that interact dynamically, which causes an unexpected variability. In this way, resilience emerges as an important component that compensates for these complex socio-technical systems in order to deal with the uncertain and dynamic environment (Saurin & Gonzalez, 2013).

According to Dinh et al. (2012), there are six main factors in the field of resilience engineering: minimisation of failures, limitation of effects, administration of procedures, flexibility, control and detection of risk and error in order to predict errors. Numerous organisational application areas have used the resilience engineering approach as a foundation in studies in other domains, as well as in the area of knowledge engineering (Hosseini et al., 2016).

In this work, the guiding concept of resilience was approached by Hollnagel (2010), from the engineering point of view, and brought the following concept to the organisational environment:

> Organisational resilience is defined as the intrinsic ability of a system or an organisation to adjust its functioning before, during, or after changes and disturbances, so that it can sustain the necessary operations under both expected and unexpected conditions (Hollnagel, 2010, p. 1).

Among the works that address the concept of organisational resilience, few have been approached in an empirical and systematic way (Hosseini et al., 2016). Predominantly, the literature has been conceptual, focusing on the development of a static basis through the establishment of fundamental concepts and principles. Some authors such as Bhamra et al. (2011) and Duarte Alonso and Bressan (2015) emphasise in their work, the need for empirical work in the area of resilience, such as through the development of surveys, case studies and frameworks. In this sense, it is necessary to understand the existing mechanisms to characterise and measure resilience to identify which elements or capacities are important in this process.

In their research, Hosseini et al. (2016), Hollnagel (2011), Lengnick-Hall and Lengnick-Hall et al. (2011) point out four interdependent capacities that analysed together make it possible to understand and analyse the performance of the resilience capacity of a system or organisation enabling it to act. These action-oriented capabilities are: responding, anticipating, monitoring, and learning (Fig. 10.1).

The organisational resilience capabilities are described by Hollnagel (2010) as:

- The ability to respond corresponds to knowing what to do or being able to respond to regular and irregular changes, disturbances and opportunities by activating prepared actions or adjusting the current mode of operation.
- The ability to monitor indicates knowing what to look for or being able to monitor what is or could seriously affect system performance in a positive or negative way. Monitoring must cover the system's own performance, as well as what happens in the environment.
- The ability to anticipate points to knowing what to expect, or being able to anticipate the future, such as potential interruptions, new requirements or limitations, new opportunities, or changes in operating conditions.
- The ability to learn from what happened, or to be able to learn from experience, in particular to learn the right lessons from the experiences.

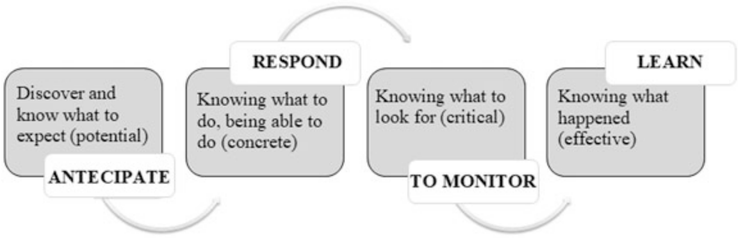


Fig. 10.1 This is a representation showing the connection and interdependence of organisational resilience capabilities proposed by Hollnagel (2010) and is adopted for this paper. Source: Adapted from Hollnagel (2010)

These four capabilities are addressed in the area of resilience engineering and point to a path beyond the adaptation and response of organisations to change, as well as monitoring, anticipating and learning in the face of what was experienced at a given time. Organisations must develop strategies that can help them prevent and prepare for business disruptions, as well as recovering in the growth process.

As a way of analysing resilience engineering capabilities, Hollnagel (2010, 2011)[1] established the Resilience Assessment Grid (RAG) methodology. This methodology presented stages of characterisation and analysis of the potential for resilience through interviews and application of a diagnostic instrument and was applied in different areas of the industry. It is verified, however, that the approach proposed in the RAG does not advance on the analysis of the determinant knowledge for the resilience capacities, this space of contribution sought for the framework described in this chapter.

The present framework (Fig. 10.2) is based on the premise that knowledge management actions support and promote the potential for organisational resilience if properly directed to the knowledge that enables employees to monitor, anticipate, promote adaptations and respond to unexpected events. Therefore, it becomes relevant to identify the main connections and gaps between the disciplines of knowledge management and organisational resilience. These theoretical elements are important, for they help to understand the elements gathered in the composition of the framework proposed in this work. Corroborating this view, some authors highlight the need for empirical work involving the development and application of surveys, case studies and frameworks connecting organisational resilience and knowledge management (Bhamra et al., 2011; Duarte Alonso & Bressan, 2015).

There are studies that combine knowledge management strategies with results and resilience capabilities, such as the work of Chalfant and Comfort (2016), that deal with the importance of shared knowledge about risks to improve the management of natural resources in Pennsylvania region. Corroborating this view, the work of Patil and Kant (2016) deals with the importance of knowledge management

[1] See: http://erikhollnagel.com/onewebmedia/RAG%20Outline%20V2.pdf

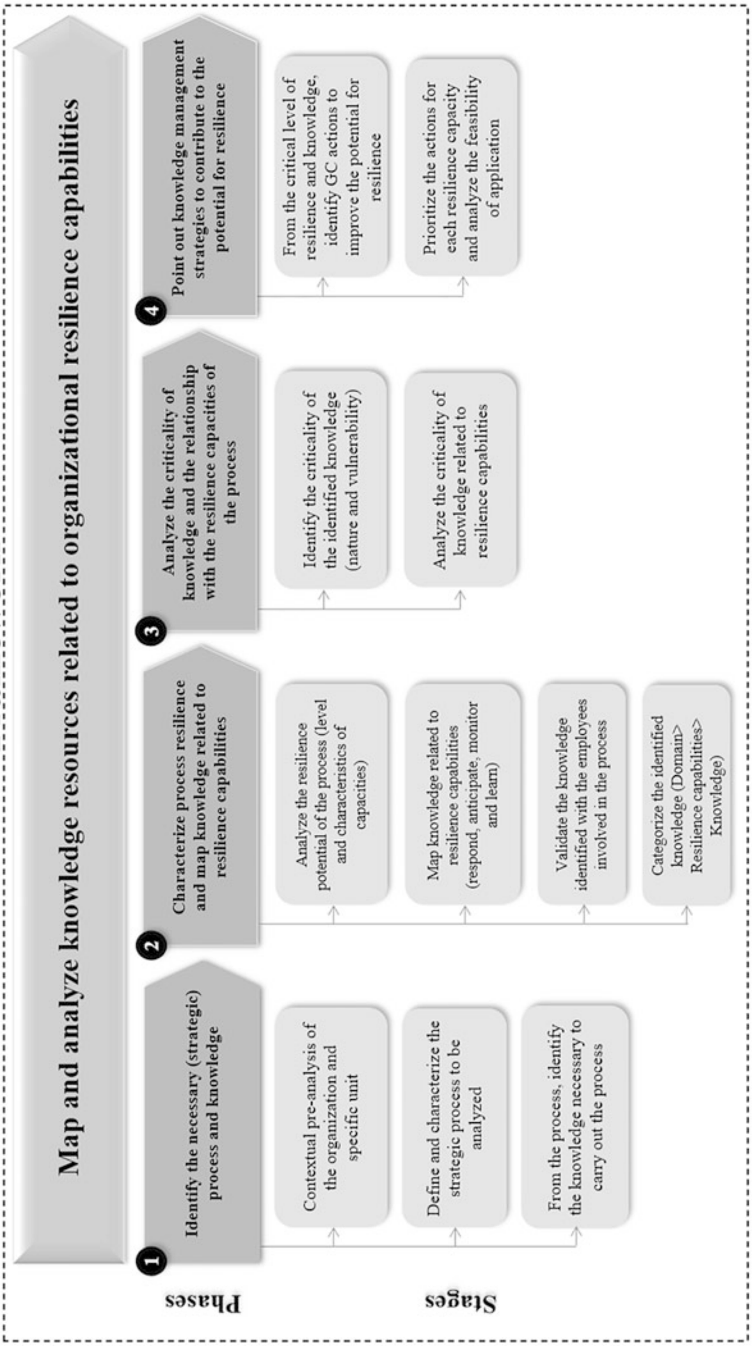


Fig. 10.2 Analysis framework for knowledge resources critical to resilience capabilities

strategies to build a resilient supply chain. For the authors, given the globalisation of business and the pressure to reduce costs, the risks and vulnerabilities in management increase, and since knowledge management is a high-level planning approach, they applied the fuzzy *analytical network process* (ANP) method to the selection of the best knowledge management actions for the specific area.

Given the relevance of studies in the area of organisational resilience, the literature points out some gaps regarding the studies found. There are models and frameworks that deal with the measurement of resilience in organisations, such as Bhamra et al. (2011), Lengnick-Hall et al. (2011) and Duarte Alonso and Bressan (2015). However, no representations that deal with the identification of their knowledge resources from their collaborators were found to carry out an analysis and characterisation of what is considered critical in order to prioritise knowledge management actions in the applied context.

Hollnagel and Woods add that it is not only resource stocks that determine resilience, but also the efficient deployment of existing resources. Efficient management of available resources is required (Van Der Vorm et al., 2011).

The differential of an organisation is not related to the amount of equipment used in its production processes, but in the requirements related to the collective knowledge generated and acquired, to creative skills, as well as the values, attitudes, and motivation of the people who have them. Thus, the management of intangibles in organisations has a fundamental role in creating value in the context of competitiveness, complexity, and changes.

In organisations today, the critical knowledge used by employees in their daily adaptations is often not recognised, documented, or made explicit and remains only as implicit knowledge by individuals and teams. In this way, if not explained, important functions and knowledge can be lost or wasted (Rasmussen, 1997), therefore reducing the organisation's resilient capacities. By exploring and analysing the way professionals anticipate, monitor, and respond to "gaps" in the organisation and make this knowledge more available, work environments can be better designed, and organisations will be better prepared to support the successes of human variability (Rankin et al., 2014).

It is necessary to understand that resilience is reinforced through the development of specialised knowledge from individuals and collectively in an organisation to respond effectively to unknown or challenging situations (Pal et al., 2014).

Salgado (2013) points out knowledge management as an essential resource for promoting resilience, that is, for the organisation's ability to manage the complexity and risks of its surroundings. Thus, in all phases of knowledge management, actions are developed to promote resilience.

The authors Ose et al. (2013) performed their work during an ordinary working condition and analysed the elements of technology, processes, people, and organisation/governance related to the four resilience capacities. This relationship is important, as it combines elements that makeup knowledge management (processes, people, technology and governance) and uses them as lenses for management practices grouped by different resilience capacities. This view pointed out by Ose et al. (2013) reinforces the contribution of knowledge management related to organisational resilience.

Although Ose et al. (2013) bring in their work an important view regarding the elements of knowledge management related to resilience resources, an analysis still occurs superficially when considering knowledge resources. For effective knowledge management, it is crucial that the organisation knows its knowledge assets in order to carry out assertive management of them.

Knowledge management as a coordination mechanism in organisations allows for more efficient use of resources, promotes interaction and contributes to an improvement in the innovative capacity and performance of the organisation (Darroch, 2005). These management mechanisms are supported by knowledge management practices that are considered as intentional, formal or informal activities or routines, oriented to properly manage knowledge aiming its efficient use and aligned with the objectives associated with a specific task (De Normalisation & Normung, 2004; Kianto & Andreeva, 2014).

In search of an approach to direct knowledge management actions to contribute to organisations' resilience potential, Neaga (2010) proposes the development of resilience through knowledge accelerators. These accelerators are understood as tools to support the development of new knowledge and are drivers of knowledge acquisition and sharing in uncertain situations and complex environments. In this way, through databases, ontologies, and maps, it is possible to contribute to the development of knowledge self-organisation capacities in complex environments in order to maintain an acceptable level of functioning in the event of disturbances. Knowledge mapping, in this context, helps to discover the location, value, and use of organisational knowledge (Eppler, 2008; Ermine et al., 2006). Critical knowledge sources are considered essential resources and are used by a company's value-adding processes (Grundstein & Rosenthal-Sabroux, 2004).

Lundberg and Johansson (2015) corroborate the perspective of the contribution of knowledge management to the promotion of the potential for resilience. The authors describe that this contribution relationship is manifested both in the form of better prerequisites for anticipation, monitoring, response, and reconstruction (Hollnagel, 2010), as well as in the application of tools and techniques that assist in this area. In this sense, the RAG methodology (Hollnagel, 2010) establishes a set of instruments to diagnose resilience capacities. However, it does not present a direction to deepen the analysis of knowledge as a determining factor for the potential for resilience.

Knowledge can be used as a source for improvisation. From experiences of real or trained situations, this knowledge can be used to improvise, even if there were no explicit preparations in advance for the specific development of actions. Thus, knowledge is particularly central to operating systems in environments of high uncertainty (Lundberg & Johansson, 2015).

Neaga (2010) argues that in order to deal with complexity, with risks and to implement the concept of resilience in organisations, it is essential to conceive knowledge as an intangible asset. Salgado (2013) highlights in his work the characterisation of knowledge management through tangible aspects such as: (1) how teamwork works, (2) the way people (re) act in specific situations and changes in

Table 10.1 Theoretical analysis units

Subject	Category	Analysis unit	Theoretical basis
Knowledge management	Organisational knowledge	Concept, types, approaches, nature	Drucker (1998), Sveiby (2001), Nonaka and Takeuchi (1997)
	Critical knowledge	Concept	Huang and Cummings (2011)
	Critical factors of knowledge	Relevance, vulnerability	Grundstein and Rosenthal-Sabroux (2008), Ermine et al. (2006)
	Knowledge mapping	Methods, techniques, types, approach	Kim et al. (2003), Eppler (2008), Chan and Liebowitz (2006), Ricciard (2009)
Resilience	Organisational resilience	Characteristics, principles, competences	Mallak (1998), Bhamra et al. (2011)
	Resilience engineering	Resilience capabilities (respond, anticipate, monitor, learn)	Hollnagel (2010, 2011)

the environment, (3) the management procedures for dealing with knowledge in complex contexts, (4) the technical tools that, clearly or ambiguously, support the creation and transmission of knowledge. Both authors deal with the relevance of analysing the knowledge resource, the contribution space of the present framework, which seeks to enable the identification and assessment of the criticality of knowledge related to resilience capabilities.

And so, based on the analysis of studies that apply knowledge management and organisational resilience, its contribution serves to promote change management, considering the proactivity and the need to renew the organisation's culture based on sustainability (França & Quelhas, 2006). The work of these authors reinforces the relevance of considering the resource knowledge as a source of information in the face of risks; however, it does not delve into identifying them and analysing their critical factors.

From the analysed literature, the units of theoretical analysis of the work (Table 10.1) that present the elements and variables of the framework were listed.

Considering the above, the next section presents an approach to identify the knowledge associated with the resilience capacities and analysis of the criticality level of this knowledge.

10.3 Methodological Procedures

The framework (Fig. 10.2) was developed through applied research, with a qualitative approach that uses Design Science Research (DSR) for its development (Peffers et al., 2007), whose steps are:

1. Identification and motivation of the problem: From the literature review, the problem and the theoretical elements of the work related to knowledge and organisational resilience were identified. In this step, the opportunity to develop the applied framework to map and analyse critical knowledge related to resilience capabilities was identified from the literature review.
2. Definition of the objectives of the solution: In the face of the problem, the objectives for the development and application of the framework were listed, involving the identification and qualification of critical knowledge to the strategic organisational processes and the resilience capacities associated with such processes.
3. Design and development: In this study, the presentation of the framework is in a flowchart of the concepts covered. It is represented by different levels in order to provide a greater picture of the sequence that illustrates the phases, their stages and the association of knowledge aimed at resilience.
4. Demonstration of the framework: In this stage, the necessary instruments are pointed out to apply the framework to solve the problem. This study illustrates the application of the framework in a technology-based organisation that works with software development.
5. Evaluation of the framework: This step is illustrated by analysing the results obtained in the case study.
6. Communication of the framework: It was carried out through the sharing of the results obtained in the application of the framework in the chosen organisation. This stage also included the confirmation of knowledge management actions that aim to contribute to expand the capacities of organisational resilience.

The elements that make up the framework are presented and illustrated in the next section.

10.4 Critical Knowledge Analysis Framework Related to Organisational Resilience Capabilities

In this section, the elements that make up the framework are presented from the theoretical analysis units that were used as lenses in its construction. Subsequently, a case study developed in a technology-based company is presented to illustrate the phases and instruments of the proposed framework.

10.4.1 Framework Structure and Case Study Description

The present framework (Fig. 10.2) aims to guide knowledge management actions to promote the creation, sharing, structuring, and dissemination of knowledge that is decisive for resilient responses. The application of the framework is divided into four phases, each involving different stages (Fig. 10.2).

The phases established in the proposed framework, as well as the way in which the steps were performed in the case study, are described in the next section.

The case study chosen to illustrate the application of the framework was developed with a technology-based company located in Florianópolis Metropolitan Region, a region recognised in Brazil for its importance in the national scenario of the information technology industry (ITI). It is noteworthy that the ITI sector represents an important economic segment for the regional and Brazilian economy (Dos Anjos et al., 2014). Faced with an economically representative scenario with a dynamic and competitive character, the technology-based company for this research is part of an environment called complex technical partner. These environments can be characterised by a large number of elements that interact dynamically, which causes unexpected variability (Saurin & Gonzalez, 2013). These environments have a set of interdependent parts that act to achieve a certain objective. Technical knowledge corresponds to techniques and technologies that involve programming and coding for the development of software and information systems. The other knowledge involves the areas of structure, management, and organisational relations.

In studies of organisational resilience, complex socio-technical contexts are approached, since, in these scenarios, people are unaware of the potential flaws that may emerge as they develop strategies in the face of system restrictions and complexity. The multiplicity of tasks to maintain an efficient and flawless operation, as well as the consequent cognitive overload, usually prevents people from reflecting on the result of their actions and anticipating or even learning from the software design, development, and implementation processes.

10.4.1.1 Phase 1: Identifying

- The first phase, represented in Fig. 10.3, aims to identify the context, characterise the process and map the knowledge necessary to execute it. This beginning calls for an analysis and prioritisation of organisational processes of greater importance or with greater variability recognised by the managers to whom they will be submitted to analysis. The phase consists of three stages:
- **Stage I**—Contextual analysis of the knowledge-intensive organisation.
- **Stage II**—Define and characterise the strategic process to be analysed.
- **Stage III**—Identify the necessary knowledge to carry out the process.

For Stage I—Contextual analysis of the knowledge-intensive organisation, the objective is to collect relevant data to understand the context and organisational unit to be analysed. For this, documentary analyses and interviews with the managers were carried out to deepen the main characteristics of the environment to be analysed (complex socio-technical system).

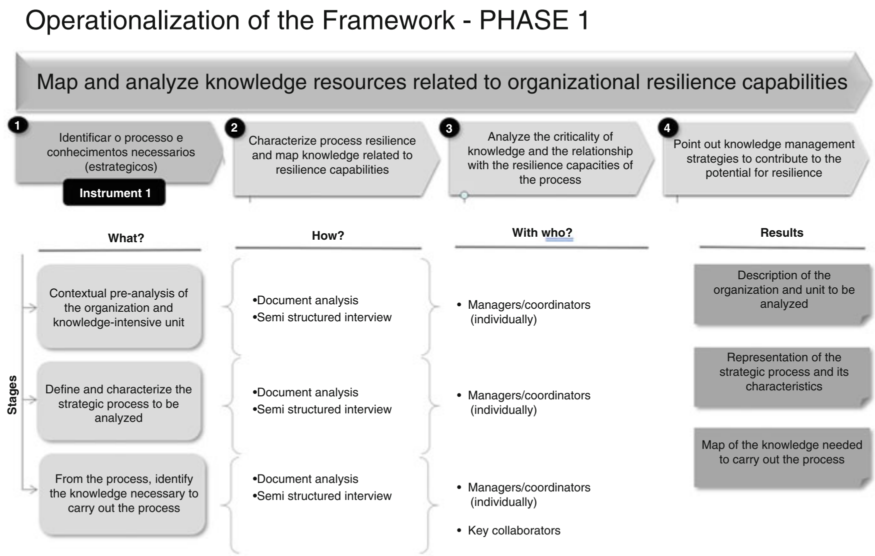


Fig. 10.3 Description of the implementation strategy for Phase 1 of the framework

The instrument that guides this data collection is adapted from the CommonKADS organisation model (spreadsheets OM-1, OM-2, OM-3) (Schreiber et al., 2000) and contains the elements that characterise the context of the organisation, such as objective, resources, people, processes, culture, and power (Table 10.4).

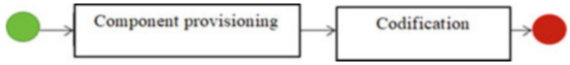
Afterwards, Stage II—Define and characterise the strategic process to be analysed, covers the definition of the process with the managers, to choose the strategic process for the development or operation of the organisation. Then, based on this identification, semi-structured interviews will be carried out individually to characterise the process. The instrument used for data collection is adapted from the CommonKADS task model (spreadsheets TM-1, TM-2), and its process representation is based on the identification of the main inputs, activities, and outputs of the process.

Then, Stage III—Identify the knowledge necessary to carry out the process corresponds to the framework of knowledge related to the process. This stage is carried out through semi-structured interviews and documentary analysis, with questions based on the questions of Ricciard (2009).

Within the scope of the study carried out at the technology-based company, **Phase 1** included actions related to the organisation's contextual diagnosis and analysis. For this, documentary analyses and interviews with the managers were carried out to deepen the main characteristics of the analysed environment. The first contact was made with the leader/manager through interviews and documents to collect the information for the organisation's description. The instrument used was extracted from the organisation model of CommonKADS (Schreiber et al., 2000)

Description of the organisation and it analysed
Small technology-based company | Software development unit
Representation of the strategic process and its characteristics
Process steps: Design □ Elaboration □ Development □ Tests □ Implementation
Map of the knowledge needed to carry out the process
Knowledge: Domains and architecture of the product, knowledge of the techniques involving languages and codes.

Key process: Software development	
Inputs	Inputs obtained from software architecture and prototyping
Activities	Provisioning components and coding
Outputs	Developed software



Types of knowledge	
Product knowledge	Domain over modules
	Product architecture
	Standards (design, coding, documentation)
Technical knowledge	Languages (Java)
	Technologies: framework, database (*Postgre*), textual indexes (*Apache Lucene* e *Numere*)
	Versioning (standard and versioning technology)
	Code integration (standard and integration technology)
	Tests (testing techniques)

Fig. 10.4 Synthesis of the main results of Phase 1 in the case study

and from the key questions, it facilitated in directing the interviews to extract the information. Then, the strategic process that is essential for the functioning of products and services was mapped and designed. This process was modelled together with the manager and some key employees of the company. To complete the first phase, the necessary knowledge for the development of the process was mapped under normal operating conditions. The instrument was based on material from Hubert and Lemons (2010), which presents a sequence of questions to externalise the knowledge of employees.

In the application of Phase 1, the following results were obtained (Fig. 10.4).

The main processes, resources, and technologies involved in the context of the organisation were identified under conditions foreseen in its planning. From its strategic objectives, the key process with its inputs and outputs and the necessary knowledge for its execution was highlighted. It is worth mentioning that the identification of knowledge with the interviewed employees was important to induce reflection on the concept of knowledge and to explain the necessary knowledge from the perspective of the process performed under ideal conditions.

10.4.1.2 Phase 2: Characterise

Phase 2 of this framework seeks to characterise the resilience of the process and map the knowledge related to the resilience capabilities. This phase consists of the following steps:

- **Stage I**—Identify the risks related to the strategic process.
- **Stage II—**Analyse the resilience potential of the strategic process and its capabilities (anticipate, respond, monitor, learn).
- **Stage III**—Map the knowledge related to resilience capabilities.

Stage I seeks to identify the risks related to the analysed strategic process—software development. As part of the case study, data were collected through semi-structured interviews with key employees and consultation of the organisation's internal documentation. Conducting research based on this identification of risks is important, as it leads employees to prospect scenarios or stimulates narratives of lessons learned in the past. In the sequence, the level and characterisation of each resilience capacity of the process are identified.

Step II contemplates the analysis of the resilience potential of the process. Through this application, the level of resilience of the process is identified, and its main characteristics are listed. The target audience for this stage is the employees involved in the development of the process.

The tool used to characterise the resilience potential of the process in the case study was the Resilience Assessment Grid (RAG) developed by Hollnagel (2010). The tool has the resilience capabilities: respond, monitor, learn, anticipate. These capacities cannot be analysed separately but jointly, as they are considered interdependent, and their analysis makes it possible to understand the potential for resilience as a whole. According to the analysis method proposed by Hollnagel (2010), the scale used to identify the level of potential resilience of the process from the median of each capacity (anticipate, respond, monitor, learn) is: excellent (5), good (4), adequate (3), insufficient (2), non-existent (1). The first question of each capacity in the instrument must follow this scale.

After this analysis, Stage III of mapping the knowledge related to the resilience capacities of the process is carried out. The collection of this stage must be carried out in conjunction with Steps I and II, with the employees involved. From these semi-structured interviews, the main knowledge related to each resilience capacity is identified. The questions related to the mapping of this knowledge were: (1) what knowledge is needed to anticipate?; (2) what knowledge is needed to respond?; (3) what knowledge is needed to monitor?; (4) what strategies are applied to promote the preservation of knowledge and learning? This step is essential as it connects the characteristics of resilience with the relevant knowledge resources to develop the knowledge management of each capacity. When carrying out this step, it is important to lead employees to reflect on each of the elements of resilience.

The description of the deployment strategy for the steps of Phase 2 is illustrated in Fig. 10.5.

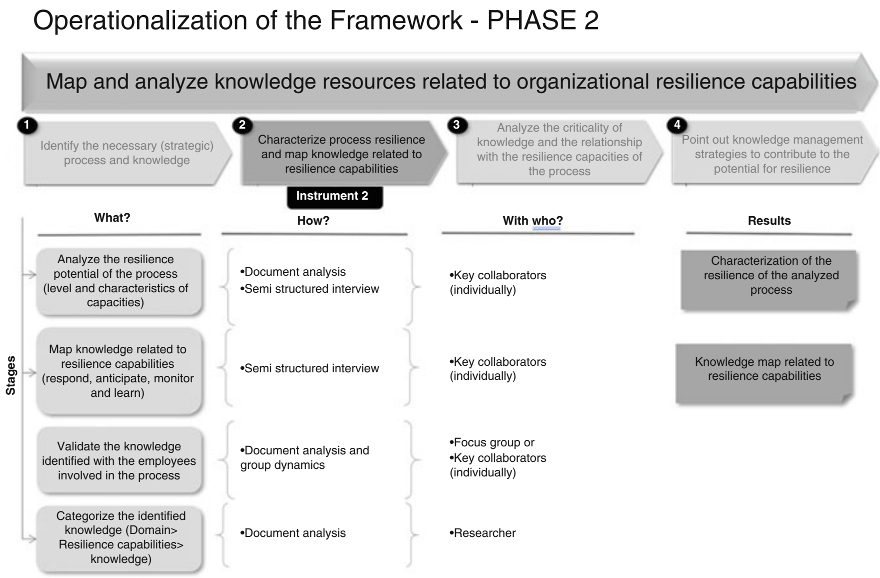


Fig. 10.5 Description of the execution strategy of Phase 2 of the framework

Phase 2 enabled the identification of risks related to the process, as well as the characterisation of resilience and the mapping of knowledge related to resilience capabilities from the software development process.

Reflection on the main risks related to the development of the process begins the direction of data collection for the projection of scenarios of changes and risks. This step was not mentioned in similar studies of resilience analysis; however, it proved to be fundamental to leverage the strategies of later data collection. As the employee is contextualised in a scenario of risk and change, it is possible to connect with the other questions of the semi-structured interview related to the analysis of resilience. In this context, the rescue of critical events involving actions taken in anticipation, monitoring, and response through the application of the technique of eliciting knowledge Critical Decision Method (CDM) presents itself as a timely approach. CDM is a retrospective interview strategy that applies a set of cognitive probes to real non-routine incidents that required expert judgement or decision-making (Klein et al., 1989, p. 464). As a technique for eliciting knowledge, the CDM contains elements of interview and protocol analysis, but in a context that emphasises examining problem-solving in naturalistic decision-making contexts (Zsambok & Klein, 1997).

The application of the RAG instrument presented a set of questions that guided the understanding of the anticipation, monitoring, response, and learning scenarios. However, it is worth highlighting the importance of adapting the questions according to the organisation's scenario and context.

The instrument composed by the questionnaire allowed, in the case study, to extract a qualitative note about each capacity through an initial assessment made by

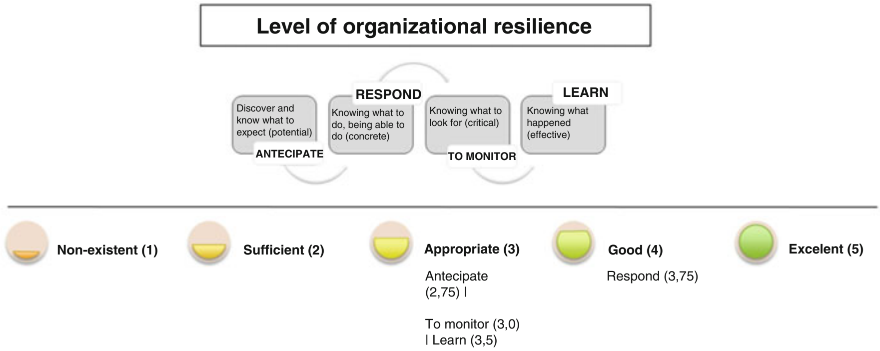


Fig. 10.6 Organisation's resilience level

those responsible for the analysed processes and management representatives. In the sequence, the instrument composed of the questions made through semi-structured interviews identified the main characteristics and gaps of each resilience capacity. It is important to highlight that although the assessment of the resilience potential indicates an "adequate" grade, the interviews allowed to detail and deepen gaps and limitations in relation to each capacity and that was not prescribed in Hollnagel's instrument (2010).

Following the data collection provided for in Phase II, in Stage III of applying the framework in the case study, the main knowledge related to each capacity was mapped to enable a more detailed analysis of the essential knowledge resources to leverage the potential organisation's resilience.

It is worth mentioning that according to the results obtained from the knowledge mapping for each capacity, the knowledge was grouped into five categories: (1) technicians, (2) related to product development, (3) response readiness, (4) detection errors and weaknesses, and (5) related to GC (storage and sharing). This perspective emerged from the content analysis of the knowledge pointed out and allows a joint analysis of the knowledge resources mapped from the resilience capacities.

The results show the main issues identified by employees in the context of the analysed organisation (Fig. 10.6). As proposed by the methodology, these issues may vary and require specific actions to develop each capacity for resilience.

Within the scope of the case study, in relation to the analysed resilience potential, gaps were identified in relation to knowledge management in the organisation. As for the documentation and formalisation of actions aimed at capacities; knowledge sharing (anticipating), absence of knowledge retention actions (anticipating), outdated lessons learned bank (learning). This characterisation allowed us to identify relevant gaps for the proposition of knowledge management actions in Phase 4.

For the ability to anticipate and respond, gaps were identified regarding the formalisation of activities, informal sharing and the absence of knowledge retention actions. These issues are critical to develop the capacity for anticipation, as it does not generate documentation and systematisation of what is accomplished or expected to occur. As a way of mitigating such limitations, the literature

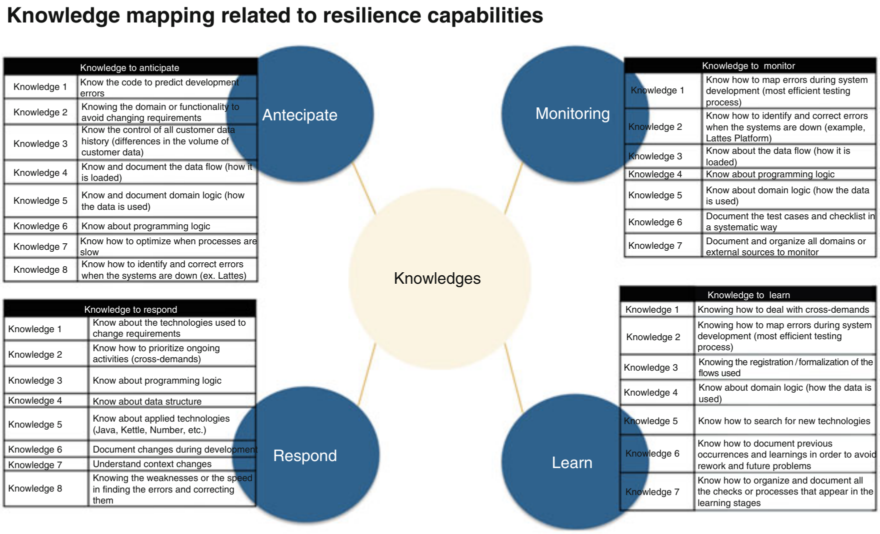


Fig. 10.7 Knowledge map focused on resilience capabilities

recommends the systematic planning and sharing of actions to detect threats and future opportunities. Thus, it avoids rework and allows registration and access to actions to anticipate possible risks. Knowledge retention actions through flexible work (mentoring and coaching), strategic thinking and support from senior management are also recommended.

The ability to monitor presented limitations and little frequency regarding the registration and systematisation of validation actions since these correspond to activities to monitor the organisation's current situation. To resolve such issues, actions to develop the detection potential are suggested in order to make it systematic and institutionalised among the organisational processes. In this sense, it is recommended to establish indicators aiming at areas such as structural and relational capital aiming at cooperation and networking, participation and trust, dependence on own resources, delay, the effectiveness of actions, return on training and capacities, involvement of the team, skills for monitoring.

As for the ability to learn, gaps were pointed out regarding the documentation of lessons learned and the focus on individual learning, restricted to individualised training and without clear guidance on how to transfer knowledge to work (Crossan et al., 1999). These are issues that limit knowledge sharing among members and make systemic and organisational learning difficult (Fig. 10.7).

The knowledge mapped in each resilience capacity can be analysed in five categories: (1) technicians, (2) related to product development, (3) response readiness, (4) detection of errors and weaknesses, and (5) related to GC (storage and sharing). It is important to highlight that each capacity has its own specificities and elements. However, through the identified categories, it was possible to point out similarities between the knowledge to facilitate its identification and management and so contribute to the potential for resilience in the organisation.

At the end of Phase 2, validation was carried out in a focus group, with the organisation's leader and the team responsible for the development, based on the characteristics of resilience and knowledge related to the capabilities to respond, anticipate, monitor, and learn from the strategic process. This step was important, as it presented and confirmed the mapped knowledge, as well as identifying possible knowledge or characteristics that had not been found in the individual interviews. This stage used the confirmatory focus group, which aims to validate the identified knowledge according to the methodological stage foreseen in Design Science Research.

10.4.1.3 Phase 3: Analyse

Phase 3 of the framework analysed the criticality of the knowledge related to the resilience capabilities of the process and is represented in Fig. 10.8. For this, two stages are performed:

- **Stage I**—Identify the criticality of the mapped knowledge.
- **Stage II**—Analyse the criticality of knowledge related to resilience capabilities (anticipate, respond, monitor, learn).

In Stage I, the criticality of the mapped knowledge is identified. Criteria based on the Club Gestion des Connaissances de Paris (2000) were used and adapted from the studies by Ricciardi et al. (2004).

The collection was carried out by means of questionnaires sent individually to key employees with knowledge. The questionnaires were sent via electronic form

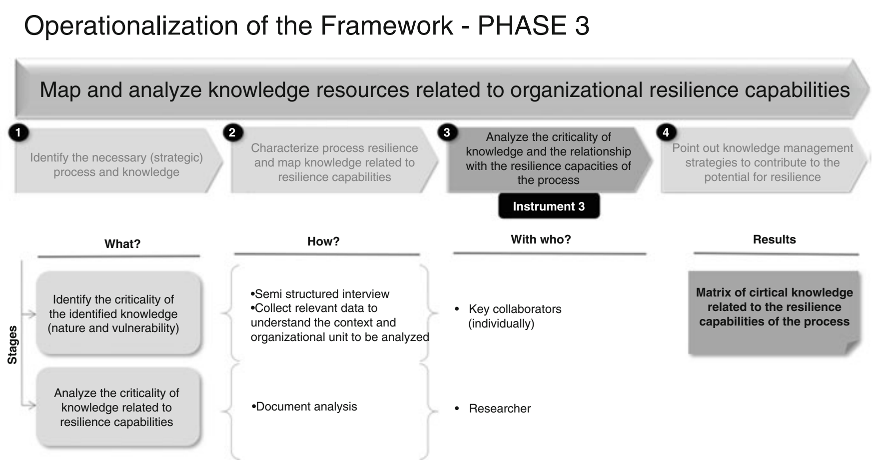


Fig. 10.8 Description of the strategy for implementing Phase 3 of the framework

Knowledge criticality map

Software Development Process				
Resilience Capacity Level				
Factors	To anticipate (Appropriate)	Reply (Good)	To monitor (proper)	Learn (proper)
F1	1, 2, 3, 4, 5, 6, 7, 8	3, 4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7
F2	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7
F3	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7
F4	2, 6, 7, 8	3, 5, 7	1, 2, 4	2, 4
F5	6, 7, 8	3, 4, 5	1, 2, 4	2, 4
F6	2, 6, 7, 8	3, 5	1, 2, 4	2, 4

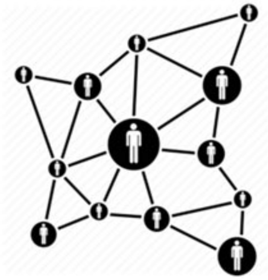


Fig. 10.9 Map of knowledge criticisms mapped

(Google Forms) by e-mail to each employee. The data are analysed according to the rating given by the interviewees, following the scale proposed by Ricciardi et al. (2004): high (3), medium (2), low (1) criticality for each factor.

In Stage II, to analyse the criticality of the knowledge, the coefficients (C) are calculated by the criticality factor as a function of the median of the grades assigned by the criterion for each knowledge. As a result, a matrix of critical knowledge related to the resilience capabilities of the process was obtained.

Subsequently, vulnerable critical knowledge, transversal to resilience capacities, was analysed. As for Phase 3, the assessment of critical knowledge helped to prioritise actions related to each capacity for resilience. The knowledge mapping for each resilience capacity shows the alignment with the characteristics pointed out in the characterisation stage and highlights the most relevant assets to be managed in the stage that precedes the possible risks and failures (Fig. 10.9).

The results obtained in the research allowed us to identify the knowledge evaluated as vulnerable, the critical knowledge transversal to the resilience capacities and also to build a map of critical knowledge based on the evaluations of each capacity.

Based on the results obtained in the research and corroborated by the literature, critical knowledge is essential to develop resilience skills and actions are identified in the literature that corroborates this analysis:

(a) The **capacity to anticipate** is reinforced by the identification of the holders of critical knowledge in order to encourage the sharing and establishment of networks to improve the capacity to anticipate possible interruptions and barriers to development (Whitehorn, 2011).

(b) Regarding the **ability to respond** to risk and failure events, it is important to distinguish between what is urgent and what is important,[2] pointed out based on the analysis of critical knowledge resources.
(c) Hollnagel (2010) states that for **monitoring** to be flexible, its base of indicators and critical knowledge must be reviewed from time to time, seeking to align with current strategic objectives and activities.
(d) For the **ability to learn**, aspects such as the recording and sharing of lessons learned are essential to leveraging the potential for resilience, as pointed out by Ose et al. (2013). For this, it is essential to select a critical knowledge base based on the organisational context in order to streamline access and synthesise the most critical factors to learning.

For Ermine et al. (2006), the analysis of critical knowledge can be a basis for proposing knowledge management actions such as structuring communities of practice and environmental verification actions. The critical knowledge map can also be used as a guide to accessing knowledge resources to develop the potential for resilience.

Therefore, in order to avoid rework, waste or loss of critical knowledge, knowledge management actions and strategies are identified in Phase 4, in order to explore ways to anticipate, respond, monitor, and learn from gaps and leverage potential organisational resilience.

10.4.1.4 Phase 4: Pointing Strategies

Based on the results obtained in the previous phases (Phase 1, 2, 3), Phase 4 of the framework aims to point out knowledge management strategies to contribute to the development of the resilience potential. It is divided into the following stages:

- **Stage I**—Relate the characterisation of resilience capacities and their knowledge with the knowledge management processes (socialisation, externalisation, internalisation, combination).
- **Stage II**-Identify knowledge management practices for each organisational resilience capacity.

Based on the results of Phases 1, 2 and 3, the main elements of knowledge and characteristics of each resilience capacity of the defined strategic process were identified. In Stage I, the processes of the knowledge management spiral of Nonaka and Takeuchi (1997) were listed as a way to structure the analysis and point out strategies for managing the knowledge resources mapped in each capacity.

The socialisation process (tacit knowledge into tacit knowledge) is the process of converting tacit knowledge into new tacit knowledge, that is, experiences and mental models are shared, and tacit knowledge and technical skills are created. In

[2] See: http://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2021.pdf

organisational practice, socialisation occurs through: training in the workplace; informal sessions and brainstorms; interactions with customers, suppliers, etc.

The externalisation process (tacit knowledge into explicit knowledge) is, according to Nonaka and Takeuchi (1997), the most important conversion mode for the creation of knowledge, as it facilitates the transformation of tacit knowledge, which is personal, context-specific, and of difficult to formalise, in new and explicit concepts. This process occurs through the use of metaphors, writing, analogies, concepts, hypotheses, and models, which are used in dialogue and collective reflection;

The combination process (explicit knowledge in explicit knowledge), on the other hand, is understood as the process of systematising existing concepts in a new knowledge system. It is caused by placing newly created knowledge and existing knowledge from other sections of the organisation in a network, thus constituting a new product, service, or management system. It means the combination of various sets of explicit knowledge, such as documents, meetings, telephone conversations, computerised communication networks, that can lead to new knowledge.

Finally, in the internalisation process (explicit knowledge into tacit knowledge), the existing explicit knowledge is reformulated by the individual and internalised as new tacit knowledge. Through externalisation, skills, and knowledge are transformed into attitudes; through internalisation, these attitudes are transformed into skills. For this, according to Nonaka and Takeuchi (1997), the following are necessary: the verbalisation and diagram of knowledge in the form of documents; manuals or oral histories; training programmes that use simulations and experiments, which also facilitate internalisation.

This analysis was carried out based on the transcripts of the interviews and analysis of the results of the previous phases. It is important to highlight that this analysis lens based on the knowledge conversion modes of Nonaka and Takeuchi (1997) does not limit future analyses based on other GC frameworks. The deployment strategy for Phase 4 in the case study is illustrated (Fig. 10.10).

Phase 4 pointed out knowledge management strategies to contribute to the development of the potential for resilience, the synthesis of the results of Steps I and II, as described in Table 10.2.

Based on the context analysed, the present study allowed us to specifically point out which actions are a priority for each resilience capacity. As the importance of developing banks of lessons learned to foster the externalisation process, reducing the lack of documentation of the activities carried out or the need to create a standard script for monitoring the validation activities and can be solved with an internal benchmarking and exchange between team members.

In view of the analyses presented, the externalisation process is identified as necessary to improve the development of each resilience capacity. The main gaps are related to the lack of documentation of activities, lack of formalisation of response actions, anticipation, and mainly the registration of the expertise of the most experienced and long-time members in the company. Outsourcing is considered by Nonaka and Takeuchi (1997) as the most important way of converting knowledge for the creation of knowledge since it aims to facilitate the formalisation of tacit and

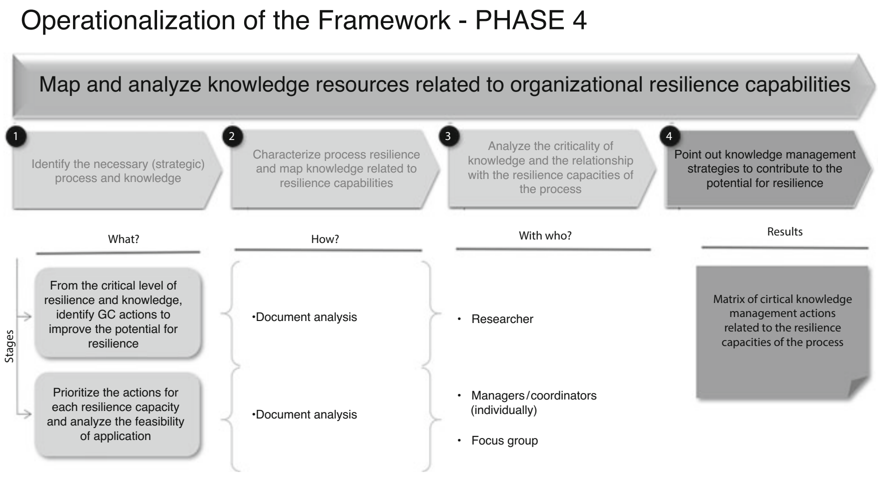


Fig. 10.10 Description of the execution strategy of Phase 4 of the framework

individual knowledge, specific to certain technical contexts in documented knowledge and shared with everyone.

The second mode of conversion seen as necessary to develop resilience skills was socialisation, that is, it represents the transmission of tacit-to-tacit knowledge. Faced with an environment that involves the structuring of technical data for the development of systems, many mental models of problem-solving and programming are developed, however they are little disseminated. The practices that involve socialisation deal with the sharing of knowledge developed in practice in new technical skills, through actions of personal interaction between employees, as in the case of the need for more frequent validation activities, with this, it was suggested the realisation of short meetings (pitches) to increase the frequency of daily interactions.

As a strategy, knowledge can be used as a source for response, anticipation, monitoring, and learning. Given the criticality of certain knowledge, it is possible to point out specific actions that contribute to increase the resilience of the process as well as effective decision-making and organisational learning. Hence, actions that encourage team learning through dynamics with the participation and engagement of employees are recommended. For these activities, the development of skills to deal with new situations (adaptation and positive learning) should be stimulated and, thus, enable the incorporation of new knowledge through collective learning and aimed at organisational problem-solving objectives.

Table 10.2 Knowledge management practices applicable to the targeted company of the case study

Ability to anticipate		
Issues to be solved	**GC process**	**GC practices**
Lack of formalisation of anticipation activities	Outsourcing	Prospecting scenarios, knowledge bank
Sporadic and informal knowledge sharing	Socialisation	Mentoring, storytelling
There is a lack of actions to retain the knowledge of the most experienced members	Outsourcing	Coaching, staff exchanging *(shukko)*
Ability to respond		
Little documentation on what is accomplished	Outsourcing	Construction of best practice manuals, bank of lessons learned
Lack of time to document	Socialisation	Prospecting scenarios, storytelling
Informal knowledge sharing about response	Combination	Knowledge bank, electronic spaces
Ability to monitor		
Lack of systematisation of the validation process	Outsourcing	Construction of best practice manuals, knowledge bank
Low frequency of validation activities	Socialisation	Pitch for sharing the validations that occurred daily, informal meetings
Lack of specific validation script for new demands	Combination	Internal and external benchmarking, virtual practice community, electronic spaces
Ability to learn		
Lack of documentation and formalisation of lessons learned	Outsourcing	Bank of lessons learned, periodic post-action review
Outdated and little used database	Combination	Electronic document management
Lack of formalised process for learning new knowledge	Internalisation	Capacity building and training, staff exchange (*shukko*)

10.5 Conclusion

The present study contributes to the integration between two conceptual bases, of knowledge management (Alavi & Leidner, 2001; Ermine et al., 2006) and organisational resilience (Van der Vorm et al., 2011; Rigaud et al., 2013), presenting a framework to analyse and characterise critical knowledge from the perspective of organisational resilience.

The proposed framework makes it possible to better target actions and investments in knowledge management aimed at developing the potential for resilience and reducing risks related to critical knowledge. The instruments applied show pictures of the knowledge resources and practices to be prioritised in the current context and can serve as guides for the organisation to direct its efforts to improve its knowledge management.

Concomitant to practical aspects, the established framework guides the development of resilience capabilities through the management of its knowledge resources. The application of the framework makes a practical contribution to the audit of knowledge through the mapping carried out in Phases 1 and 2.

This representation allows an articulated analysis between the management of the mapped knowledge resources and the identified gaps regarding organisational resilience. Traditionally, knowledge auditing is performed based on strategic objectives or based on organisational processes under normal conditions, in the case of the present framework, the results explore unpredictable and risk scenarios associated with the organisation's key processes. In this sense, the work presents as an alternative a proposition of knowledge management guided by organisational resilience.

With the current scenario of a competitive market, the rapid launch of advanced technologies and tough economic restrictions, organisations deal with a high number of risks on a daily basis. Thus, mechanisms are needed to identify risks in the organisational environment. In this framework, the risks related to critical knowledge to be managed were identified in order to mitigate the problems and impact of changes and thus improve the potential for resilience in the organisation. Based on the identification of the risk scenario, knowledge management solutions were proposed in order to maximise the probabilities and minimise the likelihood of threats.

Faced with abstract and complex concepts such as critical knowledge and organisational resilience, this work allowed an objective approach to identify the elements of resilience and map the knowledge considered critical through the combination of instruments pointed out by the literature on knowledge mapping and assessment.

Such issues present results for organisations in terms of mitigating risks related to critical knowledge, increasing their productivity and sustainable competitiveness through resilience capabilities, as well as their resources and organisational processes aligned with strategies. By applying the framework, the knowledge related to the anticipate, respond, monitor, and learn capabilities becomes visible, enabling the identification of the level of criticalities of the knowledge that determines the potential for resilience. Such mapping enables organisations to implement methods and techniques of knowledge management to mitigate the loss of knowledge that confers greater resilience to their processes.

The approach described in this chapter presents a theoretical and practical view regarding knowledge auditing, which is a fundamental issue of KM and actions and techniques are being developed to develop it. As for the boundaries of the research, from the employees' perception, risks related to knowledge were identified, economic, social, financial, environmental, etc., risks were not observed. Future work involves the exploration of the framework in organisations from different economic sectors, including governmental organisations, so that the real difficulties and opportunities in different sectors and in the public context can be mapped in depth. Although the framework for this work is generic, it is necessary to re-read it for other environments, allowing scalability in larger fields of analysis and of different natures.

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Chapter 11
How Can Simulation Support Resilience in a Digital Age?

Torgeir K. Haavik, Cecilie Våpenstad, Tor Olav Grøtan, and Stian Antonsen

Abstract This chapter explores the potentials for organisational resilience stemming from digitalised simulations. The point of departure is experiences with the case of endovascular aneurysm repair (EVAR), in which established health care professions (surgeons and radiologists) develop new patterns of collaboration through simulations based on digital re-presentations of the patient. The analytical focus is on digital re-presentations, situated as boundary objects that may mitigate potentially harmful power tensions that may hinder the development of new, cross-disciplinary practices. On the other side, digital re-presentations may also create a hyper-reality, possibly conveying new vulnerabilities, e.g., joint blind spots due to lack of articulation work needed to reveal them. The experiences from the healthcare domain are projected towards a focus on potential use of digital simulation in context of critical infrastructures in which professional roles are less historically/traditionally established, but in which there is an urgent need to build coherence and collaborative practices between IT/OT, safety/security professionals due to continuous (disruptive) digitalisation and imminent cyber threats.

Keywords Organisational resilience · Digital simulation · Re-presentations

11.1 Introduction

As society and work are digitalised, *simulation* is becoming an increasingly important method of acquiring necessary work-related skills and competences—along the axis from experience to imagination. While simulation has been an integral part of

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the training scheme in several industries—e.g. aviation and health—for a long time already, and is thus by no means a new phenomenon, it is gaining momentum both in the types of domains it is used, and for what objectives.

When simulation is introduced and used in work settings, it is usually with the aim of focused training on particular intraprofessional or interprofessional aspects such as skills, tasks, or teamwork. In aviation, for example, simulation is widely used to practice skills of manoeuvring the aircraft in particular (crisis) situations, regular tasks such as take-off and landing, and for crew resource management (CRM), including collaborative decision making. In healthcare, education simulation is used to train psychomotor skills using manikins. (e.g. CPR[1] manikins), box trainers, virtual reality simulators, and to train emergency situations using role plays in more or less simulated environments.

Digital simulation allows for flexibility in scenario building, and the use of simulation to build operational resilience has been addressed in a number of resilience studies (e.g. Carvalho et al., 2012; Saurin et al., 2014; Johansson et al., 2017; Macrae & Draycott, 2019; Wahl et al., 2020).

While several studies have addressed operational resilience (micro level), the theme of *organisational resilience* (meso level) has received less attention. In this chapter, we will discuss organisational resilience in terms of (side) organisational effects of relational work carried out between different professions that collaborate on the organisation's common goal, but at the same time "compete" for tasks, power, and legitimacy within the same organisational environment. We situate the elaboration of the interrelated operational and organisational potentials of resilience within the discourses of boundary work (Gieryn, 1983; Burri, 2008), respectively, and draw on the literature on boundary objects (Star & Griesemer, 1989) to discuss the (new) role simulators are acquiring in—or offering to—a multiprofessional collaborative community.

The chapter builds on an empirical hospital study of a simulator project in a clinical department responsible for endovascular aneurysm repair (EVAR) (Haavik & Våpenstad, 2020). In this department (or more general, in the field of EVAR), there has been an ongoing negotiation of the collaboration form and the "ownership" of the patients between vascular surgeons and interventional radiologists. While the primary intention of introducing a simulator to the department was to facilitate procedural rehearsal and patient safety, the most conspicuous effect was observed on the interprofessional relation and the politics of EVAR outside the operating theatre (we treat this as boundary work).

In our framing, drawing on Haavik and Våpenstad (2020) and Grøtan (2020b), simulation involves re-presentation. We elaborate on the double role of re-presentations offered by simulation; that of (1) the resilience potential offered by the increased number and forms of re-presentations in EVAR procedures, and (2) the resilience potential offered by the re-presentation of EVAR as interdisciplinary work with a (more) reconciled ownership and division of labour. In addition, we

[1] Cardiopulmonary resuscitation.

also take into account that digital re-presentations may also create a hyper-reality, which creates new conditions for mastery and control in a complex system. ICT thus channels a new form of power in which reality is replaced or supplemented by a "re-presented" and constantly re-organised understanding of reality.

From these particular findings, we explore the possibilities for generalisation and relevance for the field of cybersecurity/cybersafety in critical infrastructures; how might simulation influence the friction between fields such as information technology (IT) and operational technology (OT), and between security professionals and safety professionals—in ways that may influence organisational resilience potential?

11.2 Digital Simulation

Simulation of multidisciplinary work has received increasing attention recently, following the developments in hardware capacity and software sophistication. While most people have an intuitive idea of what simulation is, it is potentially so many different things that it is useful with some kind of contextualisation to be able to discuss it in a structured manner. Bailey et al. (2012) describe virtual work as work where "digital re-presentations stand for, and in some cases completely substitute for, the physical objects, processes, or people they represent" (Bailey et al., 2012). Based on the role of the re-presentations, Bailey et al. divide virtual work into virtual teams, remote control, and simulation.

Virtual teams, where the teammates are spatially separated from one another, work with or on re-presentations. In virtual teamwork, the function of re-presentations is to mediate relations between people. One example is the use of emails for communication; virtual team members operate with emails to converse with distant colleagues in lack of face-to-face opportunities. Virtual teams may also work on re-presentations, as when using a medical imaging software for making diagnosis or an ordering interface when ordering stent grafts for the next procedure.

Remote control involves working *through* re-presentations, mediating our relations with objects instead of human team members. In this way, informed by sensor-data and cybernetic process-control, workers can "remotely manipulate objects that were formerly amenable to only direct haptic control" (Bailey et al., 2012).

Simulation differs from these two other types of virtual work by eliminating the need for mediating relationships between people and between people and objects altogether, and instead allow workers to operate within re-presentations. By simulating both physical entities and processes, simulation technology may be regarded as the "most virtual" of the three virtualities. In light of that, it may seem contra-intuitive that simulation is described by Bailey et al. (2012) as the type of virtuality that requires physical referents, while the others do not. This has to do with the models that are at the heart of simulation; while the re-presentations in virtual teams may have meaning without referents,[2] model builders are depending on access to the physical objects and processes they are simulating (Bailey et al., 2012). Hence, simulation is closely linked to context, and de-contextualisation may cause loss of meaning, which in terms of simulation means poor simulation. This point was also underlined in Wahl et al.'s (2020) qualitative study of simulator training among professional maritime officers. Studying the prerequisites for learning through simulation, Wahl identified a need to expand the notion of simulator fidelity to include social factors, thereby linking simulation closely to the collaborative context it is designed to represent.

Bailey et al. (2012) illustrate how simulation may affect the structures, tasks, and roles of work. The structuring effect of technology[3] is not a new theme, however. In the context of representational work in the health sector, Barley (1986) studied the effect of new medical imaging devices on the role relations among radiologists and radiological technologists. While the introduction of identical CT scanners in two radiological departments occasioned similar structuring effects in both places, the resulting organisational forms differed. In other words, technology may have a shaping effect on organisation, but this effect cannot be understood in isolation from organisational and social context.

It is this theme—the shaping effect of simulation on organisations, in terms of both culture and structure—that is the subject of this chapter. We will first elaborate on the effect of simulation in a particular organisational context, and thereafter we discuss the possibilities of generalisation across similar/comparable contexts in other organisations. We use the findings regarding organisational culture/structure to reflect upon aspects of organisational resilience that owe some of their qualities to simulators and simulation.

11.3 Organisational Context: The Case of Endovascular Aneurysm Repair

In some categories of operations, such as EVAR, surgeons and radiologists cooperate closely. Although these are different professions, they collaborate and have increasingly overlapping skills as the methods, and their respective roles during planning and operation of EVAR procedures have developed. Successful collaboration depends not only on formal collaboration structures, but also on a collaborative atmosphere that invites to collective sensemaking and work. In our study of a simulator project (Haavik & Våpenstad, 2020), we found the simulator to contribute

[2] Modification of these representations, say, a written document or a spreadsheet, does not require correspondence with the physical world, but still convey meaning.

[3] We do not here mean "effect" in terms of technology determinism, but in terms of structuration (Giddens 1984; Orlikowski and Robey 1991), with all the multiple potentials and uncertainties associated with it.

as much to this collaborative atmosphere as to the improvement of skills, tools selection, and operation time.

11.3.1 The Division of Labour Between Surgery and Radiology in the Field of EVAR

Surgeons and radiologists belong to different medical branches known for different expertise and know-how. Surgeons are associated with hands and described as "doers", referring to surgery as a profession and identity of craftmanship (Cassell, 1991; Burri, 2008; Prentice, 2013). This differs from the views on radiologists, a profession where eyes, as in seeing and the interpretation of images, is their main activity.[4] The distinction in appearance and self-understanding is paralleled in distinguishing mechanisms through formal, institutional means through different tasks in the work with patients; the division of labour between surgeons and radiologists is thus enacted both with reference to professional competence and through institutional arrangements.

Although surgery and surgical practices still are heavily associated with practical and embodied skills, the profession has undergone profound changes following technological developments following the increasing reliance on images and image interpretation. Among others, Barley (1986) and Burri (2008) have described how the development within ultrasound, computer tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and digital X-ray technology has involved not only changes in diagnostics and treatment possibilities as such, but also affected the professional identity, the social relations, and the organisation of medical work.

These changes have been portrayed as a change from craftsmanship to sensework (Haavik, 2016), and they have brought the professions of surgery and radiology closer together, both in terms of knowledge and skills, but also in terms of actual collaboration and interchangeable tasks during operative procedures.

This development takes place in a context where power struggles over the definition of the professional domains and which does not necessarily invite to collaboration.

> The question of which groups were to control MRI images was unresolved in the early days of MRI. In recent years, practitioners from a broader range of specialities have used the technology, and so the power to interpret the scans is once more at stake. For example, in The New York Times a radiologist claimed that 'a radiologist who has spent four to five years learning how to interpret those images' would best be able to guarantee the quality and cost-effectiveness of image interpretation (Levin, 2004). Michael J. Wolk, then President of

[4] As already indicated, we note that this conception of archetypes is challenged as the professions and methods develop. In particular, as interventional radiologists are moving into the classical domain of the surgeons, the distinctions with respect to use of hands and eyes may become less obvious.

> the American College of Cardiology, responded immediately that '[in] fact, cardiologists are the physicians best prepared to interpret cardiovascular images'(Wolk, 2004). (Burri, 2008)

EVAR is a modern method for treatment of aneurysms: during EVAR procedures, a stent graft is placed under X-ray guidance at the abdominal aortic aneurysm, guided in place through the arteries from small incision points in each groin. The stent graft is made of a metal frame (the stent) that is covered with the graft material so that it forms a tunnel where the blood can flow through the stent graft instead of the aneurysm (Moll et al., 2011). The simulator, that is described below, is tailored for this method.

EVAR procedures can be organised and performed by different specialisations depending on the hospital. At our hospital, vascular surgeons and interventional radiologist, together with operating nurses and radiographers, planned and did the operation. At other hospitals, vascular surgeons perform the procedure without the presence of interventional radiologists, or vice versa. Despite originating from different fields, vascular surgeons and interventional radiologists are, at least for EVAR procedures, interchangeable. What we did see, though, was that the characteristics of both groups in terms of know-how and identity, on the one side, resulted in a partition of the work associated with the procedures but was also part of continuous effort to define EVAR procedures and the role of both specialisations, accordingly.

The formal "ownership" of the patients is with the vascular surgeons and their clinic. As a consequence, despite that the interventional radiologists take responsibilities in planning and performing of the procedure, the economic-administrative model accords the surgical department the main economic beneficiary of the patients. While the sharing of tasks related to the procedure (planning, preparation, and performing), it is only the surgical department who has a ward for the patients, adding administrative and clinical weight to the ownership.

With the evolution of aneurysm repair from open to minimal invasive surgery, interventional radiologists were recruited in order to visualise the inner body and the surgical work through imaging technologies such as X-ray and CT. With time, the sharing of tasks has evolved such that much of the tasks of the surgeons and radiologist can be carried out by both. As a result of development in medical imaging technologies and their role in the changing nature of medical work, professional competencies overlap and thereby blur differences between what surgeons and radiologist are capable of being in charge of with the consequence that both groups aspire to strengthen their position relative to the each other.

11.3.2 The Simulator

The procedure of endovascular aneurysm repair (EVAR) has seen considerable developments since its introduction in the '90s, where the patient-specific EVAR simulator can be seen as an add-on to the technologies surrounding the planning and

Fig. 11.1 Simulator (courtesy: Våpenstad)

execution of the procedure. Before we proceed to discuss the role of the simulator, we give a brief introduction of its functionality.

In 2016, a patient-specific EVAR module was added to an endovascular virtual reality simulator at the university hospital we studied (Våpenstad et al., 2020a). The patient-specific model is based on a digitally segmented part of the patient's aorta, transferred from the patient's CT images and uploaded and stitched into the simulator template, creating a virtual computer model. The operators can then perform a virtual EVAR based on the patient's aortic shape, with practical aspects including stent-graft deployment and the use of virtual X-ray images (see Fig. 11.1).

The simulator generates a virtual surgical scene with which the operators can interact using physical interfaces such as modified surgical instruments (guide wires, catheters, stent graft deployers) that go through a haptic interface. The simulator consisted of a physical mannequin with two entry points at the left and right groin as access points into the virtual femoral arteries, screens that visualised the virtual procedure, and a C-arm table side controller (the X-ray machine) and a foot-pedal to virtually move the C-arm and regulate X-rays (Våpenstad et al., 2020b).

The patient-specific model is based on the shape of the patient's aorta from just above the renal arteries to just below the bifurcations of both legs, as found in the patient's CT image. The aorta is segmented (cut) from the CT image, digitally transferred to the simulator and joined to a simulated model in the simulator. The operators can then perform the EVAR on the patient-specific simulated model. Biomechanical properties of the patient's aorta (stenosis, aorta stiffness) are not based on the patient (Våpenstad et al., 2020b).

The vendor's formulation of the simulator's specifications and affordances say a lot about medical-technical issues and possibilities for training of skills, but nothing about organisational issues such as development of the relation between surgeons and radiographers. Still, as we will present in the following, a significant affordance of the simulator came to be facilitating a closer relation between the professions, and thus reducing the likelihood of power struggles and negative side effects of such, and facilitating transfer of skills between the professions.

11.3.3 Method

The paper draws on ethnographic studies undertaken at a Norwegian university hospital in the period 2016–2019 (Haavik & Våpenstad, 2020). Participatory observation took place in a group of practitioners and researchers coming from a diversity of fields; vascular surgery (nine vascular surgeons), interventional radiology (seven interventional radiologists), medical technology (second author), and social sciences (first and second author). The group also consisted of radiographers and nurses.

Empirical data was produced along with our following of a patient-specific rehearsal module for EVAR procedures on a virtual reality simulator. With the use of real CT images from real patients, real rather than hypothetical situations were simulated. The contexts of our studies included the OR, simulated patient-specific rehearsals, preparations of the rehearsals, meetings with the simulator company, and scientific meetings and scientific work related to the clinical trials. Field notes were taken during these participatory observations, and supplemented after in connection with the author's collective reflections on the observations. Four structured interviews with vascular surgeons and interventional radiologists were undertaken to calibrate and develop interim analyses.

Thematic analysis (Braun & Clarke, 2006) was used to code the data material with respect to phenomenological (initially) and (thereafter) theoretical categories. This was done through several iterations of refinement. From this process, central themes emerged that framed the eventual findings. The methodology is inspired by Actor Network Theory (Latour, 1987; Latour, 2005), its sociomaterial ontology, the representational nature of reality, and the politics of the technology.

11.4 Main Findings

Clinical work increasingly takes place *outside* the bodily patients. Contra-intuitive as this may sound, it can be understood in light of the digital mediations taking on an increasingly central role in surgical work, and made subject to interpretation and augmented reality intervention. Here, a number of themes beyond the primary scope of the simulator are made relevant.

11.4.1 Requisite Variety/Imagination

With the changing nature of aneurysm repair procedures, not only the relation and power distribution between the involved professions is at stake, but also the robustness and redundancy offered by the two professions and their differences and similarities. In the collaboration agreement regulating their relation, it is explicitly written that it is important to maintain the competence within both teams to ensure sufficient readiness. We may think of this as requisite variety and requisite imagination that the hospital is careful not to throw out with the bath water when the opportunities of streamlining work processes are addressed.

11.4.2 Training Under Forgiving Circumstances

The simulator is offered a role after the traditional phases of planning and before the actual procedure. By preparing for the procedure rehearsing on patient-specific data on a simulated surgical scene, it can be seen as closing a gap between planning and performing that is usually conceptually, spatially, and temporally divided. At the same time, it allows human and non-human actors to interact in ways that are not recommended in the gravity of the operating room. In the simulator sessions, the surgeons and the interventional radiologists did discuss division of tasks, asked simple questions of technique otherwise inappropriate for the operating room, and discussed experiences from previous simulator sessions, creating a shared understanding and a forgiving atmosphere. By such, especially the younger operators gained important tacit knowledge.

11.4.3 A Moderator of Relationship and Collaborative Atmosphere

Although the patient-specific simulator targets a market as a training tool improving operating skills and rehearsal before procedures, above described as closing a gap between planning and the actual procedure, the operators describe it as a tool for bringing together—closing the gap—between the professions and increasing collaboration. The experienced operators affirm that the simulator does not add anything in terms of practical skills, as they were embodied years ago; instead, they grant the simulator a role similar to a formal collaboration agreement between the vascular surgeons and the interventional radiologists at the hospital. Meeting together in front of the simulator "does something with the maturity that they bring with them into the operating theatre to do the procedure" (interventional radiologist).

The initiative to the simulator project came from the interventional radiologists, and due to the personnel situation, the radiologists are also in a position to spend more time with the simulator than the surgeons, with the unspoken possibility of making it a tool more directed towards supporting the radiologists than the surgeons. It is also a radiographer that has been given the responsibility to prepare the files that are imported into the simulator.

The picture painted by our informants is that that the teams of radiographers and surgeons see the simulator first and foremost as a resource for optimising collaboration. Although it is not articulated by any of the project participants, a plausible assumption is that—in light of the surgical clinic's administrative-economic ownership to the patients—the radiologists' embracing of the simulator and the organisation of the simulator sessions contributes to balancing the "ownership" to the EVAR procedures in a way that reduces the inclination of any of the professions to gain formal terrain through power struggles.

11.4.4 Building Knowledge about Other Functions' Perspectives

It makes good sense to consider the simulator as an actor that takes an active role not only through facilitating a virtual context on which to act, but also in the ongoing boundary work between surgeons and radiologists. Hence, when Bailey et al. (2012) discuss virtual work and simulation and state that

manipulating physical objects through digital interfaces prompts changes in the organisation of work, alters the way people make sense of—and come to trust—the objects with which they work, and transforms workers' roles. (Bailey et al., 2012: 1488).they are in a highly condensed manner expressing the relationship between primary work and boundary work.

The simulator actually brings about changes to the organisation of work. For example, it facilitated a new practice of preparation meetings before operations; while previously only loosely organised in a meeting room, the meeting was moved into the simulator room and organised as a simulation session. In these sessions, the preparation of the CT images—and later the simulation sessions as such—were given to a radiographer, and the radiographer, in turn, acted as a mediator between the operators. The laconic comment from one of the vascular surgeons that "there is one good thing about the simulator, and that is [the name of the radiographer]" is a clear indication that the simulator session had a pronounced positive impact on the participants engagement and commitment.

11.4.5 Coordinating and Stabilising Effect: And an Arena for Discovering Potential Functional Resonance

The way the EVAR simulator supports the assembly of the different human and non-human resources that enter into the treatment of aneurysms, it functions as a boundary object (Star & Griesemer, 1989). Maybe even more important than its role in developing professional skills and reducing operating time, optimising equipment selection and reducing the use of contrast fluids is its role as a negotiator and stabiliser of the professional relationship between surgeons and radiologists. In a context where participation and power are at stake in EVAR procedures, the simulator actually plays a similar role as the beforementioned written and formalised collaboration agreement between these professionals—with the extra offer of also nurturing the crucial informal dimension of collaboration.

11.5 Digitalisation and Resilience

One central learning from studying a simulator project in a hospital is that a simulator is likely to play other roles than merely facilitating rehearsal on individual or group skills relating to their primary tasks. A simulator may also facilitate harmonisation of institutional arrangements and provide new contexts for boundary work that may affect the social dynamics of the whole organisation. A question for us is: how may this affect the *resilience* of the organisation?

Admittedly, in the organisational resilience research, operational resilience has been a more dominating focus than organisational focus as such—at least if we think of "organisational" as connoting to classical themes in organisational theory such as leadership, organisational structures, organisational cultures, and the like. While these themes enjoy considerable attention in safety theories like Normal Accident Theory and theories of High Reliability Organisations, the increased occupation with resilience and Resilience Engineering has increased the focus on more operational issues largely restricted to modus operandi the sharp end. While this is an important expansion of organisational safety theory, it has taken place perhaps too much at expense of more "traditional" organisational themes.

That is not to say that theories of resilience and Resilience Engineering do not address organisational issues, only that this research is less abundant and receiving less attention. In the following, we shall situate our findings from the simulator project in a resilience context, drawing on classical resilience themes and at the same time stretching these so that they make sense at the organisational level.

11.5.1 Requisite Imagination

Requisite imagination is highlighted by Adamski and Westrum (2003) as an important capability for resilient organisations. While this is undoubtedly true—finding obvious resonance both in its cybernetical heritage (Ashby, 1956) and in common sense—it is seldom operationalised how this may appear, and by which means it may be practised in organisations.

One way of thinking about the kind of digital simulation and, more general, digital re-presentation, in settings like the present case context, is its focus on *images* that easily lend themselves to manipulation. "The more manipulations, the better" says Latour (2014), referring to the vast possibilities that we are provided with through experimenting with images and other types of re-presentations without having to move real world entities. This is the kind of *imagination* that simulators may offer us; in a forgiving and clean environment, multiprofessional teams may exchange interpretative strategies and methods on a variety of thinkable and unthinkable—but imaginable—situations. While one might think of the main value of this to be of a cognitive sort, expanding and exchanging the interpretive skills amongst individuals and teams, we can also speculate on simulation producing occasions for learning about how other professions think and work in practice—in other ways than would be possible by mere telling or in actual operations where window for exploration and experimentation is narrow.

11.5.2 Functional Resonance: Cross-Functional Collaboration to Identify and Reduce Functional Resonance Potential

To explain and monitor the emergent nature of adverse events, functional resonance is a central concept of Resilience Engineering (Hollnagel, 2012). However, the task of identifying—not to speak of quantifying—the potential for functional resonance is a difficult one, and allocating resources, time, and arenas for this is not easy. To describe the potential for functional resonance is a task that is even more intricate than monitoring a system that is characterised by both complex interactions and tight coupling; you need both the domain expertise in the sharp end and the system expertise in the blunt end—and in addition, at least in an introductory phase, you need research resources that are capable of translating "functional resonance" into a local language. The simulator project we studied offered all this. The human resources and the time set aside for regular simulation sessions provided opportunities for bringing the functions (and sub functions) of the surgeons and the radiologists working methods out in "the open", including that of the clinic manager, making it available for introspection and discussion and cross-domain learning; all things that are necessary to avoid superficial, caricatured functional resonance analyses.

11.5.3 Some Reflections on Positive Side Effects of Digitalisation

In this chapter, we have discussed how the introduction of a simulator into a medical community organised for different professions that both collaborate (on tasks) and compete (for tasks), may have effects beyond the primary objective with the simulator. While the primary objective in the present case was to improve individual and team skills and improve the planning, tool selection, and time spent on the actual procedure, side effects include higher-level organisational themes having to do with the relation between professions that depend on each other's expertise but at the same time take part in continuous boundary work addressing the division of labour and the ownership of and methodical preferences for the subjects of their work. This boundary work also involves considerations of risk across the involved professions in a way that can also facilitate collaboration between professional communities, and influence structural tensions positively. In this way, the improvement of operational resilience can have positive side effects also for organisational resilience.

11.6 How Can these Findings Apply to Resilience Studies in Other Fields?

The above experiences from the healthcare domain are highly relevant for progress in the domain of cyber-physical infrastructures and industries. While these are very different contexts from the healthcare domain, they share the same need for addressing the boundaries between professions that are increasingly integrated around digital re-presentations, in the form of, e.g. simulation tools, decision-support tools, and other forms of digitally mediated and operated systems. Both the nurturing of requisite imagination and the identification of potentials for functional resonance depend on cross-functional collaboration, with the corresponding need to explicate tacit knowledge, develop a common language to address potential vulnerabilities, and address changes in the division of labour among the involved professions.

For instance, offshore oil and gas production, energy supply systems and smart grids enabling integration of renewable energy sources, and water supply systems are examples of physical domains which are rapidly digitalised, creating both the need and opportunity to address the boundary work around digital re-presentations. Here, previous industrial control systems and other operational technologies (OT) which have been carefully adapted to the specifics of their more or less closed domains are rapidly integrated with, and sometimes replaced by, generic information technology (IT) belonging to and making use of the open, global Internet. This way, OT solutions previously calibrated to their local domains to ensure safety (protection against coincidental failure) are now disruptively exposed to all the security issues of Internet technology, and to malicious intents of unknown actors far away, at a fast pace. Put shortly; this demands a metamorphosis of technical, human, and organisational capacities that most organisations are not prepared for, and for which the term “digital transformation as a process” may even be a beautification. While this presents new opportunities for organisational resilience, the challenges regarding cyber security are obvious. Strong voices argue that prevalent cyber hygiene approaches are not sufficient to deal with this, and that, e.g., the energy sector (Bochman, 2018) must hesitate to, even refrain from, taking new digital opportunities into use. This goes to show that the increasing use of, and reliance on, digital re-presentation is by all accounts a mixed blessing, depending on the approach taken.

It is, however, beyond doubt that such a practice of “cyber resilience” will have to master digital technology not only for the sake of security and safety as an outcome. It will also have to do that in manner that is compatible with the central facets of digital technology from a technical user point of view, namely re-presentations. That is, both re-presentations of physical processes and phenomena that are under (digital) control, as well as re-presentations of the digital technologies per se, e.g., inventories, software entities, supervisory processes and operating systems, threat agents, security mechanisms, integrity controls, updates and patches, to name a few. It, therefore, goes without saying that simulation may provide great value for resilient mastery of such a re-presented world.

The prospect of using re-presentations as a focus and simulation as an approach in these cyber-physical infrastructure domains must, however, reflect some key differences related to the healthcare domain. First and foremost, in the context of critical infrastructures, the professional roles are less historically/traditionally established than in the healthcare domain. Hence, the landscape of professions is more ephemeral and contested on different grounds, while at the same time, the need to build coherence and collaborative practices between IT/OT, safety/security professionals due to continuous (disruptive) digitalisation and imminent cyber threats is as least as urgent as for the EVAR case.

Grøtan (2020b) addresses digital complexity, including ICT as a re-presentation technology, in a manner that is very similar to the discussions so far connected to the EVAR case. Grøtan (ibid), however, puts more emphasis on digital technology as a facilitator and carrier of a “hyper-reality” where technical and social systems and components, at the forefront, are represented predominantly based on their ability to reconstruct the whole for various and changing purposes. This way, digital re-presentations may also create new conditions for mastery and control in a complex system. ICT thus channels a new form of power in which reality is replaced or supplemented by a “re-presented” and constantly re-organised understanding of reality. While in the EVAR case, re-presented simulations may be used to mitigate power-related tensions because the lines of tension are well established, and under a certain degree of external attention and governance, the tension lines in the critical infrastructures might be more dubious and volatile, and escaping attention. Hence, this new form of power may unfold in a less visible, and thus potentially more harmful manner in the latter case.

Moreover, while we in the EVAR case highlight virtualisation as a useful device for requisite imagination in general, concerns may be raised about how re-presentations might favour the most explicable parts of the work—formal work process descriptions, at the expense of the work forms—the less visible conditions for actually conducting the work processes (Grøtan, 2020b; Grøtan, 2020a). This might lead to a joint forgetfulness around the issue of work as imagined (WAI) and work as actually done (WAD) that might be fatal in a safety or security context, as they may create blind spots due to lack of articulation work needed to reveal them.

Compared to cyber-physical infrastructures like energy and water supply, the healthcare domain is probably more intrinsically resistant to such gaps between WAI and WAD through the pre-existing, reciprocal respect among health professions, and because patient safety is a persistent reference for successful outcome. In the cyber-physical infrastructure context, where there is probably less precedence to rely on regarding reciprocity and where the "patient's" safety is a more moving target, the reconciliation between work process and work form might more easily be jeopardised.

As highlighted by Grøtan (2020b), the re-presentation perspective opens new doors for cyber security practices. A possible advance in that respect is to devote more attention to the protection of the artefacts that works as boundary objects for key sensemaking processes and sensework in the organisation. In this respect, re-presentations will be key to understanding how a digital organisation works, and that corresponding simulations might be a very effective way of enhancing not only operational but also organisational resilience.

Other approaches may enhance our perspective further. Woods (2019) reminds us that humans are important for resilient systems as they provide initiative and understand reciprocity. From a maritime simulator-based training perspective, Wahl et al. (2020) argue that for learning to manage variability, the ability to prevent adverse events by recognising anomalies and solve problems in a flexible manner, the ability to define limits of action through shared knowledge, and the ability to operate the system with confidence can be important results of simulation. In the training setting, these effects are not the result of the simulation in itself, but the connection between the simulation setting and the social situations it is meant to represent. Both these perspectives point to exploring the links between operational and organisational resilience, with digital tools such as simulation as an important locus of attention.

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Chapter 12
Cyber Resilience: A Pre-Understanding for an Abductive Research Agenda

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Abstract Digital transformation turns critical infrastructures into cyber-physical systems, introducing unprecedented levels of complexity and vulnerability. As the evidence of surprise and shocks involving cyber-physical systems is high and rising, concepts of resilience are increasingly enrolled in discourses around vulnerability in critical infrastructures. In this chapter, we discuss the theoretical foundations for a concept of cyber resilience, and the needs, potentials, and pitfalls in this respect. Our aim is to point to a research agenda of abductive reasoning, where a concept of resilience is developed through stepwise, reflexive theoretical advances together with ongoing efforts of empirical grounding in particular cyber-physical domains.

Keywords Cyber resilience · Digital transformation · Critical infrastructures

12.1 Introduction

12.1.1 Cyber Resilience: Why?

The industrialised world is increasingly depending on digital technologies that are complicated, brittle, and fragile,[1] depending on highly skilled operators and disciplined users, conducing a multitude of ripple effects across domains, but also

[1] Computing systems can always exhibit dynamics and failure modes beyond what they are designed and tested for, triggered by coincidence or deliberation. Reverse engineering is a systematic attempt of revealing exploitable vulnerabilities. Software supply chains may be exploited to insert malicious code via third parties.

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enabling hostile influence and subversion across cyber-space. Such processes of digital transformation include critical infrastructures which are already, to a large extent, cyber-physical systems and therefore exposed to new forms of failure and malicious attacks.

At the same time, the state of the art of cybersecurity practices is constantly lagging. Serious cybersecurity incidents and breaches with unprecedented short- and long-term implications are virtually daily news. To make matters worse, the connection between the optimistic discourses of digital transformation and the far more pessimistic experiences of cybersecurity seems to be weak, at best. The rapid pace in the introduction of new technology and the lagging nature of protection measures that are brutally signified by, e.g., zero-days[2] problems imply a race that is constantly on, but in which the competition is never fair. Importantly, this is not only a technical matter. It is a socio-technical challenge where the introduction of new technologies needs to take into account organisations' ability to manage with the combination of old and new technology. In a situation where great changes are made, the organisation is struggling to keep up with the "state-of-the-art", and the full range of possible failure modes can never be anticipated and modelled, we should expect surprises to come. Moreover, the socio-technical nature of digital transformation means that the surprises are not likely to arrive in the form of mere technical failures.

Where there is a possibility of fundamental surprise demanding some form of adaptive capacity, the concept of resilience is never far away. Resilience is a concept which ultimately urges organisations to be "poised to adapt" according to Woods (2018a)—to be able to instantly rearrange their mode of operation—in order to deal with complexity and fundamental surprise. The concept is already applied in many domains, often but not only with a safety focus, but also as a theory of utilising windows of opportunity. Woods' (ibid) description of the core of the resilience concept per se can therefore be paraphrased to describe its attractiveness; it is "poised to be launched" as a combined enabling and safeguarding approach to almost any complex problem arena in which hindsight is regarded insufficient. This applies, not at least for the cyber arena.

"Cyber resilience" is, therefore, from the outset an effective catchword. In the most straightforward sense, it could be applied for "just" improving cybersecurity. At a different magnitude of scope, it could also be associated with the far more ambitious aim of safeguarding digital transformation processes. However, it lacks clarification, delimitation, and substance as a theory of action for both purposes, not to say their combination. On this background, this chapter aims to outline a

[2] (Based on Wikipedia) A zero-day is a software vulnerability unknown to those who should be interested in its mitigation (including the vendor). Until the vulnerability is mitigated, hackers can exploit it to adversely affect programs, data, additional computers, or a network. Once the vendor learns of the vulnerability, they will usually create patch-es or advise workarounds to mitigate it. The more recently that the vendor has become aware of the vulnerability, the more likely it is that no fix or mitigation has been devel-oped or taken into use. The notion of "forever-days" is sometimes used to denote persis-tent design weaknesses that are not possible to mitigate or eradicate by updates.

much-needed research agenda for cyber resilience, in the form of a preliminary theoretical position that can serve as a basis for abductive research, building theoretical concepts and perspectives based on empirical studies within cyber-physical infrastructures. We do this by first deconstructing existing theoretical positions on resilience, before we by means of a set of examples of digital vulnerabilities, discuss the prerequisites for a theory on cyber resilience. The chapter concludes with the delineation of a direction for empirical research that can form the basis for development of theory and practice within cyber resilience.

12.1.2 An Abductive Research Approach: Why and What

The background for this chapter is an ongoing research and theoretical inquiry aiming for the utilisation of resilience thinking in developing a theory of resilient action in the complex cyber-physical domain. Here, organisations depending on digital systems for upholding critical infrastructures must prepare to encounter variability, surprise, shock, and sheer hostility through hybrid threat scenarios.

Our inquiry for a practicable theory of cyber resilience has a primary focus on situated socio-technical practice, governance structures, and the technocultural impact of professional communities of risk, all made relevant by the digital transformations of critical infrastructures.

The abductive research approach is rooted in reflexive qualitative research (Alvesson & Sköldberg, 2018). It draws on a legacy of the "science of understanding"—aka philosophical hermeneutics—emphasising the significance of pre-understanding (Gadamer, 2018), and American pragmatism. The latter approach was originally focused on theorising inquiries as a practice per se (Peirce, 1935). Later, this was applied to fields of politics, education, and social improvement (Dewey, 1999). In the 1970s, Rorty (1980) turned to hermeneutics and pragmatism to rectify what he saw as mainstream epistemology's crucial mistake: naively conceiving of language and thought as "mirroring" the world.

In 2021, in a similar vein, abduction is proposed as a research strategy into management research (Sætre & Van de Ven, 2021). As a foundation, Sætre and Van de Ven (2021) refer to Peirce's classical positioning of abduction in relation to the more prevalent principles of deduction and induction; "deduction proves that something must be, induction shows that something actually is operative; abduction merely suggests that something may be". This makes abduction an inherently generative process. To stick to Sætre's and van de Ven's description, abduction is "the only logical operation which introduces any new idea; for induction does nothing but determine a value, and deduction merely evolves as the necessary consequences of a pure hypothesis" (Peirce, 1935, p. 216) The abductive approach should not be mistaken with mere idea generation as it includes idea evaluation at both individual and collective level. It is also strategic in the sense that it directs research interest into anomalies that existing research does not explain properly (Sætre & Van de Ven, 2021).

This resonates with our orientation to cyber resilience as an organisational field of study, in two ways. First, for a multidisciplinary research group, the abductive approach provides a way of unifying and "driving" the collective research process forward and acknowledging the value of preliminary results. Second, the sensitisation to anomalies rather than the regular corresponds with the core of resilience as a potential theory of action, informing a practice of dealing with surprises, anomalies, and boundary conditions, beyond recurrent problems which invite replicated responses.

The use of the resilience concept has exploded in recent years. Well established disciplines like, e.g., disaster resilience are contested by approaches like resilience engineering (Woods, 2018a, 2019), and the risk management sciences have tried to integrate resilience into their perspectives and frameworks (Stavland & Bruvoll, 2019). Hence, the abductive orientation is also an asset for critical sensitisation, selection, and assessment from an abundant mass of definitions and explanations of "resilience" in a variety of contexts.

The present chapter is part of an effort of developing the pre-understanding (Gadamer, 2018) of cyber resilience to "kick-off" the research team's empirical work, which, in turn, will contribute to further development of theoretical concepts and models of resilience in cyber-physical contexts.

12.2 Background, Motivation, and Rhetoric of Resilience

Over the last 15 years, the resilience concept has risen to be very popular, particularly in domains where hindsight is regarded as insufficient to deal with disturbance, shock, or fundamental surprises that challenge safety and security of people, society, environment, or assets.

In a nutshell, the resilience agenda is to ask why things go well and reinforce the properties behind success rather than chasing down the errors and deviations that presumably lead to (recurrent) failure. In a dynamic and complex world in which problematic events do not repeat themselves but emerge in new shapes and forms, resilience engineering and related approaches aim to transcend the limitations of hindsight.

The concept of resilience is however notoriously difficult to define exactly, as it carries a variety of meanings and invokes many different associations in different contexts. The diversity itself is sometimes seen as a source of confusion (Woods, 2019). Others argue that a variety of definitions is not the main problem, and that the crucial challenge is the operationalisation of efforts to improve it (Stavland & Bruvoll, 2019).

One of the most prevalent and lasting definitions stems from Erik Hollnagel, whose name is inextricably linked with the resilience engineering stream of work. In one of his most cited definitions of resilience, Hollnagel states that resilience is *"the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both* *expected and unexpected conditions"* (Pariès et al., 2011). This definition, although generic from the outset, is often complemented by more metaphoric descriptions of the character of the sustained operation, e.g., of resisting or absorbing stress, bouncing back—recovering to a state that equals or resembles the state before a downturn, or bouncing forward ("bouncing back better")—recovering to a new state that is regarded as an improvement. In later writings (Hollnagel, 2021), Hollnagel extends the focus (changes and disturbances) to include "opportunities", to emphasise that the scope of resilient performance *"is not just to be able to recover from threats and stresses, but rather to be able to perform as needed under a variety of conditions—and to respond appropriately to both disturbances and opportunities"*.

But resilience is also hard to delineate and encapsulate as a phenomenon to study. As the sustained operation is attributed to an intrinsic ability, we must also assume that this ability is persistent and sustained. Such a persistent ability is not necessarily endogenous to the system in question. Various definitions and metaphoric descriptions of this ability offer many hints that it derives from a synergetic or symbiotic relation to its (presumably adverse) external environment, in which the system so to say thrives from being exposed to danger, external or internal, like an immune system in a living organism, or ultimately in a Darwinian sense of the "survival of the fit" to a changing environment. By implication, a sustained presence of resilience, due to a persistent intrinsic ability, is also associated with a process of adaptation and growth that is being nurtured by the hardships that the system is facing—or seeking, more or less voluntarily—at the boundaries of its designed or otherwise constructed envelope of operation.

The concept of resilience, e.g., as apparently submitted by Hollnagel as a definition, is also *rhetorical*. That is, it is both a *description* of something happening or being achieved (sustained operation), an *explanation* of why it happens (an intrinsic ability), and a *justification* or a judgement of its value. For the latter, the dominant tone of the literature is positive; who does not want to be resilient, especially confronted with the convincing argument and experience that existing approaches fail to deliver the desired safety, security, or reliability in an increasingly complex world? But the concept of resilience put into practice may also convey a burden for those not keeping up to the standards, especially when standards derive from excellent performance of actors with more than average skills and resources. It should therefore be no surprise that resilience as a concept and theory of action is also criticised for being uncritically used as a panacea; encouraging risk-taking, and depoliticising danger in a manner that renders unprepared people, groups, organisations, or societies involuntarily and inadvertently exposed to risk and danger by trying to join a game that they are not prepared for, and for which there is no clarified managerial accountability (Grøtan, 2020) when operational attempts to be resilient actually fail. Such performativity issues are rarely addressed along with the advantages when resilience as a concept is advocated.

The *description* of resilience—as a positive outcome—is sometimes done graphically by reference to the so-called resilience curve (Fig. 12.1), depicting a valuable function (corresponding to Hollnagel's notion of the "required operation") of some sort that hits a bottom at a point of time due to disturbance, before recovering to

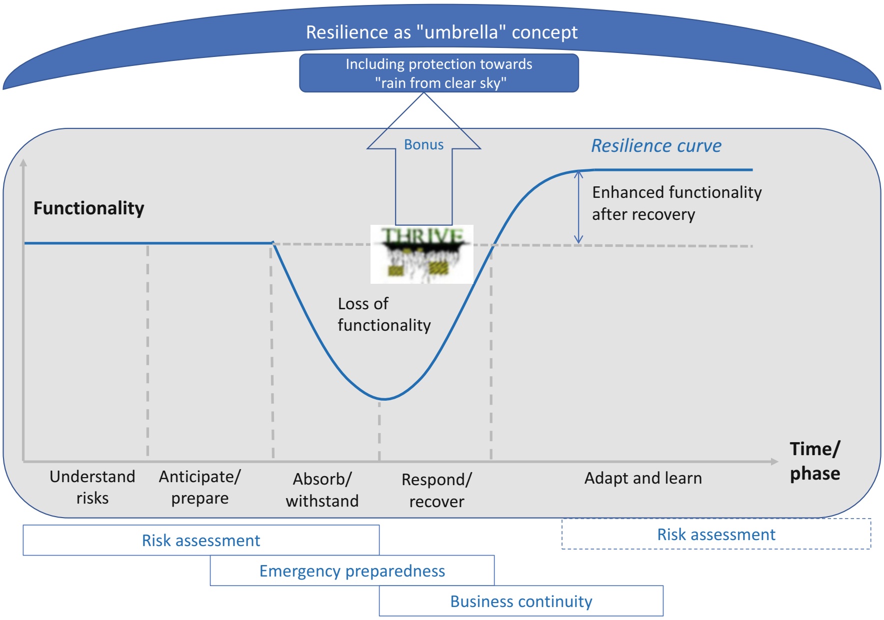

Fig. 12.1 Resilience as an "umbrella" term (adapted from Stavland and Bruvoll (2019) and Øien et al. (2017))

reduced, similar, or even improved level of functionality (Øien et al., 2017). The shape of the resilience curve invites several issues that easily catch attention; how much can the function absorb before faltering? How steep and deep does it fall? Is the bottom the point where "resilience" departs from "robustness"? How fast does the curve return? Is the return an accomplishment of degraded return, recovery to normal, or a transformation to a "higher" level?

Such issues invite qualitative as well as quantitative discussions and analyses of the actual performance but may fail to discriminate clearly between the performance of the curve per se, and the underlying factors and abilities contributing to this happening. In that respect, there is a striking contrast between the prospect of enhanced "resilience" signified by "improved" performance of the curve, and the lack of attention towards possible costs regarding the quality and sustainability of the intrinsic ability that supports the manifested improvement.

A simplistic divide may be drawn between different attempted explanations of the intrinsic ability of "adjusting prior to, during and after". This divide is important because different explanations imply different approaches for assessing, operationalising, and improving resilience.

At one edge, we find explanations that implicitly or explicitly rest on classical linear, sequential, and factorised models (or indicators) to address technical, human, or organisational performance contributing to resilience. At the other edge, we find those that rest on a pronounced complexity perspective, in which non-linearity, diversity, dynamism, and emergence prevail (Woods, 2019; Woods, 2015; Johannessen, 2019).

The former approach may be driven by an urge to integrate resilience into a risk management perspective (Stavland & Bruvoll, 2019). As illustrated in Fig. 12.1, it is then tempting to connect the dots between existing concepts and paradigms as, e.g., risk assessment, emergency preparedness, disaster management, and business continuity in a broad time perspective, implying a "phased" resilience curve. This way, the classical event-oriented risk management perspective is combined with the ultimately "eventless" resilience perspective, but primarily driven by an urge to extend the former. However, the combination seemingly also fits well with recent re-definitions of the risk perspective (Aven, 2017), focusing more on uncertainty and "knowledge strength" than on specific, a priori identifiable events associated with risk. By these ways, resilience may be portrayed and positioned as an "umbrella concept", an aggregated result due to concatenation of existing knowledge and approaches. However, it then remains unclear how resilience as a way of successfully dealing with the unexpected ("rain from clear sky" in Fig. 12.1) can be explained. Is it a sheer bonus ("gift from the sky"), a result of an unspecified additional effort, a nice, symbiotic effect in terms of just thriving from encountering danger, or an assumed, accumulated learning effect from dealing with less surprising events? Without answers to this, the original novelty and distinctiveness of the resilience concept—of being "poised to adapt"—is put at stake, and the efforts of operationalising it may, worst case, derail into a mere relabelling endeavour, in which resilience is just attributed to the existing and familiar.

The other approach to operationalising resilience takes the "eventless" premise more literally, arguably because there are no identifiable nor recurrent key "events" to focus on, analytically speaking. Instead, essential aspects of the analytical perspectives are, e.g., inherent variability in normal operations, trade-offs, dynamic stability, functional resonance, and damping strategies, all of which abandons the very idea of recognising or categorising problematic events as "deviations" in any normative sense. Moreover, the human presence is seen as a resource for initiative and reciprocity (Woods, 2019) rather than just a source of failure, and the overall problem is one of creating organisational "health" (presence of salutogenesis) rather than preventing a "disease" (absence of pathogenesis) (Grøtan, 2014, 2015). These approaches are not using the term "complex" as a mere substitute for "complicated" but employ the field of complexity theory (Woods, 2019; Johannessen, 2019; Kurtz & Snowden, 2003), which ultimately denies the applicability of linear, sequential, or factorised models to capture complexity as a phenomenon. The potential downside of this approach is that if explanations and operationalisations of resilience rest overly on complexity theories, the insights gained may be rendered estranged, intangible, and unactionable for most organisations.

At both sides of this divide, however, it is rarer to see problematisations of the distribution of tolls and other unseen, long-term effects from the creation of resilient performance from a human and organisational point of view. The complexity approach is, however, more sensitive to the potential incoherencies, diversities, dynamisms, and dynamics within the system producing it, while the other approaches tend to rest more on a unified "model" or theory.

As the resilience concept has grown rapidly in popularity, it is also a very dense field with many and mixed theoretical and scientific positions, popularisations, and attributions. As for many other fields of applied science, it is sometimes difficult to distinguish between pious wishes, verifiable results, and empirical and theoretical groundings and explanations. This challenge is constantly recharged as much of the discourse on resilience reflects a rather sharp rejection of well-known, instrumental, and tangible means, instead directing attention to more ephemeral and less tangible phenomena of systems and organisations. "Safety as an emergent property" is an example of (academically coherent) statements and proclamations that may render practitioners relying on traditional approaches, rather estranged.

Hence, if we aim to take the concept of resilience seriously and investigate how it can be beneficial in a specific domain or context, e.g., in the cyber domain, we should therefore aim to be *restrained and focused* rather than rhetorical and overly optimistic. As a minimum, we should be concerned with the following:

- **Scope and purpose.** The starting point should be a clarification of what purpose (function or "curve") the desired resilience presumably is useful for. At least from the outset, we should be specific rather than aiming for being "generally resilient" without direction or purpose.
- **Operationalisation in context.** First, we should be cautious regarding the basic assumptions underlying our attempts of explaining or guiding how resilience may be created. If we believe it is a replicable property resulting from a linear recipe based on contingencies and known ingredients, it is likely that we are aiming too short; for a robustness towards conceivable disturbances rather than being resilient towards surprise—in the sense of being "poised to adapt". Second, as the term "operationalisation" is widely applied to signify an honest intent of progress at a practical level, we should keep in mind that this term carries a risk of losing sensitivity to context. Theory-building may, in the worst case, end up with telling (fairy-)tales from "the heights of abstraction", rendering practitioners "down below" with both the burden of translation and the proof of validity. This is especially critical when we are employing complexity theory, situated representations of resilient performance, and other untraditional paradigms. Hence, before we have sufficient empirical grounding for relying on and trusting abstractions, we should conduct operationalisation as **contextualisation**, expressing the theoretical positions and assumptions in a language which is meaningful for actual practice in a chosen context.
- **Costs and side-effects.** It is critical to beware of potential side-effects; what is the cost and risk of being overambitious or unrealistic, who and what may be victimised as a result? Both the resilient system and its surroundings include actors, and it is by no means given that everyone will come out as winners in attempting to adapt toward surprises or shocks. In short, we should not aim for too much of resilience before we have an idea of the price for it.

Moreover, it should be kept in mind that resilience is a not property that is injected by design or the sheer act of applying the terms and concepts. It is paramount to acknowledge that almost any system that survives real-life operations must—by implication—possess some resilient capabilities, despite not being labelled as such, and even if its resilient merits remain in the shadows. Hence, searching for, exploring, nurturing, and theorising rudiments of resilience, while at the same time avoiding relabelling of non-resilient practices is the prime research challenge if we want the concept of resilience to make a difference that makes a difference, in the real world.

12.3 An Urgent Need for Cyber Resilience

Increased use of Information Technology (IT) and the ubiquitous digital transformation imperative form many arenas at which the limited value of hindsight is experienced every day. The expected benefits are huge, but vulnerabilities and problems are correspondingly immense, and seemingly escalating. Digital transformation nevertheless has speeded up during the Covid-19 crisis, in many countries saving the day for a lot of activities important for society and economy. However, this raise the stakes in terms of the potential consequences of fallout of energy distribution, communication, or IT services, which are almost incomprehensible before they are actually experienced. Using the energy fallout in Texas early 2021 as an example, it is easy to conceive that even if power lines and gas pipes had been properly winterised, a cyber-attack like the ones in Ukraine in 2016 (Wikipedia, 2021) could have had the same devastating effect during a period of extraordinary cold and harsh weather.

Organisations depending on digital systems for upholding critical infrastructures hence must prepare to encounter variability, surprise, shock, and sheer hostility through hybrid threat scenarios. There is, therefore, an urgent need for advances on a theory of organisational as well as socio-technical, situated practice that improves cybersecurity as it is scoped today, but also to enhance organisations' ability to deal with their reliance on cyber technology to deliver reliable infrastructural services. Despite challenges, we think that it is worthwhile to investigate the potential of resilience thinking in this respect. We denote this prospect cyber resilience.

We will here try to illustrate the need for cyber resilience with examples from the Norwegian context.

12.3.1 Episodic and Accumulated Vulnerabilities and Threats: Not Scary Enough?

Security agencies across the world rank adverse digital operations as a main threat to national, industrial, commercial, and societal security, not at least related to critical infrastructures that often are privately rather than publicly owned. Digital vulnerabilities and threats materialise as a persistent annoyance for the end-user, who is a constant target for, e.g., phishing, or other means of technical deception or social engineering. In addition, there is an intense and continuous struggle behind the scenes in which cybersecurity professionals at many levels, from vendors to national agencies, battle constantly with perpetrators that steadily invent new approaches, utilise new vulnerabilities, and apply new attack vectors. Hindsight is not by any means useless in this context, it can be instrumental for establishing a foundational level of "cyber hygiene". But while this is necessary, it is not sufficient.

At an increasing rate, industrial companies, healthcare organisations, public services, and political institutions, to name a few, are hit hard by cyber-attack incidents that take their operations down, blackmail them, require extensive end expensive rebuilding efforts, or render the victims in almost total uncertainty on how long the intruders have been operating, what they have left behind, what data they have taken away, and what the motives and intentions of misuse are. Therefore, over time, there is arguably a steady leak of industrial knowledge, healthcare data, emergency plans, critical safety device configurations, operational plans, and sensitive personal information, to name a few, that dissipate into the hands of criminals, state actors, or other unknown actors with dubious or unfriendly motives, and at great scale. This is not just a series of unfortunate events; it is a steady aggregation of vulnerabilities and risks that defies a linear understanding of its effect.

A most notable example of such an event so far as this text is written primo 2021, is the "SolarWinds", nicknamed "Solorigate" (software supply chain) attack (New York Times, 2020). This has left even the presumably most competent security agencies in near total embarrassment. As the professional responders scrambled and it became clear that the attack appeared to be the broadest confirmed penetration of U.S. government and tech sector computer networks, even the—until then hypothetical—term "Cyber Pearl Harbor" (New York Times, 2012) was used in attempts to make sense of the situation. Solorigate resembles a "black swan" in the sense that security professionals were utterly aware that supply chain attacks could happen, but the professional communities and the organised defences were still, apparently, collectively taken totally by surprise. In Norway, the victims included Norges Bank Invest Management (NBIM), the holder of the "national fortune" (named the Government Pension Fund Global) derived from the petroleum industry, with an estimated value at the magnitude of 1000 billion USD (by medio 2020). Approximately 70% of this are international equity investment. This makes NBIM a significant actor whose transactions may influence global financial markets substantially. Like many other assumed victims worldwide, 18.000 in numbers per February 2021, including some of the most strategic agencies and actors in the USA and NATO, it took NBIM several months just to discover that the backdoor was installed. This is worrisome because it is very difficult to judge in retrospect whether it has been used, e.g., for stealing data, manipulate systems, or installing other advanced malware.

We should keep in mind that resilience as a capacity is not necessarily serving the good purpose. The resilient adversary will for sure find new opportunities, fuelled by leaked information. As stated in a US hearing (US Congress, 2021), by the CEO of FireEye, the cybersecurity company that discovered the Solorigate hack, *"we may never know the scope of the attack", and "we may never know the full range and extent of damage, and we may never know the full range and extent as to how the stolen information is benefitting an adversary"*. What we know, however, is that a wide range of personal and sensitive information is on sale on the "dark" Internet.

While an attacker needs to succeed only once, the defenders must succeed every time, also when the attack takes new and surprising paths. Sadly, this imbalance is in favour of the perpetrators, and episodic, but not at least accumulated, threats and uncertainties related to consequences are the result. It seems hard to break these unfortunate chains of "standalone" events and episodes. But maybe even worse, the lack of success in that respect does not seem to influence the way the further digital transformation processes are secured, in any substantial way. Put differently, there are not many signs of "the intrinsic ability" advocated by Hollnagel, although it presumably would be most welcome.

This description applies for both the private and the public sector. For illustration, in the following, we will take a closer look at the public health care sector in Norway, and how it responded to a very serious event.

12.3.2 A Norwegian Episode: And Its Bureaucratic Resolve and Context

The example presented is not meant as a critique of the actors involved, but as an illustration of the prevalent—and insufficient—logic that characterises the handling of cybersecurity breaches, before, during as well as after.

Early 2018, a major attack on the largest Public Health Care Operators in Norway was revealed, affecting more than half of the Norwegian population in terms of potentially leaked health data, in addition to the major disruption of the service as such. For simplicity, we refer to this operator at PHCO. A year after, in 2019, an investigation of the incident by several national security agencies was closed, the case rendered unsolved (Digi.no, 2018). The Minister of Health gave a formal briefing to the Parliament (Stortinget) on February 4th, 2019. In the following, translated excerpts from the Parliamentary transcripts (Norwegian Parliament, 2021) are presented.

The Minister made it clear that *"he set the overall framework for the operation of the specialist health service through his requirements for the regional health authorities"*. He asserted that he had *"taken a number of initiatives related to* *strengthening the work with information security in the health sector"*, and that he, inter alia, had *"strengthened the board in PHCO with expertise in information security"*.

He had *"made sure that PHCO has shared its experiences from the data breach with the other health regions, in order to ensure knowledge transfer and contribute to a strengthened preparedness in the sector, and that this had been followed up systematically through regular meetings"*.

He had *"on several occasions raised the challenges related to information security with the management of the health trusts". He had "pointed out that there is a particular need for measures to reduce risk and complexity in the ICT projects and to ensure proper organisation"*.

Moreover, he *"made demands to follow up the Office of the Auditor General's findings and comments"* and demanded that *"PHCO shall report to the Ministry from the work with the follow-up"*.

He also reported that in 2017 (before the 2018 incident), a new organisation of the technology and "e-health" area in the region had been implemented. The changes were expected to *"contribute to the clarification of roles and responsibilities, and the responsibility is placed in the ordinary line"*. The changes expectedly *"will ensure that the health trusts are better involved, and that decisions are better anchored both in the health trusts and in the management of the regional health trusts"*.

The reporting in PHCO had also been changed. In this way, PHCO *"wants to clarify the challenges associated with the implementation of the individual projects in the ICT portfolio"*. It was expected that *"attention is paid to non-conformance reporting with a description of measures to close proven non-conformities"*.

PHCO had announced to change their procurement processes, and *"has also strengthened its legal capacity and expertise within the agreement area and will link this expertise more closely to supplier management"*.

A later incident in January 2019 was also mentioned, in which *"an error at a Subsidiary led to the patient record system being down or unstable at the health trusts in PHCO"*. He ascertained that *"in accordance with established routines, the hospital partner is in the process of evaluating the incident and will, on this basis, consider implementing measures that reduce the risk of similar incidents". But he also mentioned that "it appears from this report that there have been several unfortunate and demanding incidents in PHCO within the ICT area in recent years"*.

Moreover, it was stated that *"PHCO has implemented several measures to reduce risk and complexity in its ICT work and will continue this work. Among other things, the lines of responsibility have been specified in order to better anchor decisions on ICT projects"*. The Minister ascertains the Parliament that for him, *"it has been important to pay attention to safe and secure ICT systems in my overall corporate governance"*, and that he will *"prioritise following up this work in my management dialogue"*.

The Minister had, therefore, in a meeting with (all) the regional health enterprises the same January asked the health regions to cooperate—*"to create a good safety* *culture and develop competence to both prevent, detect and implement harm reduction measures against, e.g., unauthorised access to the sector's computer network".* The Directorate for e-Health and the Norwegian Health Network also participated in this work", and they *"must help reduce risk and complexity in the sector's ICT projects and ensure proper organisation with clear lines of responsibility and management anchoring".*

In conclusion, he mentioned that *"the Office of the Auditor General is now planning to carry out an investigation into the health trusts' protection of their ICT systems. This is expected to provide us with useful knowledge to prevent and strengthen the health trusts' defences against new computer attacks".*

Finally, the Minister drew attention to the fact that *"ICT projects are extensive and complex". "ICT projects are therefore associated with high risk, but it is also important to point out that there is also a significant risk associated with not further developing and modernising ICT solutions".* Afterwards, outside the parliamentary context, the Minister, however, declared that the greatest damage done by the attack was the delay of digital transformation of healthcare (ComputerWorld Norway, 2018).

The overall message is thus quite clear; there is no time to lose, we just need to go on, despite any security breach. This illustrates that the presumed benefits are just too good, we cannot resist the temptation, although security measures fail, time after time.

12.3.3 A Strange Kind of Bureaucratic Complacency

From the above episode, we can infer that the bureaucratic lines from the top of the hierarchies were active, and that a wide range of bureaucratic controls were attempted reinforced. But the crucial question is, did they make a difference? From a resilience angle, did they contribute to an ability of "adjusting prior to, during and after", to paraphrase Hollnagel once more.

The chain of similar events affecting Norway, before and after the PHCO attack is unfortunately long (ComputerWorld Norway, 2021) and indicates a disappointing answer to the above questions. Rather, it indicates a strange kind of complacency, apparently founded on the right to fail while trying hard, rather on merits of success.

In December 2020, as announced by the Minister of Health in the Parliamentary briefing in January 2019, the Office of the Auditor General initiated a simulated attack on all the health regions in Norway (Office of the Auditor General (Norway), 2020). No substantial effort was put into hiding or disguising the attack. PHCO detected this attack, but neither of the other three regions did, despite the knowledge sharing activities initiated by the Ministry of Health. The simulated attacks enabled a high degree of control over the ICT infrastructure in three of four health regions, as well as access to large amounts of sensitive health information in all regions.

Earlier, in the fall of 2020, the Norwegian Parliament itself was cyber-attacked. Quite sensationally, without presenting the evidence to the public, the Norwegian Government attributed the responsibility to a foreign state, namely Russia.

During 2020, several municipalities in Norway were attacked. A small municipality was hit especially hard in January 2021, and literally had to resort to pen and paper to conduct all their services towards its population, as even the backup copies were encrypted and thus unavailable. The restoration process was very demanding and extensive.

A common denominator, spanning from SolarWinds victims worldwide to small Norwegian municipalities, is that the amount of data stolen remains unknown. This alone should bother us, not at least seen in combination with the unregulated market offerings from data "brokers" (Wired.com, 2021). The adversary in possession of such data does not even have to be pressingly "resilient" to cause great damage.

Can the chain of serious breaches be broken or counteracted? A most striking observation is that apparently, influential actors (act as if they) think that compliance with recommendations (best practice) and reinforced bureaucratical controls will provide a fair chance of stopping the next attack. This strange kind of complacency implies a belief that sufficient foresight is at hand, and that the (ideal) recommendations are practicable for the practitioners. We see the contours of a persistent bureaucratical insistence that if everybody try harder, then we will finally stop it. At least, anecdotal evidence like the one related to the PHCO incident indicates that this strange complacency is a prevalent attitude at the higher levels of some bureaucratic and political chains of command. It is not regarded a controversial hypothesis to claim that this is more prevalent than unique, across both public and private domains.

It is not our intention to attribute this complacency to ignorance or "bad will". Rather, it is also a mirage of our own, and societies' at large, expectations of public agencies and large corporations of always being "in control".

Nevertheless, there is reason to believe that a practicable "cyber resilience" concept would find its audience.

12.4 A Clear Mission and Rationale for Cyber Resilience?

The gap between the implied bureaucratic complacency and the potential of the resilient concept seems to be wide. At best, the former can be interpreted as a persistent belief in resilience as an "umbrella" concept (Fig. 12.1) in which coping with the unexpected will be a "gift from the sky" or an accumulated learning effect, despite its lack of merit. That is hardly reassuring, considering the obvious prospect of immediate future, novel, and escalating attacks.

At the less formal cybersecurity professional level, however, the tone has been shifting for quite a while, along with the vanishing belief in the idea of perimeter defence based on the sharp distinction between a chaotic outside and the controlled inside. The acknowledgement of the impossibility of having full oversight of the inventory of complicated systems, that attacks and intrusions cannot be avoided in practice, leads to the rather resigned conclusion that we will have to deal with and mitigate the incident/attack as it happens, and that the enemy within must be a constant presumption. Resting on mainly technological means, this is attempted countered by, e.g., the so-called multi-account and zero-trust architectures, and by using identity rather than physical location as the perimeter of defence. However, for some professionals, this is possibly more of an exciting challenge than an existential problem for the organisation, or for society. It is also worthwhile to notice that the impact of such measures is regularly framed as risk mitigation and management, but not in the "aggregated" sense.

The Solorigate incident is of unprecedented magnitude, but we suspect it is likely that much of the attention will be directed toward the technological Achilles' heels, such as third parties and software supply chains, and to the a cascade effect traced back to the usual suspect—a human error in the form of a weak password due (Gizmodo, 2021). The implication of new and advanced architectures is that the responsibility for security is moved to application developers, and to the individual users ("everybody are responsible" is a common mantra). But technological fixes of past problems and system hardening along with scapegoating and bureaucratic reinforcements are ridiculously unlikely to be sufficient to prevent future incidents. Related to Solorigate, the famous cybersecurity expert Mikko Hypponen says that "it will definitely happen again" (Dagens Næringsliv (Norway), 2021).

We can, therefore, still conceive a residual space for a more developed understanding of cyber resilience to make a substantial difference, but on different grounds. The question remains, however—What are the human and organisational skills and operational patterns, including the mastery of the complicated technology, that may contribute to "the intrinsic ability to adjust. . . ." in the cyber domain? How are these skills assembled, organised, and put into operation as a resiliently functional whole, with a realistic chance of success, without the potential damage from overconfidence in resilience strategies?

The reorientation of the cybersecurity professional towards incident management resembles a resilience-informed approach, but it remains to be clarified whether these reorientations are just resilient in appearance, or also in practice. Some sort of resilience vocabulary has also been taken into use, e.g., in industrial process control contexts (NIST, 2019), but a critical reading suggests that these are to a large extent about relabelling of existing practices and recommendations, reinforced with analyses of systems and applications oriented at Advanced Persistent Threats (APT). Hence, they seem motivated by and seeking to implement the recovery part of the resilience curve presented in Fig. 12.1, and in a rather instrumental manner. In much of the same vein, a major player like Microsoft also employs the term "organisational resilience" to label its recommended line of actions in response to Solorigate, but these actions (Microsoft, 2021) are mainly about mitigations, and other recommended best practices related to protecting devices and servers, cloud infrastructures, and Microsoft 365 from on-premises attacks. Introduction of brand-new technical architectures can, with goodwill, be acknowledged as singular acts of resilience, but it is harder to attribute them to any persistent, Hollnagelian "intrinsic ability".

There is a huge leap from these approaches to the more situated investigations conducted by the "SNAFU catchers" consortium (Woods, 2017), addressing software engineering complexity related to Internet facing business platforms. Although the latter was not addressing security incidents specifically, the complexities of the incidents they unwrapped to a certain extent cancel the divide between intentional and nonintentional disturbances. These investigations rely heavily on participants' competence as well as outstanding process guidance, but they nevertheless demonstrate a real potential of employing resilience thinking in the cyber domain.

We, therefore, conclude that the time is more than ripe for a viable cyber resilience concept, with practical relevance and with sound theoretical grounding. There is no obvious path to such a practicable cyber resilience that is distinctive from prevalent cybersecurity practices, that is, not just in name only. However, we may return to what we earlier denoted a restrained and focused resilience perspective to make some strategic choices of direction. The crucial questions are for what purpose, how, and on what terms, cyber resilience can be operationalised (that is, contextualised), and what are the potential victims of overconfidence in a cyber resilience concept.

12.4.1 Scope and Purpose for Cyber Resilience in Critical Infrastructures

The security of critical infrastructures is arguably one of the key domains priorities when it comes to addressing digital vulnerabilities. These are fundamental prerequisites for the functioning of modern societies. IT in the broad sense has by now become the "infrastructure of infrastructures", making other critical infrastructures such as energy distribution and water supply cyber-physical systems. Digital transformation of critical infrastructures involves the introduction of information technology (IT) in existing operational technologies (OT), most notably the industrial control systems that perform key functions for the reliability and control of critical infrastructures. Importantly, the digital transformation of critical infrastructures means that IT and OT are not separate domains—they are increasingly fused together. Hence there is a need to not only distinguish between, but also integrate IT and OT, emancipating from a sheer IT security focus. Hence, with a combined IT/OT perspective, a resilience curve for cybersecurity of a combined IT/OT system should be a foundational scope and purpose. The challenge of this integration is huge, as architectural changes applicable in a sheer IT context are often hard to migrate into OT.

Next, the attention should also be directed at the critical function, e.g., energy supply, that is reliant on the proper functioning of the IT/OT cyber system. Hence, cyber resilience should also be targeted at a resilience curve of the critical, cyber-reliant function or service, catering for the effect of unavoidable cyber disturbances.

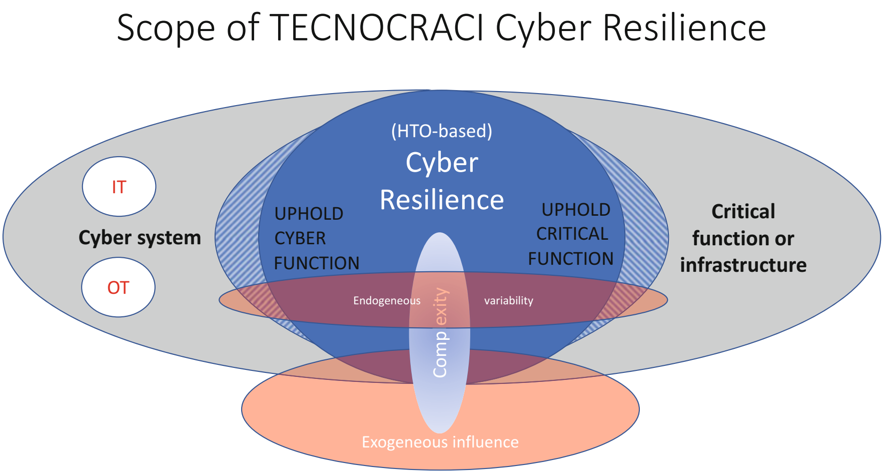

Fig. 12.2 Cyber resilience: scope and purpose

The need for this combined focus is justified by the fact that cyber technologies constantly enable and enforce changing work practices and objectives, on a combination of new and legacy technologies. IT is not just a tool that boosts performance of a work process detached from the technology itself, technology and work are deeply ingrained, and in never-ending change, although not continuously. This entanglement of technological progress and evolution of work processes is the core of successful digital transformation, not as a step but as a process, and the scope of cyber resilience should aim at the same point.

Figure 12.2 below illustrates the multiple purpose of cyber resilience. The figure signifies that a Human–Technology–Organisation (HTO) socio-technical perspective is employed, with attention to endogenous variability in the cyber-resilient system as well as exogeneous influence (including hostile activities). It also accommodates complexity theory, not as categorical description, or a straitjacket, but signifying a persistent and dedicated interest to look behind and challenge predominant and traditional interpretations of group and organisational dynamics, especially when organisations and teams are at or near their functional breaking points. By acknowledging the significance of organisational dynamics and potential breakdown, we resist the temptation of seeing the "organisation" as just a passive scenery for individuals using technology.

12.4.2 Operationalisation by Contextualisation

Cyber resilience operationalisations should enable mobilisation of the organisation that depends on the cyber system to be a source for the adaptive properties that are needed to deal with expected as well as unexpected disturbances, including fundamental surprise.

The prospect of a purely technological resilience falls on its own ground, and not even the most distant fantasies of artificial intelligence can challenge the human factor in the positive sense (Antonsen, n.d.). Weick and Sutcliffe (Weick & Sutcliffe, 2017) argue that *"reliable out-comes require the capability to sense the unexpected in a stable manner and yet deal with the unexpected in a variable manner"*. This still applies, and especially for the latter, human experience and ingenuity have an edge.

Flawed attribution, and relabelling of existing practices, may be tempting, but it will, in the long run, be more rewarding to use the occasion of exploring cyber resilience to shed new light on the rudiments of resilience that exists in the shadows of existing compliance-based paradigms (Grøtan, 2015), to employ new ways of understanding systems and organisations to nurture and develop these rudiments, and thus bid farewell to dysfunctional bureaucratic legacies from pre-cyber times.

Through a more developed concept of cyber resilience, organisations operating critical infrastructures may thus prepare for a situation in which IT/OT is a lifeline of socio-technical practices upholding critical functions that are constantly at stake and may be lost or jeopardised, while the accountability for the resilient socio-technical performance is lifted to an organisational and managerial level.

Moreover, we must keep in mind that improvisation is an inextricable part of resilient performance, for good and for bad (Grøtan et al., 2008), and that the extent and boundaries of improvisation are an organisational and managerial, not an individual responsibility.

Based on this, we may discriminate between three distinct types of operationalisation of cyber resilience, denoted "Theory A", "Theory B", and "Theory C", as indicated in Fig. 12.3, which in turn may be used as point of departure for contextualisation work.

- Theory **A**: resilience as intrinsic part of the function (curve). E.g., a redundant or fault-tolerant OT system, or a system with a feedback control loop that balances gain and performance within a defined envelope of variability and resources.
- Theory **B**: Resilience as a repository of organised, supportive resources designated to uphold a specific curve through phase-oriented contingencies, corresponding to resilience as an umbrella concept (Fig. 12.1).
- Theory **C**: Resilience as underlying principles and conditions for sustained resilient capabilities, drawing on a finite base of resources, dealing with complexity, emergence, and brittleness. In other words, being poised to adapt—without a blueprint.

A key difference between Theory B and C will be that while the former facilitates a pre-allocation and prioritisation of resources due to contingency planning, the latter is oriented towards a more general, but also more finite set of resources, priorities, and policies that may not be aligned with the need for maintaining resilient capabilities, and thus must be challenged at their boundaries, often under unforeseeable circumstances.

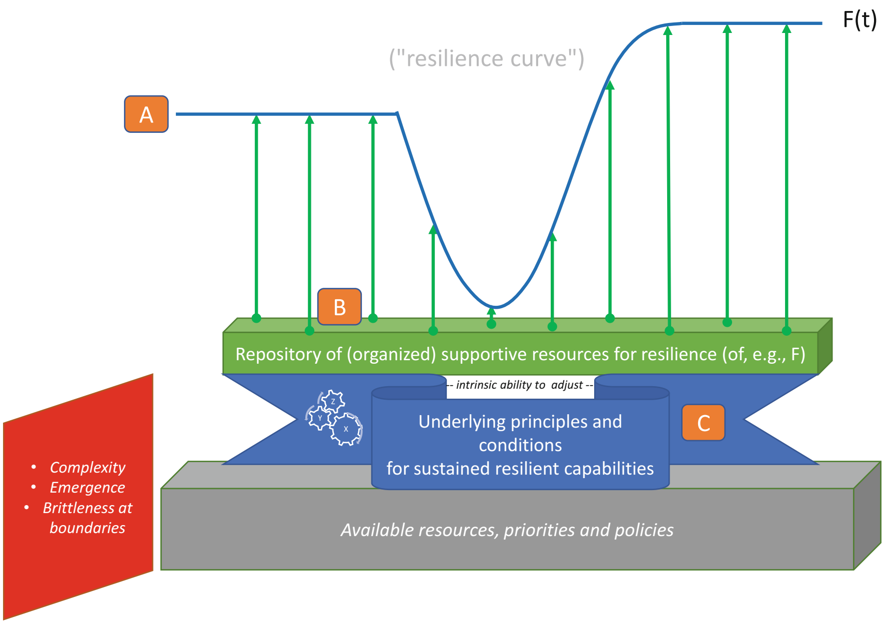

Fig. 12.3 Cyber resilience—three theories for operationalisation

Put differently, Theory B signifies the utilisation of predefined or "templated" contingencies directly oriented towards different phases of the "curve", while Theory C is a more generic expression of being "poised to adapt", meaning that the adaptive capacity per se—rather than the actual adaptive responses—is dynamic, mutable, brittle, and constantly at stake.

The theories related to Resilience Engineering of Hollnagel and Woods (Woods, 2015, 2016, 2018a, 2018b, 2019; Pariès et al., 2011; Hollnagel, 2021) are intuitively (but not unequivocally) corresponding to Theory C, because they address an underlying adaptive ability that is not directly connected to specific events. Woods' 4 concepts of resilience, "rebound", robustness", "graceful extensibility", and "sustained adaptability" (Woods, 2015, 2018a, 2018b), are of special interest, as their development also reveals an abductive process in which Woods' conceptualisations are modified according to empirical and reflexive work, inspiring the distinction between Theory B and C (Woods, 2019).

Regarding contextualisation, it goes without saying that Theory C will be more challenging than Theory A and B.

12.4.3 Holistic Consideration of Vulnerabilities and Care for Potential "Victims"

There must be a constant attention to the possibility of somebody paying the price for other's ambitions of resilience, as this is an imminent possibility even for the most modest resilience objective.

This concern is also embedded in the double objective of a resilient critical infrastructure and the resilience (enhanced cybersecurity) of its underlying cyber system (Fig. 12.2). A resilient approach to cybersecurity may be narrowly defined by its resistance to disturbance or ability to recover, but what are the implication for, e.g., implementing resilience of energy supply, and who absorbs the accumulated risk for uncertainty about stolen data?

The reorientation of the cybersecurity professional related to incident management rather than perimeter defence is a promising arena to look for rudimentary resilience, but beyond the obvious cognitive dissonance with the bureaucratical imperative and strange complacency, it must be asked whether it is ok for, e.g., a private or public critical infrastructure operator to be the battleground between "black hats" and "white hats"—cyber "magicians" unified in terms of hacking skills, separated only by ethical and moral orientations, as in a "Harry Potter" type of universe. Moreover, is this ok for society, and who will pay the penalty if the attempted "resilience" fails, or is insufficient, and shuffles the risk to others? Obviously, the very definition of critical infrastructure means that the societal costs and consequences for infrastructure failures are likely to go far beyond the limits of the infrastructure organisation (if this form of dependence did not exist, the infrastructure would not be critical in the first place). This, in turn, means that an understanding of cyber resilience in critical infrastructure sectors will need to include an internalisation of externalities—the possible societal costs and consequences that can be associated with ripple or cascade effects.

Bochman (2018) argue that we are at the "end of cybersecurity" in the sense that standard cyber hygiene approaches are insufficient for dealing with advanced cyber-attacks towards the energy systems. We should therefore refrain from taking the most advanced cyber solutions into use, due to the uncertainty involved. Rather than trying to prove Bochman wrong, a concept of cyber resilience should be a sensitising device in the search for a balance between realistic ambitions of adaptive capacity, and technological and operational risks and uncertainties, and thus contributing to identifying a responsible speed of digital transformation.

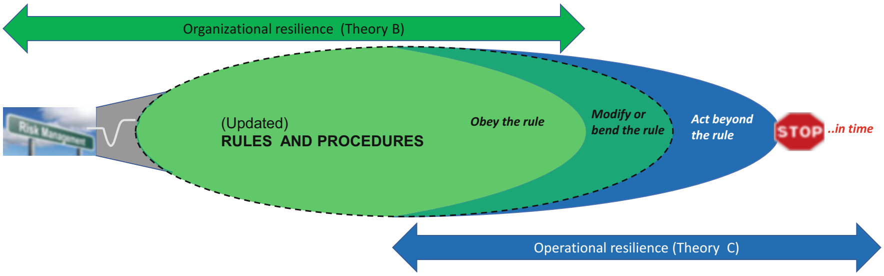

Fig. 12.4 Organisational vs operational cyber resilience

12.4.4 A Tentative Direction; Organisational and Operational Cyber Resilience

It goes without saying that there will not be any "one-size-fits-all" cyber resilience. It is likely that at the end of the day, each organisation will have to find its own composite of Theory A, B, and C contributions.

From an organisational point of view, however, it is quite clear that at least Theory B and C should be combined. As shown in Fig. 12.4, this combination encompasses organisational and operational resilience, founded on Theory B and C, respectively.

In a strict sense, the *organisational resilience* (Theory B) in Fig. 12.4 is limited to what analysts and managers engaged in risk management can anticipate, deduce, and operationalise based on existing knowledge, past experience, and external input, in order to uphold the resilience curve in different phases. This might include a mandate to "bend" the procedures in response to imagined situations. But this will inherently be limited by its "work as imagined" bias. At some point, practitioners at the sharp end will have to deal with situations that exceed organisational imagination, and the organisation will have to be generative; that is, act abductively—beyond the rule. In these situations, when even bended rules are no longer applicable, the "work as done" experience at the sharp end will be a prime repository for novel action, but also for stopping in time, before the attempted "resilience" gets out of hand. This will inevitably require the presence of a Theory C capacity, but also signifies a need for a dedicated governance capacity.

This *combination* of Theory B and C may form the ultimate "organisational" cyber resilience that we must aim for. In achieving this, middle management will have a crucial bridging function. This function will benefit from training that combines managerial and operational pragmatics, as facilitated by the Training for Operational Resilience Capabilities (TORC) approach (Grøtan, 2020).

12.5 Conclusion

The above approach is a point of departure for research aiming to achieve empirically grounded, theoretical advances that are relevant as actionable knowledge. This means that they should be as tangible as possible, yet conceptually strong. Critical infrastructures, e.g., electrical energy supply, water supply infrastructure, and off-shore petroleum industry are well-suited cases for this approach. These are cases of systems that will have their fair share of disturbances, while they are too important to fail. They are also cases of systems where their reliable and safe operation is dependent on cyber functions (the double objectives described in Fig. 12.2), and that are thus are vulnerable towards both intentional and unintentional malfunction or disturbance.

Cases within critical infrastructures are often sufficiently similar to enable the creation of common ground in terms of, e.g., combination of organisational and operational resilience (Fig. 12.4) and joint methods for empirical work and scenario design. At the same time, they are sufficiently different to visualise the contextual dependencies. For instance, the three critical infrastructures mentioned (electricity, water, and petroleum) vary in their traditions for balancing safety with security perspectives, while also being at different maturity levels on both issues. Such case studies are currently being carried out, but the need for empirical grounding of cyber resilience stretches far beyond the already ongoing initiatives.

As resilience thinking is not very aligned with prevalent safety and security organisation principles, the identification of the proper audience for the reception of theoretical advances and related actionable knowledge is an intrinsic part of the research process. Researchers or entrepreneurs looking for "proof-of-concept" derived solely from high-end organisations or systems with abundance of resources are not the primary audience. There is a need for empirical research in more "normal", or "mediocre" organisations struggling with the expectations and impacts of digital transformation in critical infrastructures. Theoretical advances of cyber resilience will not have significant impact in the real world unless it is recognisable and actionable for a majority of organisations concerned. However, resilience as a concept addresses non-trivial, demanding, and complex situations, and neither theoretical nor practical developments are likely to be able to offer quick fixes or easy ways out of these.

The resilience concept is in many ways still in its infancy, and its application in the cyber domain is far from straightforward. To explore the issues described in this chapter, there is, therefore, a pressing need for abductive research, implying substantial emphasis on stepwise, reflexive theoretical advances together with relevant empirical grounding. Empirical research should offer a basis on which to build theoretical conceptualisations while at the same time carrying a potential for application and probing at each step.

Such an approach will involve and challenge scientific domains that are not overly primed on the foundations for resilience thinking. Kilskar (2020) finds that the use of socio-technical perspectives in the field of cybersecurity practices is still in its infancy, and that there is scarce connect between cybersecurity and digital transformation as fields of study. Moreover, the resilience literature is rather scarce on addressing managerial accountability (Grøtan, 2020), and there is a persistently wide gap between systems-oriented models of adaptive capacities, and organisational science as an authoritative or significant voice.

Nevertheless, the cornerstones of future theory development should be a socio-technical perspective on situated practice and knowledge, attention to governance and managerial accountability for the risks conveyed by resilience as an invitation to novel and thus fallible practice, and a sensitivity to technocultural aspects related to generic IT and operational technology (OT) as these are expected to be constantly blended in new ways. By offering strategies for addressing cyber resilience as an empirical, but also theory-building field of study, we hope to preclude that cyber resilience ends up as an instance of "resilience as imagined", due to uncritical assumptions and decontextualised descriptions.

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Chapter 13
How Can Digital Learning Tools be Used to Promote Resilience in Healthcare?

Eline Ree and Cecilie Haraldseid-Driftland

Abstract Technology impacts almost every aspect of our lives and has become an important part of healthcare services. The most important reason for introducing technological advancements in healthcare is to enhance or maintain the high quality of care. Digital learning tools (e.g. digital guides, webinars, and dialogue forums) have the potential to increase flexibility and adaptability in healthcare which are important features of resilience in healthcare. In the current chapter, we discuss how digital learning tools can be used to promote resilience in healthcare by using examples from two research projects; one in which a digital guide to support managers in their quality improvement work is designed, tested, and evaluated (the SAFE-LEAD project), and one aiming to develop future digital learning tools for collaborative learning to facilitate resilience in healthcare (the Resilience in Healthcare project). We argue that for digital learning tools to have the potential to promote resilience in healthcare, they should stimulate individual and collective reflections and discussions. Furthermore, the tools must be found relevant by the target audience and have the capacity to create collaborative learning and reflections between relevant stakeholders within and outside healthcare organisations, about current quality and safety practice, challenges and needs for adaptations and improvement efforts. By stimulating collaborative learning, reflections, and adaptive capacity, digital learning tools have the potential to promote resilience in healthcare, and thereby increasing healthcare quality.

Keywords Resilience in healthcare · Digital tools · Technology · Healthcare services · Collaborative learning · Adaptive capacity · Reflexive spaces

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13.1 Introduction

Technological advancements have impacted almost every aspect of our lives. Healthcare provision is no exception. Technology is used to advance the field of healthcare in a range of different aspects. Professionals now have easy access to a waste amount of data such as medical records, drug information and research studies from the palm of their hand through tablets and smartphones. Frail older people can get instant assistance if needed, using motion sensors and fall detectors. Three-dimensional printers can be used to make artificial joints, and virtual reality technology can give healthcare personnel the opportunity to practice real-life scenarios without the risk of patient harm. Technology is introduced for a range of reasons, among them to ease access to information, save money, ease workflow between different stakeholders such as patients and healthcare personnel or enable and create flexibility. But most importantly, the aim of introducing technology is to enhance the quality of the healthcare services that are provided. Healthcare provision is a complex system with a range of different stakeholders who are in constant need of adapting to the everchanging circumstances (Wiig et al., 2020b). Technology and different digital solutions have the potential to increase flexibility and adaptability in healthcare, and thereby promoting resilience and high quality of healthcare services. Exploring how technology can be used to achieve this aim is therefore of importance.

13.2 Resilience in Healthcare

The concept of and research on resilience in healthcare emerged as a response to the steady rates of patient harm in hospitalised patients, which, despite an increased focus on patient safety and quality in healthcare, remained at 10% internationally (Jha et al., 2010; Panagioti et al., 2019; WHO, 2008). The traditional approach to patient safety, solely focusing on the "find and fix" methods to reduce errors and adverse events, seems to be insufficient to obtain high-quality care (Hollnagel et al., 2015). The main contrast between existing research on healthcare quality and resilience in healthcare is the shift from exploring failures to focusing on learning from how healthcare services manage to maintain high-quality care under variable situations (Hollnagel et al., 2006, 2015; Wiig et al., 2020b). The concept of resilience is used in several fields and research traditions such as resilience engineering, ecology, psychology, and healthcare. Within the safety research, resilience engineering has been advocated as a new safety management paradigm with new ways of understanding work processes in complex adaptive socio-technical systems (Righi et al., 2015). There are several definitions of resilience, but all of them include aspects of coping with complexity and adapting to changes, and systems ability to "bounce back" to normal state or to improve after disruptions and stressful events (Righi et al., 2015; Wiig et al., 2020b). These conceptualisations of resilience have been widely used in healthcare. A common definition of healthcare resilience is *"a health care system's ability to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required performance under both expected and unexpected conditions"* (Hollnagel et al., 2013). In this chapter, however, we will use the definition proposed in a recent debate paper from the international Resilience in Healthcare research program, which defines resilience in healthcare as *"the capacity to adapt to challenges and changes at different system levels, to maintain high quality care."* (Wiig et al., 2020b).

Healthcare provision is largely a collaborative effort between a range of different stakeholders. Stakeholders in healthcare could be defined as any person, group or organisation who provides, receives, manages, regulates, or pays for healthcare. Examples are patients, next of kin, healthcare professionals, managers, regulatory bodies, non-governmental organisations, municipalities, and regulators (Aase et al., 2020). Due to the high number of different stakeholders who are involved in any given healthcare provision activity (e.g., admission, handover, discharge, recovery, rehabilitation), the healthcare systems have a complex nature with multiple interactions. This results in a significant degree of performance variability, both within and across system levels. Resilient healthcare is underpinned by the premise that it is the system and the stakeholders within this system and their capacity to adapt to the constant challenges and changes around them which enable the system to maintain quality care (Sutcliffe & Vogus, 2003). Adaptive capacities include making use of both internal resources such as sensemaking and previous experiences, as well as external resources such as colleagues and networks (Sutcliffe & Vogus, 2003). A previous literature review from other sectors than healthcare shows the importance of these adaptive capacities and the ability to create flexibility, adjustments, improvisation, adaptation and responding to variability (Righi et al., 2015). The review also illustrates the lack of implementation studies exploring how interventions can best be designed to promote resilience (Righi et al., 2015). This is also supported by a review from the resilience in the healthcare field (Ellis et al., 2019). Thus, there is a need for more studies exploring how interventions might promote resilience in healthcare, and we argue that digital learning tools are examples of such interventions. In this chapter, the term digital learning tool is defined as all learning tools that provide learning material through a technological device, such as digital guides, webinars, and dialogue forums. Thus, the aim of this chapter is to explore and discuss how digital learning tools, with their inherent properties to accommodate qualities such as flexibility and adaptation, can be designed and used to support resilience in healthcare.

13.2.1 The Link Between Resilience, Collaborative Learning, and Digital Learning Tools

Learning is a cornerstone of resilience in healthcare since individuals and organisations need to learn to be able to adapt (Hollnagel et al., 2013). Learning is such a key ingredient to maintain healthcare quality (Wiig et al., 2020b). Individuals and organisations ability to adapt to change is acquired and learned as a direct consequence of the activities and interactions healthcare professionals are a part of (Billett, 2016). This means that the stakeholders within the healthcare systems learn how to behave, change, and adapt to the system they are working within through their work. More specifically, healthcare personnel's and other stakeholders' ability to adapt is a result of their collaborative learning activities, since nearly all activities they engage in is a collaborative task between multiple stakeholders (Billett, 2016).

Digital learning tools such as simulation-based activities, gaming, video-based role play, webinars, dialogue forums, and digital guides are currently used in a range of healthcare practices to support the development of individual and collaborative learning processes (Aase et al., 2020). Within healthcare, there are examples of how specialised care teams are video recorded in action and shared with entire health care teams in order to discuss, reflect and learn from real case studies (Ajjawi et al., 2020; Mesman et al., 2019; Noble et al., 2019). While little is known about which learning approaches and tools that best can support resilience in healthcare, we know that healthcare provision is a highly collaborative task and that most people today both favour and need technology due to its availability. If resilience in healthcare is depended on stakeholders' adaptive capacities related to flexibility, adjustments, improvisation, adaptation and responding to variability, as found in other studies (Righi et al., 2015), digital learning tools could be designed to accommodate such needs. Digital learning tools, therefore, hold untapped potential for advancing the field of resilience in healthcare.

13.3 Using Digital Learning Tools to Promote Healthcare Resilience: Examples from Two Research Projects

In the following, we will present two different projects that we will draw on in this chapter. One where a collaborative digital learning tool was designed, tested, and evaluated to enhance healthcare quality: The SAFE-LEAD project. The other project aims to develop future digital learning tools for collaborative learning experiences, designed to enhance resilience in healthcare: The Resilience in Healthcare (RiH) project. We will use these projects to illustrate how digital learning tools can be used to promote resilience in healthcare and discuss which features these tools should encompass to do so.

13.3.1 The SAFE-LEAD Project

The aim of the project "Improving Quality and Safety in Primary Care—Implementing a Leadership Intervention in Nursing Homes and Homecare" (the SAFE-LEAD project) was to develop, implement and evaluate an intervention to support managers in nursing homes and homecare services in their quality improvement work (Johannessen et al., 2019; Wiig et al., 2018). The main ingredient in the intervention was the SAFE-LEAD leadership guide which is a research-based dialogical tool for healthcare managers, where the overall aim is to build leadership competence in quality and safety among managers by supporting them in their quality improvement work. The project used a mixed-methods design, consisting of individual semi-structured interviews and focus group interviews of managers and healthcare personnel before, during and after implementation of the intervention, as well as a pre-post intervention survey and field notes from observation during the intervention.

13.3.1.1 The SAFE-LEAD Leadership Guide

The leadership guide was first developed for managers in the hospital setting, based on comprehensive research in five European hospitals in the Quaser project (Andersen et al., 2019). In the SAFE-LEAD project, the guide was translated, further developed, and adjusted to fit the Norwegian nursing home and home care setting (Johannessen et al., 2019; Wiig et al., 2018). This adaptation process included several collaborative workshops with co-researchers in the project (nurse counsellors from the development centres for nursing homes and home care services, next-of-kin representative) and healthcare managers (Johannessen et al., 2019).

The guide presents seven quality challenges that managers often meet in their quality improvement work; structure, culture, competence, engagement, physical design/technology, coordination/organisational politics, and external demands (Fig. 13.1), based on the Organising for Quality model (Bate et al., 2008) and results from the Quaser project (Andersen et al., 2019) adjusted to the Norwegian nursing home and home care setting (Johannessen et al., 2019). The user or patient is placed at the centre of the challenges to illustrate that the patients/users are always at the centre of all quality improvement work.

The guide is structured in a three-step process (Fig. 13.2) where the managers start by rating themselves on the seven quality challenges and then decide what they need to work on (Step 1). The guide suggests goals for each quality challenge, as well as the opportunity for the managers to create their own goals. Examples of goals are "involve patients/users/next-of-kin in quality improvement" (care coordination/organisational politics), "create reflection about the current quality improvement work" (culture), and "systematic learning of adverse events and follow-up of patients and staff after incidents" (competence). In Step 2, the managers discuss and agree upon which goals related to the selected quality challenge(s) they wish to focus

Fig. 13.1 The seven quality improvement challenges (Johannessen et al., 2019)

on. In the final Step 3, the managers make concrete action plans for quality improvement to address each of the goals selected in the previous step. The action plans include interventions/measures, responsible person(s), deadline, resources, expected changes, and a concrete plan for evaluation.

The tool was originally offered as a paper booklet, but in the SAFE-LEAD project, the researchers also developed a digital version of the guide. Results from the evaluation showed that the managers preferred and mostly used the web version (Ree et al., 2020). The digital version of the guide was developed in collaboration with NETTOP-UiS, which is a department of development of digital learning resources at the University of Stavanger (see Box 13.1).

13.3.1.2 The SAFE-LEAD Intervention

From April 2018 to March 2019, the leadership guide was implemented in four Norwegian nursing homes and four home care services. All units participated for six months (Stage 1), while four units (two nursing homes and two home care services) participated for 12 months (Stage 2). The intervention consisted of workshops facilitated by researchers in the project, where the management teams worked on

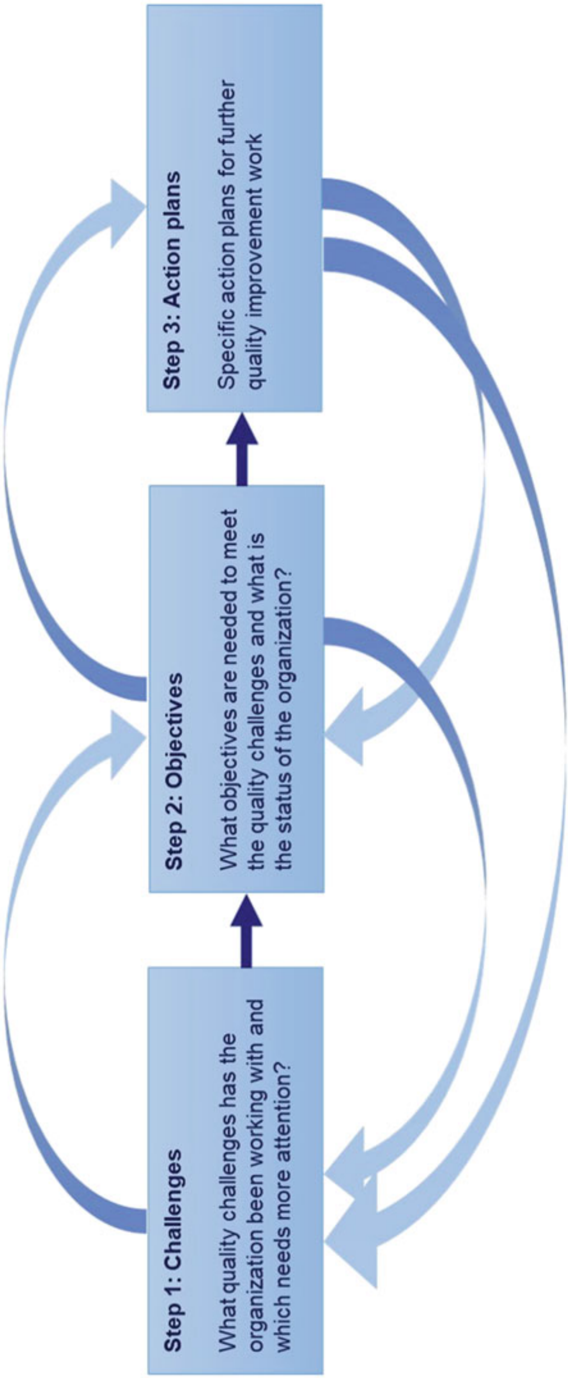

Fig. 13.2 The three-step process in the SAFE-LEAD guide (Johannessen et al., 2019)

the SAFE-LEAD guide. In addition to the digital version of the guide, the managers also had access to e-learning material such as videos demonstrating how to work through the different steps in the guide and studio lectures to support the implementation of the guide. Four workshops were conducted in Stage 1, while participants in Stage 2 received additionally two workshops, as well as more follow-up from the researchers through site visits and discussions (Johannessen et al., 2019).

Box 13.1 NETTOP: The Department for Development of Digital Learning Resources at the University of Stavanger

NETTOP is an independent department at the University of Stavanger with expertise in methods and development of digital learning content and online education, working both internally at UiS and for external clients. Most employees at NETTOP have worked on development of e-learning solutions in higher education for more than 20 years. The department has competence in the following areas: online didactics and concept development, media science, journalism, text and manuscript, video production, illustration, web and graphic design, system development, technical development and programming, web publishing and digital content management, streaming video through Media site, project management, project applications nationally and EU, finance and reporting.

13.3.2 The Resilience in Healthcare (RiH) Project

The Resilience in Healthcare (RiH) project explores resilience as a multi-level phenomenon with collaborative learning and stakeholder involvement as vital prerequisite pillars (Aase et al., 2020; Wiig et al., 2020b). The aim of the overall project is to reform the understanding of quality in healthcare through the development, implementation, and testing of a theoretical and practical Resilience in the Healthcare framework. The RiH research project has a longitudinal collaborative, interactive design, which combines meta-analysis studies with cross-country comparisons from Australia, Japan, Netherlands, Switzerland, Norway, and the UK. One of the aims of the project is to develop digital learning tools to promote resilience in healthcare across levels and settings. Active stakeholder involvement and learning from previous projects are important activities within the RiH project, which is seen as vital in order to contribute to development of new digital learning tools.

The RiH project will make use of multiple data collection methods such as meta synthesis, literature reviews, focus group interviews, individual interviews, participatory design processes, researcher workshops, as well as engage in multi-site, cross-national and international studies in order to explore what constitutes quality in healthcare.

13.3.2.1 How Can Digital Learning Tools Promote Resilience in Healthcare? Learning from Previous Studies

To improve healthcare provision through the creation of digital learning tools, the researchers in the RiH project set out to learn from other researchers' experiences from various projects. Therefore, selected members of the SHARE-Center for Resilience in Healthcare at the University of Stavanger (See Box 13.2), in Norway where invited to contribute to a two-hour workshop to discuss how digital learning tools could be developed for various stakeholders and across different levels and settings in healthcare.

Box 13.2 The SHARE Center

The SHARE Center for Resilience in Healthcare at the University of Stavanger, in Norway, which run the RiH project, has 73 affiliated researchers. Their background ranges from nursing, occupational therapists, intensive care specialists, engineers, safety specialists, psychology, innovation, pre-hospital care, psychiatry, philosophy, and medicine. They have all contributed to over 50 different research projects over the recent years concerning issues such as management, patient safety, clinical effectiveness, learning, team training, technology, user involvement and quality care. The projects are located within a range of different setting such as homecare, nursing homes, hospital, education, and prehospital care. There has also been focus on a variety of different stakeholders such as patients, next of kin, manager, healthcare professionals, students, and regulators. While the projects in various degree focus on learning and resilience they all relate to healthcare and patient safety. In total these researchers therefore hold an existential amount of experience with quality and learning in the healthcare settings.

Thirteen researchers from SHARE contributed to the workshop. In addition, two technology experts from NETTOP-UiS with experience from journalism, TV productions and extensive knowledge concerning the development of digital learning tools participated (see Box 13.1).

During the workshop, the participant first joined a 45-min interactive lecture where the two technology experts from NETTOP showed different digital learning tools they had worked on, explained which different elements such tools could be composed of and what to keep in mind when developing different tools, based on their experience. In the second half, the participants were split into groups of three and four and asked to discuss the following questions: (1) How can digital learning tools contribute to the capacity to adapt? (2) What digital learning tools would you prefer and why? and (3) What possibilities/characteristics are most important that the digital learning tools entail?

13.3.2.2 The Opinions of the "Experts"

Through the discussion, the researchers clearly agreed on four different themes; "understanding of what resilient performance is," "make room for reflection," "easy access" "must be found relevant" and "package deal."

Understanding of what resilient performance is. The participants in the workshop pointed out that healthcare workers need an awareness towards what resilient performance entails across levels and settings. They need practical examples and training in recognising when and where it occurs. Describing resilience in terms like "being able to adapt to changes" and "anticipate, monitor, respond and learn" could lead to the response from healthcare workers, that "this is business as usual." Experiencing resilience as just "everyday" practice could result in the healthcare workers missing out on the important aspect of how focusing on resilience can contribute to high-quality care. The workshop participants, therefore, highlighted that creating digital learning tools should start by creating consciousness and understanding towards what resilience is. The digital learning tool should be able to help the stakeholders who participate in the learning experience to recognise what resilience performance is and how it can be displayed at different levels. Furthermore, the participants argued for the need to distinguish between positive and negative adaptations, how to recognise that a high degree of adaptations is not equal to resilience, and that resilience is not the opposite to checklists and control, but complimentary.

Make room for reflection. Room for reflection was another recurrent theme within the workshop groups. Several of the participants described how they had experienced from previous projects and own practice that individual and collective reflection is a powerful tool to learn and improve. Reflection holds the benefit that it could be done in a short amount of time and with limited equipment. In fact, the participants claimed that one of the most important aspects concerning reflection is to create space and the possibility to come together and meet with others to discuss, reflect, and learn. Physical or more mental "checklist" concerning how to structure a reflection was also mentioned by the participants. It was believed that this could be the digital learning tool that healthcare professionals needed to create a room for reflection during a busy work schedule.

Easy access. A key aspect to remember regarding digital learning tools in the healthcare services is that it needs to be easily accessible. It was also of importance that the digital learning tool should support the development of adaptive capacities across system levels and settings. The concerns here are the multiple physical and technological barriers that exist throughout the healthcare system. Numerous legislations concerning sensitive information, firewalls within the different systems, as well as physical distance and variation in access to equipment, often create challenges when trying to introduce digitals learning tools within the healthcare setting. The technology could help ease some of these challenges by eliminating the element of physical distance, making it easily accessible through tablets and smartphones. On the other hand, the participants claimed that both technological competence and access to equipment are aspects that needs to be tackled.

Must be found relevant. One of the most emphasised themes throughout the workshop was that all participating stakeholders must find the digital learning tool relevant. Relevance could, for example, be in terms of contributing to relevant learning experiences, and connect people within and outside the healthcare organisation, creating reflexive spaces to reflect upon and discuss quality and safety issues collectively. If not relevant, the struggle of getting anything implemented would be overwhelming, they argued. Due to time restrictions, busy schedules, simultaneous tasks, and cross-pressure, the stakeholders within a healthcare setting are particularly challenging to include in new tasks. It was emphasised that there is usually not a problem with lack of will and enthusiasm, but the work pressure is too high. As with other types of technology and new tools, the tool must be experienced as helpful and relevant for the users to spend time and effort integrating it into their practices.

Package deal. Finally, the workshop participants discussed which different tools to include and how they best could be designed. In this respect, the participants agreed that the most important thing was that while there could be numerous elements to the digital learning tool and different learning experiences, everything should be a part of a "package deal." This means that every part could be used separately while also being a part of a larger package. The "package" should contain different elements that could be used by different stakeholders in different settings depending on the local needs. The main point here was that the stakeholders would not need to access multiple different platforms but could access everything they needed in one place. This also creates the added effect that they could discover something new while looking for something else.

13.3.2.3 The Opinions of Healthcare Managers: An Example from Practice

The SAFE-LEAD leadership guide is a practical example of how digital learning tools can be used to promote resilience in healthcare. Results from the evaluation of the SAFE-LEAD guide show that the guide served as an arena and reflexive space for quality improvement, where the management teams met and reflected together on quality and safety issues in their organisation, and what adaptations and adjustments were needed (Johannessen et al., 2021; Ree et al., 2020; Wiig et al., 2020a). The guide stimulated managers' collaborative reflections and learning and raised awareness about quality challenges within the nursing homes and home care organisations. Wiig et al. (2020a) define reflexive spaces as *"physical or virtual platforms in which reflexive dialogical practice occurs between people."* The reflexive dialogical practice connects tacit and explicit knowledge and is therefore key in all learning processes. Reflexive spaces are forums that bring people such as managers, health care professionals, regulators, and other relevant actors and stakeholders within and outside the healthcare organisations together to reflect upon current practice, challenges, adaptations, and improvement needs (Wiig et al., 2020a).

Some of the management teams in the SAFE-LEAD intervention included professional development nurses in the workshops and improvement processes using the guide. The managers experienced that the professional development nurse was an important bridge between the management team and the front-line healthcare staff and brought important nuances and perspectives to the discussions and team reflections (Ree et al., 2020). As shown above, one of the goals listed in the "culture" quality challenge in the guide was to "create reflection about current quality improvement work." The management team in one of the home care services in the project chose to include the healthcare staff when working on this goal, resulting in collaborative learning by use of the digital SAFE-LEAD guide. In the workshop, they discussed and reflected upon current practice, challenges, and adaptations needed to further improve healthcare quality in their organisation (Ree et al., 2021). The managers listed the following bullet points for discussions in the workshop: "what have worked well, and why?" and "what can be better, and how?" The workshop resulted in a concrete action plan made in collaboration between the managers and healthcare staff on what they should do to improve and how to go about it (Ree et al., 2021). This is a concrete example of how a digital learning tool can contribute to focus on what works well in a healthcare organisation, which is in line with the resilience in healthcare research tradition. Thus, this is an example of how to work and design interventions to promote resilience in healthcare.

Although the SAFE-LEAD guide was offered in a paper version as well as a digital tool, the evaluation of the guide shows that the healthcare managers preferred the digital version (Ree et al., 2020). This was despite that the digital version needed several adjustments and improvements to increase its user interface. The managers suggested several add-ons and adjustments to be made to make the digital guide even better and to increase the likelihood of it being used in their daily quality improvement work (Ree et al., 2020).

13.4 Conclusion

In this chapter, we have provided examples through two research projects on how digital learning tools can be used to promote resilience in healthcare. In the Resilience in Healthcare project, researchers gave their opinions on which characteristics and features digital learning tools should encompass to be able to promote resilience in healthcare potentially. In the SAFE-LEAD project, we observed and interviewed nursing home and home care managers' experiences using a digital guide to support them in their quality improvement work. Similar findings across the two projects were that the digital learning tools should make room for reflection and that it must be found relevant. More specifically, the digital learning tool should stimulate individual and collective reflections and discussions between relevant stakeholders within and outside healthcare organisations, about current quality and safety practice, challenges and needs for adaptations and improvement efforts. By stimulating collaborative learning and adaptive capacity, digital tools have the potential to promote resilience in healthcare, and thereby increasing healthcare quality.

The combination of these two projects illustrates that digital learning tools are a key element of providing the access and room that is needed to create a reflection that, in turn can enhance resilience in healthcare. However, it is important to be aware those technological advancements such as digital learning tools are just meant to reach an end and might be useless without purposeful content and user interface. Thus, digital learning tools should always be designed and developed in collaboration with the users of the tools, which was done in the SAFE-LEAD project (Johannessen et al., 2019), and will also be done in the RiH project (Aase et al., 2020).

The next steps in our research projects are to develop further and optimise the digital SAFE-LEAD guide and test the effectiveness on different healthcare quality outcomes in a cluster randomised controlled trial in nursing homes and home care services. Furthermore, through multi-site, cross-national studies and long-term collaboration between national and international researchers and healthcare stakeholders, the Resilience in Healthcare project (RiH) will apply participatory design principles to develop and pilot test a set of digital learning tools to support collaborative learning and adaptive capacities. Examples are interactive guides, webinars, simulation scenarios, and e-dialogue forums, with the use of technology that enables the learning experience to be both accessible and provided in a package-deal while making sure the content has the potential to advance their adaptive capacities.

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Chapter 14
Resilience, Digital Tools, and Knowledge Management Systems in the Pandemic Era: The IHU Strasbourg Experience

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Abstract Disasters like the recent COVID-19 pandemic can benefit from the use of digital tools and Knowledge Management Systems (KMSs) to manage the emergency and improve the resilience of the system. Such KMSs must prove the quality of the system, service, situation, and knowledge which is gathered, transferred, and shared. However, KMSs must cope with the presence of knowledge barriers, which limit to manage data and information successfully. Our chapter wants to deepen such a topic through the analysis of the case study of a web application developed by the IHU Strasbourg, one research and clinical centre, to collect and share knowledge between the end-users (citizens) and healthcare institutions, decision-makers, and public entities during the COVID-19 pandemic. Our findings highlight the need to ensure that not only the KMS possesses the recommended quality standards, but that

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specific features are put in place to cope with the presence of knowledge barriers, and the need for speed in the information flows to enhance resilience.

Keywords COVID-19 · Resilience · Web Application · Disaster management · Knowledge

14.1 Introduction

The COVID-19, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (WHO, 2020a), was defined as a pandemic by the WHO Director-General on March 11th, 2020, given its cross-country and cross-continent spread (WHO, 2020b) and probably represents one of the recent biggest disasters followed by a health emergency. According to Dorasamy et al. (2013, p. 1834), a disaster is "a social crisis situation, a deadly event, usually unexpected and unanticipated and cause human suffering". The definition of disasters includes "significant outbreak of infectious disease, bioterrorist attack, and other significant or catastrophic events" (He & Liu, 2015, p. 178) and often are followed by public health emergencies. Zibulewsky recalls the definition given by the American College of Emergency Physicians, who outlines a disaster "when the destructive effects of natural or man-made forces overwhelm the ability of a given area or community to meet the demand for health care" (Zibulewsky, 2001, p. 144). Recent examples of public health emergencies encompass the outbreak of H1N1 influenza, the Ebola virus disease in Central Africa, the SARS (Severe Acute Respiratory Syndrome), the Marburg haemorrhagic fever, in addition to widespread dysentery, cholera, measles, encephalitis B, and other conditions after relevant disasters.

When a disaster happens, disaster resilience can be defined as the ability of individuals, communities, organisations, and states to adapt to and recover from hazards, shocks, or stresses without compromising long-term prospects of development (Hernantes et al., 2017). Knowledge management systems (KMSs) have proved to help effective disaster management (Dorasamy et al., 2013, 2017), increasing the ability of the entire system to support resilience (Barbisch & Koenig, 2006; Cobianchi et al., 2020a; Therrien et al., 2017).

This chapter has the aim of investigating the characteristics of a KMS in disaster management through the use of digital tools to improve the resilience of the system, employing the case of a platform developed by the Institut Hospitalo-Universitaire (IHU), a primary research and clinical centre located in Strasbourg, France (Cobianchi et al., 2020c).

14.2 Disaster Management, Resilience, and Knowledge Management Systems

Disasters occur suddenly and demand quick reactions, creating, at the same time, uncertainty and stress (Dorasamy et al., 2013). Healthcare systems periodically need to confront and manage crises, like the recent COVID-19 pandemic, the Severe Acute Respiratory Syndrome, H1N1, and Ebola, plus natural disasters, accidents of enormous intensity, and terroristic attacks, during which they are required to deal with exceptional situations without interrupting essential services to the population.

The ability to effectively accomplish this dual mandate is at the heart of resilience strategies, which means, for healthcare organisations, the need to develop surge capacity to manage a sudden influx of patients and people in need (Therrien et al., 2017), offering a timely response (AminShokravi & Heravi, 2020). The aims of activating surge capacity and, at the same time, maintaining other essential services require resilience, which can also be defined as "the capacity of a social system (e.g. an organisation, city, or society) to proactively adapt to and recover from disturbances that are perceived within the system to fall outside the range of normal and expected disturbances" (Boin et al., 2010, p. 9).

In this regard, surge capacity can be defined as "the ability to respond to a sudden increase in patient care demands" (Hick et al., 2008, p. S51), providing "a potential means to capture and coordinate the commonalities of pandemic and disaster planning needs in order to generate a model for health systems' readiness for and response to a wide range of scenarios" (Watson et al., 2013, p. 82), also involving the local communities, who are called to cooperate (Adini et al., 2017; Berawi, 2020). Barbisch and Koenig (2006) have defined the "four S's" of surge capacity: trained personnel (staff), supplies and equipment (stuff), beds' availability and specific areas in which to treat patients (structure), and policies and procedures (systems).

In particular, systems refer to organisational procedures and specific crisis management plans able to develop surge capacity development tools (Therrien et al., 2017). The literature has highlighted how there has been little research on how these relate to system surge capacity (Therrien et al., 2017; Watson et al., 2013) from a resilience perspective. Disaster management requires activities like "mitigation, risk reduction, prevention, preparedness, response and recovery" (Dorasamy et al., 2013, p. 1834).

Knowledge management can help when a disaster occurs, and a well-designed KMS can help in handling it. Lacks in KMSs may cause major issues in managing the emergency (Dorasamy et al., 2013) as well as delays in the transition and recovery phases (Blackman et al., 2017; Dorasamy et al., 2017). On the contrary, a well-designed system can contribute to increasing resilience by empowering the fourth "S" factor (Barbisch & Koenig, 2006).

According to the literature, a well-designed KMS for disaster management should gather a group of experts together (Abouei et al., 2019; Dorasamy et al., 2017), allowing an effective platform for sharing prior experience in disaster management, helping with a timely response (Berawi, 2020; Dorasamy et al., 2013). Experts' viewpoints can help to address disaster management issues (Dorasamy et al., 2013) as well as pre-allocate resources (Arora et al., 2010). Modern systems need to facilitate more “a robust and flexible creation, storage, sharing and ultimately dissemination of a disaster-related knowledge base” (Dorasamy et al., 2013, p. 1850). In this perspective, the literature suggests how such systems can profit from the avail of social networking ideas driven by web 2.0 architectures to provide a more vibrant and live use of KMSs in a disaster emergency (Berawi, 2020; Howe et al., 2011; Huang et al., 2010; Massaro et al., 2020). This includes the use of wikis, blogs (Linstone & Turoff, 2010), mobile apps, and big data analytics (Reuter & Spielhofer, 2017; Wang et al., 2020). The ideal KMS should facilitate both informational and knowledge requirements of different roles run by multiple institutions and decision-makers (Turoff et al., 2004), coordinating efforts and allowing the effective sharing of data of various kinds (Shaw et al., 2017).

A successful KMS model (Jennex & Olfman, 2006), which can be applied for emergencies in a resilience perspective according to Barbisch and Koenig’s “four S’s” of surge capacity framework (2006), has four critical success factors (Dorasamy et al., 2017). The first one is System Quality (SQ), and it can be defined as “how well the KMS performs the functions of knowledge creation, storage/retrieval, transfer, and application; how much of the knowledge is represented in the computerised portion of the OM (organisational memory); and the KM infrastructure” (Jennex & Olfman, 2006, p. 40). When applied to emergency management, the system must enhance its usability, availability, reliability, adaptability, and response time (Dorasamy et al., 2017). The second success factor is Knowledge Quality (KQ), which is about understanding which knowledge the KMS must capture and process. The third success factor is Service Quality, which allows the KMS to use and benefit from knowledge in the best possible way, ensuring accuracy, sufficiency, timeliness, relevance, usability, and comprehension of the possessed knowledge (Dorasamy et al., 2017). Last but not least, the KMS must ensure enough Situational Quality (SQ), which deals with the unique features of a certain situation that require various responses and attitude (Dorasamy et al., 2017).

In general terms, designing and implementing effective KMSs may be difficult because of the presence of knowledge barriers (Riege, 2005), which limit the effective sharing and capture of knowledge. The literature identifies potential individual barriers (e.g. the fear to share, the presence of various skills and competencies), organisational barriers (e.g. differences in aims, goals, and culture, shortage of appropriate infrastructure, . . .), and technology barriers (e.g. lack of integration of IT systems, reluctance to use IT tools, . . .) (Massaro et al., 2012; Riege, 2005). Given the importance of KMSs to support the management and recovery phase of emergencies, it is thus essential to understand how to develop a proper KMS, ensuring the presence of key features, and trying to overcome barriers.

14.3 Case Study

The case study (Yin, 2014) was employed in collaboration with the Institut Hospitalo-Universitaire (IHU) of Strasbourg, France, a primary research and clinical centre active in medical education as well as technological transfer, dedicated to Image-Guided Surgery (Cobianchi et al., 2020c; Garcia Vazquez et al., 2020). Data were gathered during the months of March, April, and May 2020, through various sources, like the project plan, the Slack project channel, and online interviews with several staff members, to ensure validity and data triangulation (Massaro et al., 2019). All results were verified with the project team and scientific chief, and principal investigator.

The COVID-19 pandemic has severely affected the healthcare sector (Cobianchi et al. 2020a, 2020b), and the decision-makers are struggling to find effective epidemiological tools and aggregate data to rely on (Xu & Kraemer, 2020). The IHU team decided to answer the call to reduce such a gap, through the creation of a web software tool. The crisis has forced healthcare professionals worldwide to shift from individual patient-centred care to more public health ethics (Angelos, 2020; Ferguson Bryan et al., 2020), to reach more population and give more comprehensive solutions. The aim is to maximise the outcomes for the general population (Dal Mas et al., 2019) through the use of an easy human-machine tool.

In the absence of pharmaceutical treatments such as vaccines or effective drugs, non-pharmaceutical intervention (NPI) like social distancing, home isolation of suspect cases, home quarantine of those living in the same household as suspect cases, and social distancing of the elderly and others at most risk of severe disease, enforced by Governments may be the only way to limit the spreading of the virus, which, without containment, accelerates quickly, like it has happened in China, Iran, Italy, the UK, Spain, and France (Massaro et al., 2021). The fast spreading (Ji et al., 2020) shows like health authorities are often informed in a delayed manner of the development of the epidemic and, in particular, only detect the spread of the virus at a late stage, especially the minor or moderate forms of the disease (Pisano et al., 2020). In all the affected countries, web-based applications are developing in an anarchic way with similar objectives, which can be summarised as follows: (1) to help patients to make a first own diagnosis (self-assessment); (2) to advise them on what to do, depending on the epidemiological context of the country and its healthcare system; (3) to help health professionals to make medical decisions quickly; (4) to help health professionals to collect data about their patients easily. Collecting even only parts of the information gathered by all available applications on the web and from smartphones would probably make it possible to anticipate and monitor the territorial development of the virus, providing valuable epidemiological data for the future.

The IHU team, made by physicians, engineers, researchers, and information technology (IT) experts, decided to design and develop a web-based solution to federate the collection of data generated by all the web software initiatives that give patients and medical doctors access to patient counselling, patient orientation, or medical decision support.

The first aim of the project was to develop a free, open-source, non-commercial web-based platform (Dal Mas et al., 2020b; Presch et al., 2020) that allows any team around the world that is developing or wishes to develop applications to help manage the COVID-19 crisis to find the resources they need to both collect data and build their apps, by relying on a comprehensive and rigorous protocol and dataset, which is updated and validated with the latest scientific and epidemiological results. The platform allows collecting on a centralised platform all the information gathered to record it in an open-source format (OpenEHR).[1]

The second aim was to enable real-time operational reporting for healthcare organisations, regions, and nations. Such a purpose is consistent with all the International and WHO guidelines, which recommend publishing all pertinent information in real-time using unique and consistent dashboards, allowing to download the collected knowledge and data free of charge for scientific or public health purposes (Xu & Kraemer, 2020).

Moreover, the platform aimed to provide a pre-formatted toolkit, built in a rigorous and scientific-verified way, through collaboration with the international clinical community active in the research of the disease so that local initiatives can quickly publish new web-based applications for COVID while ensuring easy centralised collection. The derived web applications can be designed using layouts, languages, and measures, which can translate knowledge (Dal Mas et al., 2020a; Graham et al., 2006; Lemire et al., 2013; Savory, 2006) in an easier way for the end-users, but at the same time maintaining the common architecture for homogeneous data collection and analysis. The way the platform is built makes it suitable for any other transmissible flu-based infectious disease.

Also, the web application had to allow supporting frontline physicians and healthcare professionals in providing healthcare assessment, letting thus coproduction of the healthcare service together with the patient (Batalden et al., 2016; Biancuzzi et al., 2019; Elwyn et al., 2020), and involving the communities as recommended by the literature on healthcare resilience (Adini et al., 2017; Berawi, 2020; Blackman et al., 2017).

Figure 14.1 shows some screenshots gathered from the web application.

The platform should be built around some relevant pillars: the quality of medical data collection, with particular attention towards all the possible questions, and how these should be posed; the security and regulatory constraints to comply with GDPR (General Data Protection Regulation), HIPAA (Health Insurance Portability and Accountability Act), and all the active regulations worldwide; the implementation, to ensure full data sharing; and the self-assessment tool generator, to allow healthcare institutions or government to quickly customise the form, for a better response of patients.

[1] See https://www.openehr.org/, accessed May fifth, 2020.

Fig. 14.1 The web application: screenshots

More details about the application are summarised in Table 14.1, which maps such characteristics according to the features of a KM system in crisis management and the potential KM barriers.

Although modern technology can offer pioneering solutions and opportunities to collect and share knowledge, technological barriers like lack in compatibility can limit the effectiveness of the KMS. Analysing such aspect, the IHU team decided, for instance, to use a web-based platform, avoiding the need to download it, and to create ex-ante protocols and dashboards to process data without any further test, which may be complicated because of a lack in compatibility.

Organisational barriers make it difficult to incorporate the KMS into the culture of the institution. Pandemic disaster management requires overcoming any cultural bias or limit, to ensure that the standard is rigorous and scientific robust. An unknown disease requires a big effort by the international community, which must share epidemiological data, clinical recommendations, organisational best practice, and lessons learned. Ensuring the presence of multidisciplinary experts worldwide (Dorasamy et al., 2013) can help to update the scientific and clinical dataset and outcome (for instance, about symptoms and experimental drugs).

Last but not least, individual barriers can also represent a severe obstacle in the effective use of KMSs. In the IHU Strasbourg case, data is collected from people, who can also benefit from the app as a coproduced first aid healthcare service. Ensuring that such knowledge is well-managed, meaning collected and shared, is essential, especially taken into consideration the different competencies, skills, culture, and emotional states of the end-users. Translating knowledge (Dal Mas et al., 2020a; Graham et al., 2006; Savory, 2006) is thus important to reach the outcome. For this reason, the IHU team made sure that full customisation of the front-end was possible, in order to select the language, the look of the template, the way to formulate the questions, the measures according to the local standards (for example, Celsius versus Fahrenheit). At the same time, the dataset and internal

Table 14.1 Quality of the knowledge system and sharing barriers

	Potential technology barriers	Organisational barriers	Individual barriers
System quality	Web-based platform, no need to download it Use of a clear protocol so that it is going to be clear for everyone who is using the app to collect data	Validation by a panel of experts worldwide The tool can be replicated in the future for other flu-related symptoms	An individual barrier is the use of internet, for instance, because of age: This is why the web is used instead of a mobile-phone technology
Knowledge quality	Collection of collectors to gather data from other apps on symptoms Possibility to build dash-boards useful, e.g., to policymakers to work on policies to define, e.g., the confinement—Epidemio-logical data can be analysed without further tests or analysis Allowing to keep track of mitigation effects, popu-lation at risk, . . . Infographic approach and heatmaps	Data are comparable as despite the collection methods, the process is the same	Use of English for the community developers (the starting language was French); now the development is doing in French, English, and Spanish Try to use English in an easy way, using dictio-naries in the easiest style possible The language to the user can be changed, but still, all words are reconnected to the same concept (like fever can be said in many ways); same for measures (like measuring fever in Cel-sius or Fahrenheit)
Service quality		Validation by a panel of experts worldwide Synergy of data to create a worldwide coherent debate	
Situational quality		Validation by a panel of experts worldwide. If there are new symptoms, the experts will discuss in a dedicated template for COVID (e.g. the loss of taste and smell was not recognised as a COVID symptom at the begin-ning) Moreover, information that was relevant at the beginning later turned less relevant (like if someone travelled over-seas in affected areas)	

architecture should elaborate and aggregate information in a standardised and rigorous way.

14.4 Discussions and Conclusions

The IHU Strasbourg experience allows highlighting in practice the features of a KMS which can help disaster management, more specifically during the COVID-19 pandemic, enhancing resilience. The literature has stressed the relevance of KMSs in crisis management, to share good knowledge in a fast way, through a high-quality and well-designed system (Dorasamy et al., 2013, 2017). In ensuring the collection, transfer, and sharing of useful knowledge, some recommendations have been identified, such as gathering experts and stakeholders (Abouei et al., 2019; Dorasamy et al., 2013), and using modern technologies like web apps and data analytics to develop a KMS (Reuter & Spielhofer, 2017; Wang et al., 2020). However, the development of a KMS for disaster management, which can foster the fourth “S” factor of the Barbisch and Koenig’s “four S’s” of surge capacity framework, has specific requirements that must be considered.

First, KMS must be integrated within all the institutions that are managing the recovery strategy from the disaster. The web platform under development by IHU Strasbourg allowed us to highlight the importance not only to ensure the quality of the system, service, situation, and knowledge but also to put in place effective tools and practical actions to overcome the potential knowledge barriers (Riege, 2005). Such knowledge barriers may involve both the end-user, but also the institution or decision-maker that needs to access knowledge to plan the actions to manage the crisis. When barriers are in place, the knowledge flow is less smooth, and even the kind of knowledge can be compromised.

Second, speed is a crucial element in disaster management. Being fast, however, requires the development of a knowledge flow that proceeds fluently. Knowledge barriers can limit the exchange of essential information and the knowledge application to solve specific issues (Riege, 2005). While existing literature focuses on the characteristics of a KMS, less attention has been paid to the elements that can limit the knowledge flow and turn into an action paste reduction. In the case of the COVID-19, considering its deadly rate and its spread capacity, those problems might end up with severe consequences if not appropriately addressed.

In all, in a situation like the current COVID-19 pandemic, not only the quality of knowledge matters but also the speed in transferring and sharing knowledge, information, data among meaningful stakeholders, including the communities, who appear as central actors in the resilience perspective. Quick actions can prevent dangerous results. Ensuring that enough tools are put in place to avoid knowledge barriers can thus help the KMS to allow fast knowledge sharing and rapid responses to the crisis.

Our chapter contributes to the knowledge management theory by addressing the features of a KMS for disaster management to foster resilience, including the need to overcome the knowledge barriers to ensure effective implementation in a galaxy of institutions involved in the recovery and the speed in the information flows. Thus, the implications of our study may be useful for practitioners, which may consider our results while designing their KMSs to increase their surge capacity.

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Chapter 15
A Knowledge Graph to Digitalise Functional Resonance Analyses in the Safety Area

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Abstract We present the backbone of a knowledge graph to support the next generation of functional resonance analyses in the safety area by means of automatic reasoning services. The proposed knowledge graph is expected to incorporate existing industrial ontologies, according to the needs of safety analysts, and to handle the diversity of upper ontology models that may have been adopted for the development of enterprise-specific application ontologies. We briefly describe some possible usages of this knowledge graph, i.e. systematic exploration of safety-critical processes, analysis of misalignments of work-as-done from work-as-imagined process representations, creative design of work-as-done, and inter-company alignment of safety-critical processes to safety goals. Finally, we discuss the major implications of our proposal for safety analysts and safety practitioners.

Keywords Functional resonance analysis · Industry 4.0 · Knowledge graph · Safety management · Resilience engineering

15.1 Introduction

Nowadays, industries need to build worldwide collaborations to face the challenges given by a highly competitive society and uncertain market conditions. Their internal processes have to comply with inter-organisation collaborative processes and service level agreements. In such complex and often dynamic processes, the

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underlying safety concerns require knowledge and information sharing among the participating organisations. This collaborative setting must be properly designed not only to ensure functional correctness and process reliability but also to avoid unexpected safety consequences. In this context, industries need to share their knowledge, which is usually represented through different modelling formalisms, e.g. Unified Modelling Language (UML)[1] and Business Process Modelling Notation (BPMN),[2] and approaches, e.g. semantic languages as the OWL Web Ontology Language[3] and executable workflow languages as the Business Process Execution Language (BPEL).[4] Coping with such a variety of representation means demands a flexible approach to enable formal integration of knowledge and process models. This would enable the development of automatic services to support designers in the specification and logical verification of the collaborations (Santone et al., 2013) and system analysts in their resilience assessment activities (Hollnagel, 2012).

Ontologies are widely recognised as knowledge artefacts to support interoperability and collaboration (Missikoff & Taglino, 2004). "An ontology is a formal, explicit specification of a shared conceptualisation of a given application domain" (Gruber, 1993; Borst, 1997). It contains concepts, relationships, and axioms that can be used by a reasoning engine to make logical inferences and discover new facts about the addressed reality. In the last 20 years, ontologies have evolved from a niche research topic to be an actual facility for enterprises. Several semantic services have been developed to support, for instance, data and process interoperability and enterprise collaboration. Nonetheless, building ontologies is not an easy task, requiring dedicated ontology engineering methodologies (De Nicola et al., 2009; De Nicola & Missikoff, 2016) to support experts and practitioners. Most of the existing industrial ontologies are based on widely adopted upper ontological models, which consist of abstract concepts that guarantee the semantic correctness of the built ontologies. Among the most used upper ontology models, we cite the Suggested Upper Merged Ontology (SUMO) (Pease et al., 2002), the Unified Foundational Ontology (UFO) (Guizzardi et al., 2015), the Basic Formal Ontology (BFO) (Arp, 2015), and the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) (Gangemi et al., 2002). Accordingly, the existing industrial ontologies generally extend these upper models by addressing a specific domain of interest (e.g. logistics, procurements, aviation, safety, maintenance (De Nicola et al., 2008) and the specific industrial application (i.e. concepts related to the types of products produced in the enterprise). Domain knowledge is ingested from existing standards, specifications, and glossaries; application knowledge can be built by interviewing sharp-end and blunt-end operators and/or by analysing internal procedures.

For a semantic representation of collaborative business process models, an integrated knowledge model is required. Upper ontology models are useful tools

[1] UML web site: https://www.omg.org/spec/UML/.

[2] BPMN web site: https://www.omg.org/spec/BPMN/.

[3] https://www.w3.org/TR/owl-features/.

[4] http://docs.oasis-open.org/wsbpel/2.0/OS/wsbpel-v2.0-OS.html.

for this task as they ease the identification of semantic links between different application-specific concepts while preserving existing internal semantic structures. To the purpose of resilience assessment supported by semantics, we propose the Functional Resonance Analysis Knowledge Graph that aims to align the above-mentioned upper ontology models with an ontological representation of the basic modelling elements of the Functional Resonance Analysis Method (FRAM).

The remainder of the paper is organised as follows. Section 2 briefly presents the Functional Resonance Analysis Method. Section 3 describes the Functional Resonance Analysis Knowledge Graph. Then, Sect. 4 proposes some possible usage scenarios for the knowledge graph. Finally, Sect. 5 summarises the outcomes of the chapter.

15.2 FRAM

Industries, as well as other socio-technical systems, are set up to deliver predetermined performance in a desired manner. Therefore, the activities (in FRAM terms, functions) into which systems can be possibly decomposed are designed and prescribed to be reproducible and constant. In actual systems, these functions produce variable performance, with their own peculiar rate of variation. Indeed, a technological process can be expected to exhibit a much more limited tendency to vary than a human activity. According to the interpretation given by Resilience Engineering, such variability in performance represents the everyday expression of adaptation and adjustment from which system resilience emerges as a phenomenon. Hence, it emerges the need to offer a description of socio-technical systems in functional, not structural, terms.

The Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012) is particularly effective in providing these types of descriptions and is distinctive for several reasons. Firstly, the method is not limited by aprioristic assumptions in terms of modelling the investigated systems (the FRAM is a method-sine-model rather than a model-cum-method). This feature makes it less prone to fallacies of the post hoc propter hoc type. Secondly, the FRAM has been called an inductive-cum-deductive method because, since it has no underlying model of reality, it is neither explicitly inductive nor deductive and consequently lends itself to being used both prospectively and retrospectively (Thomas et al., 2020). Moreover—being inherently non-linear—it is particularly well suited to a holistic description of complex systems. The method aims to describe socio-technical systems in functional terms and to account for variability both at the level of the individual function and in systemic terms as an emergent phenomenon (i.e. functional resonance).

The FRAM rests on four principles:

Equivalence Between Successes and Failures The FRAM embraces Resilience Engineering position of renouncing the classical view of safety that ascribes each performance to a bimodal outcome: either correct functioning of all components or failure of one of its components. By embracing the real complexity of a system, it should be recognised that the same behaviours and performance can lead to both desired and undesired results.

Approximate Adjustments Socio-technical systems are generally intractable, and working conditions are under-specified both in principle, at the theoretical level, and in practice. One must also consider that resources, materials, labour, information, and especially time are mostly scarce resources. What happens on a daily basis is that human operators constantly adjust their performance to adapt to ever-changing internal and external conditions. This adaptation arises to various factors: (1) the physiological and/or psychological characteristics of individuals (fatigue, circadian rhythm, alertness, attention, and so on); (2) the high cognitive level used to overcome time constraints, lack of specifications and, sometimes, boredom; (3) the presence of organisational factors (external demand for quality or quantity, deadlines leading to resource constraints, changing objectives, organisational double-binds such as safety-productivity, etc.); (4) social factors (expectations for oneself or one's colleagues, adherence to workgroup norms, etc.); (5) contextual factors (too hot, too noisy, too humid, etc.); (6) unanticipated changes in the work environment (weather, technical problems). In addition, (7) ineffective communication and/or lack of trust between top management and workers, as well as (8) lack of organisational memory and culture, can exacerbate the consequences of variability associated with normal day-to-day activities.

Emergence The FRAM abandons linear reductionism in favour of a systemic view in which the individual diverse functional parts are interconnected in a network of transient relationships (i.e. couplings). The product of this dense network of functional relationships is not traceable to a resulting phenomenon in Cartesian-Newtonian terms; rather, it emerges as a collective phenomenon of relationships. These processes are the result of many activities, strongly coupled, operating on various levels of the system hierarchy, non-linear, therefore generally intractable. Indeed, the final outcomes may be due to a series of transient phenomena that existed only at a given moment in space and time. Conditions that may, in turn, be caused by other transient phenomena endlessly.

Functional Resonance The variability of performance, expression of the capacities of adaptation of the system in some transient and unpredictable conditions can propagate and combine in unexpected ways and sometimes trigger undesired emergent phenomena. The FRAM uses the notion of functional resonance to account for the emergence of a detectable effect from the activities of the sub-systems not directly perceivable as anomalous. The resonance is the phenomenon that allows a system subject to very small forces to oscillate with divergent amplitude at certain frequencies or in the presence of random forces generally not detectable. In socio-technical systems, the combination of performance variability sometimes can be accentuated until exceeding the threshold of detectability. Since this accentuated response of the system emerges from processes and activities (functions) that are mostly intentional, thus not entirely stochastic, we are referring to functional resonance.

The FRAM comprises five steps:

- **Step 0—Definition of the purpose of the analysis** in which the scope of the analysis is defined, and consequently whether its retrospective or prospective nature.
- **Step 1—Identification and description of the system functions** in which the functions (visually represented as hexagons) are identified without applying inductive or deductive models but trying to embrace the portion of the system holistically to be investigated. It is firstly suggested to operate by blocking the model at higher abstraction levels and only subsequently detailing the particularly necessary functions. This way of proceeding is called breadth-before-depth.
- **Step 2—Evaluation of endogenous variability.** The intrinsic variability of the functions under consideration must be evaluated in terms of functional phenotypes (e.g. time, precision, speed, etc.).
- **Step 3—Aggregation of variability.** The method at this point identifies the interrelationships between functions (i.e. *couplings*) that emerged in the described circumstance. The process is called instantiation (see Fig. 15.1). It is not possible to specify in advance and with precision how the couplings between the functions will be realised. Moreover, such couplings between functions may be quite different in nature from simple cause-and-effect relationships and take on different structures. Therefore, specific instances of the model (e.g. those related to work-as-done and work-as-imagined) are looked at to understand how the variability of functions may combine and to determine when these interactions may lead to undesirable outcomes. Each coupling creates a link between two functions by means of the six aspects—Input, Precondition, Resource, Control, Time—that represent the ports by which the single function can interface with another through a coupling. It is the process of an instantiation that describes the sequence of activities as well as the possible need for an activity.
- **Step 4—Develop effective measures to control variability**, which aims to manage potential occurrences of uncontrolled variability that have been identified through the previous steps.

15.3 Functional Resonance Analysis Knowledge Graph

Combining the notion of ontology with a FRAM meta-model, a knowledge graph is expected to support semantic modelling of work knowledge for resilience assessment in inter-organisational processes. According to Kejriwal (2019), a knowledge graph is a graph-theoretic semantic representation of human knowledge such that it can be ingested by a machine for the purpose of conducting reasoning and inference. Hence, knowledge graphs include data and concepts represented as Resource,

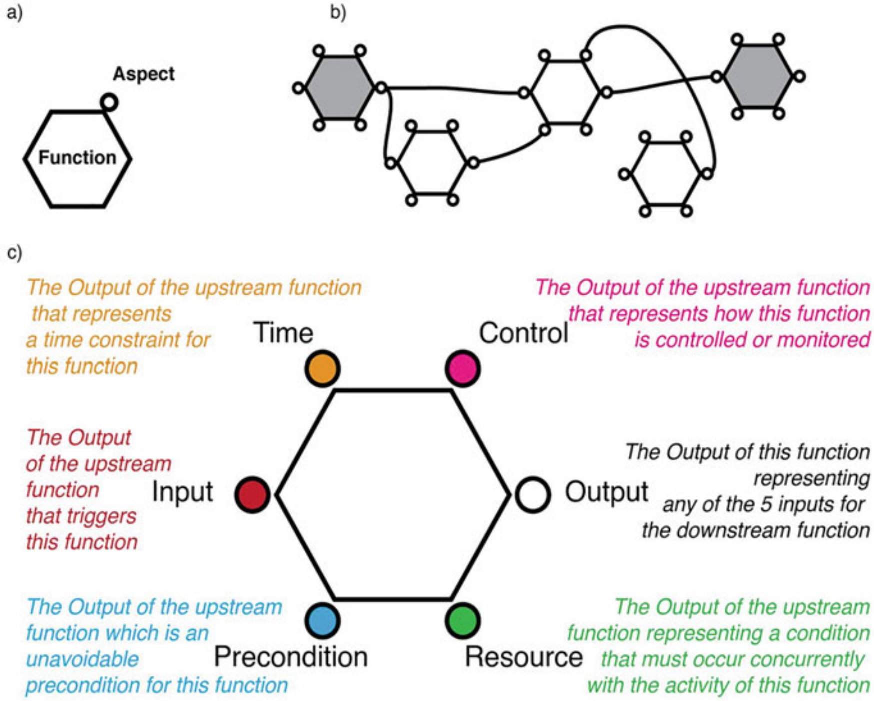

Fig. 15.1 Graphical representation of FRAM concepts: (**a**) a function is represented by a hexagon whose vertices correspond to its aspects; (**b**) an instance emerges when couplings are being established between functions. Background functions (grey) are those functions that have either only input or only output connected. Foreground functions (white) represent the core of the system's analysis; (**c**) the aspects of a function (whose meaning is detailed in the picture) represent its interface with other functions

Description, Framework (RDF) triples that can be used for advanced reasoning services (Bader et al., 2020).

In this work, we embrace a safety perspective by proposing a knowledge graph that should be able to encompass the variety and diversity of existing industrial ontologies and the need for a unified approach. Knowledge graphs are already available in the safety sector (Mao et al., 2020; Fang et al., 2020), but none addresses the problem of functional resonance analysis.

An example of what a functional resonance analysis knowledge graph may resemble is depicted in Fig. 15.2. Four different enterprises collaborate in a process, and they already use ontologies to represent their own domain and application knowledge. Each ontology consists of a public part encoding the knowledge to be shared in the collaboration processes, and some restricted parts covering sensitive and organisation private data (patents, personal details of the employees/operators, etc.). We can assume that each ontology was built by extending a different upper ontology model (i.e. UFO, SUMO, BFO, and DOLCE). Parts of these upper models

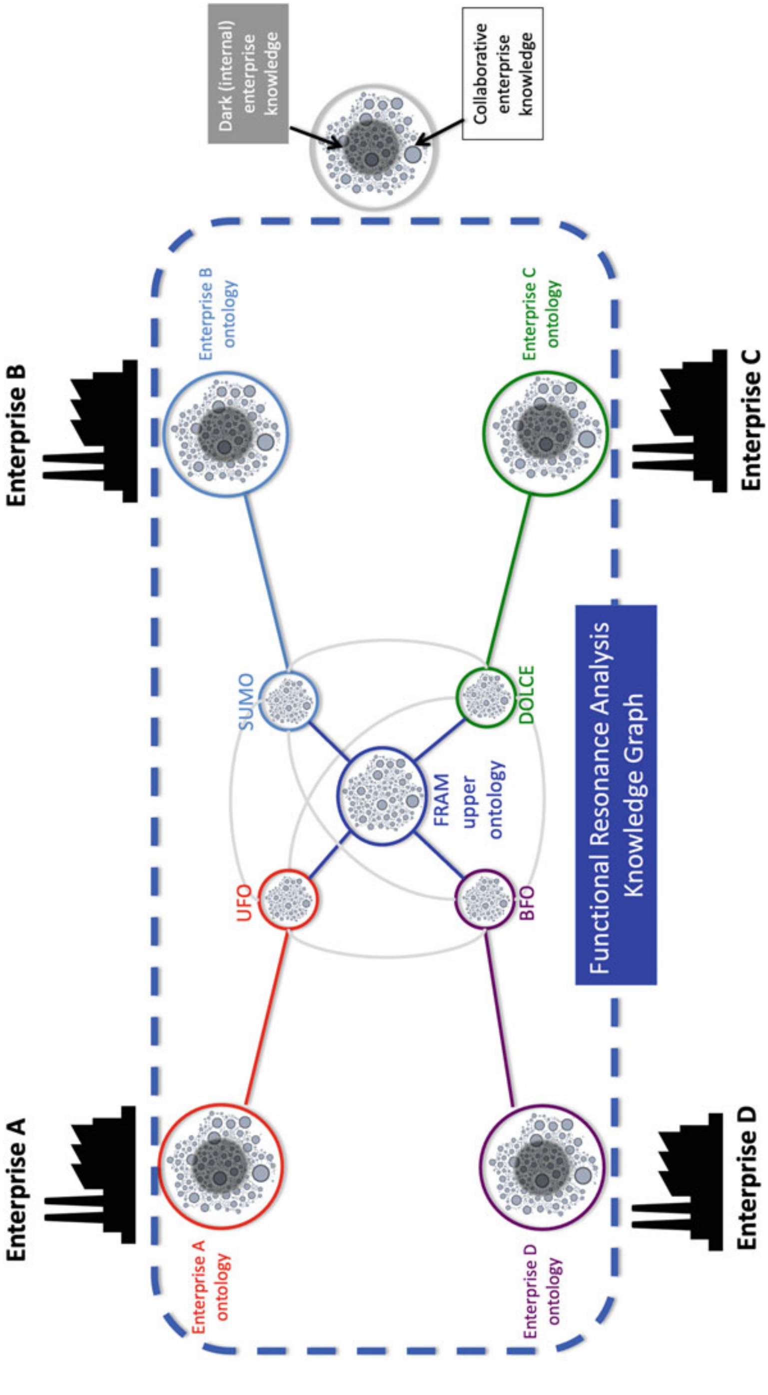

Fig. 15.2 Functional resonance analysis knowledge graph

may be mapped and aligned together in order to allow for interoperability between the different enterprise ontologies and reach a unified semantic upper model. The main component of this knowledge graph is the FRAM upper ontology (De Nicola et al., 2017; Lališ et al., 2019), which includes an ontological representation of the FRAM (Hollnagel, 2012) meta-model. The FRAM upper ontology can be linked to all the upper ontology models and, hence, to the different enterprise ontologies included in the knowledge graph.

The main advantages of the functional resonance knowledge graph can be described as follows:

1. Concepts are defined without ambiguity, so avoiding misinterpretation and possible redundancies from the usage of different syntax.
2. If an enterprise wants to merge its ontology with the knowledge graph, there is no need to modify the ontology. It is enough to connect it to the graph.
3. In this latter case, such an enterprise could leverage knowledge already represented in the graph and build new reasoning services on top of it.

The main limitation of the knowledge graph is that, sometimes, only part of the enterprise ontology can be merged to it and, hence, the rest (internal dark knowledge in Fig. 15.2) should be protected against malicious intents, avoiding cyber threats.

15.4 Foreseen Usage Scenarios

In this section, we describe five possible scenarios of advanced analysis services built on top of the knowledge graph.

Scenario 1: Systematic Exploration of Work Processes A safety analyst in a large enterprise needs to analyse possible safety issues in certain business processes. Some of these processes require collaborations with external enterprises. The analyst starts identifying components of a FRAM instance, possibly using the enterprise ontology, and may semantically annotate them by linking to concepts of the knowledge graph. The construction of this FRAM-based semantic layer provides him/her with a number of useful automatic functions: reuse of a model fragment (or just a FRAM function) in different FRAM instances, based on its meaning provided by the ontology; design support based on abstraction/refinement relationships; semantic validity of the FRAM instance based on logic rules; query sets of FRAM instances, e.g. against specific actions, variability, agents, and roles; automatic categorisation of FRAM instances/functions. Furthermore, he/she can verify the compliance of the business process repository over a new regulation or specific conditions from the collaborative process that could lead to safety problems.

Scenario 2: Analysis of Work-As-Done and Work-As-Imagined A safety analyst is hired by a production company to identify possible safety issues depending on the misalignment between Work-As-Imagined (WAI) and Work-As-Done (WAD) processes (Patriarca et al., 2021). WAI processes represent the mental or documented models related to work-related activities, where work is either a possibility (either the past or the present or the future) or a belief (i.e. how an operator imagines activities are executed). WAD processes are the actual activities as carried out in the working environment. The semantic layer added to WAI and WAD process models can be used to compute their semantic distance according to semantic similarity techniques (De Nicola et al., 2019b). Quantification of semantic dissimilarity between WAI and WAD models, enabled by the knowledge graph, may be especially relevant in the case of collaborative processes with external organisations. Indeed, both functional contracts and service level agreements are generally designed based on WAI models. Furthermore, the semantic annotation of the WAD models with the knowledge graph may support a safety analyst in performing semantic adjustments to the WAD models to align them with the requirements of the collaboration process.

Scenario 3: Creative Design of Work-As-Done A safety analyst is expected to envisage possible WAD processes starting from WAI processes collected by means of interviews with blunt-end operators. As for Scenario 1, the analyst starts identifying components of a FRAM instance, possibly using the enterprise ontology, and may semantically annotate them by linking to concepts of the knowledge graph. Then, by exploiting the computational creativity functionalities provided by a computational engine that leverages on the enterprise ontology (e.g. the CREAtivity Machine (De Nicola et al., 2019a, Costantino et al., 2020)), he/she designs possible alternatives of the WAI process. The latter have to be then validated with a selection of sharp-end operators to ensure its consistency. This approach may reveal useful to discover process variants that sharp-end-operators might not be willing to disclose unless they are explicitly asked about, or may not be aware of, due to their local bounded awareness (Patriarca et al., 2021). Note that the anticipation of plausible process variants (analyst imagination foresight) may speed up the WAD knowledge collection process finalised to setting-up a collaboration environment.

Scenario 4: Inter-Company Semantic Alignment for Collaborative Processes This scenario concerns a possible situation that could happen when two enterprises need to collaborate to develop together a product or to deliver a service. In particular, the two enterprises need to merge the public parts of the respective processes, whereas the private parts shall remain mutually unknown. In such a case, semantic rules attached to the knowledge graph may be defined to identify and protect the private organisation knowledge against external accesses/ usages. This also enables automatic separation of safety analysis models and results at the process collaboration level from those related to the internal processes.

Scenario 5: Computer-Aided Inference of Analogies Between Different Application Areas The last scenario concerns an even longer-term possibility of transferring knowledge in one application domain (e.g. air traffic management) to a different one (e.g. anaesthesia). The analyst can be assisted by a software tool in recognition of similar patterns between the two different application domains and possibly transfer solutions already adopted in one domain to the other, as supported by a shareable part of a knowledge graph.

15.5 Conclusion

Over recent decades, ontologies have been developed to support interoperability and collaboration in industrial settings. However, the variety of existing modelling approaches due to the great number of existing upper ontologies has caused a further interoperability issue between ontologies. The functional resonance analysis knowledge graph aims at being a knowledge gateway between different industries. It is expected to guarantee consistency of collaborative business processes in line with modern knowledge management. We presented some possible use cases to discuss how it might specifically support safety assessment.

As a final note, it should be observed how the richness of the survey method (as well as the depth of the analysis) is highly dependent on the experience of the analyst in charge, who often has to make simultaneously use of different qualitative instruments for the data collection process (e.g. semi-structured interviews, focus groups, questionnaires, naturalistic observation). The automatic analysis of multimedia documents (movies, audio streams) is still little exploited, although many FRAM models are created from the analysis of dozens of large documents. In this regard, even though not meant to substitute the precious work of a human analyst, the knowledge graph is expected to integrate and support traditional manual efforts. Ultimately, the creation of a knowledge graph based on FRAM has the potential to offer support in both the exploration of socio-technical systems and the elicitation of knowledge for both informational and design purposes.

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Chapter 16
Trapping Paper Checklists into Screens: How to Free the Resilience Capability of Digital Checklists for Emergency and Abnormal Situations

Guido Carim Jr, Geraldine Torrisi-Steele, and Eder Henriqson

Abstract Aviation digital non-normal checklists neither solve the problematic nature of procedures as organisational control mechanisms nor capitalise on the benefits of the technology. To create resilient operational systems, it is necessary to shift towards seeing abnormal and emergency checklists as resources for the activity: A piece of information that helps pilots assess the severity of the problem, diagnose the cause and plan, and implement a proper response when needed if needed. Fragmented checklists, integrating different resources in just one place, and Decision Support System technology are mechanisms to enhance the potential of the digital quick reference handbook.

Keywords Resilience engineering · Digital checklist · QRH · Safety rule · Emergency

16.1 Introduction

Checklists and procedures, in different forms, are common in industries where safety is of concern: from medicine, chemical process and manufacturing to aviation and nuclear; from standard operating procedures, surgical checklists, to minimum

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equipment list (MEL) and golden rules. In emergencies and system failures, the situation is not different: the operator should action the abnormal and emergency checklist, carefully crafted by those who designed or maintain the operations, technology, and process.

A design assumption of checklists and procedures is that the work context and the fault will unfold as predicted; thus, strictly following a checklist will inevitably lead to the desired, anticipated outcome. Procedures are necessary because, after all, humans are vulnerable to choosing erroneous actions and making bad decisions. And what better way is there to reduce human error other than rigidly reduce variability by constraining the action and requiring compliance with procedures (Hale & Swuste, 1998)? At least, this is the usual mindset from which procedures and checklists eventuate.

With the advent of the paperless cockpit philosophy and affordable technologies in aviation, Electronic Flight Bags (EFBs), electronic checklists and digital Quick Reference Handbooks (QRHs) are now part of every commercial aircraft cockpit. In the case of a system failure, the aircraft warning system draws the pilot's attention to a critical or urgent problem (Woods, 1994; Woods & Sarter, 2010). The fault message presented on the display prompts pilots to retrieve and action a digital non-normal checklist. The drill contains actions, decision points and notes (Burian, 2004), mostly organised in a sequence aimed at containing the failure, restoring the system, or maintaining the continuity of the flight despite the faulty system or component (Heymann et al., 2007). Hundreds of digital checklists are organised in a QRH according to announced and non-announced problems, aircraft systems or the fault severity.

Despite best efforts to digitalise and continuously improve the QRH, pilots still experience novel or ill-structured problems for which a procedure either does not yet exist or is not entirely captured by checklist (Carim Jr. et al., 2016). From the procedure as organisational control mechanism perspective (Weichbrodt, 2015), the efforts lie in closing this gap, to make the checklist as closely representative of the activity as possible (Burian, 2006a). However, this effort often results in additional, longer, and more prescriptive checklists. Similarly, digitals checklists, except for some rudimentary functionalities, become just a translation of the paper-based checklists that perpetuates the underlying design assumptions.

In an era when organisations are constantly challenged, it is paramount to create resilient operational systems able to cope with both well- and ill-structured, expected and unexpected abnormal and emergency situations. From the resilience engineering perspective, operational resilience is the capacity to anticipate, adapt, absorb and bounce back from variations, changes, disturbances, disruptions and surprises that fall outside the system-designed boundaries (Woods, 2015). Rather than waiting for situations that match their capacity, these systems self-organise their components to cope with whatever situation pushes their boundaries (Hollnagel et al., 2006).

To increase cockpit resilience, there is a need to shift away from non-normal checklists as prescriptions for the activity perspective, to understanding them as tools that support operators to cope with the residual uncertainty that is ever-present in operational contexts (Woods, 2018; Dekker, 2014). Checklists should be seen as resources for activity: Information structures that support activity when needed, if needed (Suchman, 1985; Wright et al., 1998).

In this chapter, we propose a progressive approach to checklists, which imbues resilience to the cockpit systems by helping pilots assess the severity of the problem, diagnose the cause, and plan and implement a proper response when needed if needed. After the introduction, section two describes the current state of the digital QRH and non-normal checklist used in the cockpit of commercial aircraft. Then, section three highlights the challenges and limitations present with the increasing digitalisation of procedures are section. Lastly, section four explores different pathways to redesign digital checklists.

16.2 Digital Checklists and Manuals in the Cockpit

Since the emergence of the paperless cockpit philosophy in the 1990s, and tablets and EFB's in the 2000s, aircraft manufacturers, airlines and technology companies have been developing dedicated applications for everything; from digital maps, manuals, regulations, airports, weather information to maintenance report, aircraft status and digital checklists.

Boeing (Kurtz, 2003) was the first manufacturer to release a digital version of the QRH in 2013 (see Fig. 16.1). The tablet-based QRH enabled functionalities and interactivity not possible in paper formats including (Crosland et al., 2017):

- Tracking the actions performed.
- Index list that allows quick retrieval of any checklist by title.
- Dynamic forms that direct the next steps according to the previous actions and answers. This replaces flowcharts used to guide pilots through the lines of the checklist.

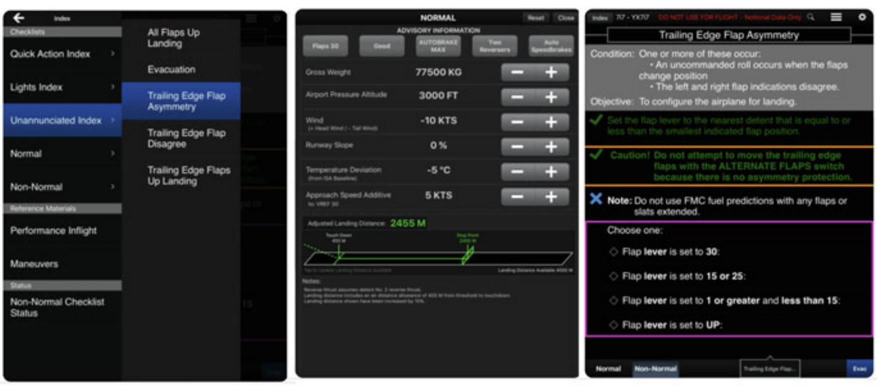

Fig. 16.1 Screens of the boeing interactive e-QRH. Source: (Boeing, n.d.)

- Calculators for the aircraft performance, either embedded in the drill or available in dedicated applications. They replace the performance charts and tables in the paper-based QRH, removing the need for pilots having to flick between the pages to complete the checklist and analyse the landing performance.
- Flexible interface, in which the background colour or the font size can be adjusted.
- Hot buttons that reduce the time required to retrieve and action the most critical checklists.

With many independent applications, the EFB's desktop quickly became cluttered, compromising pilots' ability to retrieve information easily and navigate among the many windows and documents. The industry soon realised that most of the applications relate to each other: the input or output of one application could become the input for another. Subsequently, the focus shifted to making information retrieval easier by integrating different applications and sources of information in one place, which now has been commonly referred to as Integrated Onboard information System (IOIS) (Mosier et al., 2017).

The FlySmart of Airbus is an IOIS that enables the crew to compute the aircraft performance for all the flight phases, generate documentation such as the load sheet, manage the flight progress through the flight plan, consult navigation charts, and access all the operational manuals such as the Flight Crew Operating Manual, Flight Crew Training Manual, Minimum Equipment List, and so on (Berrajaa, 2017).

Despite advancements, the e-QRH for Airbus models is not yet completely integrated into FlySmart. The digital QRH layout resembles the layout of the warning system, the search function only displays checklists containing searched terms in their title, and hyperlinks have been added to direct pilots to other checklists if needed. Unlike Boeing's e-QRH, the performance calculations are directed to FlySmart (Berrajaa, 2017).

16.3 Constraining Capability: The Limits and Challenges of Procedures and Checklists

In high-risk industries, procedures and checklists are one of the most problematic areas of human work (Dekker, 2014). The limitations of procedures and checklists arise from conceptualisation of procedures as control mechanisms (Weichbrodt, 2015): they limit the operator's degree of freedom (Hale & Swuste, 1998); are repositories of organisational knowledge; and reduce the probability of error and counterbalance human fallibility (Civil Aviation Authority, 2005, 2006).

Abnormal and emergency checklists are a special category for four reasons. Firstly, it is not possible to capture beforehand all possible unfolding pathways and contextual elements of a problem (Dekker, 2014). Secondly, it is not possible to include in just one place all of the knowledge required to deal with a fault. Thirdly, while it is widely accepted that the gap between procedures and actual work always exists (Hale & Borys, 2013), efforts are made to bridge the gap, usually with better content, better interface, more accuracy and more smart features (Burian & Barshi, 2003). Lastly, the focus on translating the paper checklist to digital medium leads the e-QRHs to mimic the paper-based procedures and avoids further exploring the benefits of the technology during the management of non-normal situations.

16.3.1 Increasing Number of Ill-Structured Problems

The design assumption of the e-QRH is the same as for a paper-based QRH: the fault evolves as expected, and the outcome is always the same if the guidelines are strictly followed (Heymann et al., 2007). Presumably, all the other systems were working perfectly before the fault occurred, only a single or a group of interrelated faults occur at the time, and the warning system always directs pilots' attention to the real problem (Burian, 2006a).

The assumptions underlying QRH design do not always hold true, though. As aircraft become more robots than machines (Carim Jr., 2016), the possibility of complex anomalous behaviour increases exponentially (Woods, 1994), leaving pilots to cope with an increasing number of ill-structured technical faults. These are defined as problems that go beyond the QRH and warning system scope.

Carim Jr. et al. (2016) found that pilots often must deal with false alarms, unclear faults that go off and then disappear without any apparent reason, faults related to deferred maintenance items, known as "Minimal Equipment List (MEL) items," and multiple concurrent non-related faults, also known as "Christmas tree" (Woods & Hollnagel, 2006). As yet, neither digital nor paper checklists encompass these challenging situations.

16.3.2 Checklist Can Never Cover the Knowledge Required to Deal with Non-Normal Situations

Non-normal checklists are insensitive to the context (Dekker, 2003) and are always based on the worst-case scenario (Carim Jr., 2016). Therefore, the knowledge required for the activity is much broader than what is encapsulated in a checklist. Still, checklist designers try to cover as much contextual variation and as many action pathways as possible through decision-trees and conditional flows, usually presented in programming syntaxes such as "IF," "WHEN," "THEN," "AND" and "OR" (Barshi et al., 2016).

If the conditions intrinsically built into the checklist do not happen, or the situation evolves unexpectedly, then the prescribed actions become irrelevant, leaving pilots the decision of "what to do next" based on a wide range of resources (Carim et al., 2016). For example Carim et al. (2016) revealed that the Embraer

190/95 pilots that participated in the study always verify if the fault is genuine. They do so because of the high incidence of false alarms in the fleet and because in some checklists "resetting" the system or the component is a common initial set of actions (Carim Jr., 2016). In instances where resetting does not work, pilots may opt for not completing the available checklist because the drill could have worsened the situation (Carim Jr. et al., 2020).

It is also assumed that checklist designers and pilots will frame the situation in the exactly the same way. Non-normal checklists are directly linked to the warning system, as though they could precisely indicate the root cause for the problem. Thus, pilots only need to find the checklist whose title corresponds exactly to the fault message. However, as reported by Burian (Burian, 2006a), it is not uncommon for pilots to accomplish a wrong checklist because the warning system may point to a disturbance rather than to the main problem (Woods, 1995). This is even more problematic when pilots have to use checklists for problems not covered by the warning system 30 (Burian, 2006b).

16.3.3 Continuous Improvement Through Better Design and Better Content Alone

Studies proposing guidelines or improvements to the design and use of the non-normal checklists adopt the human fallibility perspective. After analysing a number of safety reports and aircraft accident reports, Burian and Barshi (2003) found nine conditions related to pilot errors when using the checklist. For each condition, the authors provide design guidelines as a way to make the checklist error-proof. Therefore, the ultimate goal of the checklist is to compensate for some design flaws, overcome human limitations, reduce the possibility for error and increase compliance (Civil Aviation Authority, 2005, 2006; Boy & De Brito, 2000; De Brito, 1998, 2002). As put by De Brito (De Brito, 2002, p. 92), non-normal checklists should "reduce the number of deviations leading to serious consequences." The assumption is less errors and more compliance lead to safer operations.

Improving non-normal checklists requires the analysis of checklists as a standalone emergency tool, taken out of the context (Crosland et al., 2017). The emphasis is on the "process of following (or not) written procedures" (De Brito, 2002 p. 93, 33) rather than on the management of abnormal and emergency situations (Carim Jr. et al., 2016). Therefore, most of the concerns are around the checklist itself: Is the situation framed in a checklist as a pilot would do? Is the checklist content easy to retrieve and follow? Is the checklist aligned with the SOP and other manuals, both provided by the operator and manufacturer? Is the checklist length adequate to the time available? Have human limitations and fallibility under time pressure and stress been taken into consideration when designing the checklist content and layout? (Civil Aviation Authority, 2006; Burian et al., 2003; Degani & Wiener, 1997). Therefore, most of the best practices to design paper and digital checklists gravitate around physical characteristics of the display, the layout and format, and the instructions sequence correctness, completeness and coherence (Burian, 2004; Heymann et al., 2007; Civil Aviation Authority, 2005, 2006; Degani & Wiener, 1994, 1997).

16.3.4 Digital Procedures and Checklists Technology Have Not Been Exploited; Just Translated

We acknowledge that recent e-QRHs have embedded essential features that should be kept and even further improved, like tracking actions, dynamic forms, timer, and performance calculators. However, the types of actions, conditional steps, computational syntaxes, and the underlying assumption that all faults will unfold as predicted remain present.

Why do we still have to offer a complete checklist, from beginning to end, if the parts of the checklist are meant to be used only for specific conditions? Why do we still have an “enforced” sequence of actions as if problems always evolve as anticipated? We can understand offering a one-problem-one-drill on a paper checklist is the best solution for simple and unique faults, given the space constraints and need to simplify the retrieval of a checklist. However, the capability of digital platforms is immense and can easily overcome most of these problems.

Expressions like *Land as soon as possible in the most suitable airport*, commonly found at the beginning or the last item on paper checklists, have been transferred to digital QRHs. Pilots question the definitions of as soon as possible (“How much time do I have before the situation becomes worse?”), and suitable (“Does suitable mean an airport that has all the resources needed for landing and takeoff again later? Or does it mean any airport that I can land the aircraft safely, regardless of what happens after”?) (Carim Jr, 2016). As confusing as this one is, some checklists only bring *crew awareness* after the title. As reported by Carim Jr et al. (2016), a pilot who had experienced a problem with a component of the fuel system while taxiing questioned the expression usefulness. He assumed that the expression required the crew to monitor the problem if it happened while inflight. However, does this apply to the same problem while taxiing? He could not find the answer anywhere.

Although we understand that we cannot integrate geo-location or produce a checklist for the same problem in different phases of flight in a laminated checklist, the same limitation is not found in digital applications. Yet, the practices of paper checklists endure in the digital form.

16.4 A Way Forward

Building a resilient system requires a better description of how pilots actually manage abnormal and emergency situations and how procedures, as well as other resources, are used in practice. Once the activity of managing dynamic faults is understood, we can propose a system that supports pilots with varying experience and knowledge profiles to deal more effectively with inflight faults, particularly ill-structured ones. Rather than optimising the current digital checklists to compensate for design flaws, to improve compliance and to reduce human error, the focus should be on supporting the strategies and adaptations required by the operators to successfully complete the activity (Rasmussen, 2000). We posit that the way forward is forged by challenging existing assumptions implicit in the design and development of checklists, refocusing on the dynamic nature of the management of abnormal and emergency situations, and exploiting technologies to support pilots in their work. Rather than the specification of the activity, procedures and checklists need to provide essential information for operators to cope with the residual hazard, variability and constraints, thus guaranteeing a continuing safe and efficient operation.

16.4.1 How Pilots Actually Manage Non-Normal Situations

The revisited anomaly management model proposed by Carim et al. (2016, 2020) is a further elaboration of the original proposition by Woods (1994) and Woods & Hollnagel (2006). According to the revisited model, a fault, whether well- or ill-structured, is presented in terms of disturbances because of the lack of linear relationship between the fault cause and symptom (Woods, 1995; Watts-Perotti & Woods, 2007).

Operators manage faults through three iterative and concurrent event-driven cognitive processes: anomaly assessment, diagnosis and response (Woods, 1994). These three processes operate according to different types of reasoning: often starting with the quickest and less demanding one, such as analogical and heuristics, and progressing to more elaborate states as the problem remains unsolved, such as abductive and analytical (Watts-Perotti & Woods, 2007; Rasmussen, 1993; Rasmussen & Jensen, 1974).

Lastly, the cognitive processes operate with the support from not only the QRH and checklist but also a range of documents, manuals, tables, previous experiences, to name a few. Those resources have not been originally designed for this particular purpose and dispersed in and outside the cockpit (Woods, 1995).

16.4.2 Procedures as Resource for Activity

The alternative approach to procedures as organisational control mechanisms is Resources for Action (RfA), originally suggested by Suchman (1985). RfA contrasts with the prevailing view that maps, plans, scripts, protocols, procedures, checklists and rules direct and control action (Wright et al., 1996). Rather, they are one among many different resources that support the operators to conduct a reasonable course of action and to deal with or avoid local constraints (Suchman, 1985; McCarthy et al., 1998; Wright & McCarthy, 2003; Hutchins, 1995).

Wright et al. (1998, 2000) and Wright and McCarthy (2003) further elaborated and applied RfA to information technology. They argued that any piece of information distributed on an interface, serving the specific purpose to support the operator during the course of action, such as instructions, perceived affordances, interactive features, and previous interaction history, is a RfA. Wright et al. (2000) suggest the interface analysis from the RfA perspective should seek to reveal the meaning operators given to the piece of information on the system interface and its utility in solving a specific circumstance. In using non-normal checklists, Wright et al. (1998) point out that pilots intercalate fragments of multiple checklists to manage a certain situation since the technical problems on board are not always solved in the same sequence as indicated by checklists. For instance, different pieces of different checklists can help pilots achieve specific objectives and solve part of the problem depending on its nature (Wright et al., 2000).

Validating and expanding the findings from Wright et al. (1998, 2000) and Wright and McCarthy (2003), Carim Jr. (2016) and Carim Jr. et al. (2016, 2020) describe four ways in which the QRH are used as RfA during aviation non-normal situations. Firstly, pilots see the checklist as fragments that contain a set of actions, either therapeutic or diagnostic, with a very specific objective in solving part of the problem. For instance, before following the checklists blindly, pilots read and try to infer the fragment objective, contextual assumption and possible consequences before actioning it. Then, they compare their inference with the context faced before deciding whether an intervention is required and, if so, the course of action (De Brito, 1998). Secondly, knowing which fragment of a number of checklists may help to solve a specific feature of the problem increases the pilot's ability to combine and interleave different checklists to coin unique solutions. Thirdly, pilots not only use a fragment of the checklists; they also know that other parts of the QRH, other manuals and previous experiences (both personal and shared by colleagues) carry valuable information as well. Given that pieces from a range of checklists and other resources available in and outside the cockpit help with the whole fault management activity, Carim Jr. et al. (2020) propose to use the term Resource for the Activity instead. Fourthly, and most importantly, pilots use RfA when needed, if needed. Some faults are so common and repetitive that pilots already memorised the sequence of actions available in the checklist. In other situations, following the checklist could lead to worse outcomes, therefore prompting the crew to disregard the QRH, return to the departure airport and land as a precaution (Carim Jr. et al., 2016, 2020; Carim Jr., 2016).

Three mechanisms to implement a digital QRH as a RfA emerges from these findings: (a) provide fragmented checklists instead of one-off solution, (b) integrate different RfA in just one place to avoid redundancy and simplify the workflow, and (c) use a decision support system technology to help pilots during ill-structured faults.

Fragmented Checklists The checklist content should be fragmented into interactive blocks or iBlocks (Tan & Boy, 2018). Each block comprises a set of actions, situation patterns, and post conditions (Boy, 1998), normally dispersed among many different manuals and checklists. As the pilot completes one block, the system verifies the next priority and updates the context. This may lead to the completion of another block which can be part of another non-normal or normal checklist in a paper QRH (Tan, 2015; Tan & Boy, 2016).

Although the system may suggest different pathways, pilots are free to decide the best option, bearing in mind that for some aircraft models, they also have to complete actions presented by warning system (Boulnois et al., 2018). And each fragment could be improved dynamically: always feeding back to the system lessons learned on how people coped and how the aircraft system behaved in previous anomalies and emergencies. Helped by a search engine based on an input-process-output format, pilots could access tailored solutions for specific problems under specific conditions rather than following a decision tree with many branches, reducing the need for conditional actions and different pathways.

Integrating Different RfA Pilots employ three categories of resources in addition to the QRH (Carim Jr. et al., 2016): (1) documents physically available in the cockpit, such as Minimal Equipment List and technical logbook, (2) social resources, such as maintenance professionals and other pilots (when sharing experiences), and (3) previous individual experience, either personal or third party.

Since the document resources are dispersed in the cockpit, embedding them in a digital QRH and connecting to the checklists is paramount to reduce the time to retrieve information but also avoid task duplication. The input of one resource can be used as input by a checklist and other resources. For example combing the MEL with the checklist help pilots to assess whether a failure needs to be fixed before the aircraft can take off again and decide which destination airport is better and safely suited. Moreover, some tables and information available in the MEL complement the content of the checklist, thus prompting pilots to consult them eventually while managing a problem.

Another example is to include the Technical Logbook as part of the digital platform. Rather than presenting a list containing all past technical problems and maintenance actions and deferred maintenance items, pilots would like to be able to visually, at a glance, assess the aircraft's airworthiness status. Pilots would also like to have checklists that take into account the deferred maintenance items, thus not having to remember problems not yet fixed before actioning the checklist (Carim Jr., 2016).

Decision Support Systems (DSS) There are three functions that technology should perform to improve pilots' capability during non-normal situations (Carim Jr., 2016; Woods & Hollnagel, 2006; Woods, 1995):

- *Representation support* should help distinguish anomalous behaviour from the noisy background and from irrelevant cues. Moreover, the function should represent the multiple factors that influence the disturbances over time (human intervention, automatic system response, false alarm, another fault or faults).
- *Hypothesis generation* should support a better diagnosis by generating as many alternative hypotheses as possible given the set of evidence. It may also highlight the set of evidence covered by each candidate hypothesis.
- *Tailored Actions* should aid pilots with the trade-off between acting under great uncertainty or waiting for more evidence even in the face of undesirable consequences. This function may bring actions aimed to generate more evidence until the system is able to suggest one or more reasonable course of actions.

DSS seem to be the most appropriate technical solution to operationalise these three functions in addition to the fragmented checklist and integrated RfA. DSS are defined as interactive, flexible, and adaptable computer-based information systems designed for the specific purpose of improving decision making in non-structured problem domains by utilising data from various sources (Turban, 1995; Cats-Baril & Huber, 1987). DSS is not an automated problem-solving system, does not generate procedures for which compliance is the goal, nor constrain the decision-makers actions. Instead, the user retains their role as autonomous, active decision-makers as their insights are crucial to the problem-solving process (Sprague, 1980).

A typical DSS includes a knowledge base, inference engine and a user interface (UI). At the core of DSS is the knowledge base (normally developed from strategies employed by experts) which facilitates retrieval, organisation, and manipulation of information through an inference engine. Given inputs, the inference engine manipulates the knowledge and generates the outputs, usually as probabilities. The UI enables manipulation and scaffolding of knowledge elements, thus assisting users to more efficiently, effectively, and consistently form an understanding of the context, formulate hypotheses for the causes of the problem and delineate courses of action and their potential consequences (Arnott, 2006).

Embedded in a digital QRH, the DSS would suggest an action and broaden the possible causes for the technical problem and indicate the severity of the situation. Taken together, the three outputs: causes, level of severity and course of action, will expand the pilot's capability to assess the nature of and diagnose causes of ill-structure problems and plan and implement a reasonable course of action.

16.5 Conclusion

Paper non-normal checklists are "trapped" into digital QRHs: they perpetuate the checklists as organisation control mechanisms and severely limit the operational resilience in a commercial aircraft. Increasing airlines' resilience during non-normal situations management requires a paradigm shift from checklists and procedures as activity constraints to resources for the activity.

The chapter operationalised RfA through fragmented checklists and integrating RfA with DSS. Properly designed, the system will increase the resilience capability of the cockpit system during abnormal or emergency situations because the pilot retains control as a flexible and active decision-maker, and the pilot has the necessary resources to assist in assessing the severity of problems, diagnosing the cause, and planning and implementing a proper response when needed, if needed. This shift promotes operational resilience, enabling system flexibility and the adaptive capacity needed to cope with the residual uncertainty of non-normal situations. Even though the discussion has focused on aviation, checklists and procedures are commonplace in many industries. Operational systems are evolving to higher levels of complexity, and conventional checklists fail to impart resilience to these systems. It is hoped that the discussion within this chapter stimulates reflection and motivates exploration of RfA or other paradigms to exploit the affordances of technology for creating progressive conceptualisation of checklists and their role in dealing with complex operational systems across the industry.

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Chapter 17
The Case of Digitalisation in the Brazilian Development Bank (BNDES): How Brazilian Culture and the Institutional Values Influence the Process

Helena Tenorio Veiga de Almeida and Ricardo Luiz de Souza Ramos

Uncertainty is something which is present, desirable and necessary for evolution.
A stoic is someone who transforms fear into prudence, pain into transformation, mistakes into initiation and desire into undertaking.

Nassim Nicholas Taleb—Anti-fragile

Abstract The path and velocity of technological innovations sparked a process of digital transformation in almost every economic sector. It goes without saying that cultural aspects play a fundamental role in these processes both at a national level as well as at an institutional one. This chapter presents a case study of the Brazilian Development Bank (BNDES), an important Brazilian federal institution whose mission is to implement government policies to foster national development in different forms. The BNDES's case is particularly interesting as it focuses its attention on how intellectual capital and cultural characteristics shaped the digitalisation strategy of an important part of its operations from 2016 to 2019. For the purpose of the present analysis, two researchers were used: one involving an organisational survey directed at all 2700 employees and the other a qualitative interview with key executives. The result demonstrated that aspects like the culture of silos and its hierarchy (both also found in Brazilian Culture) acted as obstacles as it underwent this digital transformation process, even when the traditional and

This chapter does not represent the BNDES's institutional position, it is sole based on authors' opinion and experience up to March 2019.

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current process posed a threat to the existence of business model sustainability in the near future. The BNDES case sheds light on the importance of building resilient institutions in opposition to resistant ones. A strategy of change starts by recognising patterns of cultural behaviours in an organisation and the need to shape them to adaptation and suitability. Once that strategy is well implemented in a particular sector of activities, it can then act as a benchmark for future reference and guidelines of action.

Keywords Digital transformation · Intangible assets · Brazilian culture · Resilient institutions · Organisational culture · Organisational change · BNDES' case study

17.1 Introduction

This chapter will seek to tell the story of the acceleration of digitalisation processes inside one of the most important financial institutions in and of Brazil—the Brazilian National Development Bank (BNDES). It will comprise the period between 2016 and 2019 with a strong emphasis on the defining features that characterise both the organisational and human capital of this institution.

For such endeavour, we will initially layout an overall panorama of digitalisation in Brazil and raise a few cultural and social aspects as well as demographic of the population, which exerts direct influence in the shape, scope, and direction of this digitalisation process of the economy and in Brazilian society. Following this thread, we will then look at the Brazilian financial system, one of the most advanced sectors in terms of adopting digital technologies, and thus focus specifically on BNDES, its role in bringing resilience to Brazilian economy and the case of the digital transformation of BNDES from 2016 onwards.

The choice to focus on aspects of cultural organisation, a term that imbues what authors from The New Club of Paris established to refer as the intellectual capital of an institution (or intangible assets)[1] is due to the strong influence that cultures have in digital transformations and to another extent in any paradigm shift that implies a change of behaviour and *modus operandi* of the institution. Cultures can act as sources of transformation, but they also can be an impediment and even halt this process. Nowadays, understanding the culture of an organisation and to search adequate strategies in due time and engagement are currently intangible assets to construct a more resilient organisation.

The following sections show some aspects of Brazilian culture that result in difficulties to take risks under innovation's process and its reflections in a national public institution, like BNDES. The case study mostly focuses on the way found to

[1] *More details in Ordóñez & Edvinsson, particularly in the Almeida and Braga's (2014) section (p. 235) called "Evaluating Intangibles Assets and Competitiveness' in Brazilian Firms: The BNDES's approach."*

Population: 210 million

Area: 8,5 million KM^2

Nominal GDP (2019): USD 1,6 trillion

GDP Per capita (2019): USD 8,717

IDH: 0,761 Gini: 53,3

Internet Users: 134 million

Sources: World Bank Data site and Cetic.br (2021)

Fig. 17.1 Brazil in a few numbers

overcome organisational resistance to change by managing cultural capital and intellectual capital to function in the same direction. The result, as the readers will see, was a leapfrogging transformation in one important area of BNDES' operation in terms of productivity. On the other hand, it will show the tortuous path to transforming behaviour, especially when it comes to improving customer experience. Although it is possible to manage culture, it takes time to change even when they are not suitable to organisational culture. In fact, we can realise that change and continuity are both aspects of the reality that are very connected and they should be understood as dialectical relationship in order to be capable to manage culture and create organisational resilience.

For the purposes of this chapter, organisational resilience is understood as *"the ability to adapt effectively and efficiently to change, to apply learning from challenges, mistakes or successes to future conditions; and, finally, to grow and prosper"* (Moran and Tame, 2012).

17.2 Digitalization and Intellectual Capital in Brazil

Brazil is an enormous and unequal country, and this is reflected in digitalisation statistics. Some numbers place us at the top of rankings, while other figures show the size of the challenge we face in terms of digital transformation and inclusion (Fig. 17.1).

The last TIC household survey conducted by CETIC.br (sponsored by UNESCO),[2] before the COVID-19 pandemic and divulged in May 2020, reveals that Brazil has 134 million internet users (74% of the population above 10 years of age) and that it is present in 75% of Brazilian households. However, around

[2] https://cetic.br/media/analises/tic_domicilios_2019_coletiva_imprensa.pdf.

20 million households do not have internet access because they are located in far-away regions or less economically attractive areas.

The use of the internet is revealing of a society that needs an educational and professional change that incorporates digital means. The use of the internet for instantaneous messaging and social media dominates user activity (Fig. 17.2). The discussion groups or forums respond to just 11% of the user's internet activity. Regarding the search for information, what stands out is the search for health info in the older population (above 60 years of age) with university degrees and better off financially. Banking services are relevant (we will look at it in the next section), and an encyclopedic search is done by roughly 28% of users. All these figures have been stable for the last 3 years.

Digitalisation strategies began to be part of governmental agendas and of multilateral institutions worldwide, and it has not been different in Brazil. In 2018, after the construction of a multidisciplinary group comprised of Government, Academia, and Businesses, the document *Brazil Digital Transformation Strategy*, or E-Digital, was launched.

In 2020, it was time to push forward the Plan of Digital Government or E-gov.[3] The digitalisation of government proved itself to be even more important during the COVID-19 pandemic as means to guarantee essential public services to the population as well as fostering the digitalisation of private services via digital certifications, emissions of electronic documents and the interconnection of systems. Amid the COVID-19 crisis, Brazil approved the General Law of Data Protection, providing even more security and privacy to citizens' users of the internet, and it also kick-started the regulation of Open Banking.

Although there is a visible effort in developing a digital society in Brazil, those policies must be followed by investments that increase our national intellectual capital in order to really absorbed the gains of this whole new innovative environment (and minimise the negative effects). The research was conducted by two members of The New Club of Paris, Edvinsson and Lin (2019)[4] and showed Brazil in a non-comfortable position in terms of National Intellectual Capital (NIC index). Brazil's overall 2018 NIC score is worse than the 59-country average as scores for all component capitals (Human, Market, Process, and Renewal Capital) fall below the average (Fig. 17.3).

For the purpose of this chapter, we will use in Sect. 17.3.2 the Hofstede (1984) model to focus on the Brazilian cultural aspects, particularly those aspects that impact the organisations and help to model a kind of Brazilian organisational culture.

One aspect of cultural behaviour that today calls attention to is related to the concept of resilience. After decades of intense technological transformations,

[3] https://www.gov.br/mcti/pt-br/centrais-de-conteudo/comunicados-mcti/estrategia-digital-brasileira/digitalstrategy.pd.

[4] National Intangible Capital (NIC) consists of four basic dimensions with 12 indicators: (1) Human Capital (skills and education), (2) Market Capital (business attractiveness), (3) Process Capital (societal functionality), and (4) Renewal Capital (knowledge creation and innovation).

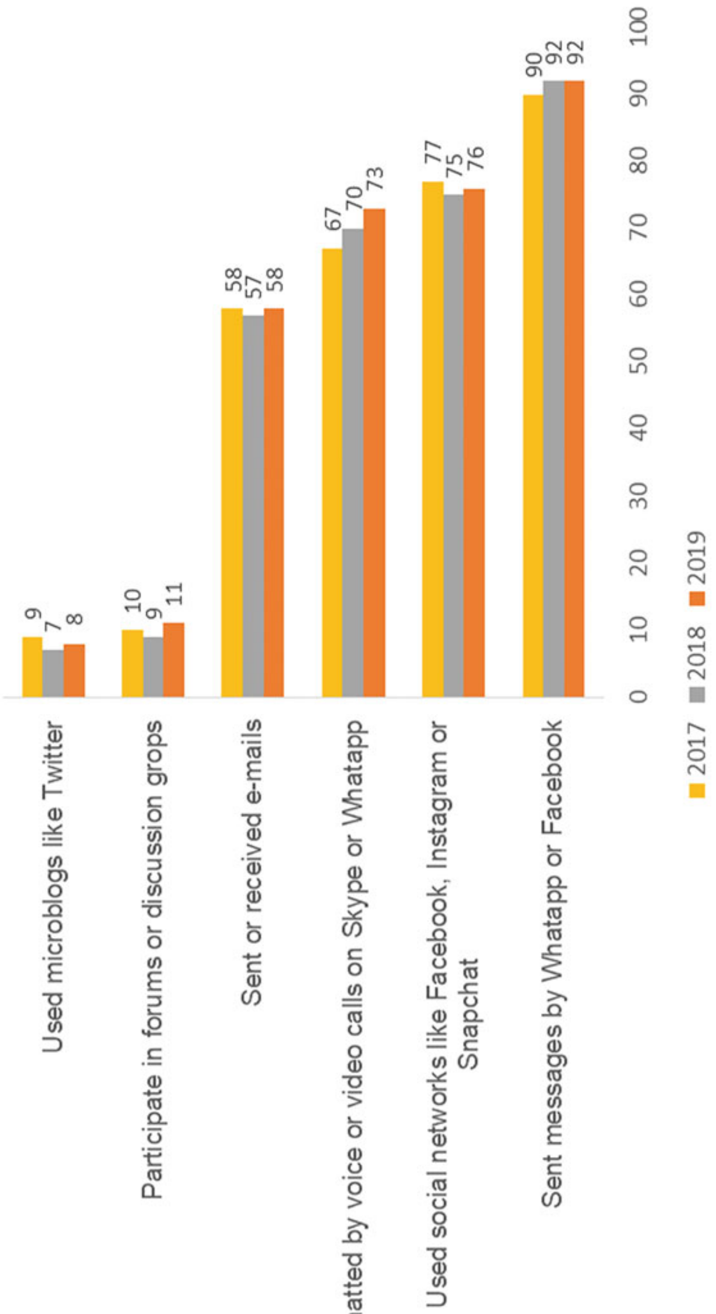
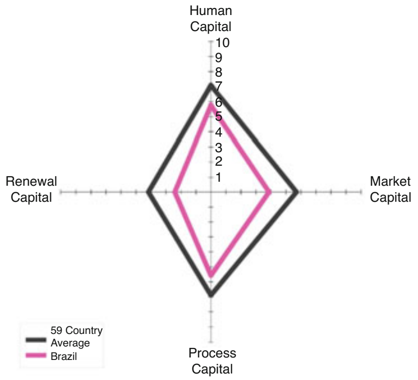


Fig. 17.2 Internet users by activities in the Web communication % of total Internet users. Source: adapted from TIC Household Survey 2019 CE

Brazil **RANK 58th/59**



AVERAGE SCORES

Overall NIC	**17.59**
Human Capital	5.74
Market Capital	3.87
Process Capital	5.57
Renewal Capital	2.41

Fig. 17.3 Brazil national intellectual capital index

climate change, international financial crises and now the COVID-19 pandemic, society must be prepared to deal with shocks and to adapt positively. Indeed, paradoxical as it may be, change is the new normal standard of our society.

In the literature, we can find different concepts of resilience; the OECD (2014) developed a guideline for resilience analysis that helps to define resilience as “the ability of households, communities and nations to absorb and recover from shocks, whilst positively adapting and transforming their structures and means for living in the face of long-term stresses, change and uncertainty.”

17.2.1 Digitalization in Brazilian Financial Sector

The Brazilian banking sector is highly concentrated, with the five biggest banks owning roughly 85% of total assets,[5] and it has displayed resilience, as evidenced by the rather smooth way it went through the latest international financial crises. The level of capital is high, and the return on equity surpasses most of its international peers. Many people think that this resilience stems back to the years of high inflation in Brazil (1980–1995) and to the restructuring and strengthening of the national financial system (PROER). The current change in scenario, with low-interest rates and new technologies, envisages an environment as challenging as the post-stabilisation (1995). The business models of banking are going through a complete

[5] Taking the USA for comparison, the five biggest American banks concentrate 50% of total assets of banking sector. https://www.folhape.com.br/economia/brasil-e-o-segundo-em-concentracao-bancaria/71541/.

overhaul, migrating to embedded finance and BaaS (Bank as a Service), both of them strongly pushed by digital transformation and by focusing on client experience.[6]

According to an assessment by McKinsey Consultancy,[7] the Brazilian Financial sector is the one that presents the most advanced digital maturity among all researched sectors. Inside the financial sector, banks take the lead. In order to arrive at this conclusion, the research used a methodology that evaluates 22 practices divided into four dimensions in each business: Strategy, Capacity, Organisation, and Culture.

> Financial service is the sector that presents the most advanced digital maturity in Brazil and is in second place in the world. Its maturity is superior to the national average in all dimensions, and its leaders stand out in relation to other leaders in Capacity, Organization and Culture.

Regarding the investment in technologies by the Brazilian financial sector, a research conducted by Deloitte together with the Brazilian Bank Federation (Febraban)[8] shows that the total budget reached R$24.6 billion in 2019, added to the expenses of the IT sector, a 48% growth in relation to the previous year. The investment in new skills and training did not lag behind as well. According to the same research, 149 thousand hours of training were ministered for the formation of 11.4 thousand professionals in agile methods in 2019.

The data relative to fin-techs in Brazil reveal the growing importance of these financial start-ups in the national financial system. According to the Fin-tech District Report,[9] there were 742 fin-techs in the country in 2020, a 34.1% growth in relation to 2019. Also, according to the study, almost half of all Brazilian fin-techs (49.6%) were born in 2016–2019. Despite all the low-growth crisis in the last years in Brazil, the start-up segment has remained strong, and the capitalisation of these companies, via venture capital, has mobilised around US$2.7 billion, 35% of these in fin-techs.

All this movement of banking digitalisation was accelerated by the needs imposed by the COVID-19 pandemic. In addition to this, 2020 was the year in which the Brazilian Central Bank determined the entry into force of Open Banking in Brazil. The first phase was concluded in November 2020 with the availability of APIs of open data for channels of customer service, products, and credit operations. The schedule is tight, and it forecasts the second phase of client data sharing for May 2021 and the conclusion for November 2021. By observing the experiences that happened in the UK and in the EU, more transformation is still expected in the banking business models in Brazil.

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[6] More about the subject can be found in MIT Sloan research briefing from Weill and Woerner (2013).

[7] https://www.mckinsey.com/br/our-insights/transformacoes-digitais-no-brasil.

[8] https://www2.deloitte.com/br/pt/pages/financial-services/articles/pesquisa-febraban-tecnologia-bancaria.html. The survey counted on the participation of 22 financial institutions, which represent 90% of the assets of this industry in Brazil.

[9] https://distrito.me/dataminer/reports/.

17.3 BNDES and the Role of National Development Banks as Resilient Institution

The interest in Development Banks has sharply increased since the 2008 financial crisis, and the BNDES, as one of the most important institutions of this type in the world, has received a lot of attention from academics and the media. BNDES acted as an important player in counter cycle policies to face the 2008 crisis contributing to attenuate the endogenous instability of private financial markets.

> The 2007–2008 global financial crisis has shown the failure of private finance to efficiently allocate capital to finance real capital development. The resilience and stability of Brazil's financial system have received attention, since it navigated relatively smoothly through the Great Recession and the collapse of the shadow banking system. (Rezende, 2015)

Although just recently lights shun on BNDES activity, the bank has a long history in the Brazilian economy. Created in 1952 to support the infant industrialisation in Brazil and to long-term finance the infrastructure projects, BNDES assumed different roles during its 67 years of activity. Palludeto and Borghi (2020) wrote the most recent BNDES historical perspective study where they show that BNDES history is nonlinear, varying with socio-economic and political changes over time. Through its trajectory, BNDES adapts itself to perform the mission received from the federal government, and it includes the response to internal and external shocks. In that sense, BNDES has been a resilient institution, managing to adapt its structure and human capital according to different situations.

A notorious shift in its activities occurred in the 1990s, when BNDES assumed the process of privatisation of state-owned enterprises, following the direction of the Brazilian economy toward liberalisation and deregulation. Another important role played by BNDES at the end of 1990s was the Export Agency program. In the absence of an Eximbank in Brazil and the growing importance of exports in a more globalised world, BNDES took hold of this role. During the 2000s, BNDES focused more on innovation, green economy, export of engineer services, internationalisation of national enterprises and support to medium and small companies. From 2009 to 2014, the loans increased substantially due to the counter cycle policy and the program to maintain the level of investment in the economy (Ferraz and Coutinho, 2019).

The present period of BNDES history started in 2016 with a new administration after 12 years of continuity and brought along a big adjustment in the bank, including reorientation and resource of funding. The size of the disbursements started to decrease, and new challenges were posed: the phasing-out of low-interest rate loans, more competition from the capital markets and banks, and a huge digitalisation of the financial sector.

More examples of adaptation and reorientation of Development Banks missions were described in Griffith-Jones and Ocampo (2018), which specifically looked at five countries in Latin America, as well as China and Germany. While it acknowledges that there is substantial variation in development banks, the potential roles are similar. Development banks can provide (1) countercyclical policies, (2) structural transformation and economic diversification, (3) promotion of green energy, (4) infrastructure financing, and (5) financial inclusion.

Based on these characteristics, we can think about Development Banks as resilient institutions and institutions that bring resilience to national economies especially working in counter cycle policies and attenuating economic shocks.

The economic crisis derivate from the Covid19 pandemic showed once more the role played by developing and public banks in dealing with a world full of uncertainty, as can be found at *PublicBanksCovid19.org*.[10]

The human capital of these institutions also has a significant part in creating resilience. The employees should be very qualified in order to learn different skills in various fields of knowledge. This is a lifelong learning process. The organisational culture is crucial in both ways: offering resistance to change and maintaining the essence of the institution even during the change of political orientation.

Before addressing the case of BNDES digitalisation, it is worthwhile a brief description of the institution, its organisational and human capital since it is through these assets that we will seek to analyse the process of digitalisation. The period that we will look at ranges from 2016 to 2019 (4 years), which coincides with the tenure of the co-author of this chapter, Ricardo Ramos, a C-level executive from the Information Technology, Human Resources, Strategic Planning and Digital Operations areas. The HR structure was composed as follows: 2652 employees, all civil servants, 82% graduated, 68% post-graduated. In terms of gender, 35% women and 65% men.[11]

17.3.1 A Glance at Current BNDES

The organisational structure is hierarchic-functional, grouped by areas of activity. The Directors and Presidents can be from outside the bank, appointed by the President of the Republic. Currently, there are 10 Directors, including the President. The managers of the areas are the Superintendents (Deputy Directors), and currently, there are 19 areas: 10 front-office (energy, industry, environment, social etc.) and 9 back-office (financial, administrative, compliance, comptroller, etc.).

The back-office provides service to all front-office areas, including the Information Technology—IT services, so that services must be prioritised in order of attendance, generating in some cases internal disputes and the appearance of a silo culture. This kind of structure highlights the silos and makes the process of prioritising resources, especially IT, painful and difficult in a state-owned organisation, such as BNDES. This has always been the organisational reality.

[10] McDonald, Marois and Barrowclough (2021): Public Banks and the COVID-19: Combating the pandemic with public finance.

[11] BNDES (2020) Annual Report, 2019 at https://web.bndes.gov.br/bib/jspui/handle/1408/20101.

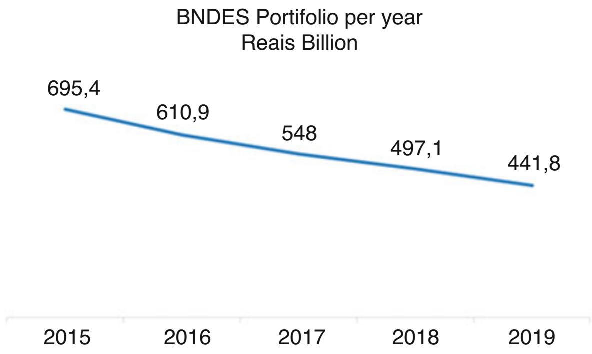

Fig. 17.4 BNDES credit portfolio (2015–2019)

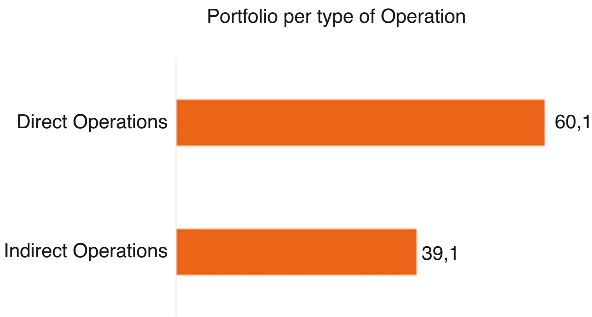

Fig. 17.5 BNDES portfolio—direct X indirect (2019)

The credit portfolio of BNDES totalled R$442 billion (approximately U $110.5 billion, a 4:1 ratio) in December 2019[12] distributed in the following manner[13] (Fig. 17.4, 17.5 and 17.6):

It is important to note the decrease in BNDES credit portfolio between 2015 and 2019 was due to two policies that were established by the Brazilian Government: an increase in the cost of BNDES funding (affecting competitiveness) and the requirement of debt prepayment that BNDES held with the National Treasury (reducing the funding available for loans).

For 2020, BNDES defined the following themes as strategical: (1) Digital transformation by supporting the use of technology and encouraging innovation in the management and provision of public services, in line with the Ministry of Economy's (ME) guidelines and the Doing Business ranking's methodology; (2) Private solutions to public problems by implementing private security, public lighting, public management, and citizen support projects (typically structured in administrative PPPs); (3) Offering financial support to microentrepreneurs and family farmers with reduced access to the traditional financial system.

Within this strategic plan, there are three distinct models of business in BNDES:

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[12] In 30/12/2019 the exchange rate was 1:4, one dollar was equivalent to 4.0098 reias.

[13] BNDES (2020) Annual Report, 2019 at https://web.bndes.gov.br/bib/jspui/handle/1408/20101.

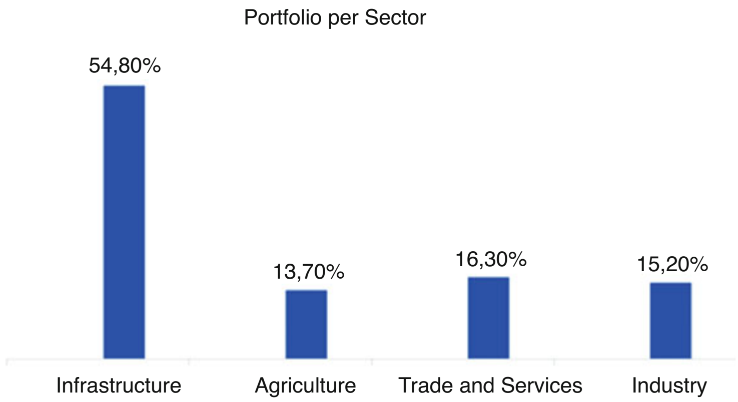

Fig. 17.6 BNDES portfolio by sector (2019)

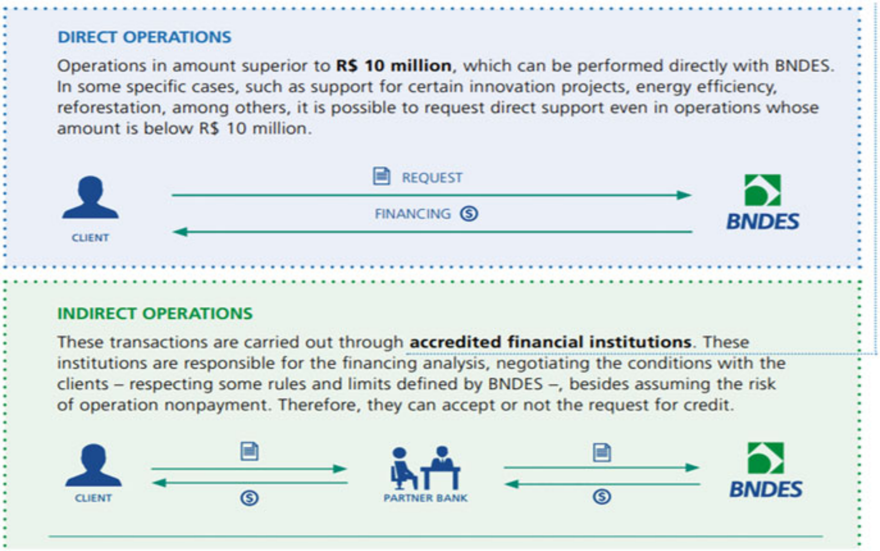

Fig. 17.7 Indirect X direct (second tier × first tier) BNDES's business model. Source: BNDES (2020)

1. Direct long-term funding (first tier).
2. Financing and guarantees to SMEs, agricultural and machinery acquisition in an indirect (second tier); and.
3. Providing service in the elaboration of privatisation projects and PPPs (public-private partnerships).

The case study unfolds related to the Indirect Model (Fig. 17.7 below), which is more similar to a retail banking model, where the provision of IT services connected with the need of digitalising of a massive number of operations are mostly needed.

BNDES indirect operations responds to almost 50% of the annual volume of disbursed resources and 99% of the volume of credit operations.

It is quite significant to note that, concerning the organisational structure for indirect operations, BNDES is fundamentally the same when we consider 2020 and the analysed period in this chapter (2016–2019).

17.3.2 Flavor of Brazilian and BNDES Culture

Culture can be perceived as an element that gives stability to the organisation, representing its deep symbolic world. Although there are many definitions for culture, all of them bring similar conceptions, which, in general, define organisational culture *"a system of shared meaning held by members that distinguish the organisation from other organisations"* (Robbins and Judge, 2013).

Of the many organisation cultural aspects, how power relations are established in the organisation is crucial to provide an environment favourable to change and, consequently, to innovate. Depending on the organisation, culture can constraint organisational change movement (in the name of stability) or facilitate it (encouraging innovation). In fact, cultural aspects can be seen as a struggling process between the status quo and pro-change forces (Pettigrew, 1979).

As the organisational culture is significantly impacted by the culture of the country, the analysis of the social context and the country's culture is essential for a better understanding of the symbolic universe of the organisation. The Hofstede model is a remarkably interesting approach since it explains some cultural dimensions of people from different countries (utilising a survey at IBM employees around the world), describing organisational culture as a set of variables that can be measured.

There are six aspects analysed by Hofstede for each country.[14] Even though the methodology has some limitations (biased sample and small scope), the study proves to be able to show some cultural traits of the countries studied, giving a very rough idea of some remarkable features of Brazil.

As we can see in Fig. 17.8, this model shows Brazil as a risk-averse society, characterised by a great distance from power, low individualism, and indulgence with its citizens. As a Brazilian state-owned bank, BNDES is, of course, influenced by these characteristics.

Organisations with a high-power distance have difficulty in establishing mechanisms of coordination n and cooperation. They are organisations that favour silos and the emergence of an environment where the process becomes more important

[14] A more complete analysis can be searched on the site http://geert-hofstede.com/brazil.html, but for the purpose of this chapter, only the dimensions considered relevant to the organisational change aspects were highlighted.

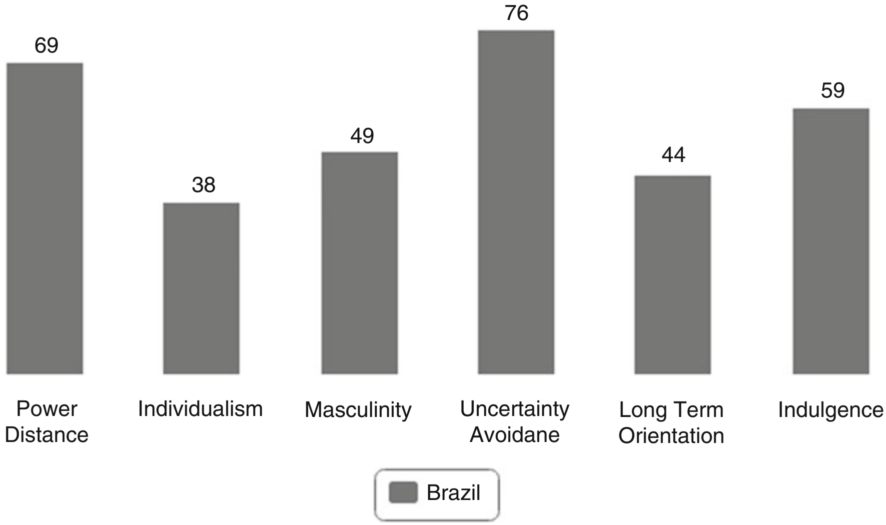

Fig. 17.8 Hofstede model applied to Brazil (The original theory proposed four dimensions along which cultural values (Hofstede, 1984) and over time Hofstede added the fifth and sixth dimension (Hofsted & Michael, 2010)). Source: Adapted from Hofstede (1984)

than the result. In this context, postponing decisions is often more rewarding than trying and, eventually, making mistakes.

In addition to the distance of power, we can also observe other very peculiar BNDES cultural traits like a strong sense of belonging to the institution, pursuit for excellence (bordering perfectionism) in the execution of public policies (recognised by third parties) and a "consensus culture" in the decision-making process. These combined cultural traits form the core of BNDES' culture. Importantly, these features have positive and dark sides. Understanding these cultural traits and the way it manages the organisation leverage the powered side.

In 2015, a survey[15] managed to capture much of BNDES cultural characteristics relating to three relevant themes: decision-making process, innovation, and learning organisation capacity. The research takes as a basis working environment research led by the Human Resources area with all employees and then added interviews with deputy directors (superintendents) and board members; and finally, was completed

[15] *More details of this research see Ramos,* 2015 *As a BNDES employee, the co-author of the dissertation tried not to restrict himself to observing the dynamics of the organization, but rather to perform a second-order observation. According to Niklas Luhmann, second-order observations are social or psychic systems capable of observing themselves in their day-to-day operations. Second-order observations constitute a key concept in Luhmann's theory of social systems because they underline the systemic constitution of meaning and understanding which are not necessarily and automatically produced in social systems but when opportunities for second-order observations emerge (Styhre,* 2008*).*

with the author's observations considering his vast experience as member of the committees. The three themes chosen unveiled quite important to manage the culture during the digital transformation analysed in this chapter.

As a result of this research, it became crystal clear that creating an environment for innovation of processes or products is quite challenging in BNDES since the culture of consensus and the existence of silos hind the flow of ideas. The high-power distance is also a relevant aspect since Innovation is intricately linked to critical reflection because an innovative organisation must encourage the employees to question assumptions and to empower its subordinates (Reynolds, 1998). There must be trust among parts in order to foster innovation. Additionally, the existence of silos and slabs in BNDES does not encourage collaboration between people and cooperative work takes its toll.

Finally, an environment that fosters innovation should encourage people to take risks, and any error is considered an inherent part of the innovation process. Autonomy and innovation capacity always go hand in hand. This did not seem to be the case for BNDES.

Paradoxically, the same cultural traits that hinder the innovation process protect BNDES from constant management changes. Such cultural traits have deep roots and often work as a safety valve. Because it is a state-owned bank, from time to time, the direction shifts, and these cultural traits impose a strong resistance to changes that, eventually, depart from the bank's mission: Brazil economic development. Over time, the organisation has developed strong resilience, being able to adapt to various changes in the environment without ever failing to fulfil its mission.

However, the resilience that protects the bank was also present in the digitisation process described in this chapter. Change and continuity were forces that had to be understood and harmonised for the change to be successful. In conclusion, the digital transformation process was carried out because the process managers, in some way, understood the BNDES culture, provided an environment of trust and created a virtuous circle among the team that implemented the change.

17.4 Digital Transformation in a Complex Environment

The digital transformation process described in this chapter occurred during a political turmoil in Brazil (after President Dilma's impeachment). BNDES faced difficulties as well, being challenged on several fronts by the Federal Audit Court and the Federal Public Attorney. The organisational climate was tense, making it harder to engage people for difficult work or to modify the current processes.

At the same time, BNDES had lost its natural competitiveness on long-term interest rates through legislation (in 2017) that changed its funding costs. An IT-enabled business transformation initiative had become essential for the institution's survival in the upcoming years, especially in the second-tier business model since BNDES cost would become higher over time and, as a consequence, it was

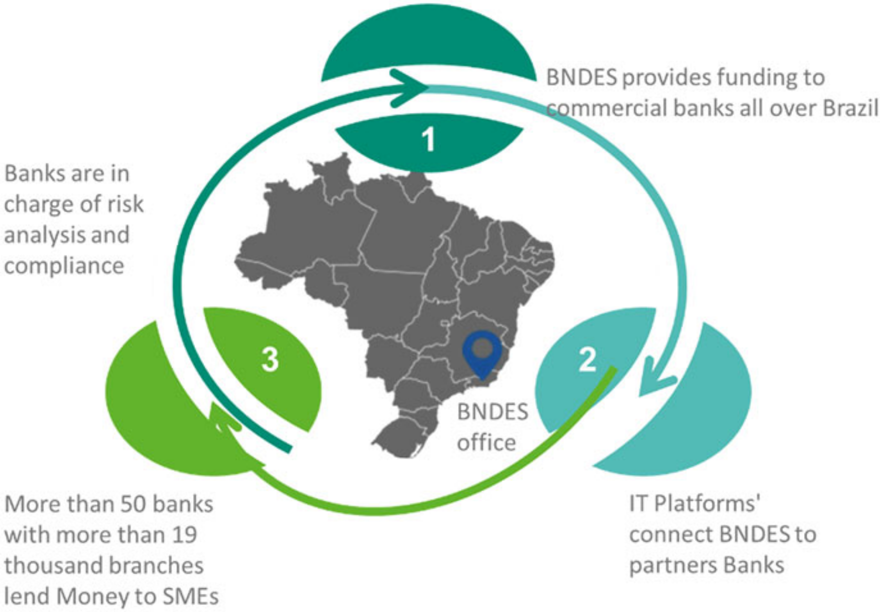

Fig. 17.9 Indirect operational ecosystem. Source: Own Elaboration

necessary to improve the productivity to reduce the transaction cost in the operations with the banks.

The following figure shows the ecosystem of the indirect (second-tier) business model, which includes more than 50 commercial national banks that act as lenders of BNDES resources, demonstrating better the need to be more efficient in the second-tier model seeing that the credit analysis is carried out by the partner banks, imposing a second margin (that of BNDES) on the end customer (Fig. 17.9).

In addition, Brazil's banking sector had gone through major changes in previous years (as shown in Sect. 17.3.1) and demanded a profound transformation in order to finance SMEs more effectively and providing a better customer experience.

17.4.1 The Organisational Context

Since 2005, BNDES had been implementing changes in its processes toward greater automation. The project was extremely ambitious and intended to make BNDES a state-of-the-art organisation in terms of processes and systems. There was a well-outlined plan to automate the administrative (implementing an ERP) and the operational systems. The project received the acronym AGIR, which in Portuguese also means "Act," and a new organisational unit was created to run it, apart from the IT area.

However, organisational resistance to change was much stronger than expected, and, 10 years later, only part of the ERP system had been fully implemented, mostly the administrative part. It is particularly important to highlight that there are many reports showing all sorts of difficulties in implementing ERP in different organisations, especially in banks with legacy systems.

Basically, BNDES has always performed most of its handmade processes, and there was an implicit fear that the productivity gains of a digital platform could withdraw from BNDES's managers their capacity to execute public policies. Here there was a clear misunderstanding between the process of thinking and execution. BNDES employees should think and contribute to public policies in a handmade process, but they must understand that the implementation of the policies must have an impact, and this is only possible if BNDES is able to run them on a large scale. BNDES employees, frequently, connect the large scale with loss of quality which, perhaps, could be true in the past, but not today with big date technological improvements.

Considering the current state of the art technology, the digitisation of processes makes it possible to implement public policies with greater productivity and better compliance. In this new context, BNDES employees should change the mindset from "controlling the execution" to "measuring the effectiveness" of public policy.

Regarding operating systems, just 20% of the indirect (second-tier) operations were digitalised. In this business model, BNDES had three platforms running different products and with a lot of manual check point. Even the most automated area needed a deep intervention in terms of process and technology. The rest of all operating systems (including direct transactions) was in a very worse situation because much more human intervention was required, and the processes were not integrated into one system.

In this context, in July 2016, a new board arrived and decided to speed up the digital transformation process by prioritising operating systems with an emphasis on the indirect business model. In addition, the board determined that BNDES should diversify its distribution channels beyond banks.

The case study of the present chapter deals with the difficulties and opportunities for digitisation of the Indirect Operations Area (responsible for second-tier operations) from 2016, considering its importance for BNDES mission (support to SMEs) and within an organisational context that favoured the formation of silos, generating a culture averse to change and innovations.

17.4.2 The Relationship of Silos:Indirect Operation Area (AOI) and IT Area

In July 2016, BNDES had a specific area (Indirect Operation Area—AOI) to deal with operations carried out through banks (second-tier transactions), which, in its majority, financed small and medium-sized companies (SME's).[16] Obviously, this area has always demanded, over time, intensive IT resources due not only to the amount disbursed, but mainly because of the number of operations carried out per year (approximately 150,000 in December 2019).

Due to the high number of operations and the need to coordinate the operation with around 50 partner banks, this area was quite averse to changes in the already setup processes. As the operations were increasing in number and complexity, the processes were getting slower. In 2016, on average, the processing time for a loan, in AOI, was 10 days (from the partner bank registering the transaction until the disbursement of the loan), mostly because there were a lot of manual interventions for increasing the control activities. These control activities could be done digitally, but, over the years, IT resources had been used to enlarge the size of the operation, developing new systems with low connections with the existing, instead of optimising the processes.

Furthermore, because of the ambitious project for processes and systems changes at BNDES (AGIR—already mentioned in this chapter), IT resources were not sufficiently prioritised to provide adequate systems for the Indirect Operations Area. Surprisingly, this area had not been prioritised in the AGIR project, it had been decided that it would be the last area to modernise. The argument used for this non-prioritisation was that this area already had some degree of automation, and the digitalisation project would start with the other operational areas of BNDES.

The Indirect Operations Area had a micro-culture quite like that of BNDES: the existence of silos and slabs, risk-averse behaviour, and high-power distance, with a hierarchical functional structure.

A remarkably similar culture of aversion to change can be observed in the IT area. In comparative terms, it can be said that the IT area had a higher power distance than the average gap from the others bank areas, being much more hierarchical. This greater managerial rigidity perception can be materialised by the greater number of managerial layers that this area had in relation to the other areas of the bank.

In July 2016, the issue of silos within IT resources was even more dramatic because there were two areas (AGIR and IT) struggling for resources. Two centres of power that hardly cooperated at the minimum level required. The three areas involved (AGIR, IT and AOI) had their structure focused on products and did not adequately optimise their resources. It is important to mention that this observed dysfunction was derived from our traits culture exacerbated by the large growth that BNDES had in the previous decade.

Additionally, The IT management at BNDES was administrated on a project basis. This led to long periods of system planning and low effectiveness in its implementation (in many cases, they were already born obsolete). The result was that, in July 2016, the Indirect Operations Area had three non-interchangeable operations platforms, a lot of manual work and a huge contingent of IT professionals working in systems maintenance. Furthermore, only 20% of indirect operations were

[16] See Sect. 17.4 and Figure 17.9.

fully digitalised (in the sense of no manual intervention). By consequence, there were many bottlenecks and many complaints from the partner banks and leading the average processing time to 10 days, as already mentioned in this chapter.

17.4.3 The Strategy for Change

The arrival of the new board, together with the diagnosis of culture made in 2015, started a change aimed at targeting the digital transformation of BNDES. The first decisions were: (1) merging the two areas of IT; (2) the head of the smallest area (AGIR) became the chief officer of the newly created area. This movement made the design of the new IT area more balanced in its power structure and reduced the internal conflicts.

In addition, the management of IT projects basis model was changed to business towers model in order to intensify the relationship between IT and Indirect Operation Areas (AOI), breaking the silos and, consequently, increase collaboration. From that moment on, the Indirect Operations Area no longer compete with the other areas for IT resources. Its prioritisation was clear, and the challenge of digitalisation was placed as a main goal for the top executives of both areas (IT and AOI). The board demand a roadmap addressing the following three years.

This whole change aims to execute a digitalisation strategy to which organisations should migrate from the business silos model (which produces great local solutions) to a business modularity model (which allows them to gain efficiency, agility, increase collaboration, improve compliance, and encourage innovation).[17]

The engaged employees in the process of change were identified by their skills (soft and hard competences), and they received autonomy and responsibility to embark on the digitalisation journey. They were agents of change and would face a huge challenge—in a short period of time (six months considering the first phase completed), the platforms should be unified, an automatic approval system should be in place (the goal was to reduce from ten to one day the time of loan approval); and, finally, bound to improve the customer experience (companies complained a lot about the service provided by partner banks).

The agents of change formed squads using agile systems development methodologies and reviewed all processes. A decision was made to implement the change on July 1, 2017, limiting this first milestone in the Harvest Plan[18] systems (representing a quarter of the annual disbursement of the area) to reduce the risk of paralysing disbursements. In addition, it was also decided to keep the old platforms in place for a while so that partner banks could make their adaptations without having to stop operating with BNDES. Within this process of change, some partner

[17] MIT model by Ross (2006).

[18] The Harvest Plan is prepared by the Federal Government, presents a set of policies to assist Agribusiness, and is valid from July to June of the following year.

banks had committed to making the changes in their operating systems, simultaneously, BNDES, thus accelerating the process.

Another important front of digital transformation occurred almost in parallel—the construction of a relationship platform connected with the end customers (the SMEs). By July 2017, most SMEs could only seek BNDES loans through the partner banks.[19] As already mentioned, for a variety of reasons, there were a lot of complaints from end customers in second-tier operations, and BNDES did not have much information about them. This information asymmetry is natural in a second-tier operation as well described in Fernandez-Arias et al. (2019): *"operating in that modality (second-tier) may lead to complex principal agent-problems."*

The new platform would be able to allow the end customer to access the financing request directly with BNDES, which would pass it on to the partner's banks that the customer chose. BNDES would have information about the end customer and the results of the loan application (or possible reasons for the loan's denial), reducing the information asymmetry. This platform was initially called "SME Channel."

In summary, BNDES board and AOI area doubled the bet by opening two digitalisation fronts: one focused on efficiency and productivity (unification of platforms) and the other focused on the customer experience. The key elements were a digitalisation roadmap with well-defined milestones, redefinitions of IT organisational structure and identification of people engaged in change in both areas. BNDES Board sponsored the change and gave the sense of urgency and priority, having in mind the difficulties encountered in the past and the new macroeconomic context in 2017 when BNDES would start a transition to a market-oriented cost of funding (initialised in January 2018).

17.4.4 From Indirect Operation Area (AOI) to Digital Area (ADIG)

The major result obtained was the full achievement of the first milestone: in July 2017, both the online platform for the Harvest Plan channel were in a production environment, and the SME platform was launched.

Despite a few mishaps, BNDES was able to build an automatic approval system (three seconds) much better than the previously established goal (one day). In August 2017, the federal government requested BNDES to offer through its online platform a new and broad working capital financing credit line for SMEs and, this request, speed up the entire process migration of all BNDES credit lines to a single platform. As already mentioned in this chapter, at that time, BNDES used to have three different platforms, and we started to unify them.

[19] As shown in Figure 17.4, the minimum loan value for a direct operation with BNDES was ten million Reais, which was normally not affordable for SMEs.

The success of the automatic operation accelerated the decision of other partner banks to migrate to the online platform. It was noticed that several banks increased their operations because now all products could be running on one single platform. Prior to the move, some banks did not operate the three platforms, being unable to offer all BNDES financing options, as the products ran on different platforms.

Naturally, some unpleasant surprises occurred. The most serious one happened with an important partner bank in our digitalisation journey. During its migration to the online platform, this bank had some problems with its operation. After researching the reasons for its difficulties, BNDES found that the new system was much safer in terms of compliance. There was a small non-compliance that manual approval was not able to get, understand, and get. With machine-to-machine approval (between BNDES and banks), all business rules were specified in the systems, and compliance was automatic along with the granting of credit. In the end, we considered the problem as an advantage.

As the transformation was in progress, other ideas emerged (like long-term fixed-rate hedge), integrations were amplified, and the organisation realised the importance of what was going on. In December 2018, 85% of the operation was already digital and, a year later, the digitalisation level of 97% was achieved with the unified operating platforms and approval in three seconds.

Some strategies overcame the expectations, and others faced more obstacles than we had anticipated. The launch of SME Channel did not repeat the systems automation success. In the new platform, the direct interaction with end customers caused frustration since BNDES was not able to induce an increase in financing transactions by partner banks. The online operating platform was not born integrated with the SME channel, which hindered information management. In addition, the partner banks did not have their systems integrated with the newly launched SME Channel, creating a lot of frustration for SMEs (end customers) that sought financing. Even nowadays, there is still much to be done to transform the SME Channel into an integrated platform of products and services between the partner banks and BNDES.

However, the launch of the SME Channel allowed BNDES to start better understanding the end customers' needs and bring new players to financing the SME's. With the SME channel, BNDES could make financial education available to SMEs, and the diversification of credit channels, through partnerships with Fin-techs enabling them to offer financing for customers possibly rejected by partner banks. However, the platform was not able to significantly reduce the information asymmetry between BNDES and partner banks regarding the knowledge of the end customer.

The process of change, of course, was not so smooth in terms of people and structure. Some people at AOI quit because either they did not agree with the change or did not adapt to the new working process, and the structure ended up changing. But, in general, resistance to change decreased as the operation's success demonstrated that it was possible to be faster, more effective and with greater compliance.

Additionally, the nature of people's work has improved. Employees started to perform more analytical and less manual tasks, which is more suited to the profile of

BNDES employees (about 88% have higher education). The constitution of multi-tasking and multi-area squads increased the interaction between people, reinforcing the propensity for collaboration.

In short, the digitisation process has improved the customer experience, decreased complaints about operations, reduced transaction costs and increased competitiveness, allowing BNDES to partially offset the loss of its competitive position based only on low-interest rates.

The change was so profound in the area that, in the middle of 2018, the Indirect Operation Area—AOI changed its organisational structure, becoming organised by processes (front, middle and back-office) and changing its name in sync with its new phase, it came to be called the Digital Area (ADIG). The internal re-branding reflected a deep culture change in ADIG, and all the processes of change induced adaptations also in the IT area where two units were created: new technologies (blockchain, artificial intelligence and machine learning, etc.) and data lake structuring.

In a few words, we overcame the resistances and placed the area cut above. We could see the huge transformation and, in some way, test the organisation resilience because we were capable to understand the new context and make a very quick change, increasing productivity and magnifying our capacities.

The success of the digital transformation in terms of productivity was a milestone for the beginning of a new phase, since, from that moment on, it was necessary to invest in a new phase of this transformation, in improving the customer experience and to spread the transformation experience to other units of BNDES.

The Open banking new regulatory system, launched in Brazil in 2020, will represent a new opportunity to reformulate the SME Channel following an international trend of Bank as a Service (BaaS) and Bank as a Platform (BaaP). The experience of digital transformation, reported in this chapter, will be important for BNDES to be able to take advantage of opportunities arising from open banking legislation. From this experience, BNDES employees were able to understand the pains and gains coming from a change process, making it possible to incorporate the seed of innovation into their culture.

Finally, it is remarkably interesting to realise that the fear of gaining productivity at the expense of substance loss (not being able to manage and execute public policies anymore because of the process automation) was buried in the pandemic. On the contrary, people understood that the digitalisation of processes provided BNDES with the ability to be more effective in the execution of public policies, giving its credit lines more capillarity, increasing the capacity in the number of operations and volume of financing. In addition, during this period, BNDES was able to launch new products very quickly (time to market) and worked as a federal government policy executor. This all incorporates compliance activities in the credit granting process itself.

The Brazilian Government has implemented its main policies to support SME's through BNDES digital platform, which would not be possible without the transformation carried out between 2016 and 2019.

17.5 Conclusion

The convergence of several technologies has been prompting a wave of digitalisation in Brazil that ranges from technological companies to more traditional sectors and recently, also, in all levels of government: state, municipal, and federal. Due to historical reasons, the Brazilian financial sector has always been well capitalised and is quite advanced in terms of digitalisation. Despite this, it has not been immune to the recent wave of innovation as it takes note of the rise in competition and possible changes in business models.

Because of its nature as a bank that supports national development and executes public policies (almost a monopoly), BNDES was focusing more on the results rather than the process of work per se and ended up being, often, a trendsetter due to its actions. However, with the advance of digitalisation in society, it has become mandatory for the bank to update itself. Be this as it may, although BNDES has belatedly initiated its process of digital transformation, it has significantly accelerated change from 2016 onwards.

During the process of digital transformation (which began in 2005 and sped up during the last years), it was perceived that the same culture of excellence that projects BNDES as a protagonist on various occasions has hampered the introduction of technology as a necessary tool to raise the impact of its own actions. The culture of silos and its hierarchy (like Brazilian culture) resisted the digital transformation process, which, in the last years, have proven to be essential for its own survival (the loss of long-term interest rate monopoly shed light on this issue). Together, the two cultural traits of the BNDES (excellence and high-power distance) hinder collaboration between people when not managed properly. For this, it is necessary to respect the culture and have negotiation skills to build agreements between participants in the transformation process.

Within this new external context of digital transformation experienced in the last years, a specific area in the bank has managed to nurture a process of change by breaking resistances and becoming a paradigm for other areas while demonstrating that it is possible to modify processes without losing the essence of its mission. From this experience, the authors believe that it will be possible to give robustness to the digital transformation in the organisation (strengthening organisational resilience) whilst preserving the excellency of its actions in management and in the execution of public policies.

Last but not least, it is important to reflect on the process of change itself. After years of struggling for a substantial change in all the processes of the organisation, the new board opted to enact a significant change by concentrating its effort on an operational area of the bank. At the end of the day, it is decisive to understand that part of the change resistance is an important cultural trait which frames the organisation resilience. An organisational resilience sometimes seems hard to deal with but imperative in a long-term survival. Therefore, the necessary skill for the manager to make big changes in a resilient organisation is to understand the culture, to know how to negotiate with the employees, engaging them, establishing goals and showing the gains of the change. In this way, resistance can be turned into momentum. This profound change, even though not without impedance, has become an example that it is possible to change without losing the essence.

It has also been perceived that the digitalisation of processes elevates the quality of work and creates opportunities of action. From the example of success in the case described here, new products were launched, new technologies are being tested (artificial intelligence, machine learning, blockchain etc.), and new movements of change are being made. The same culture that resisted to change now has become a propeller of it. Essentially, change and continuity are aspects of the same reality.

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Chapter 18
Resilience Capability and Successful Adoption of Digital Technologies: Two Case Studies

Francesca Sgobbi and Lino Codara

Abstract This chapter illustrates how resilience capability affects digital transformation by means of the case studies of two Italian middle-sized manufacturing companies that implemented important investments in digital technologies in recent years. Both companies show significant levels of resilience, which nevertheless result from different combinations of resilience drivers. One company displays a control-oriented model of resilience aimed at controlling change in the external environment, whereas the other one is characterised by a learning-oriented model of resilience intended for absorbing complexity. This difference reflects in the design and the execution of investments in digital technologies. The first company seems to perceive digitalisation as a further technological innovation in line with a traditional pursuit of efficiency. In contrast, the other company frames digital technologies a solution to increase the integration of organisational processes, besides technical ones.

Keywords Digital transformation · Resilience · Organisational change

18.1 Introduction

The impact of information technologies on employment and labour organisation has fuelled an intense discussion since the early applications of microelectronics in manufacturing (Kaplinsky, 1987), which further developed with the convergence between information technologies and communication technologies in uses

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pervasively extended to the whole range of professional and domestic tasks (Jovanovic & Rousseau, 2005). In recent years, the increasing integration between information systems, telecommunication networks, and production systems revived this debate, now centred on the effects of the so-called fourth industrial revolution. Driven by digital technologies, the latter is based on the combination between distributed sensors and actuators, information transmission across multiple channels, and decentralisation of computational and elaboration power also to peripheral production equipment (Brynjolfsson & McAfee, 2014; European Commission, 2019).

By accelerating the substitution of automatic solutions for human labour, the digital transformation prospects new models of labour division and new balances among occupations and wages, but also changes in job contents, required skills, and training needs. The academic and public debate has long focused on the opposition between optimists who claim that new applications will relieve people from fatigue and tedious tasks (Scholz & Schneider, 2017) and pessimists who forecast a polarisation between "lovely jobs" and "lousy jobs" (Goos & Manning, 2007). However, both positions reflect an inner technological determinism that suffers from the limits of a mechanistic approach to change. By overcoming the simplified vision of technological determinism, the concept of resilience provides a better understanding of the ongoing digital transformations. Resilience capability emphasises the role of contextual factors, organisational variables, and managerial guidelines in defining the organisational routines that influence the specific forms taken by technological change (Lengnick-Hall & Beck, 2005).

This chapter illustrates how resilience capability can justify different approaches to the digital transformation by contrasting the success stories of two Italian middle-sized manufacturing companies. Both companies boast a history of excellence in technological innovation and in economic and financial performance in the last decades. Both companies regard state-of-the-art technological solutions as a means to improve internal efficiency and increase the quality of sales-related services, two key conditions to keep production facilities in a high labour cost country such as Italy. Both companies have launched important projects of digital transformation in recent years. However, a significant difference exists in the approach adopted to implement these projects. While one company seems to perceive digital technologies as a further step in the "traditional" sequence of efficiency-enhancing innovations aimed at substituting for human labour, the other frames digital technologies as means of stronger process integration, whose success is enabled by formal organisational tools in support of change management.

The positive impact of investments in innovation on the efficiency of the affected processes reported by both companies supports the existence of multiple paths towards the adoption of digital technologies. This study explores the hypothesis that organisational resilience can explain the successful adoption of new technologies and its consequences on employment and job contents. In addition, the existence of multiple adoption paths can be traced back to the unique combination of component factors that characterise the resilience capability of each firm.

18.2 Organisational Resilience and Firm Success

In social studies, the concept of resilience was initially used to identify individual ability to recover from an adverse event and return to the previous level of functioning (Carver, 1998). However, the increasingly frequent occurrence of a diversified range of change experiences at different levels has significantly extended the field of application of this construct. First, resilience is a characteristic of both individuals and organisations (Coutu, 2002). Second, resilience comes into play not only to recover from a one-time shock or catastrophic event ("bouncing-back") but also to thrive under frequent, eventually continuous significant and unpredictable change ("bouncing-forward", Manyena et al., 2011). The resilient organisation "leverage(s) [...] resources and capabilities not only to resolve current dilemmas but to exploit opportunities and build a successful future" (Lengnick-Hall et al., 2011, p. 244). Accordingly, organisational resilience can be defined as "a firm's ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalise on disruptive surprises that potentially threaten organisation survival" (Lengnick-Hall et al., 2011, p. 244).

The above definition outlines that organisational resilience is an enabling factor of survival and success in a changing and turbulent environment. Based on a strong set of shared values, the resilient organisation develops a vision of its competitive environment, chooses its role within this framework, and builds up and adapts the routines that support the achievement of the organisational targets under uncertainty. The routines that embody an organisation's resilience capability concern both the exploration of the environmental characteristics and the actions to turn identified opportunities into realities. As effectively summarised by Lengnick-Hall and Beck (2005, p. 753), "high levels of resilience capacity increase the range of different routines that a firm is likely to develop for dealing with uncertainty and complexity. Moreover, high levels of resilience capacity increase the likelihood that a firm will accurately distinguish between equilibrium and nonequilibrium environmental changes".

Not surprisingly, given that resilience is an antecedent to a firm's success in a changing environment, a large share of researchers' efforts has focused on the identification of resilience dimensions and measures (Kamalahmadi & Parast, 2016). Coutu (2002) underlines that resilient subjects, both individuals and organisations, share three common characteristics: an objective vision of reality, a robust sense-making capability rooted in durable values, and a distinctive ability to elaborate and execute original and counterintuitive solutions to unforeseen challenges. Several authors stress the transient nature of resilience, which can be learned and forgotten in time (Sutcliffe & Vogus, 2003; Lengnick-Hall & Beck, 2005; Gittell et al., 2006), and its significant correlation with decentralised decision-making and cooperation (Sutcliffe & Vogus, 2003; Van der Vegt et al., 2015).

Different measures, sometimes involving very articulated approaches, have been suggested to assess organisational resilience (see, e.g., McManus et al., 2008, McCann et al., 2009; Kantur & İşeri-Say, 2012; Lee et al., 2013). For the purposes of the following empirical analysis, we adopt the compact model suggested by Lengnick-Hall and Beck (2005), who frame resilience as a blend of cognitive, behavioural, and contextual properties. Cognitive resilience concerns an organisation's ability to interpret unfamiliar situations, behavioural resilience is the capability to elaborate and implement new solutions to confront unprecedented change, and contextual resilience is the "ability to mobilise people, resources, and processes to transform these choices into reality" (Lengnick-Hall & Beck, 2005, p.752).

Lengnick-Hall and Beck (2005) stress that survival or even thriving in an uncertain environment can result from distinct combinations of resilience component factors. Resilience capabilities that leverage a different mix of cognitive, behavioural, and contextual factors could therefore explain how differentiated adoption patterns of digital technologies can lead to comparable business performances.

18.3 Digital Transformation and Organisational Resilience

Technological change provides firms with powerful tools to answer or anticipate change that involves increased complexity of their environment. Innovations based on new technologies widen and modify the set of solutions available to either reduce or absorb complexity (Lengnick-Hall & Beck, 2005). From this point of view, digital technologies do not differ from past waves of innovations.

Digital technologies, which include the creation and practical use of devices, methods, and systems to collect, manipulate, archive, and transfer digital data, have attracted significant attention in recent years because of their potential impact on labour organisation and employment. Technological innovation traditionally involved a dual impact on labour, on the one hand, substituting for the most simple and predictable manual tasks, incorporated in mechanical or automatic machineries, on the other hand, augmenting the productivity of, hence the demand for, intellectual tasks thanks to the complementarities between new technologies and cognitive, analytical, and decision tasks. In contrast, digital technologies can substitute for human labour not only in the execution of manual tasks, but also in analytical and decisional tasks, provided they display a routine and codifiable nature (Autor et al., 2003). Thanks to this capability, digital technologies extend substitution effects from manual tasks to a wide variety of white-collar tasks, while limiting complementary effects to a smaller range of complex intellectual tasks where technology-enhanced contents and elaboration power improve employees' performance but cannot (yet) substitute for human labour.

The employment consequences of technologies able to perform routine codifiable tasks independently of their manual or non-manual nature are considerable (Autor et al., 2006; Goos & Manning, 2007; Goos et al., 2009). The risks of technological unemployment or under-employment have raised significant concerns in the general public too. However, the most pessimistic visions of the employment effects of the digital transformation have been progressively sided by more cautious positions that underline the mediating role of complementary factors (European Commission, 2019). At the macroeconomic level, further analyses stressed that, besides technological feasibility, occupational change requires economical convenience and social desirability (Autor, 2015), driven also by new processes of international division of labour (Celi et al., 2018). At the microeconomic level, the increasing diffusion of a wide range of digital applications in operations indicates that the creation, destruction, and transformation of jobs are driven not only by technological opportunity, but also by the restructuring of production processes and the reengineering of existing tasks (Autor, 2013; Brynjolfsson & McAfee, 2014; Handel, 2016; Shaba et al., 2019; Codara & Sgobbi, 2020).

Organisational features affect the timing of technological change and the impact of the adopted digital solutions on operations (Loonam et al., 2018; Westerman, 2019). Past rules and procedures, organisational structures, managerial and business practices, and legacy information systems drive available paths. Therefore, in line with past waves of technological change, the adoption mode of digital technologies depends on the resilience capabilities of the adopting organisation and, in turn, reflects in the evolution of resilience component factors. This double contingency can trigger a virtuous circle between technological innovation and resilience, as the latter encourages those information-gathering activities that support innovation processes, while the former reinforces investments in learning and environment-scanning routines in search of additional innovation opportunities.

Past literature already outlined significant correlations between resilience, innovation, and technological change (Hamel & Välikangas, 2003; Ates & Bititci, 2011; de Oliveira Teixeira & Werther, 2013; Bustinza et al., 2019). With a view to providing the ongoing debate with further input, this paper investigates how organisational resilience mediates between technological change and change in labour-process flows. Based on new empirical evidence, this paper explores the hypothesis that accumulated organisational practices and competences are not only sources of resistance to change (Loonam et al., 2018; Westerman, 2019). The organisation knowledge base, which reflects into organisational resilience, also provides the tools to explore the opportunities offered by technological innovation. Accordingly, the resilience capability of a firm is expected to impact both the design and the management of investments in new technologies and to drive changes in organisational structure and labour organisation.

18.4 Research Methodology

A case study approach was adopted to explore the relationship between digital technologies, organisational resilience, and the labour process. Based on in-depth analysis, case studies allow accounting for several variables variously interrelated and, above all, specific to the observed testbed (Yin, 2018). Accordingly, a case study allows investigating a phenomenon within the peculiar environment it rises from. The outcomes of single and multiple case studies have a broader scope than the examined cases (Flyvbjerg, 2011), since their validity is based on logic rather than statistic inference (Mitchell, 1983).

Case studies outline how a phenomenon occurs and identify why it takes the observed characteristics (Yin, 2018), with the aim of shedding light on the causal links that originate the observed occurrence. A case study approach is, therefore, particularly appropriate to appreciate organisational resilience, which cannot be separated from the environment and the people it stems from (Branicki et al., 2019). More specifically, this study adopts a multi-case method based on comparable case studies (Lijphart, 1975), where the unit of analysis is the firm adopting a bundle of digital technologies. According to the comparable cases approach, the two cases developed in the empirical analysis match on several variables that are not central to the research hypothesis on the impact of organisational resilience on the outcomes of digital innovations adoption. However, significant differences in key dimensions of the resilience capability models that characterise each case promise to allow an assessment of their impact on the technology adoption process and on changes in labor organisation.

The selected cases concern two manufacturing firms that recently underwent large investments in digital technologies. In line with the multiple cases approach, the chosen companies share a long familiarity with technological innovation and an excellent capability to leverage on innovation in support of growth and economic performance, but display marked differences in resilience capability and digital strategy.

The empirical analysis based on different types of qualitative information to reduce single source biases. The sources accessed to build up the case studies include semi-structured interviews with middle and top managers involved in technology adoption processes; internal documents (brochures, company website) and external documents (press articles, Internet videos, public talks) on the companies and their innovation processes; and direct observation of the production sites where digital technologies were implemented.

Collected information spans across three areas: (a) characterisation of the resilience capability of each company; (b) contents of digital transformation projects, including decision-making in projects design and implementation processes; (c) observed and reported changes in the workplace conditions of involved employees.

Besides information on firm size, products, and industrial sector, the first group of variables operationalise the assessment of those cognitive, behavioural, and contextual properties that define organisational resilience. According to the framework proposed by Lengnick-Hall and Beck (2005), the cognitive dimension of organisational resilience originates from a combination of strong organisational identity and constructive sense-making. Organisational identity founds “on a strong sense of purpose, authentic core values, a genuine vision, and a deliberate use of language” (Lengnick-Hall et al., 2011). Consistently, the study collects firm-level information about underlying values, vision and mission, and common myths. “Collective sense-making relies on the language of the organisation (i.e. its words, images, and stories) to construct meaning, describe situations, and imply both understanding and emotion" (Lengnick-Hall & Beck, 2009). Constructive sense-making has therefore to do with the guidelines rooted in the company's culture, hence with the propensity to innovation and change (also driven by past successes and failures), the long-term versus short-term emphasis of investment plans, and the management orientation towards the external environment.

The behavioural dimension of organisational resilience, which turns cognitive properties into visible responses to uncertain situations, is shaped by two elements: the complexity and variety of the inventory of organisational routines and the presence of functional habits. The routine repertoire is closely linked to the firm's organisational design, as it affects employees' autonomy, information flows, and decision-making processes. A proxy for the complexity and variety of the organisational routines adopted by the companies examined is therefore recognised in their "dominant structural approach" (Daft, 2015), which characterises the organisational model of the firm. Daft contrasts an organisation designed for efficiency to an organisation designed for learning. The first model is dominated by a vertical structure based on strict hierarchy, centralised decision-making, and limited use of teamwork. In contrast, the second model favours a horizontal structure characterised by more relaxed hierarchy, decentralised decision-making accompanied by horizontal information flows, inter-functional teams, and liaison roles. The stronger the orientation to learning, the more complex and varied the routine inventory and, consequently, creative response to change.

If an articulate routine inventory helps facing a wider range of unexpected situations, the second dimension of the behavioural property, the so-called function habits, supports the exploration of further courses of action. Organisations able to develop "habits of investigation rather than assumption, routines of collaboration rather than antagonism, and traditions of flexibility rather than rigidity" (Lengnick-Hall et al., 2011) take advantage of new inputs for sense-making and orientation in ambiguous circumstances, thus generating different resilient responses.

The third property of organisational resilience, contextual resilience, allows for integration of cognitive and behavioural resilience. It relies on two organisational factors: social capital and resources network. "Deep social capital evolves from repeated, personal interactions between people and between organisations and is most effective when based on trust" (Lengnick-Hall & Beck, 2005). Consequently, the social capital of the observed companies is measured based on internal and external relations. In a similar way, resource networks are assessed via the extension of interdependent relationships with environmental agents (including suppliers, customers, research centres, and institutions).

The second group of variables examined by the case studies concerns the adoption of digital technologies. The interviews explore the contents of innovation programmes, the degree of decentralisation in decision-making during the implementation of new technologies, employees' involvement, and the organisational solutions to monitor the progress of the innovation projects. Thanks to the significant differences displayed by the two companies, data in this area allow assessing the coherence between the nature of the digital technology adoption process and the firm resilience capability as shaped by cognitive, behavioural, and contextual factors.

The last set of variables explores changes in the workplace conditions of involved employees (both blue and white-collars) and focuses on the width and the depth of performed tasks, autonomy, physical effort, and stress to verify the consistency with constraints and opportunities typical of the resilience capability of the two firms examined.

18.5 Resilience Capability at the Two Companies

The empirical analysis concerns two middle-sized multinational Italian companies on the market for over thirty years with headquarters in the same industrialised province of Northern Italy. The history of both companies is marked by constant attention to technological innovation and brilliant economic performance, witnessed by sustained national and international growth even during the recent economic crisis.

The portfolio of the first company—henceforth Company A—includes several thousands of part numbers from a high variety of product families of mainly simple but highly differentiated industrial components. A make-to-stock production system manages high production volumes and highly variable batch sizes produced from a limited range of commodity materials and components. In contrast, the second company—Company B—produces to order more homogeneous yet more complex and sophisticated large-sized and highly customised industrial equipment, whose components are sourced from a local network of carefully selected suppliers. Client satisfaction critically depends on the quality of post-sale services, based on remote monitoring from the headquarters and a global assistance network. The production mode, make-to-stock in one case and make-to-order in the other one, reflects in the composition of the labour force, dominated by blue-collar employees in Company A (over 50% of total workforce) and by white-collar employees in Company B (over 80% of total workforce).

Information collected by the case studies shows that the two companies display both differences and similarities in the cognitive, behavioural, and contextual properties of organisational resilience, which are detailed in the following paragraphs and summarised in Table 18.1.

18.5.1 Cognitive Properties of Resilience Capability

Both companies are characterised by a strong identity, which roots in their family business nature and in the continuity of production at the original site. Despite having adopted a consolidated managerial structure, both companies are still governed by the initial entrepreneurial family. In addition, production concentrates at the Italian headquarters and in another Western European country in the case of

Table 18.1 The sources of organisational resilience at Company A and Company B

		Company A	Company B
Cognitive properties	Organization identity	Family business	Family business
		International span, local roots	International span, local roots
		Success history	Success history
		Clear vision and mission	Clear vision and mission
	Constructive sense-making	Long-term orientation	Long-term orientation
		Technological excellence	Technological excellence
		Pride on self-sufficiency	Pride in leading a network of partners
Behavioral properties	Routine repertoire	Focus on vertical structure/efficiency	Focus on horizontal structure/effectiveness
	Functional habits	Focus on control	Focus on learning
Contextual properties	Social capital	Focus on procedures, reports, and plans	Focus on direct interactions
		Internal labor market	Internal/external labor market
	Resource network	Input commodities from global suppliers	Key inputs from local suppliers
		Selected R&D partners	Extended network of R&D partners

Company A, whereas all manufacturing takes place at the Italian site for Company B.

Company A reinforces the sense of belonging in the organisation through informal management of relations with the employees by the human resource manager, personal interactions between managers and staff, and dedicated initiatives to cultivate the corporate spirit. For instance, training initiatives that involve both workers and employees also from different units were launched to counter the rise of organisational sub-cultures as a result of rapid growth in the recent years, which has reduced the possibility of direct contact between different departments. Company B also undertakes initiatives in support of company values with special attention to technical skills, as demonstrated by the wide participation in technical workshops held outside working hours among technicians and employees.

Both companies leverage their strong organisational identity to articulate a strategy that, nourished by a clear vision and mission, complies with the challenges of the chosen competitive arena. The strategic target of both companies can be synthesised in the attempt to reconcile efficiency in the production process and high quality of customer service. However, this common target translates into different strategies. The competitive advantage of Company A is based on the offer of a complete range of standardised products, on low prices, and on the minimisation of delivery times. In contrast with the trend towards working capital reduction typical of the lean production approach that is prevalent nowadays, Company A's strategy lever-ages on the immediate stock availability of a wide range of part numbers, enabled by the efficiency of internal processes. On the contrary, accounting for the mature nature of product core technologies, Company B aims at consolidating its market leadership by focusing on products customisation, under the constraint of internal efficiency.

In the case of constructive sense-making, the second dimension of cognitive resilience, both the companies examined display a strong orientation to long-term projects and plans, confirmed by the long story of investments in research and development, equipment and machinery innovation, and training. Both corporate cultures are open to change and innovation, as witnessed by technological excellence. Pride in the excellence of internal skills and state-of-the-art technology is a marking feature of Company A, which runs all phases of new product development processes internally and customises machinery and equipment purchased from suppliers. In contrast, Company B emphasises organisational, besides technological, innovation. In addition to a widespread use of change management tools, Company B established a unit devoted to the management of continuous improvement projects throughout the organisation.

The observed firms differ also in way they perceive the opportunities offered by the external environment, with higher levels of openness displayed by Company B. As already mentioned, the production inputs that Company A sources from external suppliers mainly consist of commodities, while Company B purchases components and sub-assembled parts critical to the performance of the product from trusted partners located in the same area. Company B takes pride in leading its network of local partners, which also includes consultants and collaborators. Partners participate in innovation programmes and contribute to knowledge contamination and exchange processes. Company A also participates in national and international research projects involving other firms and institutional players, but always preserves full control of product and process innovations.

18.5.2 Behavioural Properties of Resilience Capability

Differences in products and competitive strategies affect the organisation of production processes. In Company A, manufacturing activities dominate operations, with product-specific manufacturing lines based on work cells and transfer machines. The highly automated manufacturing lines are associated to labour-intensive assembly units where jobs mainly include simple and short tasks. In Company B manufacturing processes (based also in this case on work cells and transfer machines) are limited to the external body of the produced equipment. The largest share of value-added comes from the complex assembly of internal components and sub-assemblies purchased from external suppliers. In line with the peculiarities of the production processes Company A and Company B exhibit distinct organisational designs that reflect differences in the components of behavioural resilience.

Company A adopts a functional form, and control is based on hierarchy, rules, and procedures embedded in information systems. The company recently introduced some product managers focused on specific product lines but still formally reporting to the commercial function and some project managers in charge of new product development teams that include technical, manufacturing, and commercial personnel. Despite these changes, information sharing is still limited, and centralisation of decision-making at higher hierarchical levels still persists. Company B, which is also characterised by a functional structure, displays more consolidated forms of horizontal coordination, with the presence of both integrating managers, such as process owners and project managers, and inter-functional units, such as the team in charge of continuous improvement projects. Information is shared among a wider number of employees, and decision-making is more decentralised. In general terms, Company B makes a larger use of routines that encourage employees' interactions within and outside the organisation borders, thus promoting local solutions and adjustment to unexpected problems.

The management of relations with the external environment described in Sect. 18.5.1 above appears to be aligned with the dominant organisational model of the two companies. The focus on internal processes by Company A reflects the attempt to control an orderly development of the organisational system, while Company B intentionally extends the search for new sources of learning also beyond the boundaries of the firm. Differences in the organisation design, therefore, reflect into significant differences also in the functional habits of the two companies. Interviewed managers at Company A reported a perceived need to develop new competences in change management, which the vertical orientation of the organisational design hampers. In contrast, a long familiarity with change management tools and intense partnerships with suppliers and collaborators further supported by the learning-oriented organisational design, reinforces the systematic search for new routines to face change and unpredicted events.

18.5.3 Contextual Properties of Resilience Capability

For both Company A and Company B the contextual properties of organisational resilience arising from the combination of social capital and resources network display strong dependence with the cognitive and the behavioural properties identified in the paragraphs above. In Company A, the large use of procedures, reports, and plans and the relatively limited contact with qualified external counterparts slows down the accumulation of social capital by organisation members. However, this process is partially balanced by informal industrial relations and by the predominantly internal nature of the labour market. In Company A, the average age of employees is over 40 years, tenure averages 20 years, and many executives developed their entire career within the company. Company B supports a faster growth of social capital by encouraging direct contacts among employees from different departments and units, especially in the case of technicians and clerks, and by cultivating intense relationships with suppliers, customs, and consultants. Recruitment policies show an undifferentiated use of the internal and the external labour market, as witnessed by the lower age of employees (on average 35 years) and the diversified career paths of the executives. Entries from the external labour market at all hierarchical levels further stimulate the development of social capital and the relation network enjoyed by Company B.

As mentioned above, both companies pay a strong attention to the opportunities and threats provided by the external environment. However, in line with the values of organisation identity, Company A subordinates external networks to the enhancement of internal resources and capabilities. Focus on internal resources is encouraged by the lower pressure of cultivating external suppliers who, contrary to Company B, provide commodity inputs, and by the stronger grip on internal innovation processes.

18.5.4 Resilience Capability Models

The analysis of resilience properties suggests that both Company A and Company B are resilient companies whose culture, organisational design, and resources allow for a successful management of planned and unplanned change. However, each company displays a distinctive mix of resilience properties and resilience factors. The most significant difference, which reflects in the choice of specific competitive arenas, is the marking feature of organisational identity, that is, pride in self-sufficiency for Company A and in pride in leading a network of excellent firms in the case of Company B. This difference, which replicates in all dimensions of organisational resilience, affects to a larger extent functional habits and the resources network, where Company A demonstrates a selective approach aimed at improving the control of internal processes and Company B exhibits a systematic search for exploration and contamination opportunities.

In line with Lengnick-Hall and Beck (2005), the control-oriented resilience model of Company A seems more appropriate to face an environmental change that evolves across subsequent equilibriums. Companies able to identify new equilibrium points and sketch the path to a new (if temporary) stability can thrive under uncertainty by reducing environmental complexity thanks to routines and resources focused on planning and anticipation. In contrast, the learning-oriented resilience model of Company A aligns with what Lengnick-Hall and Beck (2005) define as robust transformations, i.e., temporary or continuous change that prospects no clear equilibrium. When change displays no clear direction, companies can leverage their resilience to absorb environmental complexity by elaborating real-time contingent planes based on the systematic combination and recombination of internal and external resources.

18.6 The Adoption of New Digital Technologies

The adoption of state-of-the-art technological innovations is a well-established practice for Company A and Company B. Both automated manufacturing in past decades and introduced Enterprise Resource Planning (ERP) systems to integrate operations with Computer-Aided Design software and Computer-Aided Manufacturing (CAD/CAM) for product design and engineering.

However, the common attention paid to innovation has resulted in different programmes of investment in digital technologies. Company A has focused on Advanced Manufacturing Technologies both in manufacturing, with new automatic presses powered by intelligent systems and a transfer line with automatic retooling, and in logistics, with a new automated warehouse to replace a previous semi-automatic solution. The company information systems have been enhanced with a Manufacturing Execution System (MES) to track the steps of transformation processes. A 3D printer for additive production has also been acquired, but to date, it is only used for rapid prototyping activities. Company B, on the other hand, concentrated its investments in digital technologies in management systems, with the development of a common ERP system to replace prior function-specific software solutions and the adoption of a Product Lifecycle Management (PLM) software for the integrated management of products lifecycle stages.

The technological innovations described above reflect different logics. For Company A, the new investments are functional to achieve the level of efficiency needed in production and logistics to support a make-to-stock production system, the chosen solution to guarantee the timely order fulfilment at the base of the competitive advantage of the firm. The interventions to reduce danger and physical fatigue for operators through the automation of critical process phases are coherent with the overall efficiency-focused design. For Company B, digitisation is part of a comprehensive redesign of business processes aimed at ensuring closer coordination between internal units and customers. Moving from a make-to-order approach to a configure-to-order approach would enhance both product customisation, delivery speed, and the range and quality of sales-related services.

Beyond the specific technologies adopted, the difference between the cases examined concerns the general philosophy behind the change, which translates into different ways of managing projects. In Company A, the digital transformation has followed the same approach to technical innovation as in the past, setting itself up as a local response to the need of improving specific operations or phases of the operational processes. The portfolio of innovation projects is therefore managed as a collection of juxtaposed initiatives rather than an overall plan. Confirming this engineering approach, the design of investments in digital technologies is under the responsibility of the Technical Director, who also plays a central role in projects implementation, from the development phase to the training of users. In line with this approach, technological innovation is associated with limited changes to the organisational structure of Company A. The changes seen in recent years are mainly a result of the group's international growth and the restructuring of the main production site.

In Company B, on the other hand, the introduction of digital technologies is functional to a much larger project that also involves significant organisational changes. With the aim of developing a configure-to-order approach, the company wants to strengthen the use of lean production techniques, which implies both a reorganisation of labour flows in production (supported by the new ERP system) and the creation of geographically based inter-functional teams. These teams, supported by the PLM software, aim at anticipating customer needs and involve personnel from sales, services, engineering, manufacturing, and human resource management. The plan also included the creation of a specific Internet of Things department within the Information Technology (IT) function, responsible for projects on big data collection and analysis and on predictive maintenance. A new corporate organisational unit has also been created, including around 50 employees with information technology, engineering, and managerial skills, hired both internally and externally. Organised according to the principles of skunkworks (Fosfuri & Rønde, 2009), this unit is tasked with developing and experimenting with highly innovative technological and organisational solutions that can be exported to the rest of the company.

The diversity in the two approaches to digital innovation is also reflected in related decision-making and adoption processes. Due to the strategic importance and size of the investments required, in both cases, the drive for digital technologies has been promoted and supported by business ownership. However, in Company A, the mandate was collected and interpreted mainly by the Technical Director, who also directly oversaw the implementation phases. In Company B, on the other hand, the entrepreneur actively participated in the project design with the entire management team and numerous external consultants.

In Company A, the process of implementing digital technologies was not entrusted to ad hoc structures and did not make use of specific management and control tools. In Company B, the plan to develop a configure-to-order approach has been meticulously designed, and its implementation has been entrusted to a specific manager, who coordinates the work of collaborators in different units of the company. Lean production initiatives are entrusted to the unit in charge of continuous improvement projects, ERP integration activities are led by the IT manager, and the deployment of the PLM software is entrusted to the head of the new corporate unit in charge of developing the most innovative projects of Company B. In addition, the change management unit manages the adjustment of business procedures and the training of key users and team leaders at the operational level. Dedicated focus groups have been established to monitor the involvement of personnel not directly affected by the new digital technologies.

To date, the digital transformation has led to only slight changes in the content of blue-collar jobs engaged in manufacturing activities in both companies. The further automation of production processes has confirmed changes already underway, with an increase in machinery control and quality control tasks, to the detriment of both basic manual tasks such as parts loading and, in some cases, more professional tasks such as setup. The warehouse automation in Company A generated a similar trend.

Operators are now engaged in packing products pre-selected and conveyed by the automatic system and checking on the monitors the congruence between pack contents and orders, with reduction in errors and physical fatigue. Differences between the two companies, on the other hand, are found in the assembly area. Assembly jobs in Company B now include wider and richer tasks, which are nevertheless due to the more intense use of lean production techniques rather than to the introduction of new digital technologies.

In the case of technical roles, the digital transformation has led to an increase in the number of positions dedicated to the design and maintenance of production systems for both companies, for which higher education degrees are typically required. However, the increase in design roles and in the variety of skills required was significantly higher in Company B, where restructuring plans also based on digital technologies led to the creation of new units dedicated to designing and implementing innovative projects, in which the staff involved enjoy considerable autonomy in ideas proposal and proactive decision-making. In addition, staff participating in the new geographically based inter-functional teams experience both task enlargement, adding the interaction with colleagues from other functional areas to the usual activities, and task enrichment, by taking part in the decision-making processes managed by the team.

18.7 Discussion

The analysis developed in the previous sections allows drawing some considerations about the relationship between digital technologies and organisational resilience. These observations (and the research hypothesis that underpins them) must be obviously taken with some caution. The digital transformation processes analysed are still in progress, and described dynamics could reverse in the future.

The companies examined in the case studies display significant levels of resilience, which nevertheless result from markedly different combinations of resilience drivers. Company A displays a control-oriented model of resilience aimed at controlling change in the external environment by reducing both external and internal complexity, whereas Company B is characterised by a learning-oriented model of resilience intended for absorbing complexity and thus aligning the company with external change (Lengnick-Hall & Beck, 2005). Both companies have recently experienced a digital transformation, which differs in relation to the specific technological solutions implemented. However, these distinctions are fully consistent with differences in the resilience capability model of the two firms, the nature of the products, and the competitive advantage pursued by the two companies. The model of organisational resilience plays an important role in orienting technological innovation projects and their subsequent implementation. In fact, the analysis shows that in control-oriented Company A, digital innovation takes the form of an appropriate yet local technological response, that is, focused on the effectiveness of the technical solution and limited above all to the engineering field. Within this framework, changes in the organisational structure are strictly functional to technological efficiency. Consistently, the way digital technologies are chosen and introduced into the enterprise is characterised by centralisation of decision-making in both the design and the implementation phase. On the other hand, in Company B, with a resilience model more focused on effectiveness and learning, the digital transformation is one of the many tools in support of a wider organisation change process. The case study outlined significant changes in the business structure, both in units directly engaged in developing digital projects and in units where digital tools favour new forms of coordination and a more intensive application of lean production techniques. Again, the way in which digital technologies are chosen and adopted, marked by decentralised decision-making in both the design and the implementation phase, is consistent with the company's resilience model.

Both companies can be regarded as success cases, due to economic performances well above the industry average and increasing trends of turnover and employment. The examined case studies, therefore, support our research hypothesis by indicating that successful digital transformation is compatible with different models of organisational resilience.

In contrast, we have to report only partial support to our hypothesis on the consistency between resilience model and changes in working conditions associated with the adoption of digital technologies. In fact, the cases examined outline some effects only for white-collar employees. In the absence of significant interventions in labour organisation, the adoption of digital technologies in production is associated, in both companies, with trends already observed in prior waves of automation, such as the reduction of physical fatigue and risk for employees and the replacement of operative manual tasks with control tasks. Job enhancement for technicians and managers in result of digital innovation, although present in both companies examined, appears more pronounced in Company B. This difference can be traced back to changes in the business structure and in labour flows, introduced to a greater extent by Company B in line with an organisation model oriented to effectiveness and learning.

18.8 Conclusion

By comparing two cases of adoption of digital technologies in the manufacturing sector, this chapter has outlined how organisational resilience shapes decision-making and investment processes at the organisation level. Both the observed companies display a significant level of resilience capability that helps them interpreting the competitive environment and thriving under uncertain conditions. However, the resilience capability of each company results from a distinct blending of key constituents and this difference reflects in their approach to innovation and change. The control-oriented resilience model of one company involves a vertical orientation of the organisation design and a focus on internal resources. Accordingly, this company manages its digital projects as a collection of stand-alone initiatives focused on improving the productivity of specific processes. Projects may involve collaboration among employees from different organisation units, yet they develop independently one from each other. The other company founds its learning-oriented resilience model in the systematic search for opportunities provided by internal and external change coherently with the horizontal orientation of the organisation design and focus on both internal and external resources. To exploit the opportunities of digital technologies, this company has launched a large pool of within-unit and cross-unit projects, all sharing the common target of supporting a faster alignment with changing customer demands.

The proposed examples show that the nature of organisational resilience can help explaining different approaches to technological change by companies. However, resilience capability evolves in time due to learning processes linked to successes and failures met by organisations. More empirical evidence is needed to improve our understanding of how new technologies impact cognitive, behavioural, and contextual factors, thus shaping the further evolution of organisational resilience.

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Afterword

Ivonne Herrera

Enhancing Resilient Performance in Times of Digital Transformation

> . . .Each of those maps have been drawn for someone who could see in part but not the whole. . .You are a man looking to the world through a keyhole. You have spent your whole life trying to widen that keyhole, to see more, to know more, and now you hear that it can be widen in ways you cannot imagine, you regret the possibility
>
> Doctor Strange, Marvel Studies, Film 2016

Increased complexity, global health and economic crises, climate change, changes in the labour market and increased pace of digital transformation, all represent challenges and opportunities we experience within our societies, organisations and personal life. In the context of digital transformation, enhancing resilient performance relates to proactive adaptation and the capability to cope with uncertainties and complexity, the rapid pace of the effect of events, changes, disturbances or opportunities when everything is interconnected and operates at global scales.

Besides the robust, safe, secure and reliable system, resilience provides a complementary perspective addressing the essential need of systems, organisations and societies to sustain operation and deliver services under expected and unexpected conditions. The concept of resilience has become extremely popular and is used in diverse ways with different meanings. In this book, the overall message is that a system, organisation or society performs in a resilient manner if it can adjust its functioning prior to, during or following events (Hollnagel, 2016). It shifts attention from something that the system has to contend with, to something that the system

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sustains the ability to adapt. The performance emerges from non-linear interactions of organisations, people and systems involved in a specific activity. So, it is an action, a verb and not an attribute (Alexander, 2013; Eisenberg, 2018; Woods, 2018).

Implications of Individual Contributions

The book's content reflects the global scale of understanding and the enhancement of resilience in the context of digital transformation. It consolidates 17 contributions from 14 countries around the world, as shown in Fig. 1.

This book is rich in sharing knowledge, as well as providing practical guidance in specific areas. Insights from individual contributions among diverse domains, such as healthcare, aviation, finance and industry, include:

Assessment Methods and Experiences:

- Chapter 2 provides guidance on how to assess the potential to respond, monitor, learn and anticipate so a system can perform in a resilient manner. It addresses situations when unexpected conditions and effects propagate rapidly, while Chap. 10 proposes an approach to identify and assess the knowledge that is critical for these potentials.
- Chapter 3 presents an application of the Functional Resonance Analysis Method (FRAM) to understand complex socio-technical systems as adaptive. Performance relies on human–machine interactions and local responses to new challenges posed by increased automation and remote operations.

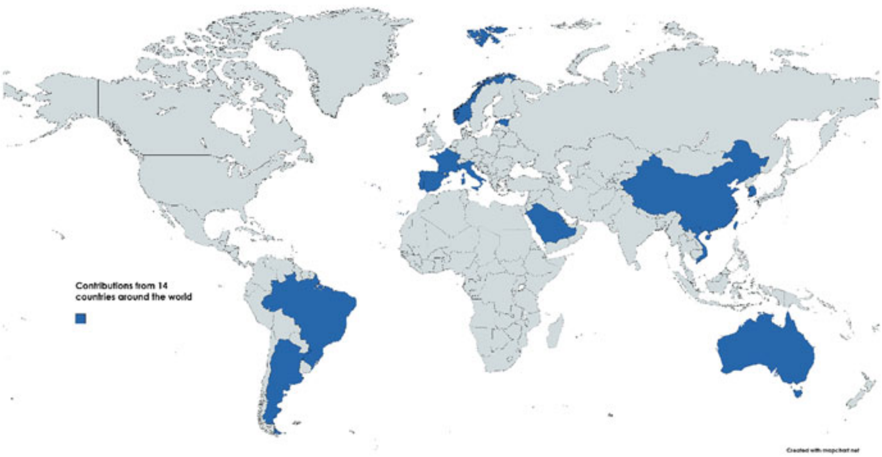

Fig. 1 Mapping the contributions to the book

- "Data is the new holy grail" Chap. 6 integrates knowledge engineering and data science methods to provide a systemic view on the conditions that have an impact on a resilient performance.
- Chapter 15 proposes knowledge graphs to facilitate systematic exploration and analysis of misalignments between work-as-done and work-as-imagined in industrial settings.
- Chapter 18 reminds us of the diverse pathways to enhance resilience capabilities while adopting digital technologies. It presents two paths, one based on control to improve efficiency and another on learning to improve organisational and technical processes.
- Chapter 7 aims to explore, at a national level, the possible relation between the concepts of Intellectual Capital, Resilience, Reliability, Sustainability, and Reputation.

Concepts, Strategies and Practices:

- Diverse concepts and practices related to social capital are described to capture and benefit from organisational conditions. Chapter 4 introduces relational capital as a relevant dimension to be integrated into auditing, addressing resilience and agility within organisations. Chapter 5 explores management strategies, practices and training that enable organisations to benefit from their intrinsic intellectual capital.
- Through action research in a healthcare organisation, Chap. 9 proposes the concept of digital ownership as a substitute for smart contracts. It includes associated strategies to take advantage of digitalisation, taking into account core organisational and individual.
- Chapter 12 proposes a research agenda in cyber resilience where efforts on theoretical advances are based on abductive and reflective reasoning and empirical grounding for specific domains.
- Chapter 16 reframes checklists in the digital context and proposes an improvement in integration. Therefore, to reduce fragmentation and diversity of checklists and procedures, it is proposed to declutter and consolidate diverse sources of information into one place.

Resilience in Design, Development and Training:

- Chapter 8 proposes directions integrating resilience knowledge and associated methods in the design and development of smart cities and the Internet of Things as well as artificial intelligence.
- Increased connectivity creates new links for interactions. Chapter 11 explores digital simulation and patterns of collaboration in the context of critical infrastructure. It addresses the need to create cooperation, collaboration and orchestrates processes across different roles and diverse disciplines, including areas where links did not exist previously.
- Digital tools provide new ways to work and have the potential to increase flexibility and adaptability in organisations. Chapter 13 investigates digital tools

to stimulate collaborative learning and reflection about existing safety and quality practices and adaptive capacity. The digital environment allows the inclusion of relevant stakeholders within and outside an organisation.

Contribution to Societal Resilience:

– Chapter 14 presents experiences from a combination of digital tools and knowledge management systems. This combination collects and shares knowledge among citizens, healthcare institutions, policymakers and decision-makers. The contribution targets the reduction of knowledge barriers and the speeding of information flows to enhance resilience.
– Chapter 17 provides evidence of the importance of intellectual capital, cultural and local characteristics. These are inherent in an organisation and a society affecting the implementation of policies and digital transformation. It proposes strategies that recognise and integrate patterns of cultural behaviours to improve adaptation and flexibility.

Future Directions

This book is the first of its kind regarding resilience in the digital age. Individually each chapter highlights specific areas for resilient performance improvement, proposing advances and opening doors to more developments. The rapid pace of increased digitalisation challenges resilience to have knowledge and solutions readily at hand. While increased theoretical advances are available, there is an urgent need to bring this resilience knowledge into practice.

We encourage and welcome progress in resilience in the context of digital transformation through exploration. This includes:

– Continue with transdisciplinary collaboration involving diverse disciplines and stakeholders to address complex socio/technical systems organisations and society as a whole. Focus on analysing interactions and patterns of performance rather than looking into components or factors. What knowledge and solutions can scale up and which remain local?
– Embrace complexity and acknowledge the co-existence of successful everyday operations, expected and unexpected events, hidden interdependencies, and rapid manifestation of cascade effects.
– Address the imbalance between theoretical knowledge and practical implementation. Hence, more guidance for practitioners to use and integrate resilience-based methods, strategies, practices in organisations is needed.
– Increase research-industry collaboration and partnership to develop solutions for specific contexts, fostering experimentation, integration and take-up of resilience solutions.
– Provide more examples about resilience in by design. In particular, consider the integration of AI, machine learning, robots and other tools and solutions that

support digital transformation. There is a need to cover the complete life cycle of digital systems from design, deployment, operation until decommissioning.

– More exploration and success stores on the opportunities and challenges associated with digital transformation for specific areas such as digital simulation, x-realities, training, digital twins, artificial intelligence, machine learning.
– Investigate principles from resilience that remain unexplored in the context of increased digitisation. This includes studies, practices and strategies associated with the everyday operation, management of trade-offs, police-centric governance, and the links between innovation, sustainability, ecology and resilience.
– Work at the intersection of disciplines, for example, exploring the link between resilience and innovation in the context of digital transformation. The combination of flexibility, creativity and improvisation might provide added value in improving capabilities and readiness to respond to diverse events.

We invite everyone to learn and navigate together in this journey of discovery, bringing together and mobilising resources to improve resilient performance in the context of concurrent changes, increased complexity and digitalisation.

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