Advancing resilience assessments:
the social dimensions
of electricity supply
in South Africa

by

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

This dissertation includes four original papers (two has been published, two submitted for review) in peer-reviewed journals. The development and writing of the papers (published and unpublished) were the principal responsibility of myself and, for each of the cases where this is not the case, a declaration is included in the dissertation indicating the nature and extent of the contributions of co-authors.

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Abstract

Electricity supply serves as a lifeline, is foundational to the effective functioning of modern society, and powers multiple layers of other critical infrastructure systems. In South Africa, Eskom, the national state-owned electrical utility, generates 95% of the country's electricity, making the South African economy highly dependent on the utility. Eskom has been caught up in socio-political, technical and financial challenges, including corruption and state capture allegations. Futhermore, owing to supply deficits, Eskom had to resort to national load-shedding from 2007 to 2008 and from 2014 to 2015. Withdrawal of labour and acts of sabotage by employees during a national strike again necessitated load-shedding between June and August 2018. Eskom is described as the biggest risk to the South African economy, by investment bank Goldman Sachs in 2017, as well as the International Monetary Fund at the end of 2018.

Resilience is a systems-level outcome that emerges as a result of dynamics within complex adaptive systems. An essential service, such as electricity, is resilient if the complex adaptive socio-technical system, from which it is produced, has the capacity to sustain delivery of the core service amidst disruption and ongoing change. A fundamental departure point for this study is the realisation that a resilient technical infrastructure is not enough to ensure the supply of essential services is resilient. The dynamics of the embedded social component is often overlooked, but contributes both inherent strength and vulnerability to the functioning of the socio-technical system that delivers the essential service.

This dissertation uses the implications of complexity thinking and resilience thinking to investigate approaches to assess and build the resilience of the embedded social resources required to ensure resilient essential service delivery. The specific objectives of the study were to: develop a conceptual framework for assessing resilience of essential services; pilot two methods for assessing and building resilience (through a principle-based formative assessment approach and a narrative-based sensemaking approach); and to describe the SenseMaker® methodology, as it is increasingly utilized in academic research. These objectives were addressed through four research papers around which the dissertation is structured:

The first paper develops a framework to conceptualise domains of resilience that distinguish between social and technical resilience investments, on the one hand, and between specified and general resilience, on the other. Specified resilience deals with resilience of

particular system components to defined threats, whereas general resilience is a generic capacity to adapt and transform amidst unpredictable threats and unforeseen risks. Investments in all four of these domains are required in complex adaptive socio-technical systems to ensure resilient essential services. The paper also distinguishes between summative and formative resilience assessments. The first involves assessments *of* resilience whose primary aim is to report to a third party what is in place. The second entails assessments *for* resilience whose primary aim is to establish, through engagement with relevant stakeholders, what resilience is required and agree collectively on how to build it.

The second paper develops and pilots a formative resilience assessment approach, using an appreciative inquiry facilitation approach to assess how the seven generic resilience building principles from the field of socio-ecological systems can be utilised to enhance general social resilience within socio-technical systems. Six participatory workshops were conducted that produced assessments situated in the collective experiences and perspectives of the participants. The study operationalised the seven resilience building principles into an assessment process that can be rapidly and repeatedly conducted to involve several members of a community. The study found participants identified opportunities to enhance resilience based on the principles of resilience governance towards adaptive and transformative resilience capabilities.

The third paper provides a detailed description of the SenseMaker® method used to perform the sensemaking-based resilience assessment in paper four. Originally developed as a decision-making tool for corporate businesses, SenseMaker® is now increasingly used by researchers, but has not been well documented in the academic literature. This paper describes the SenseMaker® method, how it can be used, and its significance and shortcomings in research settings.

The fourth paper develops and pilots a narrative-based sensemaking approach for assessing the strength of social resilience competencies and the relative combinations of specified and general social resilience resources that people draw on in the face of disruption. The approach was piloted in a national emergency exercise conducted in Eskom, which simulated sudden cascading failure across interdependent systems and functions. The study found that employees drew more on specified than general resilience resources. Results were interpreted relative to the quality of cognitive, connective and purposive sensemaking that participants displayed in response to the simulated failure.

The key contribution of this dissertation is that it provides conceptual clarity regarding the different domains of resilience that need to be considered in socio-technical systems.

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Moreover, the study develops and pilots two methods for assessing social resilience. The first assessment approach is formative and uses the seven principles; and, the second is summative, using the narrative-based sensemaking approach. The importance of sensemaking capacities in social resilience is emphasized, and methodological clarity on the use of the SenseMaker method in research settings is provided.

The findings from this study advance conceptual and methodological aspects of resilience assessments, in particular assessments of the social dimension of socio-technical systems. This study is especially significant as it was performed in a technical organization with an engineering driven culture, but focused on social aspects that affects systems-level resilience. These insights may also have relevance in advancing the assessment of social dimensions of resilience in social-ecological systems. On a practical note, the findings may assist a wide range of actors seeking to assess and build the resilience of essential service delivery in socio-technical systems.

Opsomming

Elektrisiteit is noodsaaklik vir die doeltreffende funksionering van die moderne samelewing, en dryf verskeie lae van die belangrike infrastruktuurstelsels aan. In Suid-Afrika wek Eskom, die nasionale elektrisiteitsverskaffer onder staatsbesit, 95% van die land se elektrisiteit op, met die gevolg dat die Suid-Afrikaanse ekonomie byna heeltemal van hierdie verskaffer afhanklik is. Eskom is in verskeie sosio-politiese, tegniese en finansiële uitdagings gewikkel, insluitend bewerings van korrupsie en staatskaping. Daarbenewens moes Eskom van 2007 tot 2008, en weer van 2014 tot 2015 weens 'n voorraadtekort tot nasionale beurtkrag oorgaan. Die onttrekking van arbeid en voorvalle van sabotasie deur werknemers tydens 'n nasionale staking het verdere beurtkrag tussen Junie en Augustus van 2018 genoodsaak. Eskom is as die grootste risiko vir die Suid-Afrikaanse ekonomie beskryf, in 2017 deur die beleggingsbank Goldman Sachs, sowel as deur die Internasionale Monetêre Fonds einde 2018.

Veerkragtigheid is 'n uitkoms op die vlak van die stelsel, en ontstaan as gevolg van die dinamiek in ingewikkelde, aanpasbare stelsels. 'n Noodsaaklike diens (soos die voorsiening van elektrisiteit) is veerkragtig, mits die aanpasbare sosio-tegniese stelsel wat die diens verskaf oor die kapasiteit beskik om die kerndiens op 'n volgehoue wyse te voorsien te midde van ontwrigting en voortdurende verandering. Een van die vernaamste uitgangspunte van hierdie ondersoek is die besef dat veerkragtige tegniese infrastruktuur nie voldoende is ten einde die voorsiening van noodsaaklike dienste te verseker nie. Die dinamiek van die omslote maatskaplike komponent word selde in ag geneem, al veroorsaak hierdie komponent beide die inherente krag én die weerbaarheid van die funksionering van die sosio-tegniese stelsel wat die noodsaaklike diens voorsien.

Hierdie verhandeling maak gebruik van die implikasies van kompleksiteitsleer en veerkragtigheidsleer om ondersoek in te stel na benaderings om die veerkragtigheid van die omslote maatskaplike hulpbronne wat vereis word om veerkragtige noodsaaklike dienslewering te verseker, te assesseer en uit te brei. Die spesifieke doelwitte van hierdie ondersoek was eerstens die ontwikkeling van 'n konsepsuele raamwerk om die veerkragtigheid van die voorsiening van noodsaaklike dienslewering te assesseer, tweedens om proefstudies in te stel met betrekking tot twee metodes vir die assessering en uitbreiding van veerkragtigheid ('n beginselgebaseerde, formatiewe assesseringsbenadering en 'n narratiefgebaseerde, samehangskeppende benadering), en derdens om die SenseMaker-

metodologie te beskryf, omdat dit toenemend in akademiese navorsing gebruik word. Hierdie doelwitte is bereik deur na vier navorsingsartikels te verwys; hierdie verhandeling is ook volgens hierdie vier artikels gestruktureer.

Die eerste artikel behels die ontwikkeling van 'n raamwerk vir die konsepsualisering van die areas van veerkragtigheid wat 'n onderskeid tref tussen maatskaplike en tegniese veerkragtigheidsbeleggings aan die een kant, en bepaalde en algemene veerkragtigheid aan die ander kant. Bepaalde veerkragtigheid behels die veerkragtigheid van spesifieke komponente van die stelsel wanneer dit teen gedefinieerde bedreigings te staan kom. Daarenteen verwys algemene veerkragtigheid na die generiese kapasiteit om aan te pas en te transformeer te midde van onvoorspelbare bedreigings en onvoorsiene risiko's. Beleggings in al vier hierdie areas word van ingewikkelde, aanpasbare sosio-tegniese stelsels vereis, ten einde veerkragtige noodsaaklike dienslewering te verseker. Hierdie artikel onderskei ook tussen summatiewe en formatiewe veerkragtigheidsassesserings. Summatiewe veerkragtigheidsassesserings behels die assessering van veerkragtigheid, waar die hoofdoel die rapportering aan 'n derde party is, waar hierdie derde party reeds in plek gestel is. Formatiewe veerkragtigheidsassesserings behels die assessering van veerkragtigheid waar die hoofdoel is om vas te stel watter soort veerkragtigheid vereis word, deur in gesprek te tree met die betrokke aandeelhouers, waarná daar gesamentlik besluit word hoe om hierdie veerkragtigheid uit te brei.

Die tweede artikel ontwikkel en beproef 'n benadering tot formatiewe veerkragtigheidsassessering deur die gebruik van 'n waarderende benadering vir die fasilitering van navrae, om vas te stel hoe die sewe beginsels van die uitbreiding van generiese veerkragtigheid (afkomstig van die vakgebied van sosio-ekologiese stelsels) gebruik kan word om die algemene maatskaplike veerkragtigheid van sosio-tegniese stelsels te verbeter. Ses deelnemende werkswinkels is gehou, en assesserings wat binne die gesamentlike ervarings en standpunte van die deelmers geleë is, is deur hierdie werkswinkels geproduseer. Die ondersoek het die sewe beginsels van veerkragtigheidsuitbreiding geoperasionaliseer deur hulle as die vertrekpunte te benut vir 'n assesseringsproses wat vinnig en herhaaldelik toegepas kan word om verskeie lede van 'n gemeenskap te betrek. Hierdie ondersoek het bevind dat deelnemers geleenthede vir die verbetering van veerkragtigheid geïdentifiseer het op grond van die beginsels van veerkragtigheidsbestuur, met die oog op aanspasbare en transformatiewe veerkragtigheidsvermoëns.

Die derde artikel verskaf 'n omvattende beskrywing van die SenseMaker-metode wat gebruik word om samehangskeppende veerkragtigheidsassesserings uit te voer. Hierdie

samehangskeppende veerkragtigheidsassesserings beslaan die inhoud van die vierde artikel. SenseMaker is oorspronklik ontwikkel om as besluitnemingsnutsgoed vir korporatiewe sakeondernemings te dien. Hoewel dit toenemend deur navorsers gebruik word, is SenseMaker nog nie genoegsaam in die akademiese literatuur gedokumenteer nie. Hierdie artikel beskryf wat die SenseMaker-metode behels, hoe dit gebruik kan word en die belang en terkortkominge daarvan met betrekking tot navorsingsomgewings.

Die vierde artikel ontwikkel en beproef 'n narratiefgebaseerde, samehangskeppende benadering om die sterkpunte van maatskaplike veerkragtigheidsbevoegdhede te assesseer, asook die betreklike kombinasies van bepaalde en algemene maatskaplike veerkragtigheidsdshulpbronne wat mense gebruik wanneer hulle ontwrigting die hoof moet bied. Die benadering is beproef tydens 'n nasionale noodoefening by Eskom, wat 'n skielike, uitkringende ineenstorting regoor onderling afhanklike stelsels en funksies nagemaak het. Die ondersoek het bevind dat werknemers meer op bepaalde veerkragtigheidshulpbronne staatgemaak het as op algemene veerkragtigheidshulpbronne. Die uitslae is geïnterpreteer volgens die gehalte van die kognitiewe, konnektiewe en doelgerigte skepping van samehang wat deelnemers in reaksie tot die nagemaakte ineenstorting vertoon het.

Die hoofbydrae van hierdie verhandeling is die konsepsuele duidelikheid wat dit bied in verband met die verskillende areas van veerkragtigheid, wat met betrekking tot sosio-tegniese stelses in gedagte gehou moet word. Verder dra hierdie ondersoek by tot die ontwikkeling en beproewing van twee metodes vir die assessering van maatskaplike veerkragtigheid. Die eerste assesseringsmetode is formatief van aard, en maak van die sewe beginsels gebruik. Die tweede metode is summatief van aard, en maak van die narratiefgebaseerde, samehangskeppende benadering gebruik. Die belang van die vermoë om samehang te skep met betrekking tot maatskaplike veerkragtigheid word benadruk, en metodologiese duidelikheid in verband met die gebruik van die SenseMaker-metode in navorsingsomgewings word verskaf.

Die bevindinge van hierdie ondersoek bevorder die konsepsuele en metodologiese aspekte van veerkragtigheidsassesserings, veral assesserings van die maatskaplike dimensie van sosio-tegniese stelsels. Die ondersoek is veral van belang aangesien dit uitgevoer is by 'n tegniese organisase wat oor 'n kultuur gerig op ingenieurswese beskik, maar toegespits was op die maatskaplike aspekte wat veerkragtigheid op die vlak van die stelsel beïnvloed. Hierdie insig mag ook relevant wees vir die bevordering van die assesserings van die maatskaplike dimensies van veerkragtigheid in sosio-ekologiese stelsels. Aan die praktiese sy mag hierdie bevindinge van hulp wees vir 'n wye verskeidenheid betrokkenes wat die

veerkragtigheid van noodsaaklike dienslewering binne sosio-tegniese stelsels wil assesseer en uitbrei.

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If there is no storm you don't need resilience. I am grateful for the learning opportunity Eskom afforded me to realise that I need to know more about resilience and ways to assess this system's level outcome in order to build it. Hats off to Erica Johnson, a former Eskom executive, who first recognised the need for resilience, established it as a focus for the national grid, and later extended that to the whole enterprise. Thank you to Robert Koch, senior manager Enterprise Resilience, for his supported on the journey and comments on the articles, and to the rest of the Eskom Enterprise Resilience team who participated to put theory into practise and especially in deliberating the practicality of theory.

Finally I want to thank Fanie & Abigail for their support at home as I mostly worked on this dissertation afterhours. Numerous times Abigail would ask: "Don't you have work to do?" Thank you for allowing me to get on with it. I wouldn't have been able to do this without you.

Sunninghill, January 4, 2019

Liza van der Merwe

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List of Publications

This dissertation is composed of an introduction, conclusion and the following original articles, reproduced here by permission.

Van der Merwe, S.E., Biggs, R. & Preiser, R. 2018. A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems. *Ecology and Society*. 23(2).   31

Van der Merwe, S.E., Biggs, R. and Preiser, R. (2018) 'Building social resilience in socio- technical systems through a participatory and formative resilience assessment approach', *Systemic Change Journal, 1(1).*   67

Van der Merwe, S.E., Biggs, R., Preiser, R., Cunningham, C., Snowden, D.J., O'Brien, K., Jenal, M., Vosloo, M., et al. n.d. Making sense of complexity, using SenseMaker as research tool. *Systems (under review).*   99

Van der Merwe, S.E., Biggs, R. & Preiser, R. n.d. Sensemaking as an approach for Resilience Assessment in an Essential Service Organization. *Environment Systems and Decisions (under review).*   172

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Chapter 1: Introduction

1.1   Motivation for the study

Electricity supply serves as a lifeline and is foundational to the effective functioning of modern society powering multiple layers of critical infrastructure systems, such as hospitals and water supply networks. However, the multiple layers of intertwined and interdependent services that cities and nations rely on can expose societal vulnerability if these essential services are not resilient. Owing to this complex interdependence, the impact from disruption at times ripple, or even cascade, through society at an increasing rate and intensity, causing massive disruption at multiple scales.

Electricity consumers in South Africa have become painfully aware of their dependence on the national electricity utility, Eskom, which supplies 95% of the electricity consumed in the country. In early 2008, a subtropical cyclone entered the Madagascar channel and resulted in widespread heavy rainfall over Mpumalanga lasting two weeks (Malherbe et al., 2011). As a result of depleted coal stockpile levels, the persistent rain resulted in wet coal affecting production at all power stations in that region. Thus, inadequate additional generation reserves to match electricity demand led Eskom to resort to national rotational load-shedding. In a way, this incident signalled the beginning of turmoil and turbulence in the utility, and by Joffe (2018) reports that Eskom has seen 12 different CEOs in the ten years since. To avoid the economic impact of continued load-shedding, the national government called on Eskom to do what it takes to keep the lights on. This directive resulted in extensive operational damage over the next few years, as the fleet of power stations could no longer allow adequate outages for normal maintenance. Investor Rio Tinto withdrew their plans for an aluminium smelter, the anchor tenant at Coega1, due to uncertainty about electricity supply; and, many large customers who could afford the investment went off-grid or reduced their dependence on the utility, negatively affecting Eskom's balance sheet (M&G Staff Reporter, 2009). For a number of reasons, Eskom has suffered serious financial and reputational losses and has, thus, become a controversial target for studies and investigations. This decade of churn has left emotional scars on the workforce and undermined the stability of

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[1] Coega *Development Corporation in Port Elizabeth* is a *state owned Industrial Development Zone intended to stimulate the South African economy*

Chapter 1:

the organization. The importance of essential services and critical infrastructure interdependence has left its mark on the South African economy.

As a direct result of the wet coal incident, Eskom launched a formal resilience programme in 2008. The notion of resilience has seen an upsurge in popularity across a wide range of disciplines, but has been defined in many ways, and the focus of the definition has shifted over time. Resilience can be seen as a systems-level outcome that emerges from dynamics across a complex adaptive system (CAS) (Holling, 1973). Resilience definitions initially referred to the concept as the capacity of a system to recover in the face of disruption. The notion of capacity to adapt was later added, and there is now a major emphasis on the concept of capacity to transform in order to be resilient (Folke, 2016). In this study, the researcher frames resilience as a desirable systems outcome and sees it as the capacity of a CAS to sustain its core functions while dealing with disruption and change. A resilient system has the capacity to persist in the face of disruption, adapt in the face of ongoing change, and transform by fundamentally changing the trajectory of the path it was on, either in response to disruptive change, or proactively, to sustain core functions central to more desirable futures (Folke et al., 2010). For this reason, a resilient system can persist, maintain and evolve its core functions amidst disruption and change (Walker et al., 2004; Folke et al., 2010). An essential service can be considered resilient if the socio-technical CAS, from which the service is produced, has the capacity to sustain delivery of the services in the face of disruption and ongoing change (Van der Merwe, Biggs and Preiser, 2018).

This dissertation uses the implications of complexity thinking and resilience thinking to explore ways to assess and build resilience to ensure resilient essential service delivery. The context of the case study for the research is Eskom, the South African national electricity utility, where the researcher is an employee in the Enterprise Resilience Department.

Based on the need to improve resilience of electricity supply as an essential service in South Africa, the main aim of this study was to inform alternative approaches to assess and build resilience in order to enhance the capacity of a socio-technical system (STS) to maintain continuity of its core functions amidst disruption. The objectives of this study towards this end were to: develop a conceptual framework for assessing resilience of essential services; pilot two methods for assessing and building resilience, using a principle-based formative assessment approach that operationalize the seven resilience building principles proposed by Biggs et al (2015), and a narrative-based sensemaking approach; and to describe the SenseMaker method used in the narrative-based approach.

1.2   Approach and Objectives

This study is based on the recognition that the nature of the world is complex (Capra, 2015; Schoon and Van Der Leeuw, 2015). A complexity perspective recognises the world as being unpredictable and full of surprise. As energy, information and matter are exchanged between the system and its environment, system elements are connected to external phenomena and interactions. Furthermore, these interdependencies lead to non-linear effects and unintended consequences (Gunderson and Holling, 2002; Cilliers, 2016). As a response to the complexity all around us, humans tend to want to bring order and control the uncertainty by implementing management strategies that bring about certainty and enable us to make predictions within a specified level of confidence (Bernstein, 1996). Much of the technological progress, designs and organization achieved to date have been achieved through our ability to manage and control complex systems. However, the nature of the world presents substantial limits to our ability to control systems, thus generating intractable problems that cannot be tackled in a reductionist fashion (Allen, Maguire and McKelvey, 2011). This study uses the implications of complexity as a starting point and applies complex systems thinking to the problem of resilient essential service delivery.

A fundamental departure point for this study is the realisation that a resilient technical infrastructure is not enough to ensure the resilient supply of essential services. A technical infrastructure can be designed and built to defined engineering parameters to achieve desired levels of reliability, robustness, and resilience; and, it has been the focus of many studies. However, provision of essential services requires the effective functioning of the integrated social web in the broader STS providing the service. The dynamics of the embedded social components of the socio-technical electricity supply system contribute both inherent strength and vulnerability to the functioning of the system. This study focuses specifically on understanding the social dimensions and complexity inherent in STS responsible for providing essential services. In addition, the research project explores how the resilience of the social dimension can be assessed and built.

The focal system is embedded and tightly coupled to multiple containing systems, which result in these systems mutually constraining systems emergence and available pathways. A few examples of wider coupled systems include: the ecosystem and associated ecosystem services required for energy production; the social-ecological system (SES) that demands a just transition to renewable energy; the geo-political system that seeks to electrify communities without access to electricity. While these linkages have profound effects on the focal system it is not addressed in the current study. The focus of the study is bounded to social dimensions of the focal system that affect resilient electricity supply.

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An interdisciplinary research approach was utilised for this problem-based investigation (Stehr and Weingart, 2000). The study draws on emerging concepts and tools at the intersection of resilience thinking and complexity thinking to explore the resilience of electricity supply through the four lines of inquiry described in Chapters 2-5. These chapters are in the form of original research papers (Chapters 2 and 3 have been published, Chapters 4 and 5 have been submitted for review). The objectives of these papers are as follows:

- Chapter 2 set out to present a conceptual framework for assessing the resilience of essential services, building on the ongoing resilience practices at Eskom. This framework explains investments into technical and social resilience, types of resilience and types of assessments. The specific objective of the framework is to pinpoint gaps to be addressed regarding resilience assessments of essential service delivery in the remainder of the study.

- Chapter 3 set out to use a principle-based approach in the design of a participative resilience assessment process that will foster collective social action for building resilience. The seven general principles for enhancing resilience proposed by Biggs et al. (2015) will be utilised in a formative resilience assessment to foster collective learning about systems-level resilience and to strengthen resilience in support of essential service delivery.

- Chapter 4 set out to provide a synthesis of the SenseMaker method and tool, which uses distributed ethnography to extract patterns of reasoning from micro-narratives, and is based on a complexity-paradigm. SenseMaker is increasingly used in research but not well described in the academic literature. The paper highlights strengths and shortcomings the method holds for research purposes.

- Chapter 5 set out to use a sensemaking approach described as the previous chapter to inform a resilience assessment in the context of a large scale simulated emergency exercise: to explore participants' responses; assess their relative utilisation of different resilience resources; and evaluate the appropriateness of response strategies based on systems level patterns of resilience resources utilised as derived through the use of SenseMaker.

1.3   Theoretical framing

This section introduces core theoretical constructs that this dissertation draws on, which are covered in more detail in Chapter 2 to orientate the conceptual framework, used as the overall framing of the study. The constructs with key definitions are indicated in Box 1.1.

Box 1.1 Key definitions of core constructs, developed by the researcher in the course of this study.

Appreciative Inquiry (AI) is a facilitation technique and social innovation method to stimulate change within a social system through participative dialogue and appreciation.

Capacity refers to a current ability to perform, or the measure that can be contained (volume or quantity), and is a finite resource, renewable under certain deliberate conditions.

Capability is an aptitude, ability or process that is desirable to have and that can be developed or improved.

Competency is a quality of being functionally adequate, or having sufficient knowledge, strength or skill required to deliver what is required.

Complex adaptive system (CAS) is a system with open boundaries where energy and matter is exchanged with the environment whilst the system learns in response. A CAS consists of multiple diverse agents that interact at various levels, which may result in non-linear or unpredictable effects including unpredictable outcomes. A CAS is prone to surprises.

Complexity is a systems level characteristic that causes unknowable and unpredictable outcomes due to interdependency among multiple interacting agents and systems.

Essential services meet the basic needs of a community to support a functioning economy, for example, water and electricity supply or emergency service provision. Essential services are produced by socio-technical CAS and emerge from the interplay of intricately interwoven technical infrastructures and social capabilities. These services may be provided by public or private institutions that need to ensure they sustain reliable and resilient service delivery.

Formative assessments are conducted on an ongoing basis to establish capabilities to enhance or build in order to strengthen a desired outcome.

General resilience refers to a generic capacity of the overall CAS to maintain continuity, adapt and transform in the face of any threats, surprise or unforeseen risks.

Resilience is the capacity of a CAS that enables it to simultaneously persist, adapt and transform at multiple spatial and temporal scales so that the system can deal with change and maintain its systems function amidst disruption and deep uncertainty.

Sense of coherence reflects people's coping capacity to deal with everyday life stressors and consists of the three elements of *comprehensibility*, *manageability* and *meaningfulness*.

SenseMaker is both a method and a tool for collective inquiry into the attitudes, perceptions, and experiences of groups of people based on distributed ethnography for decision support, research, and monitoring capabilities.

Sensemaking refers to the human capacity to interpret the meaning of cues they notice, which then inform their response. Sensemaking can be developed as a capability to notice complex patterns and interpret their significance to inform response options.

Specified resilience refers to the capacity of identified components to maintain continuity in the face of identified threats or risks.

Summative assessments are conducted at the conclusion of a reporting period to report on capacities that are evident or verified.

Chapter 1:

1.3.1 Complicated versus complex problem contexts

A CAS contains a large number of independent, interacting and interconnected parts (Juarrero and Lissack, 2000; Snowden and Boone, 2007) that spontaneously self-organise through the interaction of elements, both within the system and in response to the environment (Mason, 2007). A CAS is both complex (made up of multiple and diverse interconnected elements) and adaptive (has the capacity to learn from the environment and constantly change or adapt in response) (Bealing *et al.*, 2012).

Examples of CAS are economic systems, ecosystems, companies, the brain or a single cell (Cilliers, 1998). The adaptive ability of a CAS results in dynamic movement and constant emergence of new features within the system (Rogers *et al.*, 2005; Jenal and Cunningham, 2013; Johnson and Gheorghe, 2013).

Complexity thinking presents an integrated and holistic paradigm to investigate complex systems undergoing dynamic change characterized by uncertainties and ambiguities (Hummelbrunner and Jones, 2013; Jones *et al.*, 2013; Gorzeń-Mitka and Okręglicka, 2014). This stands in contrast to conventional scientific approaches that favour reductionist methods and approaches (Merali, 2000; Gee, 2009; Allen, Maguire and McKelvey, 2011). Complexity thinking holds that complex problems are not decomposable; in contrast, reductionism is based on a Cartesian approach of decomposing problems into simpler sub-elements or units (Fereidunian *et al.*, 2015), with the assumption that if the smaller problems are solved, the whole problem is resolved. Reductionist approaches aim for definitive 'solutions' to problems, while complexity thinking acknowledges that problems will not go away and rather points to the need to engage with the complexity in the system to affect its emergence through catalytic action or nudging (Thaler and Sunstein, 2008; Holman, 2010; Poli, 2013). Complexity thinking emphasizes the presence of disorder, uncertainty, self-organization, and instability (Antonacopoulou and Chiva, 2005). Moreover, it takes cognisance of free will and complex intentionality of human agents that result in emergence of novelty (Juarrero, 1999; Kurtz and Snowden, 2003). The reductionist paradigm is not false, but insufficient to describe and engage with the complexity within and around us.

Since disruption is inevitable in complex contexts, organizations responsible for delivery of essential services adopt risk management and resilience as strategic objectives in order to be risk intelligent and resilient. Organizations typically adopt good or best practise approaches to establish preparedness, for example, emergency preparedness and business continuity management that produce measurable deliverables, such as protocols, plans and procedures. However, an evaluation of actual disruptions that have occurred in the recent

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past reveals the harsh reality that incident contexts routinely far outweigh established plans and preparedness protocols. Instead, disruptions require emergent adaptive responses, which could not have been foreseen ahead of the incident, and stretch response capacities beyond what was established based on good practise before the incident. This reality has brought home the realisation that pre-established preparedness is often insufficient to deal with Taleb's (2007) black swan events but, nonetheless, require a generic coping capacity within the organizational fabric to deal with the unknowable and unpredictable uncertainty these incidents bring.

This rift in appropriate response strategies arises from the distinction between complicated and complex problem or systems contexts. Poli (2013) describes the distinction as a difference of type, not of degree. Similarly, Kurtz & Snowden (2003) describe the distinction as domains of knowable order versus complex un-order, which is not the absence of order. In other words, systems level patterns emerge and can be discerned but not used for prediction; and, phenomena appear coherent only in retrospect. An aeroplane is an example of a complicated system where there are many moving parts that have to work together for it to fly. However, if you take it into a hanger to pull it apart, all the parts will remain where you leave them overnight. In contrary, the parts of a complex system are subject to constant change, even while you are not looking. Raising a child happens in a CAS, where multiple interacting agents lead to unintended consequences and uncontrollable outcomes. Problems arising from complicated systems can be analysed using reductionist approaches and cause-and-effect logically traced to specific root causes (other than "management" as the ultimate root cause). However, in situations of complexity, multi-scalar dynamics among a myriad of intertwined systems, agents and environmental factors lead to non-linear effects and unintended consequences, which bring about unpredictable uncertainty that cannot be managed through traditional reductionist approaches. When that aeroplane is taxied out of the hanger and utilised for transporting passengers, it is embedded into a complex adaptive STS characterised by uncertainty and disruption, evident in the World Trade Centre incidents of 9/11. Only if a boundary can be drawn tight enough around the aeroplane, that excludes the effect of external variables, can problems be addressed as complicated. While the aeroplane is one node within a network that constitutes the wider air traffic system, problems at the network or systems level are always complex in nature.

Such complexity brings challenges to organizations, which typically employ reductionist management approaches to reduce unpredictability and surprise. Organizational structure, policy, procedures and plans mostly aim to deal with "business as usual", and assume a complicated problem context. Organizations may lack the agility and adaptability to deal with

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"business unusual", that is typically complex in nature. This is where organizational resilience becomes critical. In the face of unpredictable disruption, general resilience is particularly pertinent as it aspires to bestow a generic capacity for adaptability and transformability to maintain systems level function and service delivery.

Complexity approaches that aspire to instil general resilience offer an adaptive capacity for transformation to organizations, if they can embrace a paradigm that is different from traditional management approaches. Engaging with complexity requires a management mind-set that accepts unknowable uncertainty as a valid context within which to operate, rather than a problem to be eliminated through more procedures and controls. It requires being comfortable with ambiguity and surprise, and with it, the ability to navigate and harness the various opportunities and possibilities that emerge (Wilkinson, 2006). It requires complexity leadership approaches that deliberately enlarge adaptive spaces for beneficial emergence to take place (Uhl-Bien and Arena, 2017). These adaptive leadership approaches need to nurture and grow social capital within the organization to enable networked systems to adapt and evolve within a dynamically changing environment (Arena and Uhl-Bien, 2016). Furthermore, these approaches require a collective way of seeing and interpreting the world through effective organizational sensemaking, which sees problems as comprehensible, views resources as accessible for managing demands, and has a sense of purpose in meaningfully engaging in complex problems – referred to in this study as collective sense of coherence (Antonovsky, 1979; Eriksson and Lindström, 2011).

1.3.2 Resilience

Interest in resilience has soared across many fields and disciplines in response to the perpetual change, profound challenges, and unpredictable disruption prevalent in the complex systems that surround us. Resilience thinking can be seen as an application of complexity thinking, which focuses specifically on building resilience in complex systems (Norberg and Cumming, 2013; Simonsen *et al.*, 2015). The term *resilience* is used in many different disciplines (Koch, 2012) and generally refers to the ability to bounce back from a disturbance or shock (Coutu 2002). Over time, the concept of *resilience* has evolved to focus on the integrated, dynamic ability to persist, adapt and transform (Walker *et al.*, 2004; Folke *et al.*, 2010). The *resilience* construct resists closure, which makes operationalising it challenging, but Walsh-Dilley & Wolford (2015) argue that embracing this ambiguity opens up the space for productive inquiry. In this study, the researcher adopts the broader understanding of resilience as the capacity to deal with change, whether it emanates from a sudden unexpected shock, or whether it is slow, ongoing and continues to develop (Folke *et al.*, 2005; Folke, 2006).

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Resilience investments can take multiple forms. Physical components and infrastructure can be built to be robust by increasing fault tolerances and making it fail-safe (de Bruijn *et al.*, 2017). Infrastructure systems can be made to flex rather than break by increasing systems-level adaptability, modularity, redundancy, and self-healing capabilities (Lacey, 2014; Ye, 2014). Green infrastructure designs have arisen as a way to consciously incorporate a range of ecosystem services, especially regulating services, into development projects beyond the cultural aesthetic, for example, to curb erosion or flood regulation. However, these designs increasingly include supporting and provisioning services for edible gardens, renewable energy, or building climate regulation (Lavorel *et al.*, 2015; Wamsler *et al.*, 2016). Resilience investments can also enhance social competencies involving tangible measures like emergency preparedness plans, business continuity management, and disaster response plans and structures. Or, they may develop intangible social competencies like strong social networks, healthy levels of social capital or organizational agility (Koch *et al.*, 2013; Aldrich and Meyer, 2015). Green infrastructure investments to enhance resilience are typically no-regret decisions (Andersson *et al.*, 2014). Investing in resilience with regard to physical infrastructure can yield long term and sustained benefits across the full lifecycle of the asset, but requires strong financial commitment to costly 'what-if' redundancy and require long lead times for completion (NIAC, 2010). Investments into social resilience can produce returns in less time than physical infrastructure investments. But, they do not come with a guarantee, can lead to unintended outcomes and, in the words of Poli (2013), establishing social resilience is not the type of problem that can be solved once and for all, but require sustained efforts and ongoing leadership commitment.

In an organizational context, resilience is recognised as a strategic objective that can provide a competitive advantage and enables organizations to survive and prosper (Seville, Van Opstal and Vargo, 2015). Organizational resilience is defined as *"the ability of an organization to anticipate, prepare for, and respond and adapt to everything from minor everyday events to acute shocks and chronic or incremental changes"* (BS 65000, 2014). According to this guideline, organizations that pursue resilience will become more adaptive, competitive, agile and robust. Other characteristics of a resilient organization highlighted by the British Standard align with the resilience thinking notion to stay on a desirable trajectory of change and development (Folke *et al.*, 2010). Organizational resilience does not just happen; capabilities should be developed, and capacities renewed (Seville, Van Opstal and Vargo, 2015). This study investigates ways in which essential service organizations can advance resilient services provision, in this case electricity. While complex systems cannot be controlled, building resilience competencies within an organization can improve the ability

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of the overall STS to persist, adapt and transform across various scales and timeframes (Folke, 2006).

Resilience is constituted of two complimentary types, namely *specified* and *general* resilience (Resilience Alliance, 2010). *Specified resilience is the resilience of a specified part of the system to a specified shock, and can be* identified by answering the question, *"Resilience of what to what?"* (Carpenter *et al.*, 2001)*. General resilience is a general capacity of a system to face and absorb any disturbances and shocks, including novel and unforeseen ones,* (Folke *et al.*, 2010; Carpenter *et al.*, 2012). Unfortunately, these two kinds of resilience cannot be enhanced simultaneously, as there are trade-offs between establishing general and specified resilience (Folke *et al.*, 2010; Cork, 2011).

There is much interest in how to build general resilience in ecosystems, SES, communities, critical infrastructure systems, and nations. Biggs et al (2012) have identified seven principles for building general resilience in complex systems. A unique characteristic of the seven principles is that they not only point to the resilience of the system itself, but also to the governance or management of the system (Quinlan *et al.*, 2015). Differences between resilience in SES versus in STS have bearing on how the concept is respectively operationalized. Resilience is built in SES to prevent undesirable configurations, especially regime shifts (Walker *et al.*, 2002, 2009); whereas the purpose of building resilience in STS is to ensure continuity of core system functions amidst disruption and change. Another distinction is that complexity thinking is essential to build and assess both specified and general resilience in SES. Whereas organizations and the critical infrastructure systems required to deliver essential services are subject to design, control and reduction, therefore building specified resilience is complicated in nature. Furthermore, the board of directors and executive of these organizations are held publicly accountable for the manner in which they direct, govern and manage their essential service mandate. For this reason specified resilience may be required to ensure compliance with legislation, regulation, standards, best practice and good practice. These stringent requirements place a different emphasis on specified resilience in STS than what is typically the case in SES.

Social resilience can make a significant contribution to general resilience through the innate human potential for creativity and ingenuity. Hall & Lamont (2013) define social resilience as the dynamic ability of individuals, communities and societies to achieve and sustain well-being in the face of challenges to it. Besides coping capacities and access to resources, social resilience is attributed to diverse knowledge systems, institutional practices, cultural repertoires, leadership, trust, social networks, connectedness, collective identities, imaginaries, and a community's capacity for collective response to challenges through active

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cooperation (Carpenter *et al.,* 2012; Hall and Lamont, 2013). General resilience may, therefore, be modulated by social reserves and levels of social and relational capital, and strengthened through institutions such as social interaction, adaptive management and polycentric governance (Carpenter *et al.,* 2012; Van der Merwe, Biggs and Preiser, 2018).

General resilience in an organization entails a long term capability to flexibly deal with unknown or *unknowable* shocks and surprises. This becomes evident when existing plans fail, yet new response capacities are dynamically developed instead (Lee, Vargo and Seville, 2013; Clarvis, Bohensky and Yarime, 2015). An organization with general resilience can absorb disturbance while sustaining its core functions.

Humans make sense of cues from the environment to decide how to act. Investigations into sensemaking start with whether cues are noticed or not, how they are interpreted, and what informs this interpretation, as humans use the interpretation to inform their response (Kudesia, 2017). Effective sensemaking, especially in crisis situations, contributes to resilience outcomes and effective collective sensemaking can contribute to general social resilience (Weick, 1993; Casto, 2014). A high sense of coherence reflecting psychological resilience depends on the coherence between the quality of internal sensemaking with what individuals, communities and societies require to deal with the external threat (Antonovsky, 1987; Antonovsky and Sagy, 2016). Sense of coherence reflects a general way of making sense of the world. Moreover, it is a vantage point from which people in general see problems and challenges as comprehensible, understand how they can obtain the resources to manage the demands these challenges bring; and perceive facing those challenges as worthwhile. This latter sense of meaningfulness is the strongest contributor to psychological resilience, as purposive people find a way to win in spite of the odds against them.

Those who seek to build resilience need to recognise themselves as agents of transformation. Walsh-Dilley & Wolford (2015) point out the need for these resilience agents to acknowledge and accept that resilience thinking may contain epistemic and ontological contradictions and to carefully consider the implications of bestowing power. Power may imply privilege and can have political implications. Since resilience interventions can intensify the uneven distribution of capabilities, that produce trade-offs and tensions, particular attention needs to be payed to the dynamics between individual and collective interests in efforts to build resilience (Walsh-Dilley and Wolford, 2015).

1.3.3   Resilience Assessments

Since resilience enables a system to sustain critical functions amidst disruption and change, it is of strategic importance to assess the resilience of a system. To assess is to '*sit beside'*,

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from the Latin *'assidere'*, which implies an unhurried process of paying attention to something that is clearly worth the time and attention. The intention behind resilience assessments vary, two alternative ontologies are confirming compliance to legal and regulatory requirements, or verifying the adequacy of current capacities to survive and thrive. Resilience assessments provide the basis for monitoring, evaluation and learning about resilience in complex systems, can be used as a lens of inquiry to understand complex systems dynamics, and are crucial enablers for adaptive management (Angeler and Allen, 2016; Folke, 2016).

Since the concept of resilience is applied for different purposes, approaches to resilience assessments are flexible and adaptable to appropriate use in different settings (Quinlan *et al.*, 2015). Many alternative approaches are followed to produce resilience assessments. Standardised resilience assessment models, frameworks and metrics may assume linear order and a knowable system context, despite the fact that most systems being assessed are complex systems. It is, therefore, essential to consider the implications of complexity in both the system to be assessed as well as the assessment approaches, even if these are not captured by the specific tools or approaches used. Any resilience assessment approach should acknowledge: inherent uncertainty; that key trade-offs occur between simplifying the complex and deepening the understanding of complex system dynamics; and that any assessment merely provides a partial and transient perspective (Quinlan *et al.,* 2015).

Resilience assessments of SES aim to identify crucial slow system variables and their thresholds and understand the processes driving these dynamics in order to prevent regime shifts (Walker *et al.*, 2002, 2009; Resilience Alliance, 2010). Key resilience assessment approaches in the SES literature include the guidelines by the Resilience Alliance (2010), the Resilience, Adaptation Pathways and Transformation Assessment (RAPTA) framework (O'Connell *et al.*, 2015), and the online interactive Wayfinder guide[2] (Stockholm Resilience Centre, 2018). Wayfinder outlines a collaborative resilience assessment process that focuses on transformation, deliberately incorporate the resilience building principles, and adaptively incorporates at every step reflection on the outcome as input into the next (Elin Enfors-Kautsky *et al.*, 2018).

Approaches used to assess resilience have been summarised into quantitative, semi-quantitative and qualitative methods and tools (RESILIENS consortium, 2016). They may produce absolute or relative metrics and frameworks that point to strengths and opportunities for enhancements. For example, the resilience of technical infrastructure and

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[2] https://wayfinder.earth/the-wayfinder-guide/

systems may be reduced to measures of resilience capacities (Francis and Bekera, 2014), and in the field of resilience engineering they analyse systems-level abilities to respond, monitor, anticipate and learn (Hollnagel, 2010, 2011). Simulation exercises are useful to assess resilience due to the dedicated time and attention of a captive audience (Kaufmann, 2013; de Souza *et al.*, 2015). Fuzzy logic has been employed to assess organizational resilience and suggest measures to enhance organizational strategy (Aleksić *et al.*, 2013). Assessments of organizational resilience can be done against defined standards, for example published by the American Standards Institute, or the British Standards Institute, and the International Standards Organization has also been working on guidelines for organizational resilience (ASIS, 2009; BSI, 2014). These assessments would include areas of leadership commitment, resilience governance, and an integrated view across business systems to inform resilience intelligence and enable integrated response. They would also include the plans, response protocols and procedures to follow in case of disruption. Collective levels of sense of coherence can be used for workplace assessments to measure workplace responses to stress (Basińska, Andruszkiewicz and Grabowska, 2011; Vogt, Jenny and Bauer, 2013).

Approaches to assess social resilience are often done collaboratively. Community resilience assessment tools should satisfy six criteria identified by Sharifi (2016): address multiple dimensions of resilience; account for cross-scale relationships; capture temporal dynamism; address uncertainties; employ participatory approaches; and develop action plans. Assessments of social resilience may include assessments of adaptive management and collaborative approaches, system condition and outcomes, the nature of institutional mechanisms, and the effectiveness of governance models (Plummer and Armitage, 2007; Resilience Alliance, 2010). They may also include an assessment of resilience in the scales above and below the focal system, and of key slow and fast variables. Other authors have used a deliberate exploration of interdependencies on services and systems (Tyler and Moench, 2012; Lavelle *et al.*, 2015), or social network analysis and network topology and centrality (Janssen *et al.*, 2006; Aleksić *et al.*, 2013; Omer, Mostashari and Lindeman, 2014).

A recent distinction introduced to resilience assessments is between summative assessments *of* resilience versus formative assessment *for* resilience (Sharifi, 2016). Summative assessments evaluate current capacities in order to report what is in place, while formative assessments monitor progress in order to inform interventions to enhance capacities. Summative assessments are performed periodically, for example, of development projects to report to donors on progress achieved. In contrast, formative assessment practices involve an ongoing process that uses evidence from assessments as

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feedback to adjust development. Thus, formative approaches combine into transformative potential to affect outcomes (Popham, 2008).

Uncertainty inherent in complex systems needs to be considered in the interpretation of general resilience assessment outcomes. Owing to the irreducible nature of complex systems, an assessment may be indicative of patterns in the system, but should not be construed as conclusive of the system, as it merely synthesizes views from the temporal, spatial and social perspective of the assessment. Resilience indicators may provide insight on a likely resilience outcome, but it is not possible to establish with certainty whether a system will be able to sustain its core services in the future. Amidst this uncertainty, and since the consequences of failure is high, resilience assessments may offer insights as to how to improve system-level resilience across scale and time.

1.4   Case Study

1.4.1   National and organizational context

The organizational context for this study is Eskom, the national state-owned electrical utility in South Africa. It is a vertically-integrated generation, transmission and distribution operation and generates 95% of the country's electricity (Buckley and Nicholas, 2017). Eskom is among the top 10 global electrical utilities in terms of nominal generation capacity[3] and, in 2002, was awarded the prize for being the top electrical utility in the world (Khoza and Adam, 2006; Eskom, 2017). However the company has recently been caught up in socio-political, technical and financial challenges, including corruption and state capture allegations (Eberhard and Godinho, 2017). Owing to supply deficits, Eskom had to resort to national rotational load-shedding from 2007 to 2008 and again from 2014 to 2015. Withdrawal of labour and acts of sabotage by employees during a national strike necessitated load-shedding in June and July 2018. Eskom is described as the biggest risk to the South African economy, by investment bank Goldman Sachs (Bonorchis and Burkhardt, 2017), as well as by the World Bank's International Monetary Fund (Toyana, 2018).

These organizational and country level signs of distress reflect larger scale disruption across the electricity industry worldwide. Globally, the traditional large scale utility business model is facing what the media has coined a "death-spiral", which is a condition faced by utilities when their price increases no longer raise sufficient revenue to cover costs (Costello and

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[3] Total nominal generation capacity of 44,134MW across 29 power stations; total sales of 214,121 GWh; 384,712km of power lines and 276,583MVA of substation capacity with 47,658 group employees.

Hemphill, 2014). This death spiral is caused by the combined reinforcing effects of a reduction in the cost of distributed generation, for example, from solar photovoltaic cells, a reduction in electricity demand, and increasing tariffs. Moreover, many customers are shifting from being consumers to becoming prosumers, producing their own power and selling the excess into the grid whose power they only consume at times (UtilityDIVE, 2014, 2015; Baker and Burton, 2017). Studies performed by Castaneda et al (2017) highlighted some policy options that utility regulators can adopt to delay the death spiral. However, their models reveal that it is postponed rather than avoided. Although energy storage solutions are still costly, an exponential reduction in the cost of renewables is bringing disruptive innovation to the long term plans of many utilities. Nevertheless, this signifies a promising turn for transformation towards a low-carbon future (Naam, 2017). Rifkin (2011) describes the looming changes in the energy sector as a sharing economy revolution, where renewable energy will become abundant and be shared among neighbourhoods, cities and continents on an "energy internet", triggering a major societal transformation.

The immediate challenges experienced by Eskom will be compounded by global changes regarding energy provision. Following an investigation among 11 global electricity utilities, Buckley & Nicholas (2017) concluded that Eskom has failed to recognise the technological disruption brought about by renewables. Furthermore, Costello & Hemphill (2014) describe two different utility death spirals that have affected utilities. The first happened in the 1980s, as utilities dramatically increased their tariffs to recover large construction spend from ''overbuilding'' generation capacity. The current death spiral is attributed to the increasing penetration of distributed generation with prosumers eroding retail sales. In Eskom's case these respective spirals may fold into a triple helix, as the utility struggles to recover from the huge debt incurred to construct the new Medupi and Kusile coal-fired power stations. Furthermore, Eskom is negatively affected by industrial customers going off-grid to avoid load shedding and an increasing penetration of rooftop solar power due to continuing price fall. Breakthrough in battery storage technologies will further accelerate this trend. The unfortunate outcome is that the utility will sit with a smaller customer base, consisting of non-adopters and those who cannot afford alternative energy sources and from whom fixed charges will have to be recovered, which may translate to higher tariffs, and possibly collapse demand (Costello and Hemphill, 2014).

The study recognises that the focus of resilience should not be to improve the viability of Eskom as an organization in its current form. Eskom has been slow to transform its energy mix and should perhaps rather be unbundled. But rather on ways to ensure the resilience of the essential service it provides, while the organization is facing multiple crises and the

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industry is undergoing disruptive change globally. Essential service providers across the world are being subjected to change and disruption. However, they still need to help maintain system function and service delivery while the underlying technology, market, regulation and labour arrangements are undergoing huge shifts. Resilience is a suitable lens to investigate the capability to deal with change and disruption while adapting and transforming towards more sustainable pathways (Folke *et al.*, 2016).

For the sake of national security it is essential to safeguard Eskom's ability to supply electricity, while the organization is undergoing turmoil and disruption emanating from both global and national drivers of change. Castaneda et al (2017) warned that the global energy transition may disrupt societal welfare. Negative consequences identified by them include sacrificing network reliability, prosumer free-rider behaviour, affordability on the part of remaining electricity customers, and an eventual total collapse of the system. Schwab (2017), in turn, warns that the required levels of leadership and understanding to manage the fourth industrial revolution is inadequate to navigate the accompanying systemic transformations that will take place across economic, social and political systems. At present, Eskom seems stuck, and something needs to break for a release and reorganization to take place (Holling, 2001). The question is how to navigate the transition while sustaining essential service delivery.

1.4.2 Eskom's Enterprise Resilience Programme

Eskom embarked on a program of building resilience of the integrated power system as a result of the first national rotational load-shedding introduced across South Africa in 2008. Having been confronted with the complexity of failure that affected the power system's ability to deliver an essential service, Eskom leadership instituted a focus on power system resilience. The focus on the power system's resilience proved a success and was extended to cover the entire enterprise in 2013. To this end, Eskom defined the resilience capabilities that they would like to have across the organization (Figure 1-1). This conceptualisation of resilience is closely related to Foster's (2006) focus on preparedness to face disruption along with response and recovery, combined with the Resilience Alliance's focus on the ability to learn and adapt (Carpenter *et al.*, 2001; Folke, 2011). The purpose of the enterprise resilience focus is to establish standardised resilience capabilities across all divisions and subsidiaries in Eskom Holdings Ltd in order to ensure sustained electricity supply in extreme events the organization may face. These capabilities cover aspects of resilience governance, response structures, situational awareness for early warning, pre-approved plans, and integration with country structures. The plans to be established are informed by: emergency preparedness at local sites; business continuity management of time-critical business

processes within divisions; and disaster management in compliance to the South African Disaster Management Act.
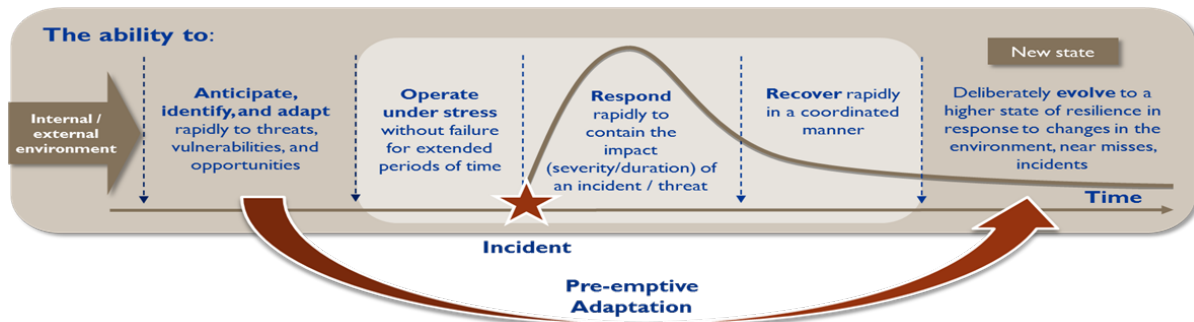
Figure 1-1 General resilience capabilities required across the organization.

Power systems are complex systems prone to cascading failure. The integrated power system is a CAS that consists of the overall value chain, including human agents, required to deliver electricity to the customer. The worst case disaster scenario which the Enterprise Resilience Programme has to establish preparedness for is a national blackout. A blackout is the unplanned loss of supply over a wide geographic area (South African Bureau of Standards (SABS), 2010). Load-shedding and curtailment measures are controlled interventions, deliberately implemented in an emergency to protect the system from collapse into a blackout. Blackouts come without notice or early warning. Sudden cascading failure is the usual mechanism by which failures propagate to cause blackouts (Dobson et al. 2007). Although a national blackout is a low probability event, the consequences will be very high. Electricity blackouts follow a power law that is a mathematical relationship where the frequency of an event varies as a power of a characteristic of the event. The distribution curve of power laws exhibits fat or heavily tailed distributions, meaning that unusual events far from the mean occur more frequently than in normal distributions (Slingerlend and Johns, 2014). Fat tail events occur more frequently than originally foreseen by conventional risk management (Guckenheimer and Ottino, 2008).

The first enterprise resilience assessment in Eskom was performed in 2013. Summative resilience assessments are performed on a regular basis to evaluate progress, identify gaps and make recommendations to build resilience across the enterprise. While general resilience has been contemplated from the start, the largest part of these assessments has been dedicated to specified resilience objectives thus far. Every year, the resilience programme deliverables and the resilience assessment adaptively influence one another. However, in spite of the concerted effort and dedication to build resilience across the enterprise, effective realisation of resilience objectives at systems-level has been slow. Factors that contribute to the slow progress include the fact that, owing to resource constraints, no consultants can be used and no new employees can be appointed. Therefore,

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the existing workforce had to take on this work in addition to their prior roles. Due to the sheer size of Eskom's operations[4] the plans, protocols and procedures to be established amount to a significant amount of work, and the resilience investment can only be deemed effective once a consistent and verifiable resilience capability has been established and integrated into the fibre of the organization. It requires a significant change management programme to bring this into effect, and might never be realized in full.

1.5   Overview of the dissertation

The dissertation is structured around four papers: one conceptual; one methodological; and two developed and piloted new assessment methodologies as outlined below (Figure 1-2). The way in which these chapters fit together is graphically summarised relative to the conceptual framework established in Chapter 2. In all four of these papers, the researcher is the lead author; the contributions by co-authors are clarified at the beginning of each chapter.
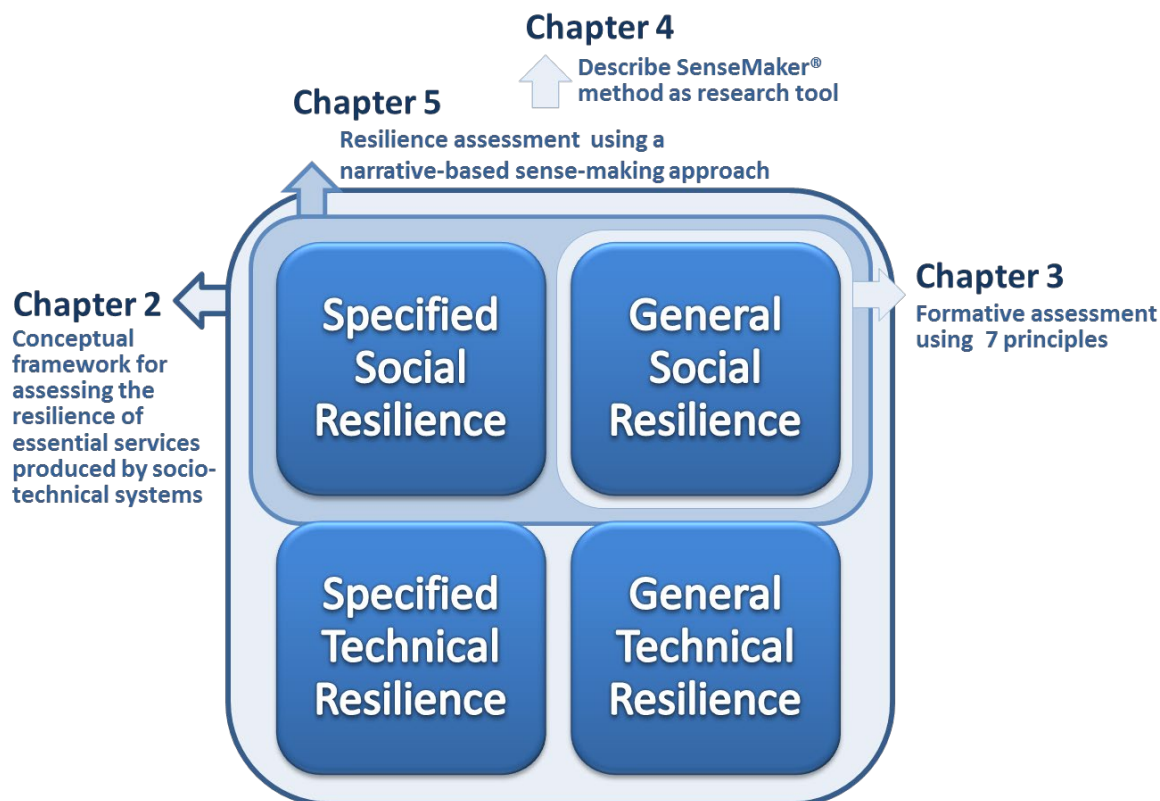
Figure 1-2 The respective papers to advance resilience assessments of the social dimensions of electricity supply in South Africa (1) a framework for resilient essential services (2) formative resilience assessments to build resilience based on general resilience building principles (3) a sensemaking approach to resilience assessments, using SenseMaker, and (4) a synthesis of the SenseMaker method and tool.

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[4] 48,628 employees by March 2018

1.5.1 A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems

Building on the ongoing work on enhancing and assessing resilience in Eskom, the first paper seeks to clarify alternative perspectives of the resilience landscape as well as assessment approaches applicable to enhance the resilience of essential services. The broad overview provided by the paper involves an exploration across multiple disciplines and serves to clarify approaches and focus areas to prioritise in the remainder of the study.

The first paper comprises a conceptual synthesis and establishes a framework to clarify domains of resilience within the STS that produce essential services. It distinguishes between social and technical resilience investments, on the one hand, and between specified and general resilience, on the other. The framework consists of domains of resilience that should be considered in assessing and building resilience in essential services. The paper draws attention to the fundamentally different natures of the respective domains and highlights the disciplinary foundations for each.

1.5.2 A formative resilience assessment based on resilience building principles

The framework introduced in Chapter 2 reveals that the biggest gap in assessing and building resilience in essential services lies in the domain of general social resilience. This entails investment into people for them to have the wherewithal to maintain systems function, even if the discontinuity they experience does not make sense and they do not know what to do. In order to appropriately respond in situations of discontinuity people need to cultivate an inclination to tackle problems, rather than shy away from them to collectively restore service delivery. The integrated power system has been described as one of the most complex systems devised by man (Candy, 2004). It requires organization among multiple disciplines to coordinate work across various business functions and vast geographic areas to produce and deliver electricity. But, general social resilience cannot be designed and built into an organization using reductionist approaches. It requires complexity thinking and relational approaches through which the appropriate conditions can be created, thus enabling the emergence of collective resilience across the social fabric of the organization.

As a reductionist approach will not lead to general social resilience, the second paper develops and pilots a formative resilience assessment approach, based on the application of the resilience building principles, proposed by Biggs et al (2015) from the field of SES. We used an innovative appreciative inquiry approach, as the process itself endeavours to enhance general social resilience within the STS. An outcome across multiple participative

assessments is the ability to draw systems-level patterns of strength and opportunities relative to defined resilience capabilities and resilience building principles. This provides an overview of where the system is at and where it needs to be strengthened.

1.5.3 Making sense of complexity: using SenseMaker as a research tool

Sensemaking offers a useful approach to extract and clarify the significance of systems-level patterns, which can be used to inform response options in the face of inherent complexity. A number of sensemaking approaches are utilised for research purpose, but the SenseMaker method is not well described in academic literature, although increasingly used in research studies. As a generic method description, this chapter is not about resilience assessments or relevant to the specific case study.

For this reason, the third paper sets the context for the method utilized in the next empirical paper and furthermore contributes to the body of knowledge on mixed-method methodologies by positioning and describing the SenseMaker® method. The paper draws on an extensive review of available material, both formal and informal, as well as the practical experience of the co-authors in the application of the method to provide the background to the tool and guidance on the use of the method for research purposes.

1.5.4 Sensemaking as an approach for Resilience Assessment in an Essential Service Organization

By reviewing the difference in nature between the social resilience competencies based on specified and general resilience resources, it becomes clear that these types of resilience offer complimentary, but, potentially, contradictory capabilities. For example, the best airline pilots have amassed embodied knowledge through their years of experience in dealing with unusual and unpredictable situations. Thus, they are able to recognise when they need to deviate from standard operating procedure and do whatever it takes to ensure the safety of the passengers and plane (Pooley, 2018). This analogy serves to illustrate what could and, perhaps, should happen in organizational situations of discontinuity. In other words, while compliance to established procedures, which members of an organization are expected to follow, is a central part of the specified resilience resources in times of great uncertainty, deviation from the rules might be what is required to arrest cascading failure or return system function.

To explore the above phenomenon, the third paper develops and pilots a narrative-based sensemaking approach as a resilience assessment method. The particular objective of this investigation is to establish the strength of social resilience competencies and the relative

combinations of specified and general social resilience resources drawn upon in the response to a national emergency exercise at Eskom. The exercise simulated sudden cascading failure across interdependent systems and functions, resulting in a national blackout and the need for participants collectively to execute black start procedures. They had to deal with the ramifications of no power anywhere, which hampered their response capability. The quality of sensemaking by responders determines the resilience of response to disruption. For this reason results were interpreted relative to indicators of specified or general resilience resources utilized, levels of preparedness and of general sense of coherence. The assessment utilised the SenseMaker method, which is described in the last paper, and was based on systems-level patterns that emerged from self-signified micro-narratives obtained from participants through a process of distributed ethnography. Results suggest general social resilience can be build by enhancing cognitive, connective and purposive sensemaking competencies at the systems level.

1.6   Personal contextualisation and motivation

This study is conducted from the position, knowledge and insights the researcher has as an Eskom employee for 26 years. She has served in various capacities, but always performed work of a technical nature. Early in her career, the researcher noticed how sophisticated technology solutions can fail as a result of social factors. For a master's thesis (completed in 1998), Checkland and Scholes's (1990) Soft Systems Methodology was used which led to insights regarding the value of balancing hard (technological) and soft (social) design considerations. The researcher learned that compromising on technological sophistication for the sake of a more appropriate social fit may produce solutions that are embraced rather than resisted by those who should use them. The researcher has tried to balance socio-technical considerations ever since.

Currently serving as Enterprise Resilience Assessment Manager at Eskom, the researcher embarked on part-time further studies to learn and develop herself as a result of an awareness that the size of the challenges faced at Eskom required personal growth and enlarged thinking. Working and studying influenced each another in a complimentary and co-evolutionary fashion. It has been a purposeful and rewarding journey to apply what the researcher learnt at work and to test and challenge her experience against the theory from the literature. For this reason, she engaged in action research throughout this learning journey.

Personally interested in a beneficial outcome from this study, finding ways to assess and build resilience is more than an academic exercise. A decline of the social morale and

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organizational climate was noted by the researcher, who heard how many employees became ashamed to admit they work for this organization and how this heaviness has an effect on people's motivation to make a difference and contribute to the solution. In addition, the disbelief and resentment expressed towards the corruption rumours was observed. At times, management action seems to indicate intellectual involvements are more important than heart-felt commitment. However, people who are committed to a cause and an outcome bigger than themselves can hold a place together, can restore disruption, and can find a way to engage constructively with challenges.

The researcher realises that Eskom's resilience cannot be equated to the resilience of essential services. However, given that Eskom currently generates 95% of South Africa's electricity, Eskom's resilience has a huge bearing on the resilience of electricity supply in South Africa. She recognises that Eskom in its current form is caught in a rigidity trap and something needs to break for the trapped resources to be released and new forms of organization to emerge, which may diversify electricity supply in the country. In the context of Eskom, however, organizational resilience has direct bearing on the capability to maintain essential service delivery amidst inevitable disruptions and facilitate the required changes in the organization, the energy landscape nationally, and the industry globally.

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Chapter 2: A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems

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Declaration

The candidate was responsible for formulating and compiling this article under the leadership and supervision of Prof Biggs and Dr Preiser. The core framework proposed and outlined in this paper was developed by the candidate.

Abstract

Essential services such as electricity are critical to human well-being and the functioning of modern society. These services are produced by complex adaptive socio-technical systems and emerge from the interplay of technical infrastructure with people and governing institutions. Ongoing global changes such as urbanization and increasing prevalence of extreme weather events are generating much interest in strategies for building the resilience of essential services. However, much of the emphasis has been on reliable and resilient technical infrastructure. This focus is insufficient; resilience also needs to be built into the human and institutional processes within which these technical systems are embedded. Here, we propose a conceptual framework, based on a complex adaptive systems perspective, that identifies four key domains that require investment to build the resilience of essential services. This framework addresses both the technical and social components of the socio-technical systems that underlie essential services and incorporates specified and general resilience considerations. The framework can be used to guide resilience

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assessments and to identify strategies for building resilience across different organizational levels.

Key Words: complex adaptive systems; critical infrastructure; electricity supply; essential services; resilience assessment; socio-technical system

2.1   Introduction

Modern society depends on a wide range of services being resilient in the face of disruption and rapid global change (Holling 2001, UNISDR 2015). This includes ecosystem services produced by social-ecological systems, as well as technologically mediated essential services, such as electricity, water and sanitation. Similar to ecosystem services, disruption in essential services can cause ripple effects with *considerable social consequence* (Schulman *et al.*, 2004; Rose, Oladosu and Liao, 2007; Pescaroli and Alexander, 2015), which can escalate to a disaster if it exceeds the ability of the affected community to cope (UNISDR 2009, 2015). Along with efforts to foster resilience of ecosystem services, building resilience of essential services is critically needed (La Porte, 2006), accompanied by practical frameworks and approaches to better understand and assess the resilience of such services.

Essential services are produced by complex adaptive socio-technical systems (Varga, 2015), which are embedded within broader social-ecological systems (Folke 2006, STAP 2015). Essential services are co-produced through the interplay of technology and social institutions – or hard and soft infrastructure – that comprises socio-technical systems. Hard infrastructure refers to physical technical assets and systems, while soft infrastructure refers to the social systems, such as institutions, users, rules and regulations (UN ESCAP 2013). Most of the current resilience emphasis around essential services focuses on development, maintenance and protection of the hard infrastructure, rather than assurance of the service itself (Auerswald *et al.*, 2006; La Porte, 2006). Investments in hard infrastructure ought to be accompanied by investments in *soft* infrastructure to ensure resilient service delivery. In the emergency preparedness and disaster management communities, it is increasingly recognized that continuity of essential services requires a focus on the broad-based resilience capabilities of communities, the private sector, and all levels of government (DHS 2010, NIAC 2010, FEMA 2015).

Ensuring the resilience of electricity supply is of particular interest to government administrators (Grid Resiliency Task Force 2012, City of New York 2013, The White House 2013, NAS 2017). Electricity supply is considered a foundational service, since many other layers of critical infrastructure, and the essential services derived from them, such as water

supply, depend on electricity (Koester and Cohen, 2012; Comes *et al.*, 2016). Like the socio-technical systems that produce other essential services, the electricity supply system is a complex adaptive system susceptible to disruption (Amin, 2015). To ensure resilience, the interlinked social and technical parts of the system have to continuously rebound from, adapt to and transform amidst the many environmental, technical, and social risks factors that can disrupt supply.

In common usage, resilience refers to the ability to bounce back or spring back into shape following a disruption. As a systems-level characteristic, resilience is an emergent property of complex adaptive systems (Cork, 2011; Aldunce *et al.*, 2015), and refers to the capacity of a system to sustain core functions in the face of disruption and change (Folke et al 2010; Biggs et al 2012). Resilience can be used in either a descriptive or a normative sense. From a descriptive perspective, the concept is neutral and refers to the persistence of the core functions and identity of a system (Walker *et al.*, 2004; Cumming *et al.*, 2005), which can be either desirable or undesirable. Examples of undesirable resilient systems include poverty traps and organized crime (Barrett and Constas, 2014; Dahlberg, 2015). More recently there has been a groundswell of interest in the normative use of resilience as an approach for managing complex adaptive systems towards desirable outcomes (Biggs *et al.*, 2012; Seville, Van Opstal and Vargo, 2015; Folke, 2016). From a normative perspective, resilience is not merely the ability to sustain core functions, but to sustain specific outcomes, such as continued production of specific ecosystem (Biggs et al 2015; Folke et al 2016) or essential services. This may entail bouncing back after a disruption, but could also involve systemic transformation and bouncing forward to a position better than before (Boin and Van Eeten, 2013; Weichselgartner and Kelman, 2015).

In this paper, we propose a framework to conceptualize and assess the resilience of essential services using a complex adaptive systems perspective. For the purpose of this article, we apply resilience normatively, and define resilience of essential services as the capacity of complex adaptive socio-technical systems to sustain the production of essential services in the face of disruption and ongoing social, technological and environmental change. The framework we propose draws on and integrates work on resilience from several different disciplinary traditions, particularly work on social-ecological systems (Biggs et al 2015, Folke et al 2016), research on the resilience of engineered systems (Madni and Jackson 2009, Park et al. 2013), and organizational resilience (Weick, Sutcliffe and Obstfeld, 1999; Linnenluecke and Griffiths, 2012) as well as practical policy guidance that focuses on critical social responses from community resilience (Cabinet Office 2011, NIST 2016). We

integrate these different strands of work based on a common underlying view of these problems as complex adaptive systems problems.

The framework we propose draws on an interdisciplinary synthesis of literature, as well as practical experience of conducting resilience assessments to electricity supply in Eskom Holdings, the South African national electrical utility. The South African experience is emblematic of the challenges facing electric utility providers, particularly in developing countries. By focusing on a clearly defined system, we aim to explore how the resilience of essential services, that underpin key functions in modern societies, can be enhanced. We suggest that this framework can be applied to other essential services and, with some modification, can also advance understanding of social-ecological resilience more generally.

2.2   Electricity supply as a complex adaptive systems problem: the case of South Africa

Globally, electricity supply systems face an increase in the number and severity of large-scale emergencies, often triggered by severe weather (Abi-Samra *et al*., 2014; Cabinet Office, 2015). In emerging economies this trend is aggravated by rapid growth in electricity demand, posing challenges for reliable service provision, and constraining opportunities for social and economic development (Bocca and Mehlum, 2012). In the case of South Africa, 95% of the electricity used in the country is supplied by Eskom, a national vertically integrated generation, transmission and distribution utility (Eskom, 2016b). In a relatively short space of time, Eskom went from global power company of the year in 2001 (Khoza and Adam, 2006), to no longer being able to maintain the national supply/demand balance in 2008, resulting in three weeks of nationwide rotational load shedding to deal with the shortfall (Chettiar, Lakmeeharan and Koch, 2009). By 2014, the South African energy profile became comparable to that of China, India, and Mexico at the time, where energy shortfalls significantly constrain economic growth to meet human development needs (Bocca and Mehlum, 2012).

Eskom initiated a resilience strategy in 2008, in response to growing electricity shortfalls, and to deal with the new reality of regular loadshedding. Initially the focus was only on power system resilience, but expanded to the whole enterprise in 2013 to deal with wider business risks that were emerging. The purpose of a resilience focus is to prepare the organization to deal with business unusual. The expanded enterprise resilience focus is to ensure an integrated overview of risks, and to facilitate an integrated emergency response capability to deal with systems-level emergencies and special events, such as the FIFA World Cup and national elections (Koch et al. 2013). There is a realization that traditional reductionist

approaches, widely used to manage technology in the organization, is inadequate to deal with the complexity of emerging systemic problems (Guckenheimer and Ottino, 2008), particularly the low-probability high-consequence risk of blackouts Eskom has to manage.

The dynamics of complex adaptive power systems cause them to drift towards a critical point, where their apparent stability can abruptly change state (Dobson *et al.*, 2007; Viejo *et al.*, 2015). The complex intertwining of unforeseeable coincidences may cause rapidly cascading failure in the power system, and, in the worst case, result in a blackout (Bo *et al.*, 2014) – a wide-area outage of long duration (NAS 2017). A blackout in turn normally results in further cascading failure across other interconnected and interdependent infrastructures, e.g. water, or telecommunications (Rinaldi, Peerenboom and Kelly, 2001; Zaidi *et al.*, 2015). Large blackouts are low-probability high-consequence events that often result in significant social and economic impact (Bo *et al.*, 2014). In most developed nations with their highly interconnected grids, a blackout is rapidly restored through interconnections from neighboring areas that still have power (Bo *et al.*, 2014). However, in the case of a national blackout, none of Eskom's neighboring electricity utilities have the capacity to restart the South African power system, which highlights the importance of resilience in general, and a black-start capability in particular. At the same time, a well-developed technical black-start plan is insufficient to ensure national resilience to a blackout incident; institutional arrangements and integrated response plans are required in partnership with priority national role players (such as fuel, water, telecommunications, and security) to effectively respond to, and deal with, the consequences of a national blackout.

Given this situation, it is clear that a fundamental, deliberate and transformative change is required within and among institutions at national, regional, and local levels to establish the necessary preparedness, across multiple sectors. This paper draws on the emerging body of work on complex systems problems (Cilliers, 2000; Westley, Zimmerman and Patton, 2006; Allenby and Sarewitz, 2011) that indicates that such transformative change can be facilitated by recognizing that the problems, such as sustaining electricity supply in the face of disruption and change, is fundamentally complex, rather than a mere technical problem. Contingency planning and response strategies need to be set up. The capacity to prepare for and respond in a coordinated fashion requires complex adaptive systems thinking (Cilliers, 2007; Bohensky *et al.*, 2015), which emphasizes the presence of the interlinked nature of technical and human systems, how they interact and tend to self-organize into different regimes, or result in disorder associated with critical stability points (Holling, Gunderson and Ludwig, 2002; Folke, 2006).

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The difference between *complicated* and *complex* adaptive systems and problems is a difference of type, not of degree (Poli, 2013). It is necessary to draw a clear distinction between these types of problems, as the methods and approaches for understanding and managing them differ vastly (Snowden and Boone, 2007; Poli, 2013) (Table 2-1). Reductionist approaches rely on problem solving strategies that delimit reality into smaller parts and apply methodologies that aim towards predictability and control (Ramalingam *et al.*, 2008). Such approaches assume that the nature of the problem is complicated. Reductionist approaches are inadequate to address complex problems. Complex problems require ongoing engagement and adaptation, as apparent solutions often give rise to new problems (Poli 2013). Complex adaptive systems thinking explicitly considers unintended consequences, the agency of people, and unpredictable novelty (Juarrero, 1999; Kurtz and Snowden, 2003; Allenby and Sarewitz, 2011). In reality, most problem situations contain both complicated and complex phenomena. It is essential for decision-makers to make sense of the problem composition, in order to apply solutions compatible with the nature of the problem at hand (Snowden and Boone, 2007).

Table 2-1 The difference between complicated and complex adaptive systems and problems, adapted from Poli (2013).

	Complicated problems	**Complex problems**
Boundary	Level 1	Level 2 (as defined by Allenby and Sarewitz 2011)
Causality	Complicated problems originate from causes that can be individually distinguished.	Complex problems and systems result from networks of multiple interacting causes that cannot be individually distinguished.
Reduction	Problems can be addressed piece by piece.	Problems must be addressed as entire systems, that is they cannot be addressed in a piecemeal way
Linearity	For each input to the system there is a proportionate output.	Small inputs may result in disproportionate effects.
Solvability	These problems admit permanent solutions.	These problems cannot be solved in full, but require systematic management. Typically, any intervention merges into new problems as a result of the interventions dealing with them (Poli, 2013).
Controllability	The relevant systems can be controlled.	The relevant systems cannot be controlled; the best one can do is to influence them. These problems have to be engaged directly; and learn to "dance with them" (Meadows 2009:70, Poli 2013).

The system boundaries described by Allenby and Sarewitz (Allenby and Sarewitz, 2011) are a useful guide to distinguishing between complicated and complex problems in socio-technical systems. *Level 1* system boundaries are defined in terms of specific technological solutions, such as electrical transformers or switchgear that aim to address a particular problem. Level 1 problems generally correspond to complicated problems that focus on hard infrastructure. However, for *Level 1* solutions to function, they are always embedded in *Level 2* systems, which incorporate the wider psychological, social, and cultural contexts that are inseparable from the technology (Ibid.). Level 2 systems are complex adaptive systems, susceptible to non-linear risks and catastrophic disruption. Technical components in the power system are typically analyzed at *Level 1*, while the overall electricity supply system should be recognized as a *Level 2* complex adaptive socio-technical system.

Eskom recognizes resilience as a strategic imperative (Eskom, 2016b). By design, Eskom has multiple layers of defence to prevent a blackout, which are actively maintained to ensure their integrity. Even though the probability of such high-consequence events is low, Eskom is committed to establishing response preparedness and employing risk reduction measures to reduce the fall-out from such eventualities (Eskom, 2016a).

2.3   Resilience thinking

Resilience thinking is an application of complex adaptive systems thinking that pays specific attention to enhancing resilience. Building resilience has arisen as a response to deal with uncertainty and external risk, limited control, deep disruption and an unpredictable future (Van Breda, 2001; Sheffi, 2005; Bhamra, Dani and Burnard, 2011; Caldwell, 2014). Resilience refers to the innate ability of complex adaptive systems to absorb disturbances or surprise and adapt to dynamic change without losing their identity or function (Folke *et al.*, 2002; Walker *et al.*, 2004; Berkes, 2007). The concept of resilience therefore includes interrelated aspects of persistence, adaptability and transformability (Walker *et al.*, 2004; Folke *et al.*, 2010). Following this line of thinking, we define a resilient socio-technical electricity supply system from a normative perspective as one which has the emergent capability to absorb large shocks, even for low-probability high-consequence events such as a national blackout, and to continue to adapt amid ongoing changes, like climate change and urbanization, while continuing to ensure reliable electricity supply in an affordable and sustainable manner.

Literature on the application of resilience distinguishes between two different types of resilience that need to be established simultaneously: *specified* and *general* resilience (Folke *et al.*, 2010; O'Connell, Walker, Abel and Grigg, 2015). *Specified* resilience refers to the

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resilience of a specified part of the system to identified disruptions, while *general* resilience refers to the capacity of a system to withstand all hazards, including novel and unforeseen ones, while continuing to provide essential functions (Walker *et al.*, 2009) (Table 2-2). *General* resilience is a generic capability to cope with uncertainty and surprise and to endure novelty and instability, including multiple shocks and cascading failure (Folke *et al.*, 2010; Walker and Salt, 2012). General resilience emerges when predetermined plans are inadequate to deal with the situation at hand, and new capabilities are dynamically developed to respond (Lee, Vargo and Seville, 2013). Resilience literature cautions that resilience investments have to be balanced across *specified* and *general* resilience, as effort channeled into developing only one kind of resilience may reduce the other (Folke *et al.*, 2010; Resilience Alliance, 2010; Cork, 2011).

Table 2-2 Characteristics of specified and general resilience.

	Specified resilience	General resilience
How to identify it	The ability to persist within a stability zone (Folke et al., 2010) through anticipation strategies, being prepared, and applying prevention (Comfort et al., 2001).	An intangible emergent capacity for adaptation and transformation (Folke et al., 2010) across multiple equilibria (North, 1993; Caldwell, 2014).
How to build it	Can be established by following best practice, through managing foreseeable risks (Garred, 2013), and by how infrastructure is designed, built, and maintained (NIAC 2010).	Is nurtured through the capacity for abductive thinking and sensemaking (Grøtan, 2013) and evolutionary self-organization (Allan and Bryant, 2014; Scolobig et al., 2015; Coning, 2016).
How to sustain it	Employs single-loop learning and aims to strengthen negative feedback loops (Antonacopoulou and Chiva, 2005): to return conditions towards a predetermined target, to remove deviations, and to keep operations within deterministic boundaries (Weick and Sutcliffe, 2007).	Employs double-loop learning and aims to strengthen positive feedback loops (Antonacopoulou and Chiva, 2005): to self-reinforce, amplify, enhance, and stimulate behaviors that enhance resilience, which includes modifying the rules that drive behavior (Holman, 2010a).

In this paper we apply the bifocal lens of complicated and complex problems to clarify the operational implications for building specified and general resilience. To establish specified resilience, a decomposition of the system and its environment is required to determine "what" internal parts should be resilient, and against "what" external aspects of the environment this resilience is required (Carpenter *et al.*, 2001). Although this reductionist approach is pragmatic, it employs a complicated approach to a complex system. Resilience associated with technical components can be engineered in a complicated fashion using classical

reliability oriented design (Holling, 1996). Experts can follow best practice or good practice (Hummelbrunner and Jones, 2013b) to establish resilience of specific parts of the system to specified shocks. However, these Level 1 components can collapse when critical thresholds are exceeded in the Level 2 systems context in which they are embedded (Pourbeik, Kundur and Taylor, 2006; Simone, 2014). General resilience therefore needs to be established across multiple facets of the level 2 system, and necessitates resilience practitioners to embrace complexity-based approaches.

A key capability that enables leaders to make sense of inherent complexity and ambiguity is sensemaking (Weick, 1995), the ability to comprehend, understand, and explain what is going on (Ancona, 2011). Sensemaking is an integral part of learning and consists of an ongoing action-oriented cycle of acquisition, reflection, and action that people go through to integrate experiences into their understanding of the world to inform action (Kolko, 2010b). Sensemaking shapes organizational behavior: how the organization makes sense of where it is and what is going on, and directly impacts how the agents in the system adapt and self-organize, which, in turn, influences how the system develops (Weick, 1995). Appropriate collective sensemaking is crucial to ensure resilient service delivery, as it directly impacts general resilience features through the effectiveness of organizational response to crisis or disruption (Casto, 2014).

2.3.1   Resilience assessment

Along with the rapid rise in interest in fostering resilience, there has been a great demand for improved approaches to assess resilience (Quinlan *et al.*, 2015). Assessments can be distinguished based on purpose (why), target audience (for whom), level of assessment (of whom), and object of assessment (what) (Terenzini, 1989; Carpenter *et al.*, 2001; Quinlan *et al.*, 2015). Many different resilience assessment methods exist. Several approaches highlight the need for participatory approaches (Almedom *et al.*, 2007; Pasteur, 2011; O'Connell, Walker, Abel, Grigg, *et al.*, 2015; Quinlan *et al.*, 2015). Other resilience assessment approaches distinguish between types of resilience, an evaluation of the actual resilience displayed in past incidents, or comprise indicators of adaptive management, adaptive governance, or transformative capacity (Cork, 2011; Walker and Salt, 2012; O'Connell, Walker, Abel and Grigg, 2015). A stated objective of many resilience assessments is to understand how to build resilience of some desired outcome.

Drawing on the literature from educational assessments, we distinguish between "summative assessments", that primarily aim to evaluate current levels of resilience for external reporting and benchmarking, and "formative assessments" that aim to build resilience through the

assessment process itself (Table 2-3). Although these two objectives are not mutually exclusive, clarification of the primary purpose of a particular resilience assessment exercise can help select a suitable approach. Summative assessments seek to standardize indicators for the benefit of comparison and to aggregate towards national or regional reporting *of* resilience (Stephenson 2010, RESILIENS 2015, O'Connell et al. 2015). Formative assessments comprise an on-going process, not a periodic product (Black and Wiliam, 1998; Duke University, 2008; Grand Valley State University, 2012). These *assessments* entail a systematic and ongoing internal process of seeking and interpreting evidence, to participatively make sense of the current levels of system resilience, and garner agreement to improve attainment of resilience outcomes. *Formative* assessments center on critical conversations among key actors in the system, to enable collective sensemaking, promote commitment to resilience goals, and adaptively stimulate the emergence of resilience throughout the system. Care should be taken that the approach used does not undermine the intended outcome. When assessments *for* enhancing resilience are conducted as punitive compliance audits, it can lead to unintended consequences and erode resilience instead of building it (Dekker and Breakey, 2016).

Table 2-3 Differentiation between formative and summative resilience assessments.

Formative resilience assessments	Summative resilience assessments
can be an ongoing process	can be scheduled periodically
"for" a resilience outcome,	"of" resilience
to facilitate a bottom-up dialogue among actors in the system,	against standardized indicators decided top-down,
to diagnose where the system is at in its levels of resilience,	for the purpose of producing a report for a third party,
to agree where resilience should be strengthened,	to give an account of what has been achieved,
through collective action towards shared resilience goals.	or comparison, aggregation or benchmarking.

Formative resilience assessment processes merge into a transformative assess-and-build cycle. Such assessments require direct engagement with the complex adaptive system to learn about the nature of the complex dynamics (Quinlan *et al.*, 2015). Key actors probe the system interactively to make sense of dynamically changing feedback mechanisms, constraints, and patterns of emergence (Juarrero and Lissack, 2000; Walker and Salt, 2006). Attention is paid to what builds, maintains, and breaks down resilience, where undesirable resilience should be disrupted, and where desirable resilience can be enhanced (Australia21,

2009; Quinlan *et al.*, 2015). The assessor is part of the complex adaptive system and probing can affect emergence of the system in unpredictable ways. Therefore, all probes should be carefully designed as interventions to enhance resilience (Holman, 2010a), while every intervention to build resilience can be used as a probe to better understand the system and its resilience dynamics. This ongoing process can adaptively transform the system's resilience over time.

2.3.2 A framework for conceptualizing the resilience of essential services

Building on the emerging theoretical ideas outlined above, and practical experiences in operationalizing resilience thinking and assessments in the context of electricity supply in South Africa, this section presents a framework for conceptualize the resilience of essential services produced by complex adaptive socio-technical systems. To conceptualize the resilience of essential services, we juxtapose the types of resilience (*specified* and *general)* and focus of resilience investment (technology or social) (Figure 2-1**)**. Although the social and technical components are interdependent, the distinction here is based on the content (Rosen, 2000) and the focus of the resilience strategy (NIAC 2010). The resulting four quadrants represent different resilience domains that can serve as a guide for how to assess and build resilience of essential services:
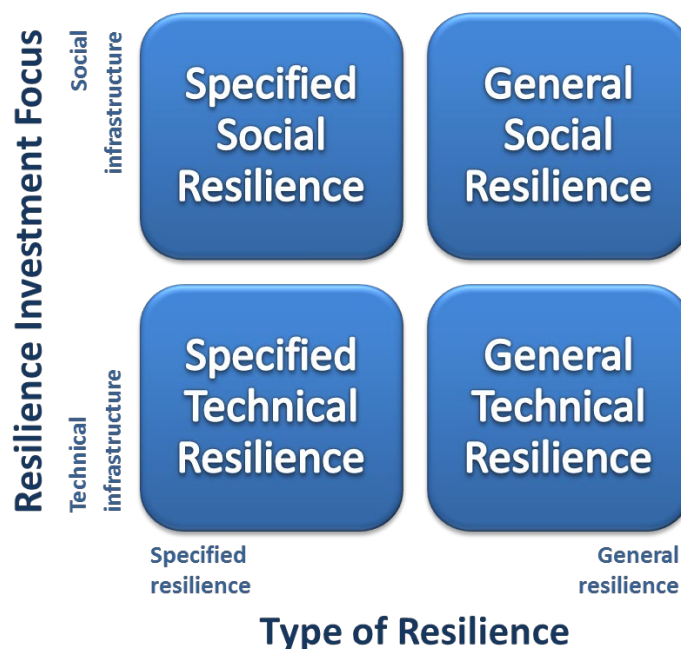
Figure 2-1 A conceptual framework for building and assessing resilience of essential services produced by socio-technical systems.

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- The "specified technical resilience" quadrant represents areas where resilience to specific risks (e.g. storms) is built into technical infrastructure, to ensure that it is adequate, reliable, and secure. This quadrant focuses on building robustness into Level 1 systems.

- The "specified social resilience" quadrant represents areas where resilience to *specific risks (e.g. disruption to critical business processes) is* established through processes and institutions in the social domain. This quadrant focuses on building specific skills, response capabilities and plans within Level 2 systems.

- The "general technical resilience" quadrant represents areas where resilience to novel and unknown risks is established through network topology or adaptive technologies that offer systems-level flexibility to enable an agile response across the system in dealing with uncertainty. This quadrant focuses on connectivity and structure of Level 2 systems to ensure systems-level flexibility

- The "general social resilience" quadrant represents areas where resilience to novel and unknown risks is established through people, processes and institutions. This quadrant focuses on collective human agency, agility and volition in Level 2 systems.

2.3.3 Differentiated resilience roles

These different forms of resilience can be cultivated at different organizational levels (operational, tactical, and strategic). The organization has been conceptualized as a layered triangle, with the operations layer being the largest bottom stratum; the tactical layer representing the middle level; and the top strategic layer representing the executive level (Anthony, 1988; Mumford, Campion and Morgeson, 2007; Ho, 2015). The different interrelated aspects of resilience (persistence, adaptability, and transformability) can occur at multiple hierarchical levels in organizations and interact across temporal, spatial, and hierarchical scales. To foster resilient essential services, we argue that the primary role of operational leadership is to foster *persistence* of core operational functions, tactical leadership's role is to develop *adaptability*, and the role of strategic leadership is to timeously *transform* the organization to survive and thrive amid disruptive change (Figure 2-2**,** Table 2-4). We also argue that specified resilience is crucial in the lower strata of organizations, while the significance of general resilience increases higher up. Operational leaders need to be aware of external threats and mindful of internal vulnerabilities to persist. In contrast, strategic leaders need to be aware of external opportunities and mindful of internal well-being of employees to proactively transform.

Figure 2-2 Resilience roles and responsibilities at different organizational levels.

Table 2-4 Differentiated focus in resilience roles at different organizational levels.

Operational level	Tactical level	Strategic level
Leadership fosters persistence through operational control in daily operations to ensure that the system has the day-to-day ability to absorb a magnitude of disturbances and to anchor essential services with minimum disruption.	Leadership establishes integrated response capabilities, adaptability through management control, continuous improvement, and scenario-based exercises to enable the organization to adaptively manage risk, to bounce back better, and to embrace opportunities to bounce forward.	Leadership takes a long-term perspective to timeously transform the organization through emergent strategic planning to survive and thrive amid uncertainty, while navigating disruptive change, to intentionally transform its identity towards a more sustainable development trajectory.

2.4   Applying the framework to build and assess resilience of electricity supply

The framework introduced above can be used to identify different strategies and interventions to build the resilience of essential services in different parts of socio-technical supply systems. Applying the framework at different organizational levels can facilitate contextually appropriate assessments that help develop a deeper and shared understanding of the complex adaptive dynamics of a system in relation to the larger context in which it is embedded, a key objective of many resilience assessments (Quinlan *et al.*, 2015). To achieve this objective, we argue that the assessment process should incorporate key resilience-building principles of facilitating broad participation, encouraging learning, and facilitating a deeper understanding of complex dynamics in the socio-technical system, while building trust and social capital (Biggs, Schlüter and Schoon, 2015).

In the following sections we discuss how the framework can be applied specifically in the context of socio-technical electricity supply systems to build and assess resilience. The four resilience quadrants can be used as a guideline for the differentiated assessment of respective types of resilience at different organizational levels. Table 2-5 suggests indicators of quadrant-specific resilience indicators, applicable to specific organizational levels.

Table 2-5 Suggested quadrant-specific indicators of resilience at different organizational levels.

	Indicators of persistence at operations level	Indicators of adaptability at tactical level	Indicators of transformability at strategic level
Specified technical resilience	Infrastructure and assets well managed to required standards, including regular maintenance and tests of back-up technologies (UN ESCAP 2013). Deploy standardized redundancy criteria, have redundant equipment available, and have efficient access to operational spares to restore network disruptions.	Technical standards are adaptively revised to incorporate learning. Adaptive assessment approaches are applied, and a portfolio of technical investments exists for disaster risk reduction (NDMC 2000). Strategic spares are available for contingencies and response (NIAC 2010). Engineers consider build-back-better and fail-to-safe design philosophies (Park et al. 2013, UNISDR 2015).	Strategic commitment to invest in resilience, reserve margins, and self-healing capabilities (DOE 2014). Decision-making considers impact of decisions on resilience of critical processes (BSI 2014). Adopt a modular substation design strategy; although initial cost is higher, it can standardize on spares and speeds up recovery (Zolli and Healy 2012, Friedrich et al. 2015, EPRI 2016).
Specified social resilience	Competent in decisions that require attention to detail and precision across multiple recurring iterations(Anthony, 1988; Mumford, Campion and Morgeson, 2007; Ho, 2015). Competent in execution of standard operating procedures, emergency roles and responsibilities, ability to execute pre-approved response plans, and ability to effectively participate in simulation exercises (Wybo, 2008).	Competent in semi-structured decisions and ensuring efficient and effective use of resources through business planning, logistics coordination, and operational improvements‡. Contingency arrangements, response plans, and risk reduction strategies are systematically reviewed and adaptively revised to incorporate learning (Saurin, Righi and Henriqson, 2013). Response structures effectively integrate across functions.	Competent in unstructured decisions that are complex, ambiguous, and far-reaching in scope, entail high levels of uncertainty, and often pertain to non-linear risks in the external environment‡. Commitment to resilience through visible leadership in good-practice disciplines such as emergency preparedness and business continuity management. Ownership of contingency arrangements, knowing and testing established plans, and actively participating in emergency simulation exercises. The ability to anticipate and avoid *foreseeable, predictable, avoidable surprises* (Bazerman and Watkins, 2008)

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	▲ **Indicators of persistence at operations level**	▲ **Indicators of adaptability at tactical level**	▲ **Indicators of transformability at strategic level**
General technical resilience	Be able to operate adaptive technology under pressure and maintain back-up and contingent systems components. Technical capabilities that allow operational flexibility often beyond the infrastructure itself, for example, demand response contracts.	Review asset condition monitoring practices and test results of deployed technologies that provide adaptive capacity and strengthen systems flexibility, for example, unit islanding schemes and black-start tests performed. Consider technology solutions beyond the infrastructure system.	Proactive investment in systems flexibility (in electricity supply these include smart metering, smart grid, containerized mobile substations, demand-side products, and supply-side mix).
General social resilience	Monitor whether people feel empowered to act in the interest of safety and resilience if contrary to what is expected. Be able to follow intuition based on deep experience in situations that necessitate that the rules be broken. During extreme events, be comfortable to apply an incident command system to perform emergency operations, even under great pressure. Employ safe-to-fail scenarios in emergency exercises that stretch people beyond the plan.	Be able to network and to mobilize support through strong social networks, third-party agreements, and memorandums of understanding that have been established. Monitor for signs of restorative or retributive justice exercised in supervision. Identify heuristics used on the frontline, verify its validity to formalize and spread guiding heuristics to be used in crises. During extreme events, be comfortable to coordinate planning, be able to integrate situational awareness during the incident to provide a common operational picture of unfolding events, execute tactical command, mobilize resources, and coordinate logistics to support operations.	Actively build a culture of resilience and safety, with restorative justice in word and deed. The ability to anticipate and avoid predictable surprises§. Evidence that they value and actively build social and psychological capital in their networks and through their leadership, practice adaptive management, and encourage decentralized self-organization during disruption (Jones 2011, Pereira and Ruysenaar 2012, Everly et al. 2013). Strengthen external and internal connections in functions, across disciplines, and with other sectors (Stephenson, 2010). During extreme events, be comfortable to fulfil the incident commander role, be able to see the big picture, prioritize objectives, take decisions in spite of incomplete information, and recognize when a phase change is evident or a regime shift has taken place.

2.4.1 Specified technical resilience

Specified technical resilience represents areas where investments can be made in identified infrastructure and assets to ensure that they can withstand specified threats, in answer to "resilience of what and to what?" (Carpenter et al. 2001, Quinlan et al. 2015 p. 3). Although the timing and severity of these specified threats may be unknown, their potential future occurrence can be probabilistically calculated (O'Connell, Walker, Abel and Grigg, 2015). This quadrant draws on what Holling (1996) described as engineering resilience, or what is known in the electric utility world as utility resilience, reliability standards, electric power infrastructure resilience, or grid resilience (NIAC 2009, Madni and Jackson 2009, Park et al. 2013, DOE 2014, NERC 2015). The specified technical resilience domain represents Level 1 technology solutions that enhance survivability and robustness (Pavard et al., 2006; Madni and Jackson, 2009; Dahlberg, 2015), following the laws of physics and using reductionist approaches.

Building specified technical resilience: Given adequate resources, infrastructure resilience can be achieved to withstand anticipated hazards through good practice, which includes intelligent engineering design that implements adequate margins of safety, quality construction, and sufficient maintenance (UN ESCAP 2013). In a utility such as Eskom, this translates into applying engineering standards (for example reliability criteria, quality controls, and routine inspections). Consideration should be given to fail-to-safe design philosophies (revert to a safe condition if it fails). Specified technical resilience can also be enhanced through a wider distribution of resources to increase redundancy. An example of increasing diversity and redundancy in electricity supply is the use of micro-grids around critical facilities or the placement of critical spares such as spare towers or mobile transformers at select locations throughout the grid to speed up emergency response.

Assessing specified technical resilience: Specified technical resilience assessments can consist of quantitative measures (Quinlan et al., 2015), benchmarks, tests and compliance with engineering standards and controls applied throughout the asset life cycle. Reliability assessments contribute towards technical resilience, but reliability is not enough to ensure resilience to low-probability high-consequence events (Stockton, 2014; Panteli and Mancarella, 2015). Due to an increase in severe weather events from climate change, the resilience of technologies already deployed should be monitored (Savonis, Potter and Snow, 2014) to harden or reinforce existing infrastructure and modernize aging infrastructure to withstand severe climate events (Panteli and Mancarella, 2015), and reliability design criteria of infrastructure should be revised to cater for new extremes.

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When infrastructure is damaged in disasters (for example, due to severe weather), the global Sendai Framework for Disaster Risk Reduction suggests that asset owners consider the option to build back better (UNISDR 2015) to enable bouncing forward (Kelman et al. 2015:22). In addition, adaptive assessment approaches can be employed to verify the reliability and resilience of current infrastructure due to the increased probability and intensity of severe weather events. A risk assessment of climate-resilient infrastructure can identify assets vulnerable to inundation or structural failure, to inform an infrastructure resilience investment strategy for disaster risk reduction (NDMC 2000). Within Eskom, the systematic application of this approach is prescribed in the disaster management strategy in the form of disaster risk assessments and disaster risk reduction. This process demonstrates the cyclical nature of assessing resilience to build resilience.

2.4.2 Specified social resilience

Specified social resilience entails specific investments in people and processes to ensure that they can maintain the continuity of critical functions when subjected to identified threats. This quadrant draws on the management disciplines of emergency management, crisis management, business continuity management and safety management, as well as literature from the fields of organizational resilience, climate resilience, and disaster management (Linnenluecke and Griffiths, 2012; Miao, Banister and Tang, 2013; Mendonça and Wallace, 2015). The adequacy of people's technical skills draws on the traditional reductionist approaches of socio-technical systems thinking and human-machine interface design (Sidney W A Dekker, 2005; Qureshi, 2007; Klein, 2008). To ensure safety in high-risk operations, the literature on high-reliability organizations highlights cultivating resilience mindsets (Weick, Sutcliffe and Obstfeld, 1999; Schulman et al., 2004; Lekka, 2011).

Building specified social resilience: Specified social resilience can be built through the adoption of established disciplines of good practice (BSI 2014). The Eskom Resilience Programme is based on the adoption of emergency management, business continuity management, and disaster management at different scales across the organization, using risk management as a common basis and incident management integrated at the time of response across functional and geographic boundaries (Koch et al., 2013). Through the adoption of these management systems, response preparedness and contingency arrangements are formally established. While these good-practice guidelines are aimed at specific response capabilities, the process can also contribute to general social resilience when people synthesize the wider context and recognize the purpose of these processes.

To develop the cognitive ability to deal with the disruption of extreme events, an effective response capability can be developed, but there is no substitute for experience (Cilliers, 2000; Casto, 2014; Doyle, Paton and Johnston, 2015). Operators need the ability to recognize system failure conditions and arrest the collapse of technical infrastructure systems. Since real resilience tests seldom occur, this experience can be built up through being exposed to stretching scenarios in simulation exercises (Wybo, 2008; Koch et al., 2013; Kellett et al., 2014). It takes 11 years in an apprentice programme, which includes extensive time on the simulator, before a new system operator autonomously mans a desk within Eskom National Control. Participation in emergency exercises and simulations is vital to build and assess resilience (Wybo, 2008).

Continuous learning is a vital resilience-enhancing principle (Biggs et al., 2012). While incident investigations assess root causes, they also propose preventive measures. Collectively, these findings can be a useful in facilitating adaptation requirements that build specified resilience. Highly reliable organizations cultivate collective mindfulness that pays attention to small signals, for example, when incidents result in responses at a systemic level that are outside of the expected norms (Weick, Sutcliffe and Obstfeld, 1999). Such organizations learn from their mistakes, and those of others, to "fail forward". At a wider scale, specified social resilience can be enhanced by changing the rules of the game, such as redesigning the regulatory framework to support resilience (NIAC 2010, Keogh and Cody 2013), by increasing the range of options (e.g. having critical load specifications for the utility or diversifying the energy options for customers), and by increasing the size of buffers, through energy demand management programmes.

Assessing specified social resilience: Specified social resilience assessments can entail a verification of established preparedness against predefined objectives in the form of authorized contingency arrangements, response and recovery plans, and standard operating procedures. Such assessments can be done based on the guidelines of good practice disciplines such as emergency preparedness, business continuity management, and disaster management. Various indicators of specified social capabilities have been recommended to enable repeatable and comparable resilience assessments (McManus et al., 2007; Hollnagel, 2010a; Stephenson, 2010; Lee, Vargo and Seville, 2013; Matzenberger et al., 2015). Within Eskom, divisional and provincial progress is monitored against key deliverables as part of an enterprise resilience programme. The role of exercises in specified social resilience assessments is to test execution against these predefined plans and to verify the effectiveness of the preparedness at a disaggregated level in organizations. Such integrated provincial and national exercises are conducted annually in Eskom.

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2.4.3 General technical resilience

General technical resilience refers to the generic ability of man-made systems to withstand any threat or disruption amid the complexity of the Level 2 systems in which they are embedded. This quadrant draws on network topology, resilience engineering, systems resilience, systems of systems, and critical infrastructure systems literature (Hollnagel, Woods and Leveson, 2006; Janssen et al., 2006; Dekker et al., 2008; McDaniels et al., 2008; Kasthurirangan and Srinivas, 2010; Francis, 2014; Stockton, 2014; Amin, 2015; Gao, Barzel and Barabási, 2016). The field of resilience engineering should be distinguished from engineering resilience described by Holling in 1996. Resilience engineering applies a complexity perspective to safety of man-made systems by ensuring that the overall socio-technical system has the capacity to withstand a threat, the flexibility to restructure itself in the face of a threat, the tolerance to degrade gracefully following an encounter with a threat, and the cohesion to operate before, during, and after an encounter with a threat (Dekker et al., 2008; Jackson, 2010).

Building general technical resilience: Building general technical resilience requires increasing systems-level flexibility, that allows bending rather than breaking (Longstaff, Koslowski and Geoghegan, 2013; Dahlberg, 2015). It entails optimizing network topology for resilience to maintain connectivity amidst disruption, although there can be a trade-off with network efficiency (Gutfraind, 2012; Gao, Barzel and Barabási, 2016). General technical resilience can be strengthened through technology that enables emergent and adaptive approaches that support novel self-service capabilities through, for example, built-in fail-to-safe modes and just-in-case contingency capacities that accommodate systems failure and manage failure and recovery (Park et al., 2013; Seville, Van Opstal and Vargo, 2015). Measures that increase system adaptation under system failure conditions include systems-level flexibility, increased observability and controllability, permeable systems boundaries that are less brittle under pressure (Rumbaitis, 2015), and tools that support rapid response and recovery (Schneider and Somers 2006, Francis and Bekera 2014, Panteli and Mancarella 2015). By extrapolating from resilience in social-ecological systems general technical resilience can be enhanced by paying attention to energy flows, systems-level feedback loops, slow variables, thresholds and interdependencies in the system.

In the electricity industry, general technical resilience is a key consideration in the focus on smart grid technology. For example, smart metering enables connectivity, with improved information flow, controllability, and dynamic reconfigurability of the system; self-healing networks enable technical systems to self-organize following disruption; micro-grids enable modularity, diversity, and redundancy (Lacey, 2014; Ye, 2014; Zarakas et al., 2014).

Regulatory requirements that enable the flexible management of real-time electricity demand reduction in the event of a range of scenarios in South Africa include the establishment of critical and essential load requirements, as well as interruptible load contracts (SABS 2010). General technical resilience can also be built into communities, for example, by diversifying energy options, such as solar-powered traffic lights to prevent gridlock when power supply fails, and through the use of peak-day pricing, stimulating energy efficiency that improves peak demand reduction and contributes to overall systems efficiency.

Assessing general technical resilience: Assessments of general technical resilience need to appraise levels of general technical resilience of the critical infrastructure system, through an evaluation of flexibility of the overall system, when under strain, or under failure conditions that may not yet be apparent. Metrics are available for the resilience of complex networks based on network topology and system dynamics (Zhao et al., 2011; Gao, Barzel and Barabási, 2016). Indicators of general technical resilience identified for socio-technical systems include safety margins, buffers and levels of redundancy built into the design and operations of the system (Madni and Jackson, 2009). Potential indicators, inferred from social-ecological systems, include systems-level connectivity and barriers (Biggs, Schlüter and Schoon, 2015). Drawing on Cork's work on resilient ecosystems (Cork, 2011), general resilience indicators applicable to assessment of technical systems include: modularity in the connections of components in the network to ensure that the overall system continues to function even if one part of the system has collapsed (referred to as redundancy and diversity by Woods (2005)); tight feedback mechanisms through which information about change is gathered and transmitted through the system (referred to as observability by Savulescu (2006)) to ensure adequate, timely, and scale-appropriate response (referred to as controllability by Panteli and Mancarella (2015)), and; levels of just-in-case economic and system reserves that can be drawn from if something untoward happens (Seville et al. 2015).

The cost of general technical resilience investments is high, and there is no certainty about when it is enough. We therefore propose balancing investments in this quadrant with resilience investments in general social resilience, as the uniquely human strength to adjust and improvise enhances the adaptability of complex Level 2 socio-technical systems (Sidney W A Dekker, 2005; Heese, Kallus and Kolodej, 2013).

2.4.4 General social resilience

General social resilience refers to investments in people and processes to ensure that the overall socio-technical system has continuity and a general ability to cope with dynamic change in the face of novel and unanticipated disruptions. This quadrant focuses on learning

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to adapt to change, preparing the system for emergent self-organization, and using complexity leadership thinking to renew the system should large shocks occur (Comfort et al., 2001; Marion and Uhl-Bien, 2001; Walker et al., 2002; Kaufmann, 2013b). This quadrant draws on psychology, behavioral and social sciences, community resilience literature (Van Breda, 2001; Youssef and Luthans, 2007; Armitage et al., 2012; Carpenter et al., 2012), the fields of ergonomics and human factors (Qureshi 2007, Klein 2008, Dekker 2012, NIST 2015), as well as that side of resilience engineering that helps people who operate within complex socio-technical systems cope with complexity under pressure and endure (Hollnagel, Woods and Leveson, 2006; Righi, Saurin and Wachs, 2015).

Building general social resilience: Eskom has identified five generic social capabilities of a resilient essential service system, namely: (1) anticipate, identify, and adapt rapidly to threats, vulnerabilities and opportunities arising from changes in the internal and external environment; (2) operate at elevated levels of stress without failure for extended periods of time; (3) respond rapidly to a shock to contain the impact (severity/duration) of the event/threat; (4) recover rapidly in a coordinated manner; and (5) deliberately evolve to a higher state of resilience in response to changes in the environment by implementing learning from near misses and incidents (Koch et al., 2013). These general social resilience capabilities can be nurtured through investment in social, cultural and educational competencies (PwC 2013).

An organizational culture of resilience can be fostered through behaviors that help employees be agile and adaptive in the face of disruption and change (Everly et al. 2013, Luthans et al. 2006). Organizations can encourage purposive self-organization (Pavard et al., 2006; Shaw, Scully and Hart, 2014; Coning, 2016). For instance, a standard incident command system (ICS) offers a flexible and highly adaptive management system that does not require pre-approved plans or standard operating procedures, but enables responders to dynamically plan and self-organize, in a coordinated manner, towards common incident objectives (Steeves, 2013). Empowering leadership that explicitly gives people permission to act in a high-trust environment (Jones, 2011c) make space for personal commitment that unlocks determination and will power (Conway, 1975), and can significantly contribute to resilient organizational response to disruption (Nguyen et al., 2016).

Assessing general social resilience: Sense of coherence (SOC) has arisen as a significant indicator of individual and societal resilience (Almedom et al., 2007; Overland, 2010; Zaidi et al., 2015). SOC refers to how people make sense of everyday reality and whether they view life and the world as comprehensible, manageable, and meaningful (Lindström and Eriksson, 2006; Almedom et al., 2007). A healthy SOC provides the ability to cope with stressful

situations (Eriksson and Lindström, 2005), contributes to preventive, protective, and restorative capacity in people subjected to disruption, and influences survival and recovery (Van Breda, 2001; Overland, 2010). Furthermore, cultivating a restorative safety culture that is just, rather than retributive, significantly contributes to resilience, as it enables an organization to learn from mistakes rather than focusing on attributing blame, which can result in covering up incidents or tampering with evidence (Dekker and Breakey 2016). Effective learning processes can be facilitated through adaptive management (Hummelbrunner and Jones, 2013a) and adaptive governance systems (Folke et al., 2005; Garschagen, 2013; Seeliger and Turok, 2014).

The general social resilience quadrant represents a highly sought-after resilience advantage, but is the most difficult to establish or assess. Assessments of general social resilience require sensemaking that engage with contextual complexity. General resilience assessment indicators adapted from Cork (Cork, 2011) include monitoring for change in (1) levels of openness in the system for the movement of people and ideas into, through and out of the system; (2) levels of social reserves, and; (3) levels of social and relational capital such as leadership, networks, community, and trust exhibited in the system (Pereira and Ruysenaar, 2012). General social resilience can also potentially be assessed by measuring and monitoring collective SOC (Ghoshal and Bruch, 2003; Lindström and Eriksson, 2006); evaluating the presence and effectiveness of the seven generic principles proposed by Biggs et al. (2015) and; evaluating the nature of the culture, informal institutions, and heuristics used to make judgements under uncertainty (Tversky and Kahneman, 1974; Douglass Cecil North, 1991; Pereira and Ruysenaar, 2012).

2.5   Conclusion

The resilience of technologically mediated essential services is critical to human well-being. These essential services are produced by complex socio-technical systems that consist of layers of critical infrastructure embedded within people and processes in organizations responsible for delivering these services. This paper makes a novel contribution by conceptualizing the resilience of essential services in terms of both specified parts and the whole of the complex adaptive socio-technical system that produces essential services. The framework we propose juxtaposes and distinguishes between specified and general resilience investments in 1) people and institutions as a social infrastructure investment, and in 2) infrastructure and assets as a technology infrastructure investment (Figure 2-1). This four-quadrant framework provides a guide to a differentiated but integrated set of resilience strategies and assessment indicators that can be applied across different organizational levels.

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We suggest that all four quadrants of the proposed framework should be applied at all organizational levels. However, the relative importance of specified and general resilience varies across these levels: specified resilience is more pertinent at the operational level, whereas general resilience is more pertinent at the strategic level (Figure 2-2). This partly explains why reductionist approaches have been dominant in considering resilience of infrastructure systems, as the emphasis is on continuity of technical operations amid disruption. However, as the concept of resilience thinking matures in essential service provision, we expect that complex adaptive systems thinking will increasingly permeate resilience practice. All four dimensions of resilience are important, but general social resilience in essential service systems in particular has generally been neglected.

Specified resilience can be built in a linear fashion based on good practice, but general resilience needs to be built in an emergent fashion, drawing on approaches from complex adaptive systems thinking. Technological resilience investments generally reduce vulnerability and mitigate failure, while social resilience investments increase available options and enhance collective adaptability. Both forms of resilience are essential to safeguard essential services against systems failure. Both reductionist and complexity-based approaches to resilience add value, and should be employed in a complementary, rather than competitive or exclusive fashion. When either approach is used exclusively it might erode resilience.

We argue that *formative* resilience assessments can be conducted "*for*" building resilience of essential services based on social and technical indicators of *specified* and *general* resilience. To stimulate the emergence of social resilience across the system, a key aspect of formative resilience assessments is identifying and conducting critical conversations at different organizational levels. By stimulating appropriate discussions at multiple levels, resilience assessments can promote adaptation and transformation of the system and stimulate the emergence of resilience across the system.

More work is required to understand the options to assess and build resilience of socio-technical systems and, in particular, of the social dynamics required to ensure resilient essential service delivery. Humans can be both the weakest link and the strongest resource to ensure resilience of essential services. More research is required on how to build a culture of resilience in key service providers, and to develop and understand techniques that foster social resilience. While we have focused on the case of socio-technical systems, we suggest that the approach we have adopted in our framework may be useful for advancing thinking and indicator development in social-ecological systems more broadly, by for instance overlaying specified and general resilience against societies and ecosystems. We suggest

that this approach can support the operationalization of resilience assessments that can identify and integrate a diverse portfolio of resilience enhancing initiatives and investment strategies.

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Chapter 3: Building social resilience in socio- technical systems through a participatory and formative resilience assessment approach

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Declaration

The candidate built on the idea to operationalise Prof Biggs' resilience building principles as the basis for a resilience assessment, using appreciative inquiry as method to solicit participation. The candidate devised the workshop objectives, the facilitation process, and material, made all logistical arrangements, facilitated the sessions, performed all analysis of results, and wrote the article. Prof Biggs and Dr Preiser provided input in the initial formulation of the concepts, as well as feedback on the workshop design and article.

Abstract

Practical approaches are required to operationalize resilience building principles within complex adaptive systems. Resilience can enhance the capacity of complex socio-technical systems that deliver essential services to maintain service delivery amidst disruption. A formative resilience assessment process was designed and tested within an essential service organization to build general social resilience to improve levels of resilience. Participative assessments were conducted with agents in the system to assess current resilience capacities against defined resilience capabilities. Participants drew inspiration from resilience building principles to collectively design next steps for collective action to deliver future resilience outcomes. An appreciative inquiry approach was employed in the workshops that enabled rapid participative assessments for building general resilience and introduced participants who knew nothing about essential service resilience. This process

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can be used on a continual basis to stimulate general resilience within the social fabric of essential service organizations.

Keywords: formative resilience assessment; resilience building principles; appreciative inquiry

3.1   Introduction

A world characterised by systemic change and disruption increasingly requires systemic resilience. Resilience is the capacity to sustain core system functions amidst contextual uncertainty and deep disruption (Ton and Wang, 2015; Folke, 2016; NAS, 2017). Essential services are produced and delivered by coupled socio-technical systems; and, both social and technical components are critical for maintaining the delivery of essential services. Interruptions of essential services delivery, like that of water or electricity, is not about *whether* they will happen, but *when*, which highlights the need to foster resilience within these socio-technical systems. A key conceptual distinction can be drawn between specified and general system resilience (Walker *et al.*, 2009; The Resilience Alliance, 2010). On the one hand, specified resilience ensures that specified parts of a system, such as business processes or physical assets, have the capacity to withstand predefined threats, for example, disaster or climate impacts. On the other hand, general resilience provides an adaptive capacity to deal with unknown and unpredictable disruption. While both types of resilience are crucial, the increasing operations volatility faced by essential service organizations highlights the importance for an intrinsic adaptive capacity for resilience (Auerswald *et al.*, 2006; Hollnagel, 2012). It may be seen as a duty of care for essential service organizations to intentionally cultivate resilience (Deloitte, 2016; Abbott, 2018).

Investing in capacities that strengthen social resilience is particularly important. Technical infrastructure is likely to fail if conditions cross the threshold of safe operations. However, when people are exposed to circumstances or challenged beyond what they perceive as being manageable, their individual and collective adaptive capacities may still enable them to survive, or even thrive (Brown and Westaway, 2011). The notion of general social resilience has been defined in terms of integrated coping, adaptation and transformation capacities in the face of uncertainty (Keck and Sakdapolrak, 2013; Folke *et al.*, 2016; Van der Merwe, Biggs and Preiser, 2018). Contributions have been made to the understanding of general social resilience (Adger, 2000; Hall and Lamont, 2013; Keck and Sakdapolrak, 2013); yet, the topic remains largely neglected (Xu, Marinova and Guo, 2015). In a framework that distinguishes different domains, in which resilience needs to be considered within essential service providers, the top right quadrant of Figure 3-1 below refers to general social resilience (Van der Merwe, Biggs and Preiser, 2018). Since social resilience is dynamic,

relational and political, the process to assess and build it should explicitly consider issues of power and participation (Keck and Sakdapolrak, 2013).
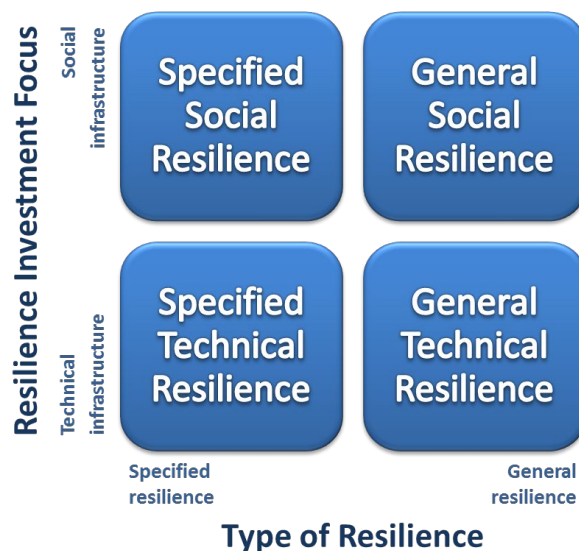
Figure 3-1 Domains of resilience identified in a framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems (Van der Merwe et al., 2018). This study focuses on the upper right-hand general social resilience

This paper reports on an exploratory study that participatively evaluated general social resilience capabilities within an essential service organization using a formative resilience assessment approach. In the study, formative resilience assessments of a particular system consisted of an ongoing participatory process, which aimed to collectively evaluate current levels of resilience, to garner agreement regarding resilience outcomes, and to promote commitment to resilience goals (Van der Merwe, Biggs and Preiser, 2018). The authors used the seven general resilience building principles proposed by Biggs, Schlüter and Schoon (2015) as a catalyst for identifying opportunities to enhance resilience in Eskom, the national electrical utility in South Africa. This article describes the process design and the execution of participatory workshops for formative resilience assessments with the following objectives:

1. Collective evaluation of current realisation of resilience capabilities in the organization;

2. Identification of areas for resilience enhancement;

3. Fostering of a shared understanding of resilience in the organization.

3.1.1 Conceptual Background: Assessing and building resilience

General social resilience can be described as a set of intrinsic enabling conditions, which endows a group of people (community, organization, or nation) with an intangible, emergent

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and adaptive capacity to maintain functional continuity and systems-level flexibility (Fleetwood, 2011; Van der Merwe et al., 2018). General social resilience can be developed through investments into people and their social arrangements. However, social resilience outcomes can be either enabled or hindered by the prevailing institutional framework (Carpenter et al., 2012; Renschler et al., 2010). Approaches to enhance social resilience include an emphasis on individual agency, collective goal-orientation, and subjective perceptions of the group's ability to cope, adapt and transform (Béné et al., 2016; Bohle, Etzold, & Keck, 2009; Feldt, Kinnunen, & Mauno, 2000). The effectiveness of individual and collective sensemaking determines the range of available response options that can be detected and enacted in a crisis (Doyle, Paton, & Johnston, 2015; Nofi, 2000). The quality of response is strengthened through strong social networks, which increase levels of trust and foster collective action (Adger, 2003; Ledogar & Fleming, 2008; Moore & Westley, 2011; O' Brien et al., 2012). A shared goal and commitment towards a purposeful or meaningful contribution significantly contribute to resilience (Harrop, Addis, Elliott, & Williams, 2006; Lindström & Eriksson, 2006).

The social-ecological resilience literature proposes seven interwoven resilience building principles (Biggs, Schlüter and Schoon, 2015) (Figure 3-2 & Table 3.1). Folke (2016) describes the principles as mechanisms that create the space for spontaneous exploration and the building of trust and social capital to resolve collective action challenges amidst multiple trade-offs in complex systems. The principles are embedded in the Resilience, Adaptation Pathways and Transformation Assessment (RAPTA) Framework (O'Connell et al., 2016) and applied in the resilience assessments of Quinlan et al. (2015). Cosens and Fremier (2014), Selberg et al. (2017) and Sterk, van de Leemput & Peeters (2017) suggest that the principles provide guidance for operationalising resilience. The authors of this article argue that these resilience building principles also apply to socio-technical systems that qualify as being complex adaptive systems.
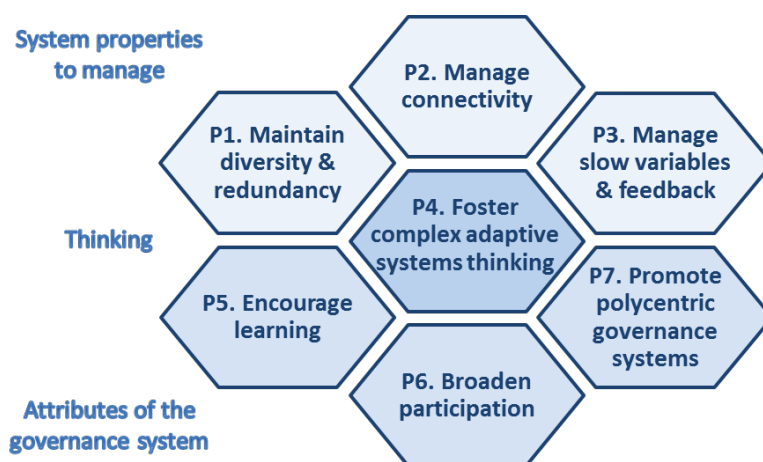
Figure 3-2. Among the 7 generic resilience building principles, the first 3 refer to components in the system, the last 3 to governance of the system, while the middle principle is central, as it informs how the system should be understood and managed.

Table 3-1 Brief description of the seven generic resilience building principles (Biggs, Schlüter and Schoon, 2015; GRAID, 2016):

	Principle	Description
P1[5]	Maintain diversity and redundancy	A diversity of components in a system, like species and actors, landscapes, livelihood strategies, knowledge systems and institutions provide response diversity and functional redundancy to change, or dealing with uncertainty and surprise.
P2	Manage connectivity	Connectivity among habitats, species and people provides links across networks for species, resources, information, or social cohesion to flow, disperse, migrate, or interact.
P3	Manage slow variables and feedbacks	Understanding and monitoring of slow systems variables, feedbacks, and their thresholds, particularly of regulating services, to establish effective governance structures, and avoid regime shifts.
P4	Foster an understanding of complex adaptive systems	Understanding that unintended consequences, disruption and uncertainty is to be expected due to emergence, multi-variate, multi-level and multi-scalar interdependence, and unpredictable dynamics in systems.
P5	Encourage learning and experimentation	Continuously learning and adaptive experimentation, since knowledge of systems is always partial and incomplete.
P6	Broaden participation	Engaged multiple stakeholders with an active interest to be involved in management and governance process, as this builds trust and a shared understanding that incorporates multiple perspectives.
P7	Promote polycentric governance systems	A governance system with: multiple interacting governing bodies at different scales; disciplinary focus; forms of organization and sources of authority to act from, thus improvinge connectivity and learning across scales and cultures and addressing of problems at the right level by the right people at the right time.

A distinction can be made between formative assessments for resilience and summative assessments of resilience. The former explicitly aims to develop resilience as an outcome, while the Participatory approaches are essential to achieving the objectives of formative resilience assessments. Broadening participation (P6) involves the active engagement of diverse stakeholders in management and governance processes at multiple levels and

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[5] In this paper, we will use a short-hand notation to refer to individual principles, by a capital P followed by its number, e.g. P5 is Encourage learning.

scales across the system (Leitch, Cundill, Schultz, & Meek, 2015). Participative management practices enable reflection and sharing. Moreover, they build relationships of trust, facilitate social learning, support institutional change, and encourage collective action (Biggs et al., 2012). Resilience thinking using participatory processes fosters a better understanding of, and engagement with, the system being governed (Audouin et al., 2013; Sellberg, Borgström, Norström, & Peterson, 2017). The application of the principles of encouraging learning (P5) and broadening participation (P6) will, in turn, strengthen social connections (P2) and enhance polycentric governance owing to the synergistic interaction among the principles (P7)—which highlights the mutual interdependence between the principles (Schlüter, Biggs, Schoon, Robards, & Anderies, 2015). The optimal balance among the principles are contextual and vary across time and space (Biggs, Schlüter and Schoon, 2015).

In this article, the authors use an appreciative inquiry (AI) approach to design the facilitation process used to introduce the seven principles for building resilience into the formative assessments. AI is a facilitation process that supports diverse groups in addressing complex social problems, specifically aimed at systems level transformation. Social innovation approaches like AI foster collective action, and are particularly useful for facilitating formative and participatory processes (Holman, 2010). AI can be used to stimulate the emergence of beneficial patterns in complex social systems (Holman, 2010) and has been used as a strategy to enhance social resilience (Cojocaru, 2014; McArthur-Blair and Cockell, 2018). AI is an approach used in facilitation that help to appraise and examine the social potential of an organization (Cooperrider and Whitney, 2001). Guided by principles of collaboration and appreciation (Cooperrider and Srivastva, 1987), this approach creatively engages people; and, through its generative capacity to foster dialogue, it can stimulate possibilities for informing collective social action (Cooperrider and Srivastva, 1987; Holman, 2010). The appreciative mode of inquiry assumes a possibility-centric approach for designing organizational change processes and gives meaning to the members of an organization through the *"interpretive schemes"* used to guide dialogue, decisions and actions (Cooperrider and Srivastva, 1987, p. 131; Bushe, 2011).

3.2   Design of the Participative process for formative resilience assessments

3.2.1 Case study: Eskom and its Enterprise Resilience Programme

The organizational context for this case study is the Enterprise Resilience Programme in Eskom Holdings, a national, vertically integrated electric utility wholly owned by the South

African government. The utility employs 48,000 employees, produces 95% of the electricity consumed in the country, and holds 73% of the generation capacity among 12 member countries in the Southern African Development Community (Eskom, 2018; SAPP, 2018). This degree of connectivity illustrates the interdependence between the organization, the socio-technical systems that deliver electricity and the region. However, the organization is facing a confluence of challenges, not expanded on here (Eberhard and Godinho, 2017; de Villiers, 2018; Gibbs, 2018). The health and resilience of the national economy is so intertwined with that of the utility that investment bank Goldman Sachs described Eskom as the biggest risk to the South African economy (Bonorchis and Burkhardt, 2017).

More recently, between June and August 2018, industrial action by unions resulted in the withdrawal of labour and in critical infrastructure damage, allegedly caused by sabotage, leading to national rotational load shedding, further impacting the economy (CBN, 2018; Hlatshaneni, 2018; News24Wire, 2018; Paton, 2018). Load shedding is a risk control mechanism to prevent a much bigger disaster – a national blackout – a sudden unexpected interruption of supply to the whole country (SABS, 2010). While load shedding is experienced by customers as service interruptions, it is a strategy that deploys rotational load reduction, executed by the System Operator to safeguard the national power system from collapse (SABS, 2010). South Africa first experienced load shedding in 2008 due Eskom's inability to maintain the supply-demand balance required for power system stability (Chettiar, Lakmeeharan, & Koch, 2009). A national code for emergency load reduction (NRS048-9) was established after the load shedding events in 2008 (SABS, 2010). This code establishes a specified resilience capability—to both prevent and recover from a national blackout. Nonetheless, such systemic interruptions of electricity supply across the nation have a significant economic, social, and political impact on the country (IRMSA, 2016; NERSA, 2015).

Triggered by the national rotational load shedding in 2008, Eskom initiated a formal resilience building programme (the Enterprise Resilience Programme) that focused on the integrated power system, extending focus to the entire enterprise by 2013. The programme identified five general social resilience capabilities that should be developed in the organization: (1) the ability to anticipate, identify, and adapt rapidly to threats, vulnerabilities and opportunities arising from changes in the internal and external environment; (2) the ability to operate at elevated levels of stress without failure for extended periods of time; (3) the ability to respond rapidly to a shock to contain the impact of a threat; (4) the ability to recover rapidly in a coordinated manner; and (5) the ability to deliberately evolve to a higher state of resilience in response to changes by implementing learning from near misses and

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incidents (Koch et al. 2013) (Figure 3-3). This contextual and systems-based understanding of resilience capabilities can be seen as a timeline: (1) prior to disruption the organization needs to proactively anticipate and adapt; (2) if disruptions occur, members of the organization need to effectively respond and recover; and (3) retrospectively, the organization needs to reflect on lessons learned in order to deliberately evolve to a higher state of resilience.
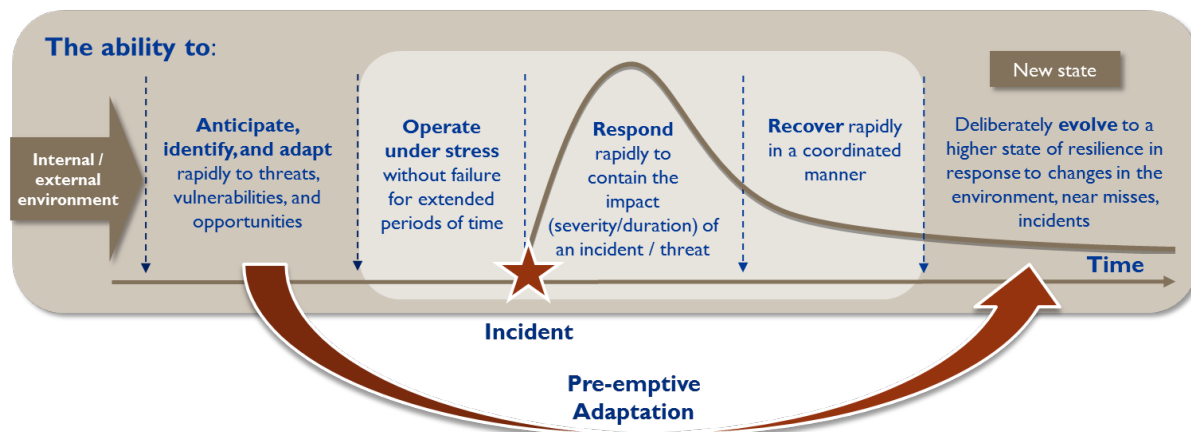
Figure 3-3. Eskom has identified five general social resilience capabilities that they aim to develop across the organization. The ability to anticipate and adapt to change and deliberately evolve to higher state of resilience should be done continuously, while operating under stress. Responding and recovering are associated with specific incidents or events, both planned and unplanned, expected or unexpected. The arrow at the bottom points to the ideal to sufficiently and pre-emptively anticipate, adapt and evolve to avoid being disrupted at the organizational level.

The Eskom Resilience Programme constitutes an ongoing organization-based commitment to build and assess resilience. While the programme typically employs summative assessments against specified resilience objectives, a need was identified to extend awareness of resilience thinking and commitment towards resilience more widely across the social fabric of the organization. The explorative study described in this article was devised for this identified purpose. Resilience building workshops were designed as a particular type of intervention to formatively assess general social resilience, and thus played a specific part in the wider programme.

3.2.2 Participatory workshops

Six workshops were conducted over four months in three locations between mid-January and early May 2018, in the Gauteng province of South Africa, where participants collaboratively engaged in formative resilience assessments. Ninety employees participated on an anonymous and voluntary consent basis, and sixty written feedback forms were handed in after the workshops. The workshops were scheduled to last 3 hours, and time was tightly managed. Although, participants were invited from across the business, a convenience sample based on employees involved in the resilience programme and willing

to commit time from their schedule, was initially used. This was followed up with snowball sampling, which involved asking participants to nominate colleagues to be invited to future events. This was to be included in their written feedback at the conclusion of the workshops. The snowball sampling approach, thus, contributed to participants being from diverse business areas, which was reflected in the feedback as a valuable source of learning.

3.2.3 Workshop design

The approach used to design the resilience building workshops integrated formative resilience assessment goals with the appreciative inquiry process. Moreover, concepts from Eoyang & Holladay's (2013) adaptive action framework were incorporated in the last step of the workshop process. A bottom-up, or collaborative approach was used for the diagnosis of current levels of resilience. Moreover, this approach led to agreement regarding where resilience needs to be strengthened and collective action towards those goals. The process design followed five distinct steps based on a facilitation approach informed by AI principles.

The AI process has been described as an approach that fosters knowledge exploration across four domains: theoretical discovery; metaphysical dream; normative design; and a destiny to deploy (Cooperrider and Srivastva, 1987). These areas were initially known as the AI 4-D cycle, but since topic selection is a strategic consideration for successful AI, this was later suggested as an important first step in an extended cycle that constitutes 5 steps in total (Cooperrider, Whitney and Stavros, 2008; Bushe, 2011). The extended 5-D AI cycle consists of the following steps: (1) define the appreciative topic; (2) discover the best of what is; (3) dream about what next; (4) design what should be; and (5) deploy a pragmatic destiny to create what will be (Cooperrider, Whitney and Stavros, 2008; Bushe, 2011). While these steps describe what to do, AI has a growing number of guiding principles, which explains why the approach works in a particular way (Table 2-2) (Cooperrider and Whitney, 2001, 2005; Whitney and Trosten-Bloom, 2003; Schroeder, 2013). Figure 3-4 illustrates the 5 steps and shows where the 7 resilience building principles were inserted into the process. AI principles considered in the workshop design are outlined in Table 3-2.

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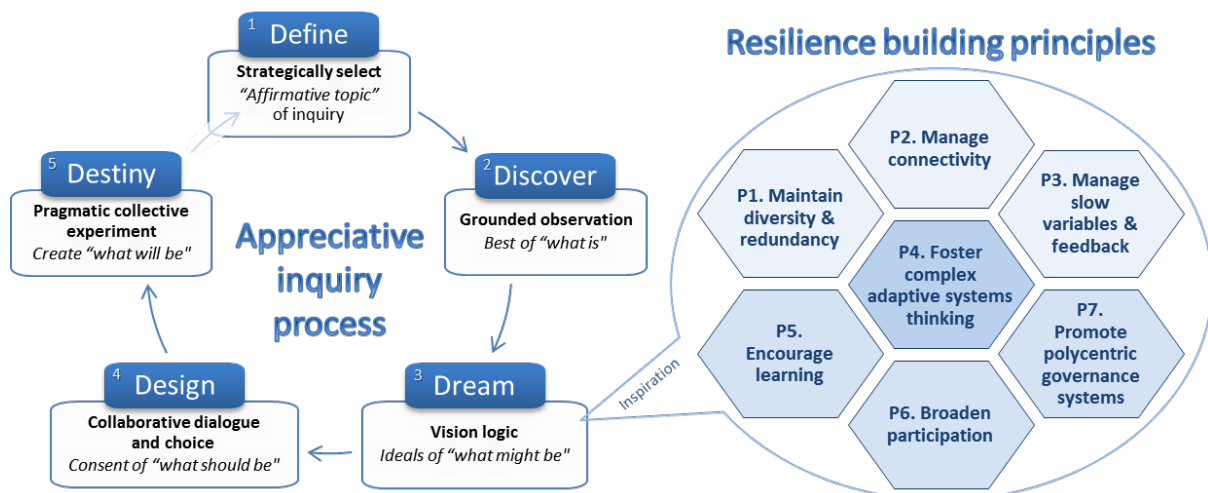
Figure 3-4 The extended 5-D AI cycle, which can be used as an ongoing process, was used to conduct the resilience building workshops, while the 7 general resilience building principles were infused as inspiration for the vision logic when participants defined future resilience ideals.

Table 3-2 Principles of Appreciative Inquiry that inform the steps in the cycle (Cooperrider & Whitney, 2001):

Poetic Principle	We all co-author the organization's story; therefore, carefully consider the topic of inquiry, as it determines what is focused on
Anticipatory Principle	Images of the future inspire action and guide current behaviour; therefore, positive images of the future can be powerful mobilizing agents in the present
Positive Principle	Positive questions catalytically lead to lasting and successful change
Simultaneity Principle	Inquiry is intervention as inquiry and change take place simultaneously; therefore, the questions we ask set the stage for what we find
Constructionist Principle	Reality is subjective and socially created through dialogue and discourse; thus, how an organization knows its knowledge is interwoven with its destiny

3.2.3.1 Step 1: Define an affirmative topic of inquiry

The specific question selected to define the topic of inquiry is important, as the AI approach is based on the assumption that the process of inquiry is inextricably linked with change narratives and processes: The process of inquiring shifts perception, and thus changes our view of the world (Faure, Rosenzweig and Van Tiem, 2010). The topic of inquiry was set by the workshop agenda and focused on building resilience in the organization's ability to deliver an essential service. Participants were introduced to the resilience capabilities as identified by Eskom (Figure 3-3) as the basis of the continued conversation.

Through the workshops, we looked to glean an understanding of generic resilience building principles shown to enhance the resilience of ecosystem services produced by social-ecological systems. The insights gathered were applied to reflecting on ways to enhance the resilience of essential services produced by socio-technical systems. In accordance with the

poetic principle (Table 2-2), setting this objective allowed the joint conversation to define a shared interpretation of resilience as being possible, innovative, and worthwhile.

3.2.3.2 Step 2: Discover the best of what is

The objective of the discovery phase of the workshops was to understand the system's currents levels of resilience through seeking interpretive knowledge. The process of discovery consisted of two parts. The first was based on the five defined organizational resilience capabilities of Eskom; and, the second was based on the seven resilience building principles. To tune into the "appreciative eye" and leverage of the transformative power of stories, as described by Schroeder (2013), participants were asked to share a quick personal account about resilience. To set the scene, they were told they were in an airport departure lounge waiting for their flight, when a good friend from long ago waved them down, clearly in a hurry, but also interested to quickly ask a burning question: "I heard you guys are building resilience in Eskom. Please tell me what you are doing that works?" Participants were asked to choose a single resilience capability, place a colour sticker on the poster to mark the one their story was about, and quickly tell their friend a personal account, based on one of the following:

- A time when… we did well.

- What do you value about… what is in place?

- What we tried that works (… even if just a little bit).

- What you like best about what we have / do.

In the first part of the discovery process, participants shared 66 first-hand accounts of a time they found resilience was evident in the organization, and identified which particular aspect of organizational resilience it related to. Using coloured stickers, participants marked the organizational resilience capability their story pertained to, leading to a visual distribution of narratives in the room (Figure 3-5). Afterwards, groups voted to determine, according to majority rule, whether they felt Eskom overall exhibited resilience in those areas.

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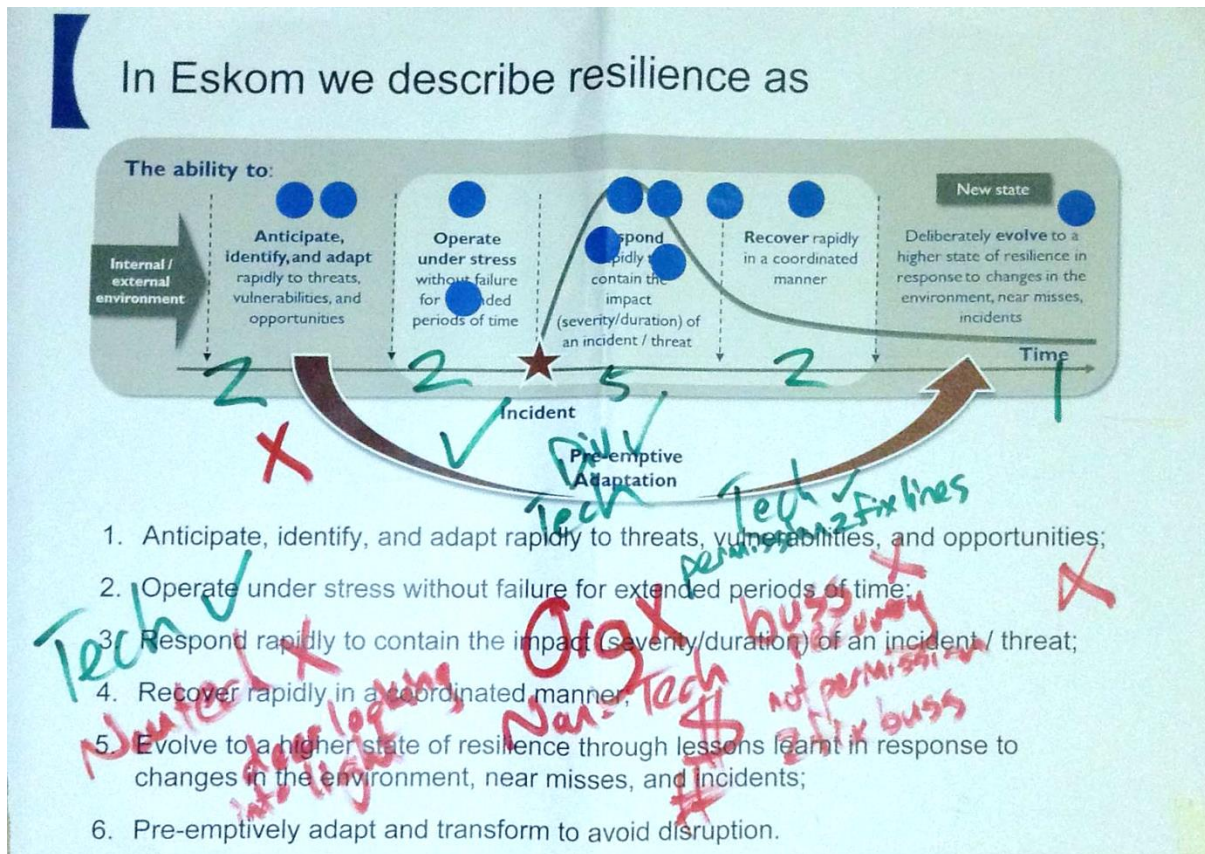
Figure 3-5 Photo showing the distribution of stories relative to Eskom's resilience capabilities, as well as the outcome of the group votes.

For the second part of the discovery phase, the resilience building principles were introduced and examples of its application in social-ecological systems were illustrated using multimedia. Participants were then asked for examples of the application of the resilience building principles in the organization. These were noted on a flipchart and served as a visual reminder of the principles for the rest of the workshop.

3.2.3.3 Step 3: Dream of what might be

In order to create positive images of future possibilities, the objective of the dream phase of the workshops was to explore where participants saw opportunities to enhance resilience. Against the background of the shared understanding that had emerged in the room regarding the desired resilience capabilities and the generic resilience building principles from Step 2, participants were asked to vote on a large poster depicting a matrix of the capabilities and principles. Each participant was given seven blue and seven red colour voting stickers. They were asked to place blue colour stickers on the poster to show where the organization was already doing applying the principles towards Eskom's required resilience capabilities. Red stickers were placed on the poster to show where the

participants saw possibilities for building resilience, in particular where the organization could and should focus time and energy (Figure 3-6).
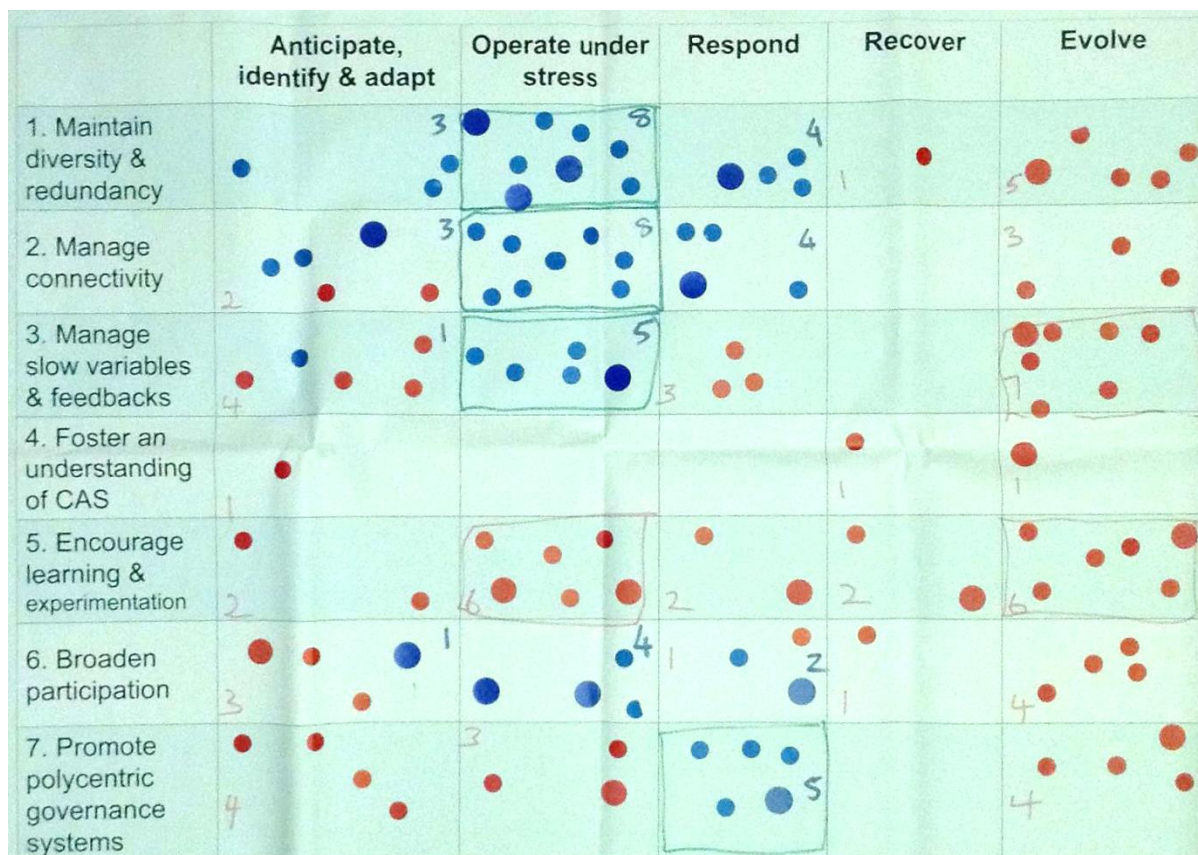
Figure 3-6 Photo of the voting outcome from one of the groups. The areas with the highest red dots were selected to collectively work on further.

The voting process served as a logical break halfway through the workshop, when people could grab refreshments and chat while everyone finished casting their votes. Across the six workshops, a total of 295 votes were cast indicating where the organization is already applying the seven principles to Eskom's resilience capabilities. This was relative to 342 votes that identified intriguing possibilities to focus on improving resilience through the application of the principles.

Once all participants had voted, the facilitator counted the number of votes of each colour in each intersecting block to identify the clear winners. A total of 16 areas were identified to explore ways of improving the selected resilience capabilities through the application of the resilience principles, forming the basis for Step 4. While there was diversity in the areas selected by different groups, some areas were selected more than once (Table 3-3).

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Table 3-3 Areas selected to collectively identify resilience goals and next steps for actions through AI's dream, design and destiny steps.

		Anticipate & adapt	Operate under stress	Respond	Recover	Evolve
	16	6	2	0	2	6
1. Maintain diversity and redundancy	2	1			1	
2. Manage connectivity	0					
3. Manage slow variables and feedbacks	2	1				1
4. Foster an understanding of complex adaptive systems	0					
5. Encourage learning and experimentation	7	1	2		1	3
6. Broaden participation	2	1				1
7. Promote polycentric governance systems	3	2				1

3.2.3.4 Step 4: Design what should be

The objective of the design phase was for the participants to establish where the system needs to go to improve attainment of resilience outcomes through collaborative dialogue. In the context of AI, Schroeder (2013) highlighted that people commit to and enact desired change if they have free choice over their level of contribution. The top three areas for potential improvement were identified based on the number of votes. Participants were asked to divide themselves into those three topics to join the conversation that most resonated with them. Each group was tasked with discussing what is possible in that area if they apply the selected resilience building principle to it.

Each group had to then create a bold statement of ideal possibilities that described the desired future as if it has already happened. Afterwards, each group shared their possibility statements with the larger group. The areas selected were based on votes that indicated where the group saw compelling opportunities to build resilience. These areas were applicable to the socially construed opportunity recognised in the room, while the possibility statements were provocative and connected to Cooperrider and Srivastva's (1987) generative AI principles, summarised in Table 3-2.

3.2.3.5 Step 5: Destiny of what will be

Through seeking agreement on collective action, the objective of the destiny phase was to agree how best to reach the resilient futures that the participants had defined in the previous step. The destiny phase can also be called *delivery* (Cooperrider, Whitney and Stavros, 2008). Based on the possibility statements that the groups had defined, they were asked to discuss where they saw new options for action from the conversations. To leverage uncertainties in complex adaptive systems, Eoyang & Holladay (2013) propose asking three very simple questions in an ongoing adaptive action cycle: (i) What? (ii) So what? (iii) Now what? The last question is to have a plan for taking action. To this end, groups had to discuss and agree on the technical or social enhancement of resilience.

Just as the AI process is meant to be repeated, so the adaptive action cycle, proposed by Eoyang & Holladay (2013), is meant as an ongoing process that enables innovative and responsive ways to respond to change, opportunity and disruption. Participants were, therefore, encouraged to ask themselves the same question again and again.

3.3   Insights emerging from the workshops

In this section, we discuss the insights that emerged from the workshops in terms of the objectives of the assessment:

3.3.1 Collective evaluation of current resilience capabilities in the organization

The evaluation of current resilience capacities consisted of participants sharing personal accounts of resilience, which were used to map narrative patterns. Thereafter, group consensus was used to reveal whether the organization exhibited the respective capabilities. Based on a contextualised understanding of resilience building principles, individual votes provided more nuanced insight into current capabilities. The evaluation process of the defined resilience capabilities fostered a sense of shared learning among participants of what resilience entails, and why it matters. Participants saw an emerging picture unfold of the evidence of resilience in the organization through hearing individual narratives and seeing the voting outcome. In this way, the process contributed to social learning, which builds resilience (Cundill *et al.*, 2015).

Participants indicated that the ability to anticipate and adapt (29%), followed by the ability to operate under stress (28%) were central to their personal experience of resilience in the organization. Participants involved in the resilience programme shared accounts of where resilience capacities made a difference in practice. They also reflected on the amount of

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work done to date towards the deliverables of the Enterprise Resilience Programme. The opportunity to share experiences and privately held perceptions created the space for shared reflection. In fact, one of the participants expressed her appreciation for the opportunity to meaningfully contribute to the objectives of the Enterprise Resilience Programme. Even participants who were not directly involved in the Programme did not hesitate to share examples from their own experience that were applicable to the defined resilience capabilities. This illustrates how participants intuitively connected with the organizational resilience objectives and were able to relate their own accounts without difficulty. When reflecting on the process, a participant noted that s/he found it beneficial "that we as the candidates were able to give our own opinions and ideas of how we see, or view, resilience within the organization".

The voting outcome reflected views on current resilience capabilities in the organization at group consensus and individual level (Figure 3-7). After the participants were provided with a brief illustration of each of the social-ecological systems principles, they gave their own examples of its application in their workplace context. Interesting results emerged when participants illustrated the principles by using either beneficial or detrimental examples, which were based on the application or absence of the principle (Figure 3-8 & Table 3-4). Furthermore, most illustrations were in a social context, with one or two examples of technical, material and financial resources.

Figure 3-7. Group and individual votes on the extent to which the five resilience capabilities defined by Eskom are realized. The length of the bars reflect number of votes, the group consensus votes on the left illustrates majority rule group votes on whether the organization has that capability in place (positive in green), or not (negative in red). The groups were unanimous that the organization always operates well under stress, but does not learn lessons from incidents in order to deliberately evolve to higher levels of resilience. The Individual votes on the right illustrates outcome of the individual votes where participants felt the organization is already doing well applying the resilience building principles against those capabilities, versus where Eskom should invest more to develop resilience. The number of individual stories told to illustrate the various resilience capabilities appear on the right of the diagram (one story straddled capability 2 and 3, hence the halves).

Relative number of practical illustrations of the principles that were detrimental or beneficial
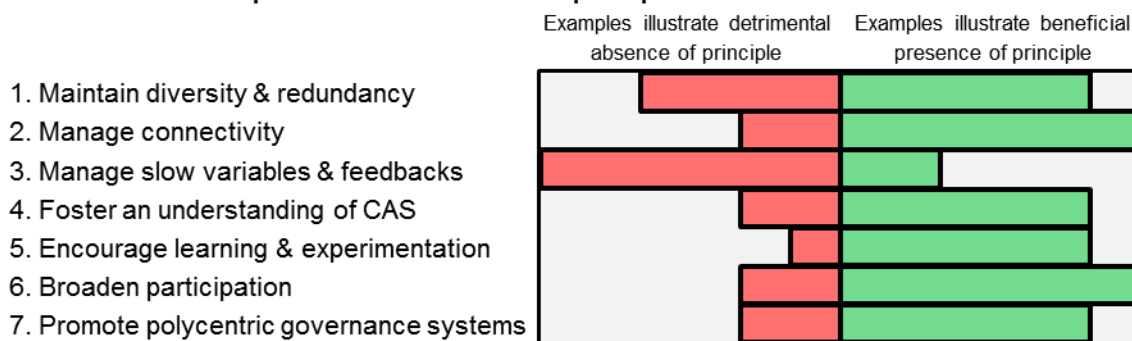
Figure 3-8 llustrations of the resilience building principles in practice either depicted examples where the principles were present (green) or absent (red), and length of bar reflects number of illustrations. Participants mostly described the application of these principles in their context in positive terms, except for P3, manage slow variables and feedbacks. The general consensus is that the organization is not applying the insights from P3.

Table 3-4 Examples participants shared of the practical applications of the resilience building principles in their contexts. Positive applications of the principle are listed as beneficial; while negative consequences due to non-adherence to the principles are listed as detrimental.

	Beneficial	Detrimental
1. Maintain diversity and redundancy	Diversify the power mix through renewables; Keep strategic spares; sports teams have people sitting on the bench	Loadshedding drove industry players off grid and eroded the customer base that were paying bills and now rather help themselves than rely on interruptible supply
2. Manage connectivity	Physical networks for electricity distribution; Communication and information flow happens through relationships, enable resources and ideas to flow	The Ebola outbreak and the spread of HIV happened along network connections; functional silos result in a disjointed organization
3. Manage slow variables and feedbacks	A reduction in cost of solar power and energy storage is slowly eroding the need for utilities; monitor the health dashboard for operational sustainability	Poor succession planning lead to an aging workforce; failures in financial governance and poor contract negotiations led to wasteful expenditure on capital expansions
4. Foster an understanding of complex adaptive systems	If you found an effective way of engaging teenagers, use that same wisdom with employees. You cannot control people, but you can attempt to influence them.	Managers look for global recipes of success, then try to implement its wisdom locally, but it doesn't work to transplant solutions into another context
5. Encourage learning and experimentation	Encourage job shadowing; play simulation games like Pandemic that require strategic cooperation; enable flow from research to pilot	Information Technology's decision to switch off Google Earth is stopping employees from accessing map information, and no access to YouTube

	Beneficial	Detrimental
	implementation, to adapt and evolve	inhibits online learning opportunities
6. Broaden participation	Employee engagement; involve customers & community in research; like a relay race; find financial solutions from non-financial people; empower end users with self-service analytics	Human Resources is facing a dilemma with needing to reduce staff, keep employees engaged, and retain core skills, but are trying to do it without consultation
7. Promote polycentric governance systems	Integrated structures: Provincial Resilience Teams, cross functional disaster management working groups, and multi-disciplinary sustainable development advisory committees	A safety net anchored at only a few points; can't catch someone jumping from a burning building by holding the blanket on only three corners

Table 3-5 highlights areas where participants felt that the organization was already applying the different resilience principles in realising resilience capabilities at Eskom. Although the results of the survey were subjective and contextual, they reflected the perceptions of the participants of how they collectively made sense of their reality. Both group and individual votes were unanimous in two areas: (i) the organization could operate under stress for extended periods of time; and (ii) the organization did not learn from experience to deliberately evolve to higher levels of resilience.

These results confirmed Auerswald et al.'s (2006) recognition that infrastructure systems face unprecedented stress and Hollnagel's (2012) prescription that resilient systems need to deal with continuous stress. Participants felt that levels of stress in the organization are countered through high levels of connectivity (Table 3-5). However, this result did not necessarily imply that the organization was resilient while operating under stress. The work of Hannah, Uhl-Bien, Avolio & Cavarretta (2009) on leadership in extreme contexts suggests that effective leadership may attenuate levels of stress in the organization.

Table 3-5. Vote tallies reflecting where participants felt the organization is doing well regarding the application of the seven resilience principles to achieving Eskom's resilience capabilities. Font size is scaled by the numbers of votes.

	Votes	Anticipate & adapt	Operate under stress	Respond	Recover	Evolve
We are doing well	295	67	79	66	51	32
1. Maintain diversity and redundancy	42	3	16	11	.	11
2. Manage connectivity	57	14	29	8	4	2
3. Manage slow variables and feedbacks	34	5	11	10	5	3
4. Foster an understanding of complex adaptive systems	24	4	4	9	5	2
5. Encourage learning and experimentation	46	17	3	4	12	10
6. Broaden participation	44	13	11	13	4	3
7. Promote polycentric governance systems	48	11	5	11	20	.

The weakest organizational resilience capability turned out to be the ability to evolve to higher levels of resilience through learning. It was unanimously voted as absent by the groups and contributed a mere 11% of the individual votes (Figure 3-7 & Table 3-5). This is not uncommon in organizations; hence, there is a substantial body of literature arguing that learning needs to be recognised as a deliberate organizational capability that needs to be built (Elliot, 1998; Kaliner, 2013; McNaughton, Wills and Lallemant, 2015). The results of the study suggest that Eskom needs to become more intentional in deliberately fostering processes that allow learning and change to be more easily embraced and built into the organizational fabric.

3.3.2 Identification of areas to enhance resilience

Participants had the opportunity to collectively identify areas where resilience needed to be enhanced in Eskom. They had to choose from areas based on the seven general resilience principles proposed by Biggs, Schlüter and Schoon (2015). A nuanced matrix pattern emerged from the individual votes to reflect where participants saw the possibility of applying each principle to the respective resilience capabilities (Table 3-6). Most opportunities were recognised in the areas of the first and last resilience capabilities, which are associated with being proactive and retrospectively reflective. The principle that participants regarded as having the greatest potential opportunity for improving Eskom's resilience capabilities was P5, to encourage learning and experimentation; followed by P3 and P7. A similar high level pattern emerged (P5, followed by P7) for the areas identified to focus resilience investment from the AI processes of dream, design and destiny (Table 3-6).

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Table 3-6. Areas where participants recognised intriguing possibility and felt the organization can and should focus to improve resilience. The font size is scaled by the number of votes.

	Votes	Anticipate & adapt	Operate under stress	Respond	Recover	Evolve
We see opportunity to improve	**342**	**102**	49	46	35	**110**
1. Maintain diversity and redundancy	**46**	15	5	2	9	15
2. Manage connectivity	**32.5**	9	2	9	3	10
3. Manage slow variables and feedbacks	**56.5**	21	6	10	3	17
4. Foster an understanding of complex adaptive systems	**39**	11	6	6	6	10
5. Encourage learning and experimentation	**65**	11	17	8	7	22
6. Broaden participation	**48.5**	18	4	6	5	16
7. Promote polycentric governance systems	**54.5**	18	9	6	2	20

Participants collectively expressed the need to enhance resilience governance, as three out of every four votes were cast against the P5-P7 cluster, which describes attributes of the governance system, (Table 3-6). The utility resilience literature often focuses on the ability to deal with disruption (respond and recover) and engineering specifications to enhance technical infrastructure (P1 & P2). In contrast, the bottom-up, participatory process highlighted the need to focus on aspects of resilience governance (P5-P7) and, specifically, to focus on proactive processes prior to, and reflective learning processes following, disruption (anticipate and evolve).

This choice places emphasis on the need to enhance social capacity for resilience. These findings reflect and underscore a need to focus on resilience as the transformative capacity described by Keck & Sakdapolrak (2013) in terms of the ability to participate in governance processes and to transform societal structures themselves.

Owing to the abstract nature of P7, it came as a surprise how many times group votes gravitated to focus on it. The social processes that create the conditions for effective polycentric governance structures to emerge include the following: building trust and social capital; strong leadership; ability to bridge scales; coordination across scale and governance units; and negotiating trade-offs among users at different scales (Schoon *et al.*, 2015). Eskom's organizational hierarchy does not operate in a polycentric fashion; but, the cross scale integration this form of governance can bring has the potential to enhance resilience.

The conversation about the practical implications of P3 was heated and emotive. Participants expressed frustration about the apparent lack of awareness or focus in the

organization on monitoring slow variables, but also alluded to the fact that these would be difficult to evaluate. This awareness confirms the point made by Biggs, Schlüter and Schoon (2015) that it is difficult to manage slow variables in practice.

A few groups raised the concern that the organization seemed to focus on the wrong targets through a relentless push on short term performance indicators that drive incentives, yet did not support long-term organizational sustainability. Thus, short-termism is prevalent in the performance management systems of private and public sectors that work on slow variables and tipping points. Biggs, Gordon, *et al*. (2015) suggest that the resilience of essential service delivery may rely on keeping slow variables in the socio-technical system below critical thresholds. Therefore, it seems prudent to identify key slow variables and feedbacks across the system. Moreover, thresholds in these variables, which may trigger large systemic changes, should also be identified (Plummer and Armitage, 2007; Walker *et al.*, 2012).

Some principles not selected by participants to focus on is worth mentioning. P3, which received the second highest number of individual votes, was described by every group in the form of negative examples (Figure 3-8). Moreover, it was only selected twice to identify resilience goals and next steps for actions (Table 3-3). This may be due to the request for the workshop participants to focus on what could, and should, be done at the time of the study. Furthermore, while P4 was not rated as a principle that the organization is doing well in, it was also not identified as a principle to invest energy in. It would appear that this short intervention did not do justice in explaining the complexity thinking paradigm. To operationalise the resilience building principles, basic explanations are required in order to succinctly convey the power of the complexity paradigm, to clarify the difference between complicated versus complex approaches, and to make a compelling case for complex adaptive systems thinking.

3.3.3 Fostering of a shared understanding of resilience

Based on the outcomes of the workshops, it seems that the process used to assess the resilience capabilities required by the Eskom Resilience Programme, resulted in a shared understanding of social resilience and stimulated greater commitment towards general resilience. Participation among a diversity of stakeholders builds trust and relationships, promotes an understanding of system dynamics and facilitates the collective action required to be resilient (Leitch *et al.*, 2015). A common theme of participant feedback was the diversity of voices and views that contributed to enrich the conversation. Moreover, a shared understanding of the organization and its resilience capabilities emerged. Many alluded to

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the group work, where they were participating with different colleagues from across the business, as the most significant part of the workshop.

Participants also mentioned how much they learned from one another, for example, in the following statements: "It's very empowering to learn from colleagues who were part of the group"; "thinking outside the box around resilience within our organization, and interaction across all divisions that was mind blowing on lessons learnt"; and "I have learnt so much from the theory and peers." A study of the written feedback revealed that participants developed a deeper understanding of collective resilience, came up with promising options for resilience enhancements, and were comfortable that they would be able to recognize a resilience outcome based on their learning from the workshops.

Above all, participants described a transformed social reality as the resilient future they dream of and for which they designed bold statements (Table 3-7). These results suggest recognition that enhancing general resilience requires alternative ways of thinking about and seeing the world. Of the 16 focus groups, 13 described new ways of thinking, 12 referred to new ways of doing, 10 mentioned new business realities, and only 2 spoke about new technology tools. These new social realities described by the participants suggest social transformations, which often include redefining social values, institutions and practices (Westley and Antadze, 2010; O' Brien *et al.*, 2012; Flood and Romm, 2018).

Table 3-7 A summary of areas identified to enhance resilience in Eskom and the focus of the enhancement.

		Anticipate & adapt	Operate under stress	Respond	Recover	Evolve
	16	6	2	0	2	6
1. Maintain diversity and redundancy	2	**Social**: transformation in strategic leadership and thinking			**Social**: efficiency through skills development	
2. Manage connectivity	0					
3. Manage slow variables and feedbacks	2	**Technical**: situational awareness and models for prediction and patterns through analytics				**Social**: credible & reputable organization, energized and responsive workforce
4. Foster CAS understanding	0					
5. Encourage learning and experimentation	7	**Social**: innovative organization that encourages workforce to embrace change	**Social**: empower workforce, listen to every voice, people centred solutions **Financial**: sustainability through good governance		**Social**: Workforce valued, involved & produce innovation, operate efficiently, recover cost and world class	**Social**: share more narratives and tell more compelling stories **Social:** creative and innovative workforce, agile and responsive organization **Social:** setting the benchmark through effective learning and research opportunities
6. Broaden participation	2	**Social**: engage employee ideas and perspective, led and driven by employees, not government or politics				**Social**: inclusive approach, embrace diversity, value opinions and knowledge, recognize staff as interested parties
7. Promote polycentric governance systems	3	**Social:** healthy accountability, enough trust to share success, disentangle negligence from corruption (just culture), purpose (why we do what we do) **Technical:** Predictive sensing and alert system, to enable distributed awareness, collaboration and action				**Social:** collaborative decision making: consulting and involving diverse perspectives from multiple interested parties to improve bird's eye view, insight and foresight

While a focus on resilience in utilities often refers to the ability of an organization to maintain its essential service delivery amidst disruption, the participants in this study found the insights gained from the discussions useful for contributing to change management processes in their particular organization. This suggests that reflection on the application of resilience building principles may enhance the capacity to deal with change.

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3.4   Reflections

Social resilience is a key characteristic of successful societies (Hall and Lamont, 2013). An underlying objective of formative resilience assessments is to contribute to the collective awareness and understanding of resilience among the agents in a system. In the study described in this article, a formative outcome was adopted as the main objective of the resilience assessment. The assessment involved the design of a participatory process (P6) to contribute to learning processes (P5) that stimulates understanding of the overall complex adaptive system (P4) and allows participants to design their own cross-functional resilience building interventions (P7). It would appear that formative resilience assessment processes can directly contribute to enhancing resilience across the system through the application of the very principles themselves. This article described the development and implementation of a novel approach to formatively assess general social resilience based on Biggs, Schlüter and Schoon (2015) and Van der Merwe et al. (2018). Using this approach, the authors were able to evaluate the realisation of resilience capabilities in the organization at the time of the study. Furthermore, the approach enabled us to collaboratively identify areas where resilience needed to be enhanced, and foster a shared understanding of resilience across the system. The practical implications of the study described in this article point to a process that can be easily replicated and utilised by practitioners to operationalise resilience building principles in other contexts.

This article has demonstrated how a practical application of the principles could be used and applied towards conducting a formative resilience assessment. Not only was this assessment conducted for a resilience outcome, it also served as learning for participants involved. For participants involved in the formal resilience programme, the workshops triggered awareness of the notion of resilience and reflection on this phenomenon. A participant involved in the official organizational resilience programme commented how the workshop brought home the realisation that resilience is much more than the formal response plans and structures being developed in the Eskom Resilience Programme. Even though more than half the participants were not familiar with the particular resilience programme before exposure to the workshop, the process contributed to a shared understanding of resilience and how it can be built. This study suggests that resilience assessments can use narratives to establish awareness of current resilience in the system. In addition, participatory dialogue can co-create visions of desirable resilient futures.

The authors found the AI approach suitable for facilitating formative resilience assessments. Appreciative inquiry is an approach to social innovation that stimulates normative dialogue. In addition, it engages people through collaboration and appreciation, to jointly design

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desirable futures and presents "provocative new possibilities for social action" (Cooperrider and Srivastva, 1987, p. 359). These characteristics directly contributed to a participatory process to diagnose: (i) where the system was at in its current levels of resilience; (ii) where resilience needed to be strengthened; and (iii) how to attain these shared resilience goals through collective action. While the AI approach focusses on what works and what is good in a system, the approach we utilised interjected reality checks during the collective group vote whether aspects of resilience were not yet adequate, as well as when participants raised examples of the absence of principles detrimental to overall resilience. These discussions reflected contextual reality, but did not spiral groups into negative discussions. Bushe (2011) demonstrates that if the AI approach is used with agents involved in a system, they tend to take the needs and interests of the system into account and may be willing to sacrifice personal interests to increase the competence and capacity of the system. One participant commented, "It provided a broader illustration of what resilience is, and that we can contribute as junior employees in the industry". And, another wrote, "The voting session was very interesting, since it made me think about what I can do to assist in problem solving." We suggest the AI approach is a useful practice that can be added to the repertoire of resilience assessors committed to a journey of participative and formative assessments.

In essence, the formative assessments of the study involved an ongoing process to assess and adaptively build resilience based on the outcome of the assessment. The formative assessment approach reported in this study was deliberately designed as a rapid small group intervention with a view to more widely influence thinking and extend the conversation across the organization. Typically resilience assessments seek to understand resilience within complex adaptive systems and require long-term commitment from a dedicated team. However, the intent of these short sessions was to enable wide-spread participation and to contribute to slow but systematic penetration of resilience thinking across the social network. These rapid formative assessments, thus, constituted one type of intervention as part of a wider on-going programme to build and assess resilience.

In stark contrast to the outcome of the workshops that apparently fostered understanding and appreciation for resilience, merely a month elapsed before the industrial action incidents that led to load shedding between June and August 2018. The strikes mostly hampered operations at the power stations in Mpumalanga, while the workshops were conducted in the province of Gauteng. Yet it would be naïve to suggest a wider penetration of these workshops could have prevented these incidents. We are confronted with the necessity for essential service resilience, along with a simultaneous realisation that there are no silver bullets.

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While South Africa's resilience is critically linked to the resilience of the socio-technical system that produces electricity, the challenges experienced by the South African utility are not in isolation. Berst (2013) summarised an energy industry report by Citibank (Channell *et al.*, 2013) and argued that utilities are dinosaurs waiting to die. The anticipated global energy transition is switching to a renewable energy economy (Buchsbaum, Olszewski and Joubert, 2018), which brings uncertainty and potential social instability among the very people who have been keeping the lights on. In a free market, essential service companies may come and go, but in countries that exert control over their state-owned companies and regulate essential services, organizational failure is not an option. The social dimension of such organizations could be the weakest link and the strongest resource to ensure resilience of essential services. Further research is required for effective approaches to build essential service resilience and navigate global energy transitions while keeping the lights on.

3.5   Conclusion

We are now in an era of transformation, in which management structures of essential services must build and maintain socio-technical resilience as well as the social flexibility needed to cope, innovate, and adapt. The study described in this article applied the resilience building principles outlined by Biggs, Schlüter and Schoon (2015) to a formative resilience assessment to instil and cultivate general social resilience within the social fabric of an essential service organization. The process enabled shared learning and creatively engaged people to foster dialogue for the collective assessment of resilience. Moreover, it stimulated provocative possibilities to enhance resilience through collective action (Cooperrider and Srivastva, 1987; Holman, 2010). The study developed a principle-based formative resilience assessment approach that is suggested where innovative social resilience building interventions are sought. Transformability is a fundamental part of resilience formulation (Walker et al., 2004), which is indispensable for essential service delivery. Resilience involves being able to adapt to change and navigate the white waters of transition without disrupting the essential services modern society depends on. Amidst systemic change and disruption, approaches to cultivate systemic resilience are crucial.

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Chapter 4: Making sense of complexity: using SenseMaker as a research tool

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Declaration

The candidate devised the idea and structure of the article, invited co-authors to contribute and coordinated all input. A few paragraphs were provided by Marietjie Vosloo and Charmaine Cunningham for consideration and inclusion, while the other contributors provided editorial comments on the work.

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Abstract

There is growing interest in studying processes of human sensemaking, as this strongly influences human and organizational behavior as well as complex system dynamics due to the diverse lenses people use to interpret and act in the world. The Cognitive Edge SenseMaker® tool is one method for capturing and making sense of people's attitudes, perceptions and experiences. It is used for monitoring and evaluation; mapping ideas, mind-sets and attitudes; and detecting trends and weak signals. However, academic literature describing the tool-set and method is lacking. This introduction aims to guide researchers in choosing when to use SenseMaker and to facilitate understanding of its execution and limitations. SenseMaker can provide nuanced insight into systems-level patterns of human sensemaking that can provide insight to nudge systems towards more desirable futures, and enable researchers to measure beyond what they know.

Keywords: SenseMaker tool; mixed method; complex systems; social complexity; sensemaking

4.1   Introduction

Social systems continuously engage in sensemaking processes which shapes behavior and organizational structure (Weick, 1995). The process start when people sense cues from the environment, make sense of it, then enact their interpretation to express their identity, and shape their world (Kudesia, 2017). Sensemaking is a cognitive process that allows us to structure the unknown, to understand and explain the world, and to inform action (Daft and Weick, 1984; Weick, 1988, 1995; Dervin, 2003; Weick, Sutcliffe and Obstfeld, 2005; Colville, Pye and Carter, 2013). Through sensemaking processes, information is interpreted and meaning assigned so as to inform behavior on both the individual and collective scale (Weick, 1993, 1995; Weber and Glynn, 2006). In addition, all sensemaking processes are informed by culture, prevailing narratives, knowledge systems, and experiences (Daft and Weick, 1984; Weick, 1995). How people act, in turn, shapes their social realities and influences future sensemaking in an ongoing cyclical process (Weick, 1988).

People make sense of the world and give meaning to life through the construction of narratives (Fisher, 1985; Dervin, 1998; Niles, 2010; Snowden, 2011). How people make sense of the world is reflected in their everyday micro-narratives, the anecdotes or "small stories" people tell in social interactions. Narratives are, therefore, particularly useful for exploring social patterns of cognition (Kurtz and Snowden, 2003). Social knowledge extracted from daily rhetoric can point to what informs decisions, action, interests, and principles and, thus, may be useful for discovering what is considered public truth and

preferable behavior (Fisher, 1985). Micro-narratives contribute more to participative modes of sensemaking than "big stories" do (Caracciolo, 2012). Furthermore, these fragments collectively disclose identities, motivations and attitudes (Niles, 2010; Casella et al., 2014). Sensemaking, narrative and culture are, therefore, interwoven and give feedback to one another in complex ways.

The patterns that emerge in the narratives, heuristics, and memes of individuals, groups, or organizations are avenues for systemic meaning-making that enables researchers and decision makers to explore the complex dynamics of social systems (Waddock, 2015; Finidori and Tuddenham, 2017; Haynes, 2018). Reductionist approaches to analyze social complexity are limited in the explanations they can offer (Weaver, 1948; La Porte, 1975; Morgan, 2005; Castelliani, 2014), as they ignore key dynamics and features of complex adaptive systems (Byrne and Callaghan, 2013).

Sensemaking is a research approach that aims to explore and understand the ambiguous dynamics of complex social systems (Kurtz and Snowden, 2003, 2007; Uhl-Bien and Marion, 2009; Audouin et al., 2013; Lemaster, 2017). A sensemaking approach abductively explores connections and patterns between elements to understand systemic relationships (Kolko, 2010; Klein, 2013). Several sensemaking research methods exist, including: Dervin's (1998, 2003) sensemaking methodology; Weick's (1993, 2001) organizational sensemaking (Weick, Sutcliffe and Obstfeld, 2005); soft systems methodology (Checkland, 2000); narrative analysis (Patriotta, 2003); discourse analysis (Thurlow and Helms Mills, 2009); participative narrative inquiry (Kurtz, 2014); Waddock's (2015) exploration of memes for large system change; and visual sensemaking for meaning-making and social transformation (VanPatter and Pastor, 2016).

The purpose of this article is to introduce the SenseMaker [6] tool and the Cynefin sensemaking framework on which it is based. Originally developed as a narrative-based mixed method tool to inform response options in organizations (Snowden, 2010), SenseMaker is now increasingly being used in trans- and interdisciplinary academic domains (Elford, 2011; Ray and Goppelt, 2011; Dunstan, 2016; Mark and Snowden, 2017; Polk, 2017; Bartels et al., 2018). While much has been written about different management applications, mainly in grey literature, the use of SenseMaker as a research approach is not well described. This article aims to help researchers understand SenseMaker and evaluate whether it is a suitable tool for their research. To this end, the article provides an overview of

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[6] SenseMaker® is Software as a Service, available through Cognitive Edge, of whom David John Snowden is the founder and chief scientific officer (Cognitive Edge, 2018a)

the four steps of designing and implementing a SenseMaker study and reflects on its limitations for research.

4.2   The Cynefin framework and SenseMaker tool

The Cynefin[7] sensemaking framework is recognized as one of the first practical applications of complexity thinking in the field of management science (RAHS, 2008). The Cynefin framework emerged at the turn of the century as a guide to distinguish between different types of problem contexts (obvious, complicated, complex, chaotic) based on degrees of predictable order (Kurtz and Snowden, 2003) (Figure 4-1). Decision-makers can situate their context in a domain, and the framework guides suitable responses for each decision context by clarifying the kinds of challenges and types of practice associated with each (Snowden & Boone 2007). While the obvious and complicated domains are characterized by known and knowable causality, the complex and chaotic domains are characterized by uncertainty and non-linearity, and in the central domain of disorder, the appropriate response is still unknown (Brougham, 2015). As situations and circumstances change, the problem context can dynamically move between domains.
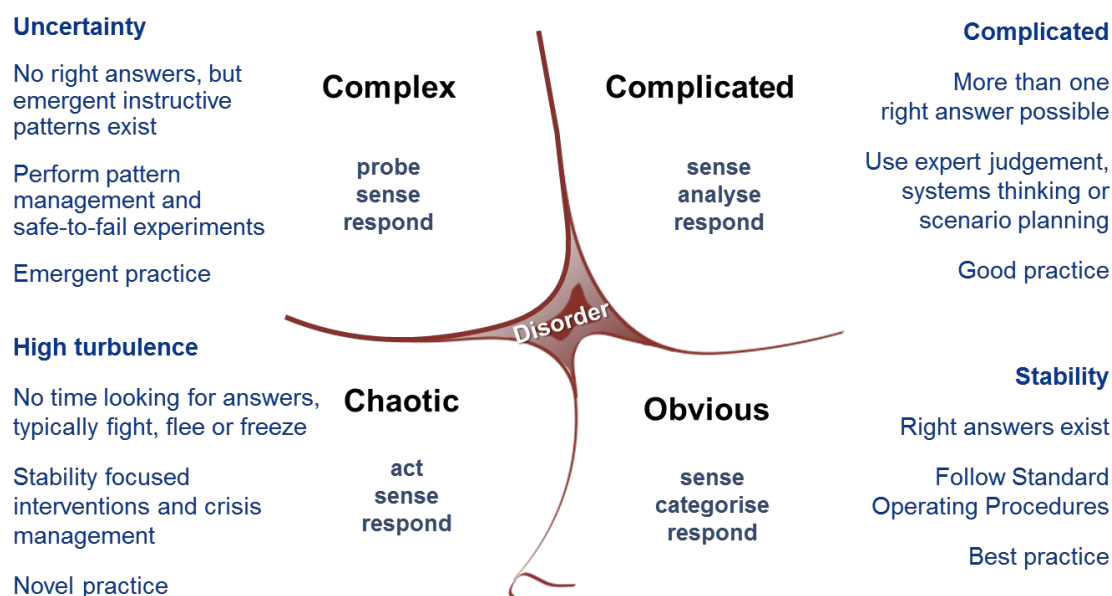
Figure 4-1 The Cynefin sensemaking framework highlights differences among decision domains (Kurtz and Snowden, 2003). The SenseMaker tool is specifically designed to explore the complex but can be used across all domains.

Within the complex domain, Snowden and Boone (2007) suggest interacting with the system through what they call 'probing' – small safe-to-fail experiments. As a result of this probing, managers sense patterns that emerge from the system and respond in ways that either encourage or discourage undesirable system behavior – a response described as

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[7] A Welsh word describing a sense of place, or habitat (pronounced Kih-neh-vin)

pattern management (Snowden, 2002). Each response initiates the next probe, in an ongoing adaptive cycle.

SenseMaker originated in the field of knowledge management and was specifically developed to explore emergent narrative patterns in the complex domain of Cynefin, although its use is not confined to this domain (Snowden 2000). SenseMaker entails probing to solicit micro-narratives from the system context, then looking for emergent patterns from the narratives, and responding with pattern management to explore what Juarrero (2010) refers to as the "adjacent possible".

SenseMaker is both a tool and a method for collective inquiry into people's attitudes, perceptions, experiences and reflections. Conceptually SenseMaker is grounded in insights gleaned from complex adaptive systems and the cognitive sciences applied to the analysis of social systems (KMWorld, 2005; Ali, 2014; Castelliani, 2018). It links micro-narratives with human sensemaking to create advanced decision support, research, and monitoring capability (Cognitive Edge, 2017). The narrative-based method and accompanying software support the process of sensemaking of patterns in complex social systems and allows one to assess and monitor their continuously evolving nature (Deprez, Huyghe and Van Gool Maldonado, 2012; Mager, Smith and Guijt, 2018).

SenseMaker differs significantly from other narrative-based research methods (Snowden, 2010) that typically involve immersive field-based observations and multiple in-depth interviews. The latter can result in an intermingling of the views, voices and values of the researcher and the research participants (Creswell, 2007; Caine, Estefan and Clandinin, 2013). The SenseMaker method replaces immersive interviews by the researcher, as micro-narratives are sourced from people's lived experiences by facilitators from the community. However, narratives may also be obtained directly using collection tools available from a webpage or as an application (app) on a smart device. SenseMaker is a form of distributed ethnography, as it transfers the onus of interpretation of narratives from the researcher to participants. Through this self-signification, SenseMaker removes ethnographic coding and expert re-interpretation, as participants assign meaning to their own micro-narratives, which enables large scale explorations, reduces researcher bias, and allows for more objective analysis (Guijt, 2012; Milne, 2015).

SenseMaker is a mixed method that combines first-hand narratives with the statistical authority of quantitative data (Fierro et al., 2012; Milne, 2015). Research questions are built into the SenseMaker instrument as signifiers (concepts that anchor the plotting of micro-narratives in space). A signification framework consists of predetermined questions that

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guide the inquiry, solicit micro-narratives and clarify interpretations which extract associated meanings of the narratives from participants (Cognitive Edge, 2018b; Mager, Smith and Guijt, 2018). Signification takes place when participants answer signifier questions on the micro-narrative they shared, and in the background numerical coordinates are associated to the micro-narrative relative to the signification framework. This innovation provides linked qualitative and quantitative data that can be assessed in parallel. When the set of signifiers are plotted in SenseMaker, it displays mathematical patterns that reveal a map of the social landscape, to detect and distil variations in patterns of cognition (Deprez, Huyghe and Van Gool Maldonado, 2012; Milne, 2015; Mager, Smith and Guijt, 2018). Thus, the signification framework becomes the basis for exploring the relevance of patterns, underlying relationships, norms, and dynamics in a social system (Mager, Smith and Guijt, 2018).

4.3   Applications

SenseMaker supports participative processes of collective inquiry and shared sensemaking and has been used for: monitoring and evaluation; impact assessment; and the facilitation of complex development and social intervention planning across various disciplines and sectors (Fierro et al., 2012; Guijt, 2012; Jenal, 2016). Although many applications in the commercial and intelligence areas are not documented, known SenseMaker cases can be grouped into three areas: (i) monitoring, evaluation and measuring impact; (ii) mapping of ideation cultures, mind-sets and attitudes; and (iii) detecting trends (See Table 4-1 below).

The approach is deemed particularly well suited to resilience research as the ability to detect change in mind-sets or pick up on emerging trends can feedback into adaptive management practices, and monitoring and evaluation of programme effectiveness can inform resilience building interventions within communities. Its contribution to resilience assessments is worth highlighting: airline flight operations are assessed against resilience engineering principles (Dijkstra, 2013; Moriarty et al., 2016); communities targeted for economic development and upliftment are assessed based on social pathways to cope, adapt and transform towards prosperity (Will, 2016; Gottret, 2017); the primary researcher performs resilience assessments in an essential service organization for the effectiveness of sensemaking in extreme events response and the overall utilisation of types of social resilience resources. SenseMaker provides evidence and supports assessments, allows researchers to measure beyond what they know, may reveal views not expected, and 'rehumanises' data by bringing in participants' voices (Deprez, Huyghe and Van Gool Maldonado, 2012; Jenal, 2015). Anomalies and outliers can serve as weak signal detection that might represent emerging opportunities or obstacles (Milne, 2015).

Table 4-1 A range of documented SenseMaker applications grouped into three key areas based on application objective

Monitoring, evaluation & measuring impact	Mapping of ideation cultures, mind-sets & attitudes	Detecting trends
o Inform programme monitoring, impact evaluation and to report to donors (Jenal, 2015; Van Hemelrijck, 2016) o Grass roots needs assessment, inform intervention design and guide future action (Jenal, 2015; Metheou and Bhagani, 2014) o Measure programme outcome and impact (Jenal, 2015) o Measure aspects of decent work beyond compliance to decent working conditions (Mager et al., 2018) o Monitor and measure social change and evaluate systemic change (Guijt, 2012; Jenal, 2015, 2017) o Assess recipient inclusiveness (Deprez et al., 2012, 2016; Guijt, 2016; Huyghe, 2015) o Story evaluation method for community work (Boss, 2011; GlobalGiving, n.d.; Guijt & Hecklinger, 2010; Maxson, 2012) o Mechanism for delivering biosocial response to HIV/AIDS (Burman, 2018b) o For public policy, shape policy consultation and target messaging to increase effectiveness (Milne, 2015)	o Picking up attitudes and values, gain insight, reveal blind spots (accounts of 9 different social experiments) (Mattila, 2018) o Assess level of resilience in complex systems (Dijkstra, 2013; Gottret, 2017; Moriarty et al., 2016; Will, 2015, 2016) o Understand climate change adaptation responses to inform policy (Milne, 2015; Lynam and Fletcher, 2015; Lynam and Walker, 2016) o Explore reasons for poor safety record (Sardone & Wong, 2010) o Market research and to monitor change in strategic decision making (Likens et al., 2016) o Gaining insight into consumer motives (Ophoven, Pauwels, & Stienstra, 2011) o Gain insight on people's perceptions and understand dominant and deviant patterns (Jenal, 2015) o Assess gender issues and power dynamics impacting the life's of girls and investigate factors contributing to child marriage among refugees (Fierro et al., 2012; Bakhache et al., 2017; Bartels et al., 2018) o Monitor patient health care preferences in treatment of HIV/AIDS between traditional and biomedical sectors (Burman, 2018a)	o To identify the early signs of social change (SITRA, 2018) o Monitor changing norms about drinking and driving among the youth (Stienstra & Noort, 2008) o Futures study to explore citizen expectations of national governance in 10 years' time (Koh et al., 2013) o Micro-scenario planning for weak signal detection and crowd sourcing scenarios for futures planning and foresight (Cognitive Edge, 2015) o Establish user acceptance of newly implemented technologies among deployed soldiers (Jaye et al., 2014) o Visualise complex interconnecting elements of intellectual capital in a financial services firm (Cuganesan and Dumay, 2009) o Detect weak signals in changing choices and attitudes towards HIV/AIDS (Burman et al., 2016)

4.4   Guidelines for using SenseMaker as a research approach

The four high level steps in the SenseMaker method consist of: (1) initiation of the tool, either through selecting an off-the-shelf scan, or designing a signification framework from first principles; (2) story collection and data capture; (3) explorative pattern analysis and collective sensemaking of the meaning behind the patterns; and (4) responses to act on the insight gained through safe-to-fail intervention strategies (Figure 4-2). The SenseMaker toolset that supports the method is available as an online Software-as-a-Service suite and consists of various software modules covering design, collection, view, and analysis (Figure 4-3).

Figure 4-2 The SenseMaker involves four iterative steps to: 1) design and set up the instrument; 2) probe a social context for narratives using distributed ethnography; 3) make sense of patterns across the narratives; and 4) respond based on the insights and adaptively nudge the system towards more desirable futures.

Design	Collect	View	Analysis	
SenseMaker Designer	**SenseMaker Collector app**	**SenseMaker Explore app**	**SenseMaker Analyst**	**SenseMaker Explorer and SenseMaker Modeler**
An online administrator interface that allows SenseMaker practitioners to create and customise new projects that can be used for narrative capture. Once the administrator publishes the project it becomes available through the use of a unique code to capture narratives.	To be used by participants or data collectors for collecting narratives and the signification of those narratives. Alternatively capture data directly from a website through any web browser.	Project code access available on request, to monitor the number of narratives captured, see high level patterns among the narratives, and read individual narratives – not recommended practise.	A web-based analysis tool, currently less powerful than Explorer and Modeler, but with a more intuitive user interface and new functionality like x-y-plots.	An application that runs off a computer and access data locally that was extracted from the online-database. An analytical platform for finding statistical correlations, to slice and dice data; build 3D landscapes; compare patterns among sub groups and more. Has largely been replaced by the online SenseMaker Analyst.
Web front-end to an online configuration and data management service.	App that run on Apple or Android smart devices.	App only available on Apple iPad.	Web interface to an online analysis tool.	Software installed on an Intel based platform, requires a Java plug-in.

Figure 4-3 The SenseMaker software suite supporting the execution of the method consists of six web-based and app modules that cover design, data collection, exploration and analysis.

4.4.1 Step 1: Initiation through to instrument deployment

The questions that drive the inquiry determine the approach to be followed during design, which in turn determine what can be derived from the analysis afterwards. This initial step is critical, as effectiveness of the SenseMaker approach hinges on the combined effect of instrument design and capturing sufficient numbers of narratives.

4.4.1.1 Conceptual design

The conceptual design includes a view of the problem context, potential participants and the degree of participation that will be followed (Snowden and Boone, 2007; Deprez, Huyghe and Van Gool Maldonado, 2012). Determine the concepts to be incorporated into the signification framework. Usefulness of results are strongly influenced by social fit of the constructs, so pay attention to align concept clarity and structure, described by Podsakoff, MacKenzie, & Podsakoff (2016), to within-group language and meaning of those concepts, described by James & Jones (1974). Off-the-shelf frameworks may be utilized to circumvent design effort (Deprez, Huyghe and Van Gool Maldonado, 2012). If there is conflict to be resolved, one might focus on making visible the perspectives of the different groups involved. However, in a monitoring application, one would typically compare results with an earlier collection to see whether shifts have occurred. To address participant literacy concerns, one could consider recording oral narratives and using pictures in the signification

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framework. If joint sensemaking will be used, it is useful to consider following a participative design approach (Jenal, 2015).

4.4.1.2 Detailed design: signification framework

During detailed design, researchers establish the signification framework and prepare the online instrument for data capture. A signification framework is designed to elicit the concepts researchers want to explore and is used as the basis for analysis later. The framework solicits a micro-narrative from participants, followed by questions of clarification, through which participants self-signify their narrative. The clarification questions use widgets that create conceptual space relative to the concepts utilized in a framework. These widgets are novel relational filters like triads, dyads and stones, which capture nuances in the experiences of participants that traditional surveys cannot convey (Mager, Smith and Guijt, 2018). Refer to the additional online material for illustrations of these widgets. Deliberate ambiguity among options in the signification framework invites people to exercise their own judgement, which triggers slow thinking and retrospective sensemaking (Weick, 1995; Kahneman, 2011). Ambiguity also adds flexibility to the framework to support abductive research or pre-hypothesis explorations (Elford, 2011).

Eliciting micro-narratives: To encourage participants to contribute micro-narratives, the framework starts with an open-ended question which serves to invite the participant to relay an observation or an anecdote (Figure 4-4). Kurtz (2014) advises that the best stories to work with are told from a person's own perspective. The elicitation question should implicitly or explicitly invite positive and negative stories. The researcher should stay clear of prompts that can be answered with platitudes, as these do not stimulate personal reflection or useful signification patterns. Photos can be used to trigger a response; or, there might be two prompts that allow the participant to choose the prompt that resonates most. Although stories are typically collected anonymously to ensure confidentiality, respondents can be given a choice whether their story can be shared or not. Once the participants have shared their story, they are asked to provide a title which triggers another layer of meaning-making, and is used as a handle for the micro-narrative and associated metadata during analysis.

If a close friend was thinking of working for your company, describe ONE experience or event that you would tell them so that they understood what it's like to work around here.

Describe what happened:

□ If you'd rather no-one had access to the above material, please check this box.

Give your experience a name:

Figure 4-4 This is an example of a prompt for a micro-narrative. Prompts should elicit a personal anecdote of an experience that left an emotional impression on respondents. This prompt is from the off-the-shelf Culture Scan by Cognitive Edge used to get a sense of organizational culture seen from employees' perspectives (Cognitive Edge, 2017b).

Self-signification of narratives: The process of self-signification of the narratives is done by participants through interactive widgets that consist of dyads, triads, stones and multiple choice.

Dyads: A dyad widget consists of a slider used to indicate the relative strength of a concept, quality, belief or outcome along a continuum between two opposite extremes, where the extremes are described as either mutually negative, positive, or neutral (Mager, Smith and Guijt, 2018) (Figure 4-5). A dyad is suitable to determine the value of a concept with a bipolar structure and based on Aristotle's 'golden mean' carry exaggerated opposites at the ends, like ranging from extreme excess to deficiency (Wicks, Berman and Jones, 1999; Dunstan, 2016; Podsakoff, MacKenzie and Podsakoff, 2016). Respondents are invited to indicate a location along the slider that best fits their anecdote (Guijt, 2016). SenseMaker assigns a percentage to the two opposite variables based on the given location as an indication of the relative strength for each variable. Dyads are used to explore underlying beliefs, test a disguised hypothesis, or to measure the strength of assumed modulators (Guijt, 2012). Snowden (2008) describe modulators as the underlying factors that interact with each other and the system and may include attitudes, perceptions, and emotional intensity. Dyads are also useful to detect movement and direction of change in desirable system behavior to verify effectiveness of systems level interventions.

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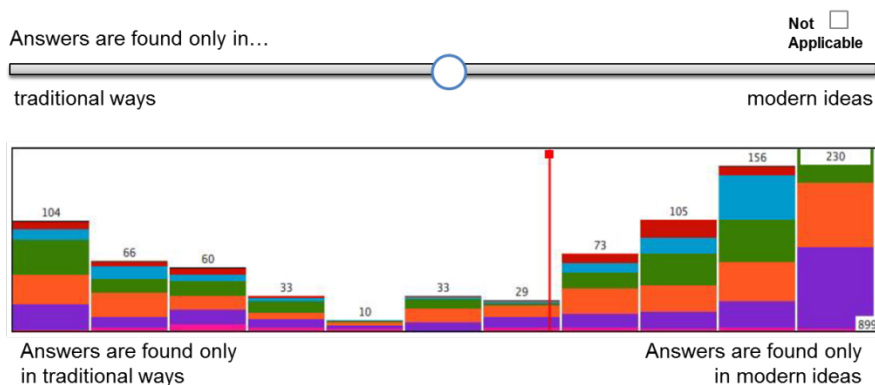
Figure 4-5 A SenseMaker dyad is a continuum between two opposite extremes. Participants use the slider to indicate where their narrative is located. The results shown reflect views from 1000 stories collected in Southern Africa for a grassroots needs assessment among communities subjected to consecutive droughts and floods. These results indicate that few respondents think answers can come from a combination of both traditional and modern ideas (Metheou and Bhagani, 2014). The colours reflect age groups, with over 50s shown in purple.

Triads: A triad widget is a triangle with labelled corners and is used to convey the relative importance of three concepts (Mager, Smith and Guijt, 2018). Triads are useful to probe trade-offs and reveal subtleties and undercurrents in the system. Participants are invited to place a dot in a triangle to indicate the relative strength or influence of the concepts in the corners relative to their anecdote (Lynam and Fletcher, 2015; DeLong, 2016). The indicated position in the triad will return three numerical results which always sums to 100, representing the relative weight of the named corners (refer to Figure 4-6 for an example of values for the three variables for a given location).
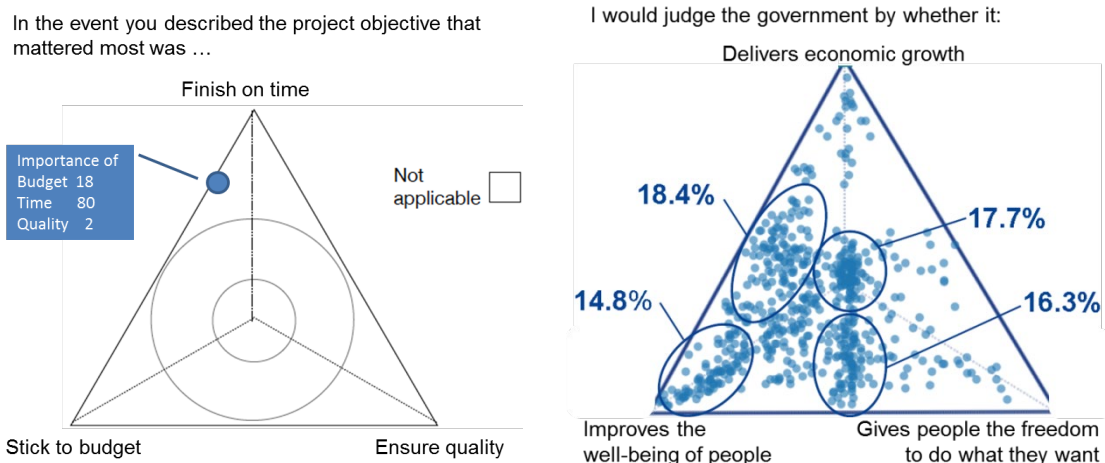
Figure 4-6 A SenseMaker triad has labelled corners that are all either positive, negative or neutral. Respondents indicate where their narrative is located in this space by dragging the marker to the position that best describes their anecdote. The closer the marker is to a corner, the stronger that quality is in the context of the anecdote. The example on the left shows the numerical values that would be assigned to each corner for the indicated location of the marker. This diagram indicates that quality was compromised in order to finish on time. The triad on the right shows results from a futures study conducted during 2013 among 600 respondents in Singapore regarding their expectations of national governance in 10 years time. This shows the government's clear preference for focusing on constituent well-being. Each dot refers to a narrative and

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associated signifier data, while the percentages reflect the number of responses that fall within the respective circles (Koh, Koh and Kiat, 2013).

Stones: A stone widget consists of a canvas, on which named markers can be placed, where meaning is assigned on the canvas either through named axes or pictures. A stone widget is used for a relative comparison of more than three elements along two axes that make visible how different parties perceive the same issue (Mager, Smith and Guijt, 2018). When participants place named stones on the canvas, Cartesian coordinates are recorded as percentages for future analysis. Stones are considered more evaluative than triads but can be challenging for participants. It is a good idea to limit the number of stones to be placed on a canvas to avoid cluttering the user interface. Another version of this filter blends the slider and stone concept by asking participants to place various stones on a canvas with effectively a single dimension, which simplifies the user experience (Figure 4-7).
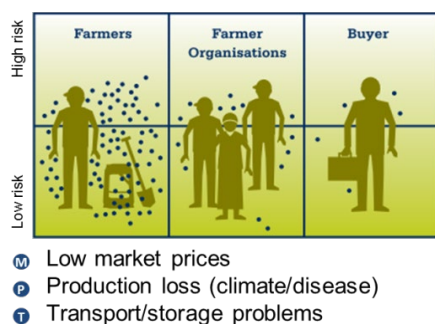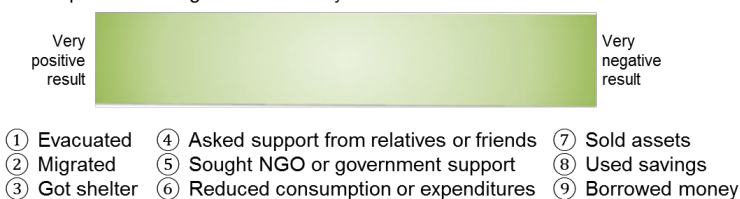
Figure 4-7 Stones are placed on a canvas to illustrate relative location, as illustrated in this Inclusive Business Scan on the left. The scan was performed by Rikolto VECO to gain insight into smallholder farmers' inclusion in formal markets across the world (Deprez, Steen and Ongeval, 2016) The one dimensional stone slider on the right illustrates how a filter can reveal the coping strategies employed as well as evaluate relative effectiveness (Will, 2016).

Multiple choice questions can serve to clarify aspects of the anecdote or capture participant demographics (Mager, Smith and Guijt, 2018). The multiple choice options should be informed by consideration of the various categorizations that would be useful to filter results during analysis, e.g., age, gender, location, or feelings linked to the anecdote (Figure 4-8).

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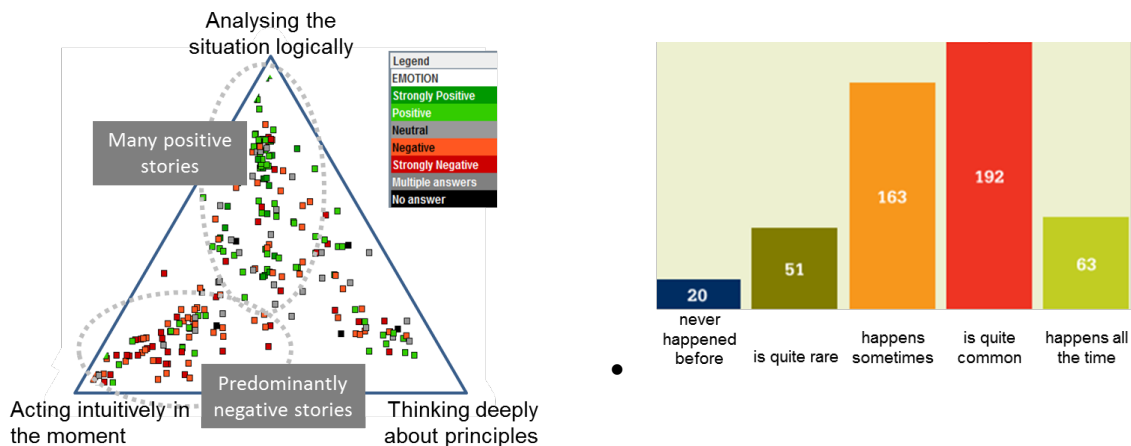
Figure 4-8 Multiple choice questions are useful for filtering results during analysis, as illustrated in the triad by results from a corporate investigation into the nature of decisions made in crisis. The results colour are coded according to the emotion people associate with their narrative to highlight the emotional effect different types of decisions have on the workforce (unpublished). The bar graph shows the distribution of narratives relative to a multiple choice about how common the type of occurrence is. This was especially useful for picking up weak signals among the 20 incidents that had never happened before (Huyghe, 2015).

4.4.1.3 Instrument usability tests and online deployment

The SenseMaker method and instrument design is particularly sensitive to a cultural fit between language used and meaning of the concepts in the signification framework and among the target population. Anthropological considerations during field tests are essential to verify usability by the intended community (Smith and Yetim, 2004). Social usability should consider contextual differences of ethnography, belief systems, knowledge systems, social formulations, language and meaning (Chilisa, 2005). A good social fit will be subjectively pleasing to intended participants, and options in the signification framework will resonate with them (Lidwell, Holden and Butler, 2010).

Usability tests with the target community follow an iterative refinement process and are valuable towards meaningful data and useful patterns from the study. Paper versions can be tested initially; but, following deployment of the online collection instrument, thorough usability tests have to be performed with members of the target community before full-on capturing commences.

4.4.2   Step 2: Story collection: narrative collection strategy and data capture

Once the instrument is ready to go live, data capturing can be done on paper, online on the web, or through the SenseMaker Collector app. All paper based input has to be transcribed into the system. For online capturing, the link to the website can be circulated electronically to request participation. When using the SenseMaker app, Internet access is not required

during interviews, as the data is saved locally on the device and synchronized once connectivity is established.

Members of the target community may act as gatekeepers to solicit participation. Interviewers should be comfortable with the data collection tool and trained in the project intent to improve the quality of narrative collection. They should also know how to elicit a relevant anecdote as well as how the data is to be used afterwards. In addition, they should understand and be able to explain the signifiers (Deprez, Steen and Ongeval, 2016; Mager, Smith and Guijt, 2018). Interviewers can type the anecdote shared by participants, take a photo, or make an audio recording. If participants are comfortable with electronic devices and abstract concepts, they can be shown how to complete the first signifier, after which they can continue themselves.

Creative strategies are required to ensure capturing at scale, as it can be challenging to collect sufficient numbers of narratives. A nonparametric sampling framework is recommended to ensure validity and the statistical significance of findings (Jenal, 2015). Broad sampling ensures depth of penetration through sufficient responses, especially if differentiated insight is required within and between sub-groups (Milne, 2015; Jenal, 2016). SenseMaker is best suited to studies with large samples, and Mager et al. (2018) recommend that researchers aim for a minimum of 200 stories for a basic level of confidence. Mass collection methods to operationalize the concept of distributed ethnography (allowing for qualitative data capture at quantitative scales) include the following: kiosk-based capture at social gathering places; participant observations from students sent out as apprentices; situational gathering at special events like games, parties or festivals; samples of employees requested to collect micro-narratives from people matching specific criteria; and arrangements across an organization that target a focused time for participation (Snowden and Stienstra, 2007; Guijt and Hecklinger, 2010).

Ongoing capture enables continuous monitoring of shifting data patterns to enable adaptive management as interventions are rolled out (Charney, 2017). To achieve ongoing data capture, researchers might consider replacing regular organizational reports with captured narratives or daily journaling. They could also build human sensor networks consisting of customers or employees, which can be activated as the need arises (Cheveldave, 2013).

4.4.3 Step 3: Exploratory data analysis and Sensemaking

SenseMaker analysis utilizes abductive reasoning and serves as the primary sensemaking step in the method . Sensemaking commences once sufficient data volumes are reached, or once data collection has been completed. User input from the triads, dyads and stone

widgets provides numerical data that can be statistically analyzed and visualized, while results from multiple choice questions are used to filter and further explore the data.

Based on distinctions between quantitative and qualitative research paradigms by Goertz and Mahoney (2012), SenseMaker analysis is suitable to explore associated meaning and relationships between concepts, and not for measurements or inference on causality.

Sensemaking consists of exploratory analysis, which involves pattern seeking by the researcher followed by collective sensemaking including interactive and participative sessions (Deprez, Huyghe and Van Gool Maldonado, 2012). It is done by iterating between patterns, associated signifiers and narratives to find out what constitutes the pattern and search for the contexts which inform such dispositions (Casella et al., 2014).

Narratives should always be treated systematically. Consideration should be given to how the narratives are handled; and, a choice should be made before the analysis begins, as dipping randomly into the stories can lead to interpreter bias. Where applicable, researchers should note permissions assigned by participants to their narratives when analyzing data (Figure 4-4).

4.4.3.1 Exploratory analysis

A data preparation step is often overlooked but is crucial to the quality of the analysis. The quality of the data in relation to the purpose of the study should be assessed, issues corrected where possible, and the limitations imposed on the conclusions by the unresolved issues noted.

It is recommended to start the analysis with a broad bottom-up exploration of patterns across the dataset. The signifier framework provides a broad theoretical foundation from which to investigate emergent patterns of how narratives cluster. Utilize theories that underlie the design to support and develop contextual understanding of patterns in the dataset. Researchers should also look for statistical correlations between signifiers, keeping in mind that variables derived from triads have negative correlations owing to a loss of the degrees of freedom (DeLong, 2016). Furthermore, DeLong (2016) suggests using the geometric means to investigate central tendency of triad data because of the "closure" constraint on variables that add to 100.

The bottom-up exploration can be followed by a top-down process that starts by listing the guiding questions and identifying which combinations of signifiers are relevant to those questions. The exploratory analysis notes links or contradictions between patterns and interesting patterns that emerge should be followed up.

The interactive exploration of patterns and anomalies is supported by SenseMaker's visualization and statistical analysis tools; or, researchers can use R or Tableau if preferred (Webster, 2015). Clusters of stories may be identified from signifier plots and subjected to thematic analysis to assist with the interpretation of the patterns. Disintermediation is achieved by giving decision-makers direct access to the raw narratives for a rich description of what informs the patterns and by allowing them to make their own interpretation of the meaning behind the data, without being constrained by expert interpretation (Elford, 2011; Snowden, 2015, 2016a) (Figure 4-9).
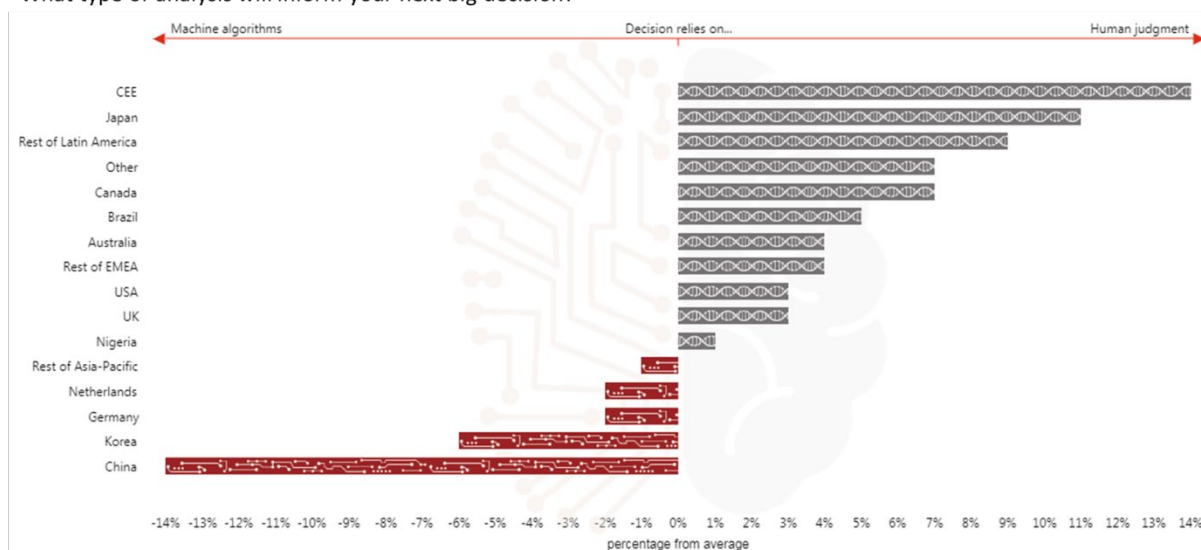
Figure 4-9 Patterns emerge across narratives relative to the signifiers, as illustrated by these results from the Big Decisions Survey[8] conducted by PwC in 2016 among 2,106 executives from sixty-eight countries to monitor how corporate decision making is changing. The results are derived from dyads and show the difference in outcome, based on their country of origin, of the type of analysis that will inform the individual participant's next big decision.

The next step is then to confirm the conjectures that arise after exploration through further analysis, e.g., by checking whether the responses to other signifiers support the conjecture or by thematic analysis of the narratives associated with the patterns .

It is worthwhile to identify and refine possible interventions throughout the exploration and collective sensemaking. Identify clusters of stories where the situation might be nudged in a beneficial direction through encouraging "more stories like these, fewer stories like those" (Cognitive Edge, 2015; Snowden, 2016b). A small group of outlying stories might represent important weak signals (Figure 4-10). A single unusual anecdote is enough to show possibility and might provide a good idea for a safe-to-fail probe.

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[8] Interact with these results at https://www.pwc.com/us/en/services/consulting/analytics/big-decision-survey.html

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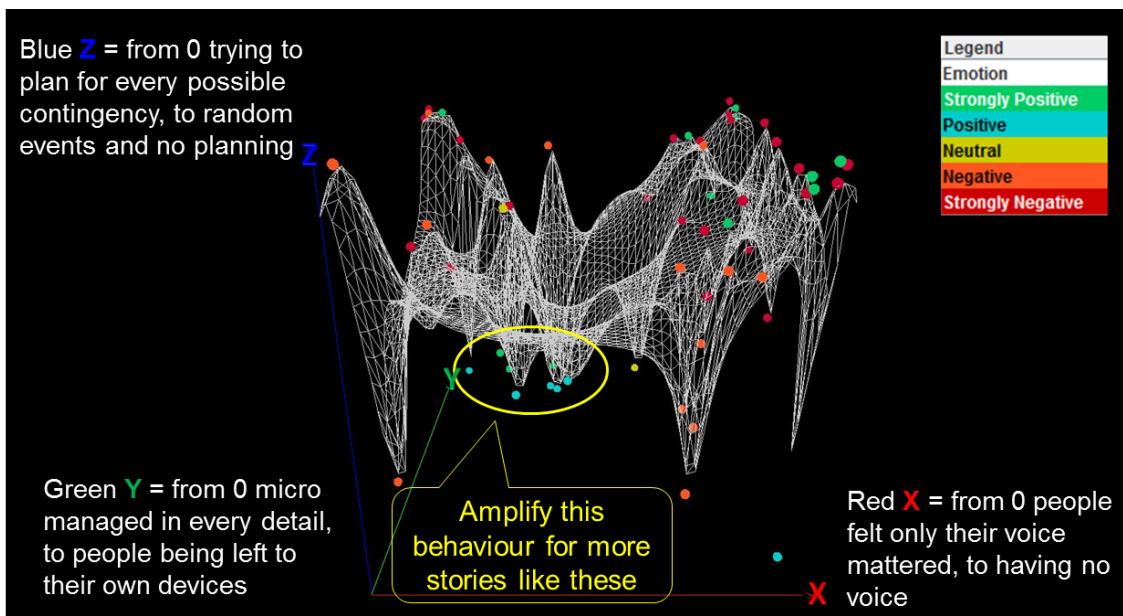
Figure 4-10 A three-dimensional fitness landscape, created in SenseMaker Modeler[9], by juxtaposing three dyads, reveals a cluster of positive stories. The behaviour exemplified in that pattern should be amplified to encourage more stories like these (unpublished).

4.4.3.2 Collective sensemaking

Collective sensemaking involves returning the information to a wider audience to solicit reflections on the emergent patterns and what underlies them. Chilisa (2005) argues that culturally sensitive research ethics ensure that research findings are validated by the researched community. To facilitate collective sensemaking, a useful practice is to share the results from the exploratory analysis with participants in a workshop setting. The purpose of collective sensemaking is, through conversation, to seek to uncover and make sense of the patterns of thinking that led to the behavior made visible in the patterns. If participants in the study give permission for their voices to be heard, story packs can be compiled to clarify patterns by extracting illustrative stories to support meaning making. Participants and other stakeholders often enjoy having story packs returned to them and discussing the significance of the findings to deepen insights and inform action (Deprez, 2015). The ultimate test of conjectures is to subject them to collective sensemaking, or verify them through safe-to-fail experiments.

Collective sensemaking produces a shared map of what is going on and enables coordinated action (Ancona, 2011). Some development practitioners consider this participative collective human sensemaking process, with actors in the system, as the core of the methodology (Deprez, Huyghe and Van Gool Maldonado, 2012). It provides change

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[9] SenseMaker Analyst generates two-dimensional fitness landscapes showing narrative density as contours

agents in the system with the ability to: detect signals from the results; gain insight into correlations not previously understood; verify the effectiveness of interventions; develop new ways to engage in the system; and adaptively improve their strategies (Jenal, 2016). These collaborative interpretive processes can lead to: in-depth interpretations; grounded perspectives; shared understanding which ensures alignment and buy-in; accelerated innovation; and enlarge the diverse brainpower collectively engaged in change-making (Humantific, 2015; Mager, Smith and Guijt, 2018).

4.4.4 Step 4: Response to affect change in the system

For Snowden the purpose of a sensemaking approach is "making sense of the world so that we can act in it" (Cognitive Edge, 2018a). Pattern management aim to "amplify the positive and dampen the negative" to achieve "more stories like these, fewer stories like those", which is the guiding heuristic for safe-to-fail intervention strategies (Snowden and Boone, 2007; Martens and Rotmans, 2015). Pattern management works to influence feedback loops in complex adaptive systems that constrain and enable the evolution of a system (Jones, 2011).

Continuous monitoring provides the ability to track shifting patterns over time, monitor their rate and trajectory of change, and explore reasons for shifts from the narratives (Deprez, Huyghe and Van Gool Maldonado, 2012). This awareness brings valuable insight and learning opportunities and can inform adaptive management (Charney, 2017). Early detection can lead to quick feedback loops in response to changing system dynamics and enables fast exploitation or fast recovery by enacting small course correcting adjustments to nudge the system towards desirable outcomes (Casella et al., 2014). Nudging a system in this way to an "adjacent possible" is easier than bringing about large shifts (Thaler and Sunstein, 2008; Snowden, 2016c).

4.5   SenseMaker limitations and suggestions for future development

Researchers should consider limitations to the SenseMaker approach to assess and manage risk implications to their research objectives. One of the main challenges is that the initial investment in becoming familiar with the approach sets a high barrier to entry; but, with experience the tool becomes easier and more cost effective to use (Deprez, Huyghe and Van Gool Maldonado, 2012).

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4.5.1 Research method

SenseMaker is primarily an exploratory method suitable for abductive research and pre-hypothesis studies, as it explores patterns and relationships to reveal what is not known, and can produce novel surprises (Elford, 2012; Dunstan, 2016; Polk, 2017). On the other hand, SenseMaker data can validate or challenge a hypothesis, pre-defined assumptions or expectations (Mager, Smith and Guijt, 2018). Furthermore, Mager et al. (2018) advise to only embark on a SenseMaker study if key stakeholders are prepared to actively engage in sensemaking, value hearing different voices and would be receptive to the whole distribution of patterns, including outliers.

Contrasting responses have been reported from the application of the SenseMaker method. Respondents often welcomed the opportunity to share their concerns (Fierro et al., 2012). Some participants offered to recruit other participants from outside their immediate circles whilst others observed that the process of completing the survey felt therapeutic and asked for further opportunities to participate. On the other hand, it has also been reported that participants abandoned a survey and decision-makers that commissioned the study abandoned the project (Casella et al., 2014).

Various ethical issues may arise in the use of SenseMaker. Technology that engages with social dynamics may be "beneficial or harmful, empowering or dangerous, depending on the context in which they are used" (Fredette et al., 2012, p. 118). The researcher needs to consider whether this form of research makes participants vulnerable by revealing information that might be used against them. Although stories are typically collected anonymously, it may be possible to deduce where some stories are from. Respondents should be given the option to restrict access to their own narrative. It is important to consider who may access the stories and how they plan to use them. It is also important to manage expectations, as respondents may assume that telling their story will lead to tangible responses. A wider ethical consideration, aligned with possible transformation agendas that may inform the research, is whether those researched will be treated with dignity and integrity, or whether insight into the stories opens participants to be manipulated (Chilisa, 2005; Kara and Pickering, 2017).

While strength of the SenseMaker method is to transpose personal responses into numerical values, the subjective self-signification process paradoxically contributes to limitation in this research approach. Since the SenseMaker approach apply techniques from natural sciences to social sciences, it may be criticized as scientism after Hayek (1942). Haack (2017) describe scientism as an inflated admiration of natural science, while losing sight of the fallibility of its limitations. As social phenomena cannot be quantified or measured

meaningfully, the numerical data derived from SenseMaker is weak. While numbers lends it to scientific-looking techniques, the application of statistical analysis to weak data may be criticized as scientistic. Similarly, SenseMaker analysis produces impressive apparently quantitative diagrams, but do not overestimate its strengths. Hayek (1942) warn that the application of natural science techniques to social phenomena may lead to a loss of the human factor, which according to Miles (2009) may lead to an inhuman and depersonalized science. To counter this impersonal inclination towards scientistic reduction in social sciences, Miles (2009) advocate researchers adopt a humanistic outlook that view participants and their communities as irreducibly complex, and Haack (2017) call for human mindedness. For this reason, heed Goertz and Mahoney (2012) to not overanalyze quantitative results, as it is indicative at best. Furthermore, any conjectures that arise from SenseMaker analysis should be held lightly, verified collectively and tested adaptively through safe-to-fail experiments, and remain open to surprise.

4.5.2 Socio-technical considerations

Implications of the digital revolution easily crowd the space required for narrative research using electronic media. Miller and Horst (2013) warn that an implication of digital approaches is that possibilities of abstraction and quantification have expanded at the expense of social connection and face-to-face interaction. When people are asked to construct a micro-narrative on an electronic device, the effects of the technological acceleration may lead to a loss of depth and meaning. After years of narrative based sensemaking, Kurtz (2013) advises that narratives shared by participants who engage with the narrative collection process and have time to reflect on their narrative increase the utility of patterns revealed "by orders of magnitude". This awareness highlights the need to intentionally design the data collection process and train the interviewers to maximum effect. It is both tough and vital to create a liberating space where narrative work can take place (Polk, 2017).

The project team needs to consider information security controls and how to implement them. The software does not prevent anyone from reading the stories that participants asked to be confidential. Anyone with a project code can view the data through the Explore app. Project code access is therefore only available on request, and the project owner needs to ensure confidentiality of data by keeping project codes restricted. From a technology perspective, the SenseMaker apps currently appear to work more reliably on Apple than on Android devices. This can be overcome by only using the web interface for capture, as it is more platform agnostic or, consider to standardize the interface if the project allows, for example by providing interviewers with Apple iPad's.

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4.6   Conclusion

SenseMaker is a tool and method specifically designed to explore and make sense of complex emergent social patterns. Classical narrative research methods enable researchers to make sense of mind-sets, behavior and patterns of cognition; but, they are resource intensive and do not scale well. The SenseMaker tool brings mixed method benefits to narrative research for distributed ethnography. Moreover, it readily scales to allow many voices to be 'heard' and integrates narratives and ideation signifiers with numbers and patterns. It provides a visual synthesis of people's experiences, values or views relative to signifiers deployed for research. Insights that emerge from the sensemaking approach can inform strategic change interventions and used to monitor change over time. These insights can be a catalyst to stimulate the emergence of beneficial patterns and dampen undesirable patterns of behavior.

Particular consideration should be given to: a culturally appropriate and contextually grounded design of the signification framework and field tests; socially appropriate data collection strategies; and joint sensemaking sessions for participative knowledge construction.

SenseMaker presents a unique opportunity to explore the complexity of social dynamics within organizations. Insights derived from collective sensemaking may be used to nudge intractable contexts towards more beneficial futures.

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Chapter 5: Sensemaking as an approach for Resilience Assessment in an Essential Service Organization

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Declaration

The candidate came up with the idea for this study, devised the instrument, coordinated all arrangements to get the instrument online and execute the survey, performed all analysis, wrote up the results, as took the lead in writing the paper with input from Prof Biggs and Dr Preiser.

Abstract

Essential service organizations are increasingly interested in processes to assess and build their resilience to ensure an uninterrupted supply of services, such as electricity and water. This study applied a sensemaking approach to assess the composition of social resilience in a national essential service organization in South Africa, using the SenseMaker tool to collect narratives and surface patterns. The assessment involved respondents' sensemaking of resilience resources utilised, in response to a national emergency simulation exercise that infused conditions of equivocality. Findings indicate that participants utilised specified resilience resources, while general social resilience resources were better suited to the scenario. Furthermore, the participants' sense of coherence had a positive bearing on preparedness, involvement, and expectation of outcome. Thus, a strong sense of coherence in its members appears to be the organization's strongest social resilience resource. In particular, this study suggests that a sense of coherence can enhance resilience-thinking, inform resilience-building interventions, and be used as a measure of effective sensemaking for a resilience outcome. This study indicates that SenseMaker is a useful tool for assessing social resilience and can reveal opportunities for leadership interventions.

Keywords: social resilience; general social resilience; sensemaking; sense of coherence; resilience capacities; emergency exercise

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5.1   Introduction

Modern day society has developed a critical dependency on essential services, such as water and power provision (Rose et al. 1997). An alarming increase in extreme events, such as floods and hurricanes, is revealing the interconnected nature of these services, and the cost of disruption to society (Carreras et al. 2007; Hallegatte 2015). Although essential services are delivered via a technical infrastructure, they are produced by complex adaptive socio-technical systems (Varga 2015). However, resilient technical infrastructure is not enough to sustain service delivery in the face of extreme events; the social resilience of human and institutional processes, within which technical processes are embedded, is another prerequisite (Omer et al. 2014; Van der Merwe et al. 2018).

Essential service organizations are increasingly interested in assessing and building their socio-technical resilience. As an interdisciplinary concept, the notion of resilience is seen as an emergent property of complex adaptive systems and is defined as the ability to sustain core functions amidst disruption and change (Folke et al. 2010; Biggs et al. 2012). To promote continuous operations in the face of disruption, and speed restoration of critical services following disruption, the capacity for resilience can be assessed at systems-level to guide its development (Zolli and Healy 2012; Folke 2016)

Assessments of current resilience capacities can be undertaken to offer recommendations to enhance it. A recent framework to assess and build resilience of essential services identified four domains based on the target for investment (hard technical vs soft social infrastructure), and the distinction between specified and general resilience (Van der Merwe et al. 2018) (**Error! Reference source not found.**). Specified resilience aims to ensure that an identified set of components may be able to withstand identified threats, for instance time-critical business processes require business continuity plans to deal with the unavailability of key resources like technologies, or human resources (BCI 2010). In contrast, general resilience establishes systems-level flexibility to enhance coping capacity amidst unpredictable threats and surprises (Carpenter et al. 2001; Folke et al. 2010). While technical resilience is relatively well-studied, more research is required to assess and build social resilience within essential service organizations, such as the electrical utility that is the focus of this study (Figure 5-1).
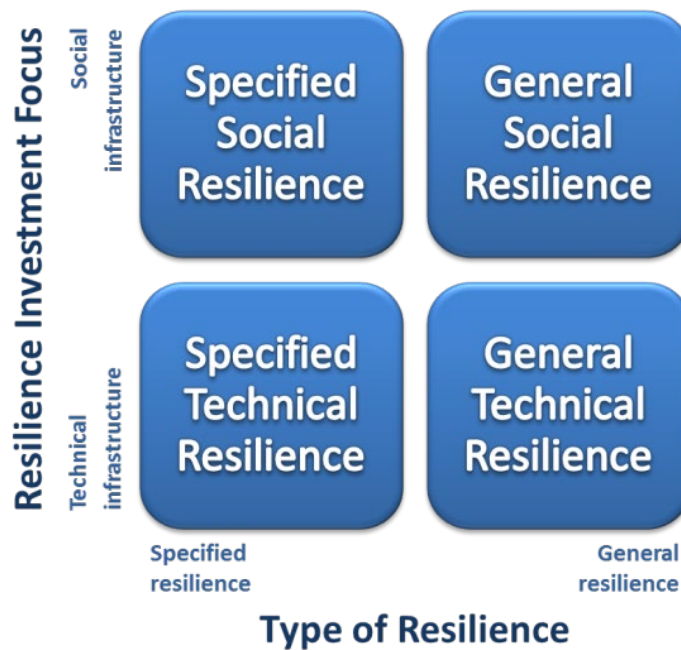
Figure 5-1 A conceptual framework differentiates between four domains of resilience to consider in building and assessing resilience of essential services produced by socio-technical systems (Van der Merwe et al. 2018).

Social resilience is the capacity to cope, adapt and transform, while sustaining well-being (Hall and Lamont, 2013). Enhancing social resilience can increase the proactive, adaptive and transformative capacities of an organization or community (Keck and Sakdapolrak, 2013). Social resilience resources include institutions, social structures, interpersonal relations, individual and collective sensemaking. Social resilience may enable essential service organizations to navigate between normal business management and times of disruption (Wybo, 2008). Within essential service organizations, specified social resilience is the capacity of specified people and processes to maintain continuity while withstanding specified threats, while general social resilience is the capacity to maintain continuity or rapidly restore service delivery amidst unknown and unforeseen disruption. Specified social resilience can be built through adherence to good practice disciplines for a predictable response capacity, whereas general social resilience requires wide-ranging social, cultural and educational competencies (Van der Merwe, Biggs and Preiser, 2018). Building general social resilience is therefore a strategy for dealing with uncertainty and complexity.

Systems level methods for social resilience assessments is an emerging concept (Lavelle *et al.*, 2015). Current approaches include: assessments of collaboration and adaptive management outcomes (Plummer and Armitage, 2007); adaptive capacity, institutional mechanisms and governance models (Engle, 2011); resilience in containing system and sub systems; exploration of slow and fast variables and of interdependencies on services and systems (Resilience Alliance, 2010); and social network analysis (Omer, Mostashari and Lindeman, 2014). These approaches all require expert exploration and analysis into specific

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areas of interest. In contrast, a sensemaking research approach can reveal patterns in a system based on participant perception, without requiring expert re-interpretation.

In this study, a sensemaking approach is used to assess collective social resilience owing to its ability to uncover patterns in people's perceptions within their socio-cultural contexts, including high-pressure environments (Milne, 2015; Cognitive Edge, 2017). Individual sensemaking involves an initial awareness of cues from the environment, how these signals are interpreted (or misinterpreted), and how the individual enacts the interpretation (Kudesia, 2017). Sensemaking studies reveal people's perceptions, or how they make sense of experiences in particular socio-cultural contexts (Kurtz and Snowden, 2007). Probing the way in which individuals and organizations as a whole respond under pressure can uncover the interpretations they make during individual sensemaking, which can reveal prevalent mind-sets that inform action. Insight from such an assessment can be used to pre-emptively identify factors that may aid or hinder future resilience outcomes.

This paper aims to assess the composition of social resilience within an essential service organization using a sensemaking approach. We do this using the SenseMaker tool, a software solution developed by Cognitive Edge that analyses patterns across many micro-narratives for research, monitoring or decision support (Cognitive Edge, 2018). The case study focuses on a large, national and vertically integrated electricity utility, which generates 95% of the power consumed in South Africa (Eskom, 2016). The resilience assessment was based on reflections from a country-wide emergency exercise that simulated an extreme event with complex interdependent failures. A sensemaking approach was used to reveal how employees in the organization made sense of the emergency situation and its multi-layered disruptive implications, in order to inform intervention strategies to increase resilience and improve organizational response to disruption. The specific objectives of the study were to determine:

1. The extent to which responders utilised general versus specified social resilience resources in dealing with the emergency situation.

2. The effect of participants' sense of coherence (Antonovsky, 1987a) on individual responses. The role of sense of coherence in sensemaking is discussed in the next section.

Before describing the method and indicators employed in the study, we provide a brief review of the factors that contribute to specified and general social resilience and that influence sensemaking. An understanding of these factors was used to design the SenseMaker survey instrument used in this study.

5.2   Sensemaking and sense of coherence

Effective sensemaking in a crisis is a prerequisite for effective emergency response from individual responders to the organization as a whole (Dekker et al. 2008; Casto 2014). Sensemaking is a continuous process of establishing situational awareness under conditions of uncertainty and complexity (VanPatter and Pastor 2016). Sensemaking becomes crucial when situations are unusual, unclear, or equivocal, and is therefore of particular importance to the resilience objective of navigating disruption without loss of critical systems function (Folke et al. 2010; Maitlis et al. 2013; Kudesia 2017). Sensemaking is an ongoing action-oriented cycle of acquisition and reflection that people go through to integrate experiences into their understanding of the world, which informs their action (Kolko 2010; Maitlis et al. 2013). While sensemaking often takes place subconsciously, the quality of sensemaking can be enhanced to improve the outcome of actions through conscious awareness of the sensemaking process and the underlying assumptions that inform it. Collective sensemaking requires mutual understanding through group norms and shared mental models towards collective action strategies. Effective sensemaking can be fostered through Boyd's observation, orientation, decision and action competences, commonly known as the OODA loop (Osinga 2005), and Weick & Sutcliffe's (2001, 2005, 2015) mindfulness practices for high reliability organizations.

In order to practise and enhance organizational sensemaking, organizations can perform emergency exercises that simulate disruption to provide exposure to rarely used procedures. Furthermore, the exercises can confirm the validity of response plans and the readiness of formalised structures to coordinate response and recovery (Wybo 2008). Emergency simulation exercises allow participants to engage with complexity, instability and uncertainty. Thus, they offer safe-to-fail opportunities to advance collective sensemaking and build social resilience into the organizational fabric. Sensemaking and social resilience are especially important in the context of low-probability, high-consequence events, where responders have limited opportunities to learn from personal experience to improve their response (Kunreuther et al. 2014).

Sense of coherence (SOC) reflects people's general resilience, i.e. their ability to cope and recover from crisis (Antonovsky (1987b). It is an internal viewpoint that affects perception and coping behaviour (i.e., sensemaking), through which they generally see the world as coherent and which can alleviate or aggravate the impact of stress (Almedom et al. 2007; Muller and Rothmann 2009; Eriksson 2016). This worldview provides innate strength coherent with the demands of their external environment and an aptitude for adapting to changing risk contexts (Lindström and Eriksson 2006; Zaidi et al. 2015). SOC is core to the

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salutogenic literature that focus on people's health, resources and well-being (Eriksson and Mittelmark 2016). The strength of SOC is influenced by upbringing and shaped by life circumstances, such as working conditions, and can be improved through intervention (Antonovsky 1987a; Veres-Balajti et al. 2014). SOC consists of the three interwoven dimensions of comprehensibility; manageability; and meaningfulness (Antonovsky 1987b; Lindström and Eriksson 2006). The strongest contributor to resilience is meaningfulness, i.e. the ability to perceive challenges as worthwhile to engage in (Antonovsky 1987a; Harrop et al. 2006; Lindström and Eriksson 2006).

SOC has been used to reflect social resilience amidst multiple challenges (Almedom et al. 2007; Braun-Lewensohn and Sagy 2014). Individual SOC has measuring scales with high reliability and validity (Eriksson and Lindström 2005). Measurement of SOC as a collective construct has been explored in families, communities, organizations, and nations (Elfassi et al. 2016). SOC is pertinent to organizations and often used in workplace assessment as it can affect the ability of employees to execute key tasks, particularly under conditions of stress and uncertainty (Muller and Rothmann 2009; Basińska et al. 2011; Idan et al. 2013).

5.3   Specified and general social resilience

The resilience, sensemaking and salutogenic bodies of literature respectively offer insight on how to build resilience to deal with different types of situations, and each make a distinction between dealing with routine versus unforeseen disruptive situations (Table 1). Specified resilience is required in response to foreseen eventualities, while general resilience is required to deal with unknowable unknowns. The sensemaking literature point out that these different contexts require distinct forms of organizational sensemaking and a fundamentally different nature of organizational coordination of action, while the salutogenic literature point out the different types of social resources that contribute to strong SOC and in these respective contexts prevent tension from being transformed into stress. Similarly specified and general social resilience resources are built and strengthened differently (Table 5-1), and building only one kind of resilience may erode the other (Resilience Alliance 2010; Sagy 2016). Since these resources contribute in different contexts, identifying the composition of resilience resources drawn upon in a specific context can provide insight on suitable resource utilisation and latent capacities. This insight can guide an organization to develop a balanced repertoire of resilience capacities.

Table 5-1 A general theme emerge when combining types of resilience, types of resources that contribute to strong sense of coherence and types of sensemaking contexts organizations need to respond to in order to coordinate action.

	Specified Resilience	General Resilience
Types of resilience	Specified resilience refers to the resilience of specified parts to identified disruptions, and is required to respond to foreseeable eventualities that unfold roughly as experts could predict, to return performance to the baseline. This capacity can be established through the adoption of good practice guidelines, leading to specified preparedness, pre-approved plans and verifiable capabilities, and is often produced to fulfil governance and compliance obligations (Van der Merwe, Biggs and Preiser, 2018).	General resilience refers to a system's ability to absorb disturbance and retain its function, and is required to deal with unexpected eventualities, especially to maintain essential functions amidst uncertainty of unpredictable disruption, even if a new equilibrium is established through the incident. This capacity emerge from an intangible capacity to withstand any hazards, including novel and unforeseen ones (Walker and Salt, 2012; Van der Merwe, Biggs and Preiser, 2018). It is tightly intertwined with adaptive capacity and the ability to self-organise (Holling, 1973; Carpenter *et al.*, 2001).
Different contexts require distinct forms of organizational sensemaking where the nature of organizational coordination of action is fundamentally different	In routine situations, where experience is meeting expectations, control and coordination can be exerted to improve organization, and respondents need to focus on established structure (Bakken and Hernes, 2010). Generically subjective understanding can be used to establish structural mechanisms (rules, habits & routines) for effective coordination of action, independent of who is involved (Weick, 1995; Kudesia, 2017).	In contingent situations, cues from the environment are equivocal, and require sensemaking to interpret its nature and meaning, and respondents need to focus on ongoing relational processes (Bakken and Hernes, 2010). Innovative new intersubjective understandings need to be developed to deal with the crisis at hand, which will be uniquely constituted by the actual people involved (Weick, 1995; Kudesia, 2017).
Types of social resources preventing tension from being transformed into stress and that contribute to strong SOC	Specific resistance resources are particular resources used to deal with specific situations or stressors, typically only drawn upon when required (Mittelmark, Bull, Daniel, & Urke, 2016), for example a specific helpline number. These resources consist of services, structures or capacities established through societal action (Mittelmark *et al.*, 2016).	Generalized resistance resources are characteristics with wide-ranging utility and regularly accessed that enable people to cope effectively with stress (Idan, Eriksson, & Al-Yagon, 2016), for example a social network to draw on. These characteristics arise from cultural, social and environmental conditions and socialization experiences (Eriksson, 2016; Sagy, 2016).

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A finite set of resources cannot be pin-pointed as necessary and sufficient to guarantee a resilience outcome, instead resilience has, what Podsakoff, MacKenzie & Podsakoff (2016) describe as a family resemblance concept structure. The resources identified for inclusion in this study were selected from a wide range of social resilience literature, areas of interest to the Eskom Enterprise Resilience Programme, and narrowed down in an iterative and participative manner among members of the Eskom Enterprise Resilience Team.

5.3.1 Specified social resilience resources

Specified social resilience resources enable predictable response to a disruptive event. Within an organizational context, a clear organizational mandate clarifies purpose and provides a focus for collective action in the face of disruption which may contribute to continuity of essential services. Adherence to this mandate can be used as a legal measure to evaluate response effectiveness in post-incident investigations (Abrams 2015). However, employees need to be assured that they have permission to act on this mandate.

It is also clear that technical expertise is required for individuals to succeed in their assigned line of duty (Schön 2016), particularly in the face of disruption. Competence can be verified against good practice guidelines. However, in periods of deep uncertainty, deep technical expertise needs to be accompanied by the ability to perform reflection-in-action (Schön 2016). Novel solutions emerge as a result of the interplay between knowing and doing (Wybo 2008).

Formal institutions in the organization clarify the rules of the game (North 1991; Wybo 2008). These include procedures and protocols that can be drawn upon in times of crisis. On the other hand, adherence to rules should not be too strong during periods of deep uncertainty. Instead of following protocol, employees need to adopt novel approaches, including positive deviance, to be resilient (Lindbert and Schneider 2012). However, this requires healthy levels of agency and self-organization, diversity of perspectives, and a flow of new information (Mertens and Recker 2017)

Preparedness should be established and can be verified through simulation exercises to evaluate and improve arrangements (Wybo 2008). This exposure builds up the required intuitive capacity to deal with foreseeable events. Pre-approved response plans and contingency arrangements formalise preparation and outline protocols to deal with disruption. Agents need to: (i) know about the various plans; (ii) understand when to evoke them; and (iii) have the capacity to execute applicable plans (Herbane 2010). Although plans rarely match the requirements of deep uncertainty, the planning process itself establishes shared mental models for a collective understanding of the big picture. Moreover, it fosters

collaboration through social network formation for distributed response capacities (Nickerson and Sanders 2014).

While specified preparedness is based on well-thought-out response plans, none the less, the context of a disruption is often different to that envisaged. Disasters can disable structures, leaving plans and procedures inappropriate (Kendra and Wachtendorf, 2003, quoted by Wybo 2008). When unforeseen crises threaten to overwhelm and destabilise organizations, general resilience becomes essential.

5.3.2 General social resilience resources

While specified preparedness is based on well-thought-out response plans, the context of a disruption is often different to that envisaged. Disasters can disable structures, leaving plans and procedures inappropriate (Kendra and Wachtendorf, 2003, quoted by Wybo 2008). When unforeseen crises threaten to overwhelm and destabilise organizations, general resilience resources becomes essential and enable an emergent adaptability.

Social networks are a key source of general social resilience (Moore and Westley 2011). When these networks are characterised by sufficient levels of mutual trust and social capital, they enable the flow of resources, ideas and people across boundaries. Furthermore, they provide invaluable innovation, problem solving and collaboration capacity in conditions of great uncertainty (Walker et al. 2006; Nickerson and Sanders 2014). To act in networks of trust people need to be empowered with appropriate levels of individual autonomy, thus agency is a vital contributor to social resilience (Bohle et al. 2009). Agency will ensure distribution of decision-making power in complex situations (Jones 2011). Employees need a sense of ownership, influence and agency to ensure business continuity amidst the uncertain complexity of disruption (Feldt et al. 2000).

Dealing with unexpected disruption requires a shared vision and understanding of the big picture. Shared mental models constrain collective action and are considered as an informal institution (North 1992). In order to increase the validity of the understanding that informs action, shared mental models of the systems context should be established prior to an incident. This would establish common ground that is crucial for collective situational awareness, distributed cognition and effective response (Nofi 2000; Doyle et al. 2015).

The ability to apply new thinking in a crisis is an important contributor to an effective resilience outcome. "Out-of-the-box" thinking in the heat of the moment requires deep expertise and the ability to rapidly act on decisions based on perception, pattern recognition and appropriate mental models (Doyle et al. 2015; Schön 2016). Highly tuned experts take

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years to develop the ability to perform "reflection-in-action", respond and lead in ill-defined situations of extreme pressure.

5.4   Method

5.4.1 Case Study

This case study draws on Eskom's Enterprise Resilience programme which was initiated in 2013 to establish specified resilience capacities across the national utility. Factors that contribute to general and specified social resilience were drawn from literature across multiple disciplines and narrowed down to a practical set of indicators through interviews with the utility resilience manager and exercise coordinator. The investigation set out to establish the composition of social resilience resource utilisation in response to a large scale emergency simulation.

A national simulation exercise was selected as the basis for the assessment owing to the levels of control that can be employed in exercise design. This study focuses on an exercise conducted on 3 October 2017 that simulated a major systems failure after an undetected infiltration of the IT network two months before. On the morning of the simulated emergency, employees experienced an unfolding simulated scenario of a targeted cyber-attack that affected mission critical systems. Initially administrators of a distribution management system noticed suspicious activity taking place on the electrical network. Users and administrators across the organization were blocked from accessing their systems. Before long, notices popped up on screens that workstations were encrypted, along with bitcoin payment details to have it restored. The attack cascaded into a national blackout. Although the organization had to perform a black-start and systematically restore the supply and demand balance across the country, communication failed owing to lack of power that affected restoration coordination. Unhappy customers broke out into protest action and vandalism at organizational sites across the country. This led to a damaged infrastructure, and stakeholders were dissatisfied with delays in restoration. The simulated scenario was believable, but unprecedented in terms of organizational experience, and thus, characterised by equivocality.

This type of context typically triggers sensemaking, and requires general resilience resources to deal with the disruption. The exercise required integrated responses across all functional divisions in the organization and provinces across the country, significantly different from normal business requirements. The simulation exercise took place at more than 40 venues across the country and involved the participation of teams of about 500 employees with operational, tactical and strategic oversight roles. The assessment also

evaluated the degree to which people felt that centralised service functions anticipated their support needs and delivered the required services. Having all supporting services centralised can improve business efficiency and yield global optimisation. However, this might introduce single points of failure that potentially affect all operating divisions requiring those services, as the ability to respond to disruption necessitates ready access to required resources (Zobel and Cook 2008; Hollnagel 2009).

5.4.2 The SenseMaker tool

SenseMaker[10] is a patented software solution and method for collective enquiry into the attitudes, perceptions and experiences of groups of people. It blends complex adaptive systems thinking, psychology and anthropology (Milne, 2015). People's narratives reflect their individual sensemaking. SenseMaker is a mixed-method that supports narrative-based action research, while analysis of the patterns in SenseMaker data can reveal nuanced identities, motivations and attitudes to support meta-level sensemaking (Deprez, Huyghe and Van Gool Maldonado, 2012).

A SenseMaker instrument consists of a signification framework designed around core construct, pre-determined by the researcher and based on the research questions. Participants are probed to recall and share a particular situation they experienced. They are also expected to give it a title and answer questions that identify where their narrative is positioned relative to the concepts in the signification framework. The inclusion of deliberate ambiguity and neutrality in the signification framework aims to produce nuanced perspectives and invite participants to cognitively engage and exercise judgement in order to locate their narrative relative to the signifiers. By interpreting their own micro-narratives through self-signification, participants provide the primary qualitative and quantitative data used in subsequent analyses (Deprez, Huyghe and Van Gool Maldonado, 2012). While there is a limit to the social factors that can be explored using such sensemaking, it can reveal perspectives typically concealed.

5.4.3 Instrument design

The web-based survey consisted of a prompting question that solicited a short observation from the simulation exercise that either gave the participant hope or scared them, followed by various questions that asked respondents to signify meaning in relation to their

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[10] SenseMaker® is Software as a Service, available through Cognitive Edge, of whom Prof David John Snowden is the founder and chief scientific officer (Cognitive Edge, 2018).

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observation. The signification framework solicited feedback on the resilience indicators in **Error! Reference source not found.**2.

Table 5-2 Social Resilience indicators employed in the assessment

Specified Social Resilience indicators	General Social Resilience indicators
o Established preparedness o Direction from a mandate o Technical competence o Guided by rules & procedures o Response plans to follow	o Sense of coherence • Ability to make sense of new situations • Ability to manage in new situations • Ability to find meaning and purpose o Strong social networks • Cooperation within teams • Coordination with other functional teams • Centralised service functions anticipate support needs and deliver services o An understanding of the big picture o Permission to act o The ability to apply new thinking in crisis

The survey was designed to capture the aspects in Table 5-3 using triads, dyads, stones and multiple choice questions:
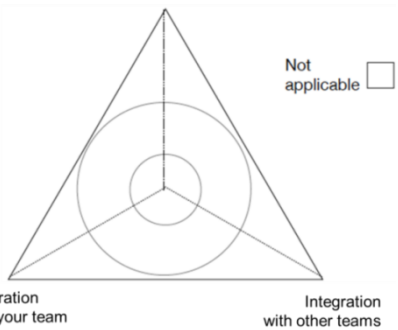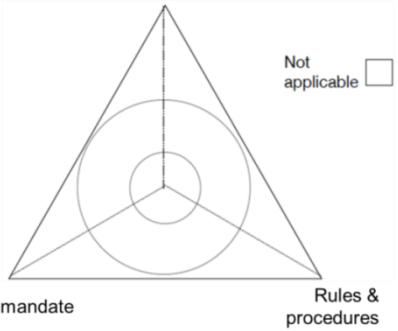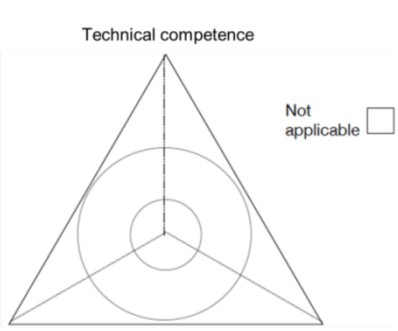
- Triads invite responders to indicate relative weight among three equally balanced concepts (Deprez, Huyghe and Van Gool Maldonado, 2012). Balanced concepts reduce incidence of response bias as there are no right or wrong answers. In the centre of the triangle, concepts have equal weight, while the closer to a corner the heavier that concept relative to the other corners (Refer to Table 5-3 Aspect 2 to see how triads were employed). The three results returned by the instrument for the three corners will always add to 100; thus, values from a triad are constrained among three variables (Figure 5-2). Triads were used to establish behavioural patterns across the system by asking responders to indicate the relative strength of specified vs general resilience indicators employed in their observation.

- Dyads are used to establish a distribution pattern around Aristotle's 'golden mean' relative to polarities of extreme absence and excess. It is used to test the effect of modulators, disguised hypotheses, or levels of perceptions (Deprez, Huyghe and Van Gool Maldonado, 2012; Guijt, 2012). The result range is from 0 to 100. Perceptions about the effort that people felt they put into preparation and levels of SOC as a resilience modulator were measured using dyads (aspects 3 and 6 from Table 5-3 employed dyads.) Standard SOC scale instruments include those adapted for large population surveys based on only three questions (Lundberg and Peck, 1995; Schumann *et al.*, 2003). A novel approach in this exercise was to employ three dyads as an indication of SOC, not the standard Likert-based surveys.

- Stones represent named markers that are placed inside a canvas, where space has associated meaning based on the named axes. The relative location of the stones to one another reveals the participant judgement. The result for each stone returned by the instrument consists of a set of Cartesian coordinates each ranging from 0 to 100. (Aspect 4 from Table 5-3 employed stones). Triads are abductive and descriptive, while dyads and stones are inductive and evaluative (Guijt, 2012). Stones were used to establish perceived levels of support and service participants enjoyed during the execution of the exercise.

- Multiple choice questions are used to collect demographic data and allow for the visualisation of patterns within the data. Demographic data were used to understand the function and role of participants in the exercise and the organization. In this example analyses can also be colour coded in terms of: reported emotion; perceived preparedness; or for how long respondents will remember the incident. (Aspects 1 and 5 from Table 5-3 employed multiple choice questions.)
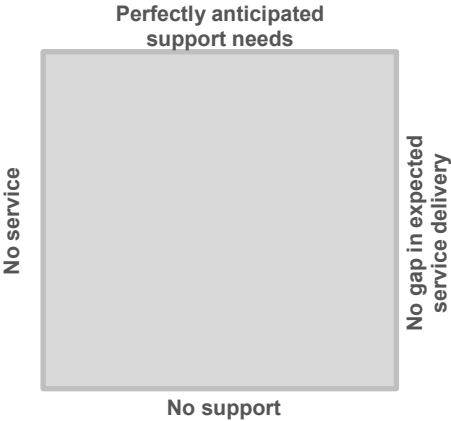
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Table 5-3 Aspects evaluated by the instrument and an illustration of what the signifiers looked like to participants on the web page

Aspect to evaluate	Signifiers utilised in the instrument design
Their response	Think back to an experience in the exercise that either: (choose one) o scared you, OR o gave you hope regarding Eskom's ability to respond to challenges. Briefly describe what happened: _____ If your entry above had a news headline what would it say? _____ How long will you remember this observation for? o Trivial, will forget soon o For a long time o For some time o For a lifetime

Table 5-3 Aspects evaluated by the instrument and an illustration of what the signifiers looked like to participants on the web page

Aspect to evaluate	Signifiers utilised in the instrument design
Specified or general resilience resources participants employed during their response	**Triad 1:** In your observation the quality of response was influenced by… Established plans Not applicable ☐ Cooperation within your team Integration with other teams **Triad 2:** In your observation people were led by… Applying new thinking Not applicable ☐ Their mandate Rules & procedures **Triad 3:** Peoples' sense of empowerment was impacted by… Technical competence Not applicable ☐ Permission to act Understanding the big picture
Views on levels of preparedness in the organization to effectively deal with the scenario encountered	This observation shows that Eskom's preparedness to deal with an incident is like … Not Applicable ☐ We haven't lifted a finger We haven't left a single stone unturned

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Aspect to evaluate	Signifiers utilised in the instrument design
Indicators for the strength of social networks: cooperation within teams; coordination with teams from other areas; and connectedness among functional areas that need to effectively cooperate to respond to large scale emergencies	Aspects from Triad 1, as well as this stone tool: Based on your observation, place these functions on the colour canvas based on the actual service and support you received from them on that day. Leave out the ones you did not need, or tick N/A if you did not need any of them. o Commercial o Human Resources o Information Technology o Real Estate o Security o Telecommunications o N/A Perfectly anticipated support needs No service No gap in expected service delivery No support
Relative to how they saw challenges in the exercise	If this scenario was real you foresee it could have resulted in (Choose the top 3 that apply to this situation) o Total confusion o Successful recovery o Site shuts down o Eskom survives intact o Loss of governance o SA survives o Complete disintegration o Eskom seizes opportunities & thrives o Eskom ceases to exist o Don't know o SA fails / collapses
Sense of coherence as participants' assessment of how they normally cope with stress and disruption	To give us a glimpse on the overall manner in which you deal with tension and stressful situations, please indicate your general approach to life's challenges along these sliders: You have what it takes, or know where to get what you need, to manage situations Always Never Not Applicable You feel that you are in an unfamiliar situation, can't make sense of it, and don't know what to do Always Never Not Applicable

Aspect to evaluate	Signifiers utilised in the instrument design
	You have the motivation to make a difference to situations, and can see the meaning of your contribution as worthwhile Always ⟷ Never Not Applicable ☐

Since we recognise the value of SOC as a resilience measure, and resilience is required to deal with complexity (Plummer and Armitage, 2007; Folke, 2016), we operationalise SOC's comprehensibility as the ability to make sense of unfamiliar situations. Antonovsky (1993) motivates the usefulness of SOC in dealing with complexity and conflict; however, his SOC scale equates comprehension with predictability, a correlation criticised by Flensborg-Madsen, Ventegodt, & Merrick (2005) as being too narrow an interpretation to do justice to complexity.

5.4.4 Data Collection

Participation in the emergency exercise was based on predefined roles and responsibilities of employees into emergency response structures in the various divisions across the value chain. Observers were placed at every location where emergency response structures had to be activated to monitor response countrywide. A few days after the exercise, all participants and observers who signed the exercise attendance registers were electronically invited to participate in the SenseMaker study on an anonymous and voluntary consent basis. The invitation pointed to a webpage which prompted them to reflect and share an observation that stayed with them following the exercise. Over a period of one month, 87 entries were received – a response rate of 17.4%, leading to a confidence level of 85% with a 7% margin of error.

The response rate was low as data collection was only initiated a few days after the exercise to guarantee retrospective sensemaking (Kolko, 2010), Reflection-in-action is characterised by little thinking space and takes place in the heat of the moment. On the other hand; reflection-on-action involves recollection and reflection on past events (Schön, 2016). In an unpublished 2015 study, using the SenseMaker tool during a national exercise in the same utility, reflection-in-action responses yielded high levels of participation but appeared shallow and optimistic compared to responses from reflection-on-action. Allowing participants to cool down before inviting their participation holds the risk of fewer participants but can lead to potentially more thoughtful observations.

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5.4.5   Analysis

Analyses were performed using SenseMaker Explorer version 2.5, the online SenseMaker Analyst, and Microsoft Excel 2010. The quantification between specified and general resilience resources was derived from the responders' interpretation of the relative utilisation of respective resources to the emergency response. The resilience assessment was based on systems-level usage patterns of responders' reliance upon specified versus general social resilience resources. Patterns across the library of micro-narratives were visualised graphically, while patterns across the signified indicators were tested statistically using T-tests. A geometric mean was used to determine central tendency of the data to equalize the ranges among widely different values (DeLong, 2016).

5.5   Results

The results from the SenseMaker survey provide insight into the reliance on specified vs general social resilience resources during an emergency, and the effect of a SOC on participants' responses.

5.5.1 Reliance on specified versus general social resilience resources

The results show that responders utilised specified social resilience resources more than general resilience resources (Table 5-4). At the same time, there was greater variability in the use of different general resilience resources than in specified social resilience resources. With regard to general social resilience capacities, understanding the big picture was strongest, while permission to act straggled behind all other indicators. Among the specified resilience capacities, adhering to rules and procedures came out strongest. Direction from a mandate was the weakest resource, particularly among responders working at local sites, for example power station operations.

A comparison of ranked triad values shows usage pattern clusters, and distribution between low and high strength of the different resilience indicators, grouped into the three triads (**Error! Reference source not found.**2). Results for permission to act were bunched together very low. A mere 8% reported that having permission to act contributed to the quality of response, and the 75th percentile of permission to act is below the mean of all the other indicators. Integration with other teams and the capacity to apply new thinking was poor. Although the central tendency for being led by rules and procedures was ranked highest among all variables, its distribution pattern is both irregular and widest between the 25th and 75th percentile. Indicators reflecting strength of social networks, in descending order, were reported as follows: (i) service functions could anticipate the support they needed to

provide; (ii) service functions delivered the services required of them; (iii) cooperation within teams; and (iv) coordination with other teams.

Table 5-4 Among the triad derived resilience indicators (colour coded from lowest value in red to highest in green) specified social resilience resource were drawn upon more readily on average than general social resilience resource during response to the simulation exercise.

Specified Social Resilience resources		General Social Resilience resources	
Guided by rules & procedures	33.8	An understanding of the big picture	31.9
Technical competence	28.8	Cooperation within teams	28.4
Response plans to follow	22.7	Coordination with other functional teams	20.7
Direction from a mandate	22.3	The ability to apply new thinking	17.5
		Permission to act	16.8
	26.9		23.1
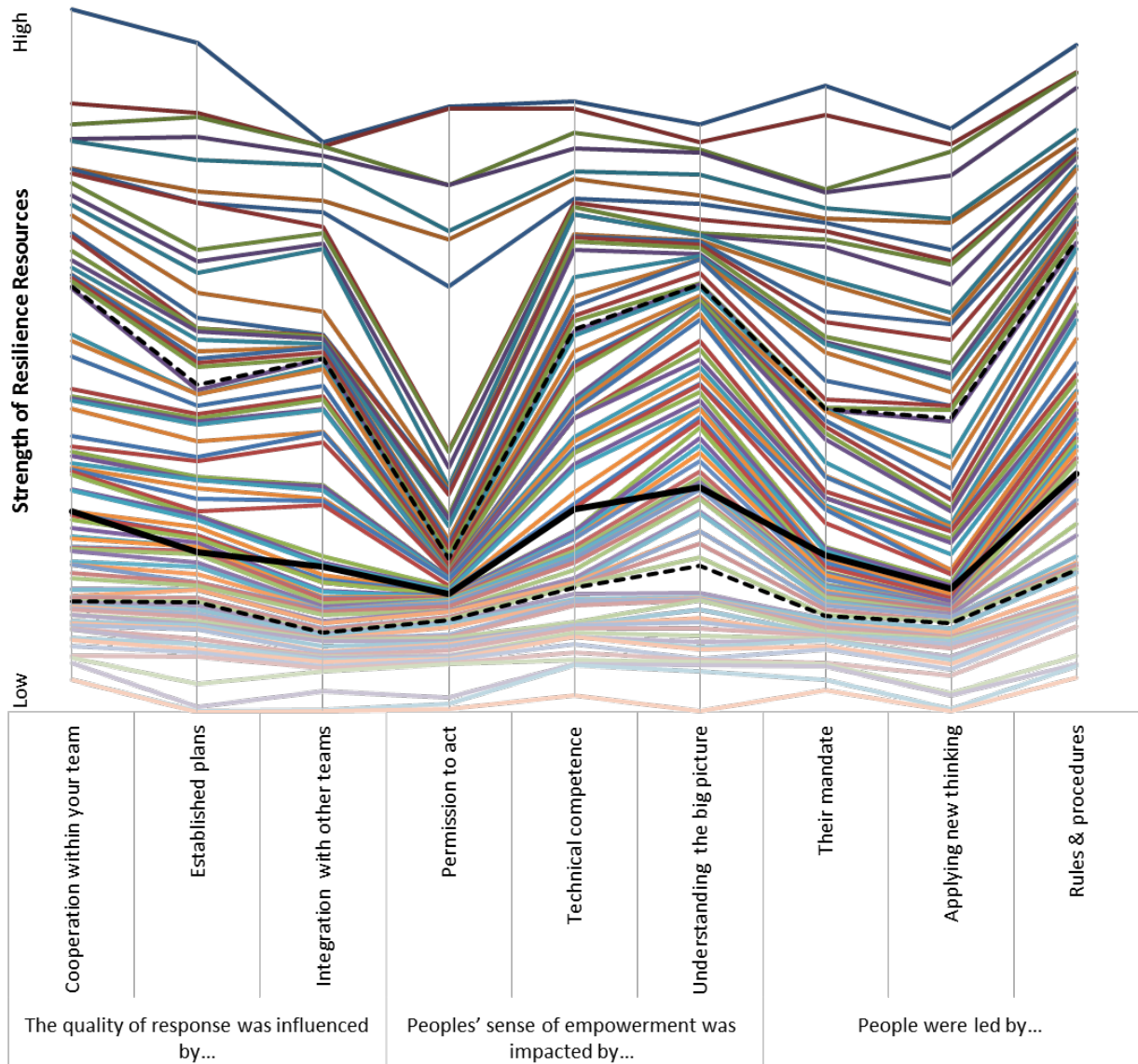
Figure 5-2 To illustrate relative usage patterns within and across different social resilience indicators, values were ranked within each indicator, grouped in their respective triads, and joined to highlight distribution patterns. The lines are ranked from dark as highest contributing strength, to light as low contribution. The solid black line represent the geometric mean, and the black dotted lines the 25th and 75th percentile.

5.5.2 Effect of sense of coherence on response

Levels of preparedness (specified social resilience indicator) and SOC levels (general social resilience indicators) were derived from dyads and only had an indirect effect on the exercise as preparedness was made beforehand, and sense of coherence refer to a general tendency, rather than specifically on the day. Respondents rated the three SOC dyads much higher than the contribution from effort invested to establish preparedness (Table 5-5). Purposefulness was strongest, followed by comprehensibility with manageability lagging just slightly behind. Statistical correlations, using a T test at the 0.05 level, showed a significant difference in the SOC meaningfulness score between those who were hopeful (x=80.33, n=63, p=0.032) versus those who were left scared (x=73.59, n=22, p=0.032) by their

observation. Similarly, a significant difference was evident in the SOC manageability score between those who foresaw that the country could fail and the economy collapse (x=72.88, n=8, p=0.034), compared to those who foresaw the country would survive (x=80, n=26, p=0.034).

Table 5-5 Dyad results show levels of sense of coherence was rated much higher than the effort invested to establish preparedness.

Specified Social Resilience resources		General Social Resilience resources		
Established preparedness	55.4	Comprehensibility	Sense of coherence	74.9
		Manageability		73.7
		Meaningfulness		77.5
	55.4			75.4

No relationship was observed between people's overall SOC and their preference for specified or general resilience resources. Nevertheless, micronarratives in the empowerment triad revealed that the higher their individual SOC levels, the more people felt empowered to act when they understood the big picture (**Error! Reference source not found.**5-3). Furthermore, the handful (8%) of respondents empowered to act, had SOC levels on the 75th percentile. People with a healthy SOC were led by their mandate and adhered to rules and procedures as opposed to those who applied new thinking in action.

Juxtaposing views of preparedness along the horizontal axis and the combined SOC along the vertical (Figure 5-4) revealed that the majority of respondents with a high SOC prepared well. However, a number of the employees who felt that the experience scared them professed little preparation and lacked emergency response capacity.

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Peoples' sense of empowerment was impacted by…
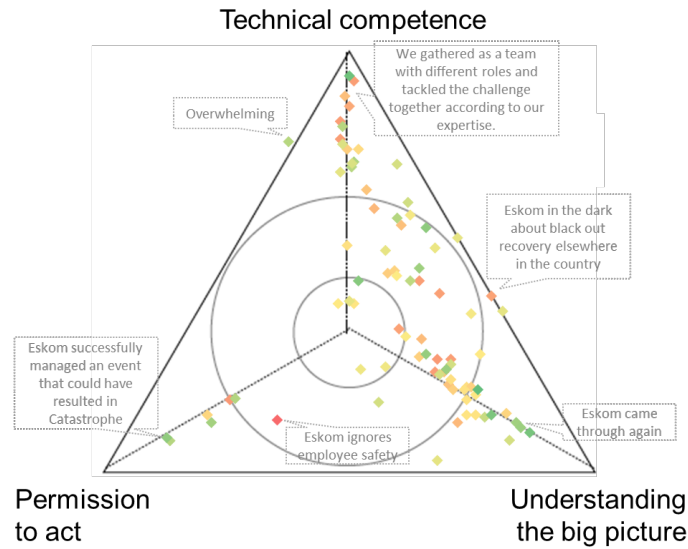
Figure 5-3 Micronarratives in the empowerment triad show the source of being empowered to act amidst the emergency. Narratives are colour coded by sense of coherence from low (in red) to high (in green). Few people felt they have permission to act, and people with higher levels of SOC reported a better understanding of the big picture.
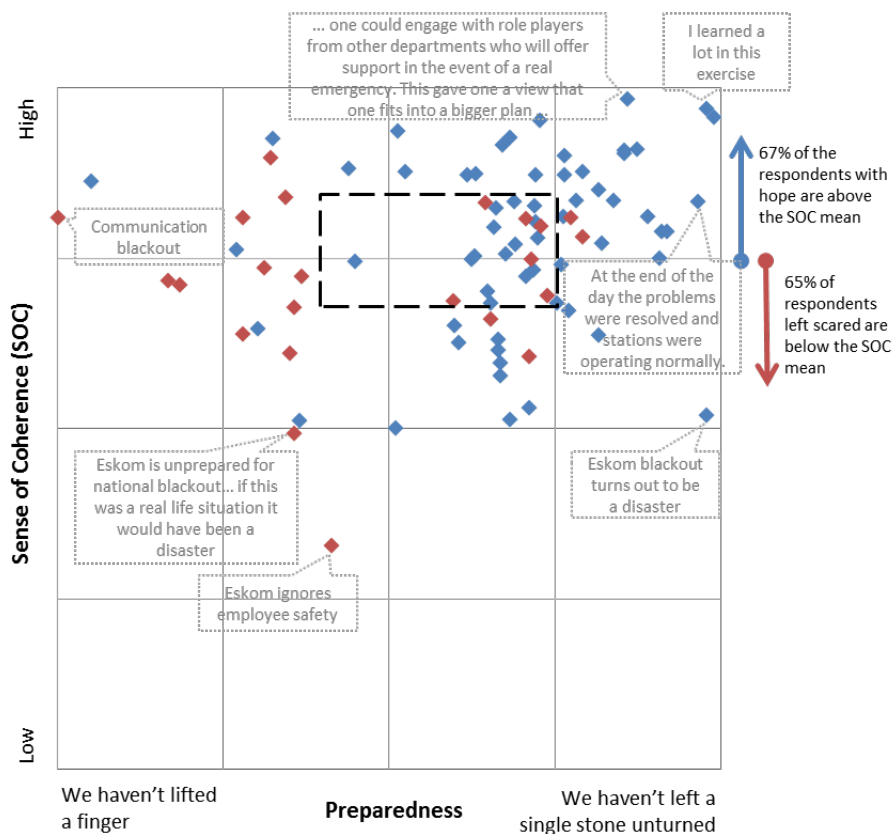
Figure 5-4 Scatter plots of levels of preparedness relative to levels of sense of coherence. Data points are colour coded by the emotion participants felt based on what they saw: red if scared and blue if they have hope. The black dotted line box on the graph indicates the area between the 25th and 75th percentile of both axes. Micro-narratives are shown at selected data point to illustrate the stories behind the data.

5.6   Discussion

The aim of this study was to assess social resilience within an essential service organization that delivers electricity. Organizations like these have a duty to establish resilience (Park et al., 2013). In the case of electricity, an extended interruption of supply often affects customers beyond the initial area of impact, as illustrated by remote customer outages up to three weeks after Superstorm Sandy (Lacey, 2014). The assessment was based on an emergency simulation exercise, which tested response preparedness and provided an invaluable opportunity for assessing resilience to extreme events. This section discusses the key findings from the study in terms of resilience and also SOC (Fiure 5-8). We conclude with a reflection on the limitations of the study and directions for future research. The approach advocated in this study may prove useful for assessing resilience on the part of essential, ecosystem-based or community services organizations interested in understanding the balance of specified and general social resilience resources utilised in response to specific events.

5.6.1   Reliance on specified versus general social resilience resources

As far as we are aware, this is the first study that has attempted to quantify and compare reliance on general versus specified social resilience resources in a particular context. Owing to the dynamic nature of systems resilience, there are no agreed upon measures to reduce this complex notion to numbers (Quinlan et al., 2015). Quantitative systems-level resilience measures exist for specific types of resilience, such as: community disaster resilience; adaptive capacity and resilience planning strategies; engineering resilience of networked infrastructure systems; and supply chain resilience (Zobel and Cook, 2008; Reed, Kapur and Christie, 2009; Frazier et al., 2013; Lee, Vargo and Seville, 2013). However, the social components of complex systems are not readily reducible to resilience metrics (Walker et al., 2004). This study used a novel sensemaking approach to distil social resilience indicators, indicative of the type of social resilience resources drawn upon in a particular context. This approach prompted participants to interpret the type of resilience resources enacted in their response. In line with research conducted by Quinlan, Berbes-Blazquez, Haider, and Peterson (2015), this case study illustrates an assessment context where resilience measures might contribute to a deeper understanding of system dynamics.

The study recognize that the equivocality of the scenario in the emergency simulation called for a degree of general social resilience resources to be drawn upon, while the results suggest that responders relied more on specified social resilience resources than general social resilience resources (Table 5-5). Weick, Sutcliffe & Obstfeld (1999) advocate organizations to deliberately create and maintain multiple modes of paradoxical response

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and decision making capacities to contribute to problem solving. Although specified resilience involves vital resilience competencies easier to establish than those of general resilience, they may have limited usefulness in confronting the unknowns of extreme events. Specified resilience resources that were drawn upon resulted in imbalances, owing to the simultaneous underutilisation of general social resilience resources. In fact, the latter would have been more appropriate in dealing with the equivocality of the scenario. It is essential that an organization has the flexibility to shift between the two sensemaking modes identified by Weick (1995) to enable utilisation of the different types of resilience. The implications are unpacked below but do not hold well for the social resilience of the essential service organization in question if it is unexpectedly confronted with Taleb's (2007) black swan.

It is essential that an organization has the flexibility to shift between the two sensemaking modes identified by Weick (1995) to enable utilisation of the different types of resilience. In spite of relatively strong levels of technical competence, respondents were unable to innovate by applying new thinking to the crisis. This appears to be due to a perception of not having permission to act with self-determination. This view is known to erode individual agency and impact organizational response in the heat of an emergency (Bohle et al. 2009; Brown and Westaway 2011). A commitment to *"do something"* in crisis hinges on: intuition established on deep expertise; the ability to perform reflection-in-action; and, notably, agency to act (Wybo 2008; Schön 2016). A perception of not having permission to act, results in a crisis of confidence that compromises the mind and erodes cognitive performance (Mullainathan and Shafir 2013; Schön 2016). Reflection-in-action is produced when technical expertise is accompanied with the required levels of confidence. This may lead to vital creativity and novel solutions in uncertain and complex situations (Schön 2016).

A strong preference for compliance to rules and procedures often accompanies a perception of not having permission to act (Fiure 5-3 & Table 5-4). This suggests that employees prefer to play safe and by the book, rather than trying something novel and being reprimanded for stepping out of line. Reliance on established structures indicates an organizational response that is expected of routine situations, but may be inadequate to contingent situations (Bakken and Hernes, 2010)(Table 5-1). However, the contingent situation required organizational coordination that focuses on ongoing relational processes and develops unique and innovative intersubjective insight in dealing with the crisis at hand (Weick, 1995; Bakken and Hernes, 2010; Kudesia, 2017). Strong institutional rules result in habitual responses that lack deliberate intent. This situation can be described as "lock-in" as it stifles adaptability and effective responses to complexity (Fleetwood, 2008; Uhl-Bien and Arena, 2017). Unfortunately, rote rule following, especially in periods of uncertainty, causes inflexibility and may contribute to unsafe outcomes (Dekker, 2015). In crisis situations, rules

and procedures might need to be broken to prevent cascading failure (Wilkinson, 2006). Empowering leadership should encourage positive deviance, which contributes to improving performance and achieving goals on an ongoing basis (Mertens and Recker, 2017). However, expecting this level of agility of the organization in question, may require institutional transformation (Fleetwood, 2008).

Established preparedness and pre-approved plans may be nullified when the reality of an incident invalidates planning assumptions. Respondents in the study realised that standard procedures were inadequate for the challenges of the scenario; yet, they failed to take direction from their mandate to self-organise. Employees, especially those involved in operations at local sites, need to be encouraged and empowered to act on their mandate when the confusion of a crisis nullifies pre-approved plans (Fiure 5-4). Adaptive action that results from the ability to self-organise is a crucial resilience enabler (Bohle, Etzold and Keck, 2009; Brown and Westaway, 2011; Zolli and Healy, 2012).

Eskom seems to lack quality integration across functions, as there was poor cross functional coordination and service delivery. When a complex system undergoes large-scale disruption, the effectiveness of social response is related to strong social networks (Nickerson and Sanders 2014). During extreme events, response teams need to maintain a shared understanding of the big picture and to be dynamically in step with the unfolding situation to enable a flow of resources, ideas and people across the social network to match the demands of the moment (Nofi 2000; Casto 2014). Despite understanding the big picture, the low levels of integration with other teams, indicated that insight did not lead to action across the value chain. A similar pattern was revealed in service delivery, where functions were better at anticipating the required support than in delivering them. Due to the functional silos in the organizational structure, connecting across the value chain is not normal. In fact, this integration capacity is required to deal with large scale extreme events and emergency simulations where social networks enable distributed coordination (Militello et al. 2007; Uhl-Bien and Arena 2017). Thus, general resilience may be built by strengthening individual agency and connectivity across the value chain.

Institutional structure can erode individual agency and participants in the study demonstrated a sense of disempowerment and a strong preference for sticking to rules. A possible contributor to this state of affairs is an institutional metaphor prevalent in the organization of a safety focus that combines "zero harm" with "zero tolerance", where failure is followed by finding fault and pin-pointing dismissible offenses. This mode of justice erodes perceptions of empowerment, attributed by Himmelstrand & Archer (2002) to downward causation. However, it is known that systems-level safety does not improve by blaming those at the

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sharp end for failure (Flin, O'Connor, & Crichton, 2017; Weber & Dekker, 2016). A just culture focuses on empowering people to learn from failure and emphasises restorative justice rather than retributive justice (Dekker, 2007; Dekker & Breakey, 2016). Inayatullah (1998, 2005; 2015) proposes that deep and lasting organizational change requires: metaphorical transformation; the critical examination of current worldviews, metaphors and myths in use; and the deliberate design of metaphors that align with a desirable future.

Our results suggest that valuable general social resilience resources are underutilized in Eskom at present, especially the intrapersonal resilience competency of purposeful agency. However, as the patterns described are symptomatic of organizational level issues, interventions aimed at individual level factors are likely to increase frustration and feelings of powerlessness (Wallerstein, 1992, quoted by Harrop et al., 2006). The organizational culture and socio-political context shapes choices made in the system, and pathways should be explored to transform the organization's social context (North 1991; Mullainathan and Shafir 2013). Leaders that engaged in building resilience are agents of transformation (Walsh-Dilley and Wolford 2015). Uhl-Bien and Arena (2017) describe enabling leadership principles and practices that nurture and fuel the emergence of adaptive responses in a system.

5.6.2 Effect of sense of coherence on response

The findings of this study suggest that a sense of coherence (SOC) has an effect on participants' responses to the emergency simulation. These results confirmed deductively a hunch detected abductively after Timmermans & Tavory (2012), through the combination of previous field studies to assess resilience using SenseMaker in the same organization, and two different theoretical frameworks: that effective sensemaking in the moment of crisis is necessary for a specific resilience outcome (Weick, 1988, 2010); and that sense of coherence is a measure that predicts a general resilience outcome (Antonovsky, 1987a, 1987b).

While the SenseMaker signification framework was used to reflect responses on the day of the exercise, the SOC indicators were used to reflect general stress responses. Participants with a high SOC were prepared to face the scenario. Moreover, they foresaw success in the outcome and retrospectively felt hopeful about the future. The few individuals who were confident about their permission to act had a high SOC score; and just as their understanding of the big picture increased, so did their SOC levels. This confirms the literature that SOC levels affect perception and event assessment and are an incentive to action in the face of difficult tasks and assignments. In addition, high SOC levels enable individuals to cope with difficulty and to effectively use mental models and competences

(Harrop *et al.*, 2006; Basińska, Andruszkiewicz and Grabowska, 2011). On the other hand, those with low SOC scores were not prepared and scared by the experience. This is consistent with the literature that shows that low SOC levels expose people to detrimental work-related patterns of behaviour, stress and professional burn-out (Antonovsky, 1987a; Basińska, Andruszkiewicz and Grabowska, 2011).

Although specified social resilience resources were utilised more than general ones on the day of the exercise, the results suggest that the latter may contribute more to the overall levels of social resilience of the organization, owing to high levels of individual sense of coherence (Table 5-5). Thus, emergency response role allocation should consider individual SOC, and cultivated collectively throughout the organization. This proposal aligns with past studies in essential service organizations conducted among nurses and social workers across several hospitals and in a psychiatric in-patient unit. These research projects considered the SOC levels of a selection of workers and aimed to carry out intervention strategies to advance individual and collective SOC. The researchers recognised that workers with a high SOC were able to muster adequate resources to adapt in the face of insurmountable problems amidst difficult working conditions (Basińska, Andruszkiewicz and Grabowska, 2011; Idan, Braun-Lewensohn and Sagy, 2013). In light of this research, we propose future research on cultivation of a collective SOC rather than individual level interventions.

The SenseMaker results of this study showed that purposefulness is the strongest of the SOC resources and that it contributes most to resilience (Feldt, Kinnunen and Mauno, 2000). Moreover, purposefulness is tightly interwoven with agency, values and responsibility (Tappolet, 2016). Thus, commitment to shared values is key to resilience leadership and impacts attitudes and motivation in the organization (Duman, 2017). We suggest cultivating purposefulness as a catalyst to stimulate the emergence of general social resilience within the organization that features in this study. However, this intervention requires enhancing levels of empowerment that is essential to an individual's sense of meaningfulness (Feldt, Kinnunen and Mauno, 2000).

5.6.3 Management implications for building general social resilience through investments in SOC

We suggest that there may be more value in the application of the salutogenic model for building resilience of social systems, including essential service systems in the face of climate change or disaster. On the one hand we suggest that SOC may be interpreted and applied as a three-dimensional sensemaking capacity towards a more resilient outcome.

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Someone with a high sense of coherence (1) cognitively makes sense of the dynamic and unpredictable context; (2) makes sense of accessing the resources required to resist and cope (3) makes emotional sense of their ability and motivation to act with purpose. On the other hand these SOC constructs correlate with the cognitive, interpersonal and intrapersonal competencies identified by the National Academy of Sciences (2017) to be assessed and strengthened in students towards college success and personal resilience. Furthermore, formative assessments have been suggested as a means to develop these cognitive, interpersonal and intrapersonal competencies (Linquanti 2014).

During the study, the SOC dimensions became a way of making sense of themes throughout the assessment. We found SOC at systems-level to be significantly different from the sum of the individuals in the system; results confirmed by Sagy (2014) and Mana et al. (2016). However, each of the resilience resources utilised in the signification framework contributes to one of the SOC dimensions (Table 5-6). Collective SOC measurements have been developed for families and communities based on the degree of consensus among members with regard to their perceptions of group comprehensibility, manageability and meaningfulness (Braun-Lewensohn and Sagy 2014). We explored an alternative approach by evaluating current organization-level SOC capacities against the identified competencies based on the results. Using thematic correlation we describe these systems-level social resilience capacities required in a socio-technical system to face unforeseen disruption as follows: (1) Key actors across the system exhibit a tacit cognitive capacity to make sense of the dynamic context in a crisis, share a collective understanding of the big picture, and demonstrate the ability to apply new thinking in crisis. (2) The overall response demonstrate quality social network integration, that enable flow across these connections through which people can access the resources required to manage in a complex incident and to cope. (3) People exhibit emotional maturity, commitment and volition to act upon their values and contribute amidst the difficulties and challenges posed by the situation. Using this categorization we performed a high-level assessment of systems-level response patterns during the incident (Table 5-6). Furthermore, suggestions have been made to enhance collective resilience capacities (Table 5-6).

Table 5-6 Correlations emerged retrospectively between the resilience resources and the SOC dimensions which opened up new approaches to assess and build resilience across the system

SOC construct	Resilience resources used in the framework and associated ideas from the literature	Assessment of organization level capacities	Ideas to enhance collective resilience capacities
Comprehensibility	An understanding of the big picture o Situational awareness o Appropriate mental models of systems functioning and behaviour o Distributed cognition The ability to apply new thinking in crisis o Ability to reflect-in-action o Deep expertise based on years of experience o Mental models and pattern matching o Utilise tacit knowledge o Bring creativity into crisis situations	o Understanding not followed by action o Poor cognitive sensemaking of the overall situation o Weak collective comprehension o Lack of creativity in response.	o Active development and promotion of shared mental models and guiding heuristics (Dekker et al. 2008; Doyle et al. 2015) o Guidance of collective response to low-probability, high-consequence events in training and through emergency simulation exercises (Kinder and Stewart-Harawira 2018)
Manageability	Strong social networks o Social capital & mutual trust o Anticipation of support needs o Delivery of required service by centralised service functions o Distributed cognition through shared mental models o Connected strength through links between nodes, not robust nodes per se	o Inadequate cross functional integration and weak social networks o Less ability to allow the flow of resources where required in crisis o Compromised levels of overall manageability	o Enlargement of the adaptive space to allow flow of resources through the social network (Uhl-Bien and Arena 2017) o Building of mutual trust across functional silos o Engaging in cross functional simulation exercises and board games that stimulate strategic cooperation (Wybo 2008)

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SOC construct	Resilience resources used in the framework and associated ideas from the literature	Assessment of organization level capacities	Ideas to enhance collective resilience capacities
Meaningfulness	Permission to act o Personal agency o Commitment to "do something" o Ownership o Empowered to act given a mandate	o Low levels of: empowerment and agency o Lack of commitment to do what it takes o Erosion of emotional ability to make sense of challenges o Compromised levels of collective meaningfulness.	o Empowerment of respondents o Provision of reassurance of being allowed to do what is required when necessary, and of valuable contribution in making a difference to society o Cultivation of view of resilience challenges as worthy of investment and engagement (Pel et al. 2016)

Hereby we can categorise all the general social resilience resources we used in this study into (1) cognitive competencies from cognition; (2) interpersonal competencies from connection; and (3) intrapersonal competencies from contribution. These correlations emerged retrospectively and open up new approaches to assess and build resilience across the system, as well as an alternative view on systems-level resilience competencies. This leads to a visual summary of the overall approach as outlined in Figure 5-5 where prior preparedness established towards specified social resilience leads to a more predictable response, while the SOC competencies contributes to general social resilience which enables an emergent adaptability. While specified social resilience resources are objective, this study suggests that subjective resources play a key role in general social resilience.
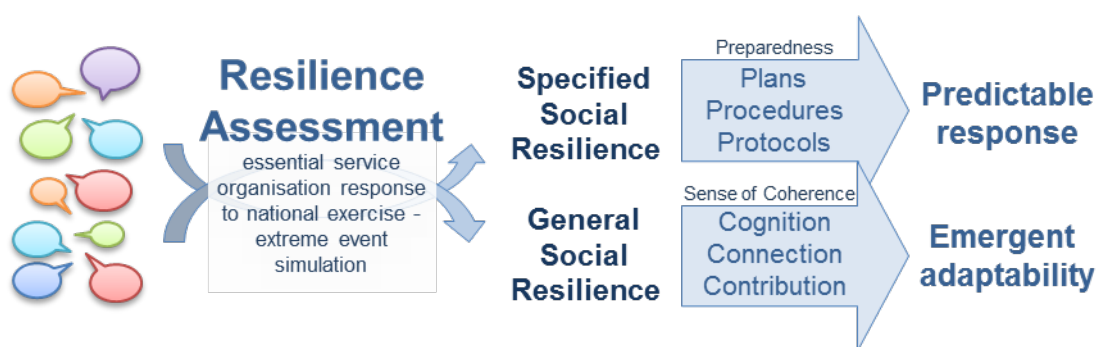
Figure 5-5 A narrative-based sensemaking method was used in a resilience assessment to quantify and compare types of social resilience resources utilised by responders across the organization in response to a national emergency simulation exercise.

5.6.4 SenseMaker as a social resilience assessment tool

SenseMaker is employed for resilience assessment in contexts such as airline flight operations using engineering resilience principles (Dijkstra 2013); participants in economic development and upliftment programmes that establish capacities for coping, adaptation and transformation (Will 2016; Gottret 2017); and planned for people serving on the frontline using neuroscience and performance psychology principles (personal Skype conversation with Dr Ian Snape from Frontline Mind, July 2017). Our study shows that, through the use of SenseMaker as social resilience assessment tool, it is possible to establish usage patterns and preferences between specified and general resilience resources. Overall patterns are discernible from aggregation of signifiers; but at the same time, each data point is linked to a micro-narrative, which helps illustrate the personal experiences behind the patterns. Our results suggest that the approach developed in this study can be employed in essential service and other organizations interested in responses to extreme events.

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5.6.5 Limitations of the study

The results of this study focus on initial response to a ubiquitous emergency simulation and should be seen in the light of the confusion and inherent uncertainty of the first few hours of a large scale emergency (Correia et al. 2017). By implication the findings from this assessment cannot be extrapolated to indicate overall incident response, which in reality may last multiple days or weeks.

The results reported in this paper reflect findings that emerged from SenseMaker analysis, but these were not subjected to verification among members of the participant community, so as to not influence the compilation of the normal exercise report required as part of Eskom procedures. Although SenseMaker analyses use statistics and visualisation to bring patterns to light, the data remains subjective in nature. For this reason Goertz and Mahoney (2012) warn that these patterns or propositions are indicative at best, and should be verified. Collective sensemaking is considered by Deprez, Huyghe and Van Gool Maldonado (2012) as the crux of the SenseMaker method, i.e. when patterns in the data are taken back to participants or shown to members from the community, to ask them what they see in the data and especially to ask them what is informing those patterns. Collective sensemaking leads to rich discussions as members of the community collectively try to make sense of these patterns and support or contradict the initial list of propositions the researcher compiled from analysis alone (Mager et al. 2018).

There is little clarity regarding how much of a particular resource type is enough to ensure a resilience outcome. As much as resilience cannot be measured in absolute terms, there are no levels at which resilience is adequate to all challenges. Therefore, opinions on relative quantities of different types of resilience resource required, will remain subjective and open to debate.

The use and meaning of language in SenseMaker can contribute or constrain the outcome of an assessment. There were aspects of the signification framework that should have been better phrased to avoid confusion. For example, there was confusion among participants due to the use of a double negative in the SOC comprehend dyad. However, this anomaly was corrected in the data to counteract the double negative. Logical consistency in the language of grouped dyads may improve data validity.

A SenseMaker study should ideally involve at least 100 participants within sub groups of a community to make valid comparisons and to understand unique differences between groups. Thus, due to the small number of collected narratives, the results of this study cannot be generalised.

5.6.6 Future research directions

This study highlights the need to find effective organizational resilience-building programmes in essential service providers. A better understanding is required of the tandem contribution from specified and general resilience capabilities towards a more resilient outcome, especially for emergency response to major incidents. Building social resilience is a complex problem that cannot be *'solved'* and requires ongoing commitment to adaptive, reflexive and emergent approaches (Dunn et al. 2016). More work is required to understand how collective SOC influences organizational sensemaking and response to disruption and ongoing change.

5.7 Conclusion

Social resilience is the best way to cope with surprise and general resilience is vital to an essential service organizations ability to withstand unknowable and unpredictable disruption. This paper describes an assessment of social resilience within an essential service organization based on sensemaking of participants' reflections following a national emergency exercise, to formatively suggest resilience building interventions. The resilience assessment was performed to establish whether general resilience is apparent relative to specified resilience, to understand the composition of these types of resilience resource utilised in organizational response to an extreme event. Resilience is a dynamic capacity, but the assessment indicates that, on the day of the simulation, social resilience in the utility was constrained cognitively, as regards manageability and purposiveness owing to a lack of agency.

This paper made a novel contribution to assessing social resilience by separating and quantifying the specified and general social resilience resources drawn upon in an essential service organization. The assessment was based on narrative-based sensemaking of a large-scale emergency simulation exercise. Sensemaking is a promising approach to uncover emergent patterns from micro-narratives that underlie people's experiences, preferences, and cognitive biases. The approach would be repeatable in any organization, or large scale response, by selecting resilience indicators relevant to the context. Thus, sensemaking may lead to insights that organizational leaders can utilise to dynamically stimulate resilience capacities.

The study linked a resilience outcome under conditions of equivocality, with effective sensemaking at the individual and organizational level and utilised sense of coherence (SOC), which reflects aspects of resilience and sensemaking, as a general social resilience measure. Our results suggest a correlation between SOC and a resilient disposition in

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response to extreme events, which is worth further exploration. Further research is also required to understand how to effectively enhance SOC at an organizational level (Van Breda 2001). Moreover, this study underscored that cultivating a strong SOC appears to be a crucial enabler to build and foster social resilience (Muller and Rothmann 2009). We suggest that essential service organizations can increase their resilience by promoting a sense of meaning and purpose in employee contribution by highlighting the value of the lifeline services that they provide to communities.

This study proposes a new organising logic for how to make sense of systems-level resilience, based on the presence and quality of cognition, connection, and contribution in the overall system. This approach closely aligns with the resilience assessment frameworks used by Lengnick-Hall & Beck (2005) of organizational resilience capacities and Duman's (2017) measure of resilience-thinking in organizational leadership. However, the approach used in this study contrasts with resilience measures often applied to critical infrastructure systems of absorptive, adaptive and restorative recovery capacities (Francis and Bekera 2014). It is also different to measures from the field of resilience engineering of potential in systems to respond (know what to do), monitor (know what to look for), anticipate (know what to expect) and learn (know what happened) (Dekker et al. 2008; Hollnagel 2009).

Social resilience needs to be built in organizations to better prepare for dealing with low likelihood, high impact events. Although in the case of Eskom this will probably require institutional transformation, general social resilience is essential to sustain important essential services. The increasing interdependence between society and its essential services necessitates approaches to make sense of current levels of social resilience. Moreover, these approaches may present guidance on how to build future social resilience

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Chapter 6: Conclusions

6.1　Introduction

Due to the critical dependence of modern society on essential services, such as electricity, it is important for essential service providers to ensure continuity of service delivery amidst inevitable disruption and unrelenting change. Resilience is the capacity of a complex adaptive system that enables it to simultaneously persist, adapt and transform at multiple spatial and temporal scales, so that the system can deal with change and maintain its systems function, amidst disruption and deep uncertainty (Holling, 1973; Folke, 2016). Although much research goes into resilient critical infrastructure, the focus is often on technical considerations, which are mostly controllable, while social considerations, which are every so often uncontrollable, have not been a major research focus. The main aim of this study was to explore approaches to assess and build resilience in order to enhance the capacity of a socio-technical system that deliver essential services to ensure continuity of its core functions amidst disruption and change.

Maintaining the resilience of essential electricity services is particularly pertinent in South Africa. Challenges have been experienced across the nation with electricity supply interruptions due to rotational loadshedding, with severe implications for the economy (Bonorchis and Burkhardt, 2017). Ninety five percent of South Africa's electricity is supplied by the nationally-owned utility, Eskom, which has been belaboured by allegations of corruption and state capture. This study drew on this specific context to explore ways to assess and build social resilience within the utility, and thereby to contribute new thinking and approaches to assess and build resilience of electricity supply in South Africa.

While a resilience focus acknowledges that disruption is inevitable, the emphasis is on how to deal with disruption when it happens. The effectiveness of the collective response to crisis may speed service restoration, return system stability or determine whether a bigger disaster is prevented. The National Disaster Management Centre in South Africa considers a national blackout a worst-case national disaster scenario. Eskom's resilience focus includes plans and preparedness to respond to a national blackout. The insights of this study may assist a wide range of actors seeking to assess and build resilience of essential service delivery by

socio-technical systems; and may also have relevance to advancing the assessment of social dimensions of resilience in social-ecological systems.

In order to ensure resilient essential service delivery, this study set out to advance ways to assess and build resilience within a socio-technical system that produces an essential service. The study was exploratory in nature, and deeply based on a complexity and resilience thinking approach.

The main objectives of the study were to:

- Develop a conceptual framework for assessing resilience of essential services (Chapter 2)
- Pilot two methods for assessing and building resilience:
  - Principle-based formative assessment approach (Chapter 3)
  - Narrative-based sensemaking approach (Chapter 5)
- Describe the SenseMaker method used in the narrative-based approach (Chapter 4)

6.2   Summary of Key Findings

The key objectives were investigated by means of four papers, comprising chapters 2-5 (Figure 6-1). The first has been published, two are under review and another completed to be submitted. Here we briefly summarize the main findings from each chapter.

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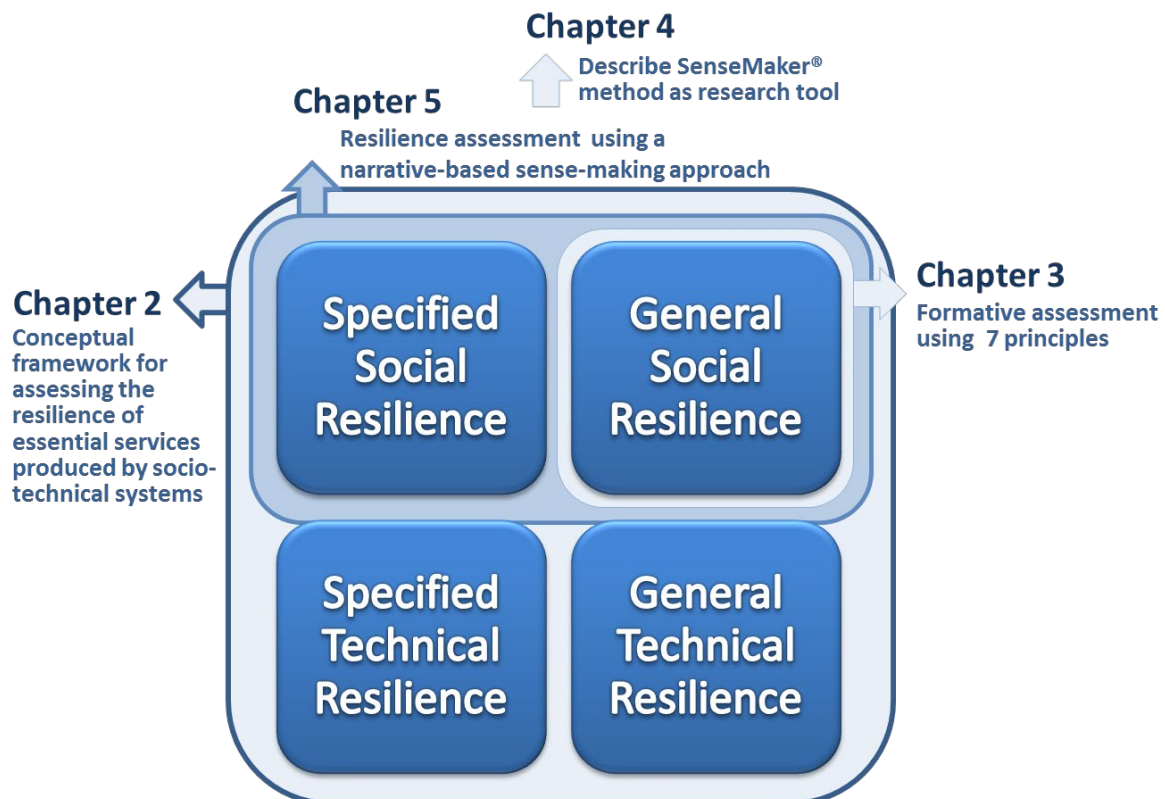
Figure 6-1 How the various chapters contribute to the framework established in Chapter 2.

6.2.1 Chapter 2: A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems

Due to the contextual reality of Eskom's situation, I set out to propose a framework to conceptualize and assess the resilience of essential services using a complex adaptive systems perspective. The proposed framework identified four key domains, differentiating between general and specified resilience investments in the social and technical aspects of socio-technical systems respectively. The *specified technical resilience* quadrant represents areas where resilience to specific risks (e.g., severe weather) is built into technical infrastructure (e.g., transformers or power line pylons) to ensure that it is robust. The *specified social resilience* quadrant represents areas where resilience to specific risks (e.g., disruption to critical business processes) is established through specific capabilities, plans, processes and procedures through social arrangements. The *general technical resilience* quadrant represents areas where resilience to novel and unknown risks is established through adaptive technologies and network topology that offer systems-level flexibility to enable an agile response across the system in dealing with uncertainty. The *general social resilience* quadrant represents areas where resilience to novel and unknown risks is developed in people to advance agency, volition and agility.

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The chapter further discussed the different resilience building and assessment approaches which each of these domains point towards. These respective approaches are summarised in Table 6-1.

Table 6-1 Implications of the four domains of socio-technical resilience for building and assessing resilience.

Specified Social Resilience	General Social Resilience
Build: Specified social resilience can be built through the adoption of established disciplines of good practice, for example the management disciplines of emergency management, crisis management, business continuity management and safety management (Linnenluecke & Griffiths, 2012; Miao, Banister & Tang, 2013; BSI, 2014; Mendonça & Wallace, 2015).	*Build:* General social resilience capabilities can be nurtured through adoption of resilience building principles, investment in social, cultural and educational competencies and an organizational culture of resilience that foster behaviours that help employees be agile and adaptive in the face of disruption and change (Luthans, Vogelgesang & Lester, 2006; Everly, Smith & Lobo, 2013; PwC, 2013).
Assess: Specified social resilience assessments can entail a verification of established preparedness against predefined objectives in the form of authorized contingency arrangements, response and recovery plans, and standard operating procedures.	*Assess:* Assessments of general social resilience require sensemaking that engage with contextual complexity. General social resilience can be assessed by evaluating the presence and effectiveness of the seven generic principles proposed by Biggs et al. (2015); measuring and monitoring collective SOC (Ghoshal and Bruch, 2003; Lindström and Eriksson, 2006); and evaluating the nature of the culture, informal institutions, and heuristics used to make judgements under uncertainty (Tversky and Kahneman, 1974; North, 1991; Pereira and Ruysenaar, 2012).
Specified Technical Resilience	**General Technical Resilience**
Build: Given adequate resources, infrastructure resilience can be achieved to withstand anticipated hazards through good practice, which includes intelligent engineering design that implements adequate margins of safety, quality construction, and sufficient maintenance (UN ESCAP 2013).	*Build:* Building general technical resilience requires increasing systems-level flexibility, that allows bending rather than breaking (Longstaff, Koslowski and Geoghegan, 2013; Dahlberg, 2015).
Assess: Specified technical resilience assessments can consist of quantitative measures, benchmarks, tests and compliance with engineering standards and controls applied throughout the asset life cycle.	*Assess:* Assessments of general technical resilience are performed at the critical infrastructure systems level through an evaluation of flexibility of the overall system, when under strain, or under failure conditions that may not yet be apparent.

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This conceptual framework forms the basis for situating all the chapters in this dissertation (Figure 6-1). As it highlights the core dimensions of resilience, and their interplay, relevant in socio-technical systems, it can serve as a guide in future research and inform practice.

6.2.2 Chapter 3: Building social resilience in socio- technical systems through a participatory and formative resilience assessment approach

The second paper developed and piloted a participative formative resilience assessment process to foster collective sensemaking and social action for building general social resilience. This exploratory assessment used the seven general resilience building principles proposed by Biggs et al (2015) and an appreciative inquiry approach.

The process was conducted with different participants across six participatory workshops, structured around the steps of appreciative inquiry. The workshops generated rich narrative accounts of resilience practises within Eskom; contributed to collective learning about required resilience capabilities in the organization; produced an assessment of areas of strength and opportunities, and elaborated on those areas collectively seen as having the most opportunity for enhancing resilience.

6.2.3 Chapter 4: Making sense of complexity, using SenseMaker as research tool

The third paper set out to introduce the SenseMaker method and the Cynefin sensemaking framework on which it is based, by drawing on experience in the use of the method. Cynefin has emerged as a widely utilised sensemaking framework to distinguish between different decision contexts. The SenseMaker method and tool was developed as a service offering from Cognitive Edge, to distinguish ideation patterns, to serve as a decision support tool, for monitoring and evaluation, or for detecting trends. Both the Cynefin framework and SenseMaker tool are the brain child of Prof Dave Snowden.

SenseMaker was employed in the narrative based assessment in Chapter 5, was effective to support resilience assessments of complex social dynamics, and has potential to be utilized in social resilience assessments in future.

SenseMaker has been employed in organizations and institutions since the turn of the century, and is increasingly used in research, but has not been well-documented in the academic literature. This chapter set out to fill this gap, and offers prospective researchers some guidance in the use of this tool. Since social reality is inherently complex (La Porte,

1975; Holling, 2001; Jones, 2011), the contribution of this chapter is applicable to both upper quadrants of the framework.

6.2.4 Chapter 5: Sensemaking as an approach for Resilience Assessment in an Essential Service Organization

The resilience programme in Eskom sets out to establish specified resilience capabilities by establishing best practise in identified management disciplines across the organization. However, the framework established in Chapter 2 highlighted the essential difference between contexts where specified social resilience and general social resilience resources are required. This raised the question of the extent to which general social resilience has emerged across the organization without having been a targeted outcome to date.

To assess the composition of social resilience within Eskom, a narrative-based sensemaking approach was adopted due to its suitability to inquire into systems-level patterns within complex social contexts. The SenseMaker tool was utilised for this purpose, and prompted participants to reflect on the relative extent to which they relied on specified versus general resilience resources in the face of a simulated large scale technological failure, with disastrous consequences for South Africa. Eskom's annual national emergency exercise presented the context for the study, and involved all employees across the organization that need to adopt emergency response roles during disruption.

Results indicated that respondents utilized specified resilience resources more, even though few of these were appropriate for dealing with the simulated disaster scenario. This result is not surprising as this is what people were conditioned to do. However, these results highlight the extent of the challenge to develop a balanced portfolio of specified and general resilience capabilities into people's arsenal, and more so, how to develop the intuitive understanding of which is most appropriate in different contexts.

To conduct the study, a variety of indicators were used to assess the relative contribution of specified versus general social resilience resources in the face of the simulated emergency (Table 6-2). The indicators were determined in context, but the approach is adaptable and repeatable to assess response to particular incidents and extract learning. This chapter further suggest that core cognitive, connective and purposive competencies may contribute to enhancing general social resilience across essential service providers.

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Table 6-2 Indicators used to assess specified and general social resilience in the narrative-based resilience assessment.

Specified Social Resilience	General Social Resilience
Established preparedness	Sense of coherence
Direction from a mandate	• Ability to make sense of new situations
Technical competence	• Ability to manage in new situations
Guided by rules & procedures	• Ability to find meaning and purpose
Response plans to follow	Strong social networks
	• Cooperation within teams
	• Coordination with other functional teams
	• Centralised service functions anticipate support needs and deliver services
	An understanding of the big picture
	Permission to act
	Ability to apply new thinking in crisis

6.3   Summary of Key Contributions

This section summarizes the key contributions of the dissertation taken as a whole. I distinguish here between theoretical, methodological and empirical contributions which the dissertation has made.

6.3.1 Theoretical contributions: Conceptualizing resilience in socio-technical systems

This study leaned on resilience concepts that emerged from the study of ecosystems and integrated social-ecological systems. This choice was informed by their treatment of the problem context as a complex adaptive system and advances to assess and build the resilience of beneficial ecosystem services from the Millennium Ecosystem Assessment framework complimented my focus to assess and build the resilience of essential services which modern society has developed such a dependency on. It seemed appropriate to apply the thinking that emerged from that investigation when considering resilience assessments of essential services. Furthermore, as the resilience of ecosystem services has to be investigated in the context of the intertwined social-ecological system, not only of the ecosystem, the resilience of essential services depends on tightly coupled social and technical systems dynamics.

Complexity thinking is essential to build and assess both specified and general resilience in social-ecological systems. However organizations and the critical infrastructure systems required to deliver an essential service are subject to design, control and reduction, building

specified resilience is complicated in nature. Furthermore, the board of directors and executive of these organizations are held publicly accountable for the manner in which they direct, govern and manage their essential service mandate. For this reason specified resilience may be required to ensure compliance with legislation, regulation, standards, best practice and good practice. These stringent requirements place a different emphasis on specified resilience in socio-technical systems than what is typically the case in social-ecological systems. None the less, this study has shown that socio-technical systems may benefit from a more holistic view on resilience from the application of the concepts that emerged from social-ecological systems.

6.3.1.1 Social dimension of resilient essential services

The framework proposed in Chapter 2 offers conceptual clarity and guidance as to how to distinguish between different aspects of resilience in socio-technical systems. In particular, it highlights the critical role played by social systems in the resilience of essential services. Although technological advances will continue to accelerate, technologies don't work on their own; they are embedded within broader social systems to function. This framework was born from the pain of being in Eskom and observing first-hand the social impact on people's commitment in response to the extreme challenges in the organization. I realised that resilience of electricity in South Africa does not hinge on reliable parts or well-devised plans. It requires people's hands, heads and hearts to be engaged in the system that underpins this essential service.

The domains of the framework are fundamentally different in nature, informed by different disciplines, and with unique approaches to assess and build resilience in each. The framework incorporates respective resilience foci associated to organizational levels, with resilience roles defined at operational, tactical and strategic levels, and suggest quadrant-specific resilience indicators at these organizational levels. Assessments of current domains of resilience across the organizational levels can clarify the nature of resilience to be built, and inform a balanced portfolio of resilience investment strategies. This framework provides a basis for developing practical approaches and indicators for assessing and building resilience.

6.3.1.2 The interplay of complex and complicated approaches

A distinction that informed the domains of resilience is the fundamentally different problem contexts, namely complicated versus complex contexts, which respectively require specified and general resilience (Table 6-3). Since these types of resilience are appropriate for different types of problems, it has distinct implications for how to build and assess resilience in respect of different types of problem contexts. The human tendency is to increase order

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and control through institutions and organization, which utilize complicated approaches. However, there are substantial limitations on our ability to control the complexity all around us. Furthermore, we cannot avoid disruption and surprise. Complexity approaches are required to match complex problems.

A key distinction between specified and general resilience objectives is that the former is more tangible and measurable than the latter. Specified resilience can be established through preparedness of specified parts of the system to known or anticipated pressures. However, general resilience requires complexity based thinking. While specified resilience can be established through a programme of good practices, general resilience requires appropriate conditions where adaptive relational approaches can be cultivated for resilience to emerge. Organizations tend to favour the tangible nature of specified resilience objectives, as they can be delimited in a defined scope, planned for and formally managed in implementation. Moreover, the deliverables can be measured and evaluated to comply with governance and assurance objectives.

Resilience scholars have suggested both specified and general resilience needs to be build, as effort channelled into developing only one may undermine the other (Folke *et al.*, 2010; Cork, 2011; O'Connell *et al.*, 2015). Resilience challenges encountered always consist of a combination of problems that may succumb to complicated approaches and others that can only be tackled in complex ways. But since methods and resources have bounded applicability both these types of resilience are required simultaneously, and to be directed towards its own kind of challenges (Table 6-3). Specified and general resilience offer complimentary, but contradictory, capabilities. Therefore, investments into resilience have to be balanced across both specified and general resilience, to ensure they are established simultaneously.

Table 6-3 Resilience concepts can be delineated relative to two types of problem contexts, being complicated and complex, which has implications for how resilience is to be built, and how responses to these problem contexts manifest.

	Complicated context	Complex context
Types of problems	*Complicated problems* originate from conventional causes that can be individually distinguished, admit permanent solutions, and can be addressed piece by piece (Poli, 2013). Complicated systems are controllable, can be modelled, and its direction predicted. This is a domain of knowable order.	*Complex problems* cannot be addressed in a piecemeal way, or solved in full, have to be engaged directly, and result from networks of multiple interacting and emerging causes that cannot be individually distinguished (Poli, 2013). Complex systems can be influenced, but not be controlled, and no single model can capture all the properties of a complex system (Cilliers *et al.*, 2013). This is a domain of complex un-order, which is not the absence of order.
Types of resilience	*Specified resilience* refers to the ability of a specified part to persist against identified disruptions, and to keep operations within deterministic boundaries (Weick and Sutcliffe, 2007; Walker *et al.*, 2009; Folke *et al.*, 2010). It contributes stability to organizations.	*General resilience* refers to an emergent capacity to adapt and transform across multiple equilibria, while continuing to provide essential functions and to enhance resilience (Folke *et al.*, 2010; Holman, 2010; Caldwell, 2014). It contributes to processes of change in organizations.
Types of technical resilience	*Specified technical resilience* refers to robustness of identified infrastructure and assets to withstand anticipated hazards or threats through engineering design standards and good practice (Van der Merwe, Biggs and Preiser, 2018).	*General technical resilience* refers to the generic ability of man-made systems to withstand any threat or disruption through emergent and adaptive capabilities that provide systems-level flexibility (Van der Merwe, Biggs and Preiser, 2018).
Types of social resilience	*Specified social resilience* contributes to organizational stability and entails specific investments in people and processes, through the adoption of established disciplines of good practice, to ensure that they can maintain the continuity of critical functions when subjected to identified threats (Van der Merwe, Biggs and Preiser, 2018).	*General social resilience* contributes to organizational change and refers to investments in people and processes, through complexity thinking, multi-loop learning and purposiveness, to ensure functional continuity of the system and a general ability to adapt and transform amidst any disruption or change (Van der Merwe, Biggs and Preiser, 2018).

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	Complicated context	Complex context
Types of sense-making contexts	When organizations *make sense of routine situations*, they focus on established structure and institutions, to exert control for effective coordination of action, irrespective of those involved (Weick, 1995; Bakken and Hernes, 2010; Kudesia, 2017).	When organizations detect equivocal cues that require *sensemaking in contingent situations*, they develop innovative new intersubjective understanding, uniquely constituted to the actual people involved, and focus on ongoing relational processes to deal with the crisis at hand (Weick, 1995; Bakken and Hernes, 2010; Kudesia, 2017).
Types of knowledge that should inform sensemaking and response in different types of contexts	Sensemaking in routine situations is informed by e*xplicit knowledge*, which is tangible and can be stored and management using information technology. This knowledge is codified information that has been disembodied, making it generally useful irrespective of those involved. This functional knowledge can be conveyed through teaching, and can be shared with others as formalized procedures (Burnett, Wooding and Prekop, 2005; Kamoche and Maguire, 2011).	Sensemaking in contingent situations is informed by t*acit knowledge*, which is intangible, internal and intuitive. This knowledge is highly context-specific, and difficult to articulate without being prompted by a specific need, as it is based on the specific insight, understanding, experience, skill and expertise of the individuals involved. This intuitive knowledge is situated practice that can be embodied through praxis and shared with others in conversations through ongoing informal interaction. This knowledge is socially constructed and emerge negotiated at the collective level (Burnett, Wooding and Prekop, 2005; Gherardi, 2006; Kamoche and Maguire, 2011).

While the framework serves to distinguish between the natures of these domains of resilience it should be noted that specified resilience focuses on one part of a complex system that is effectively nested within a larger system, where general resilience is more relevant to the continued identity of the whole system. If actions are taken to intervene in a system to enhance the resilience of a specified part of the system to a known disturbance/shock, then adequate care should be taken to ensure the action does not inadvertently erode the resilience of another part of the system, creating unintended consequences. If these parts of the system were nodes in a network, strengthening a node does not necessarily strengthen the network, and may even expose vulnerabilities elsewhere in the network. It may at times be necessary to reduce capacity from some nodes to achieve network optimization. For this reason a resilience portfolio need to balance specified and general resilience building strategies and consider trade-offs across multiple scales.

In terms of social resilience, an implication of this distinction is that the cognitive and knowledge framing social agents need to utilise for sensemaking in these respective contexts differ, as approaches appropriate in one context may be ineffective in the other. The study focuses on general social resilience, the findings underscore that both specified and general resilience are required and that they respectively require complicated and complex approaches. This requires appropriate levels of ambidexterity to be developed within the social system, and a keenly developed intuition to know which approach to employ in different contexts (Table 6-3). Table 6-4 highlights the contributions made by the respective chapters relative to this distinction between complex and complicated problems.

Table 6-4 An overview of the contribution of each chapter to building and assessing specified and general resilience through complicated and complex approaches respectively .

	Use complicated approaches to build specified resilience	Use complexity approaches to build general resilience
Chap 2	Management practices and engineering standards	Enable emergence and facilitate systems-wide flexibility, adaptability, and transformation
Chap 3	—	Process to build resilience through social innovation for intentional and purposive collective action
Chap 4	—	Sensemaking as research approach of systems level patterns that emerge across micro-narratives based on ideation patterns
Chap 5	Adherence to formal institutions like plans, rules and procedures for control and structure	Emergence of adaptive management through acting on intuitive expertise through social network connections for a cause

6.3.1.3 Role of sensemaking in social resilience

Sensemaking is a critical component of social resilience, as it determines interpretation frameworks, situational awareness, and response (Burnett, Wooding and Prekop, 2005). Effective sensemaking in times of crisis has been linked to a resilience outcome (Weick, 1988; Maitlis and Sonenshein, 2010; Casto, 2014). Therefore developing an effective collective sensemaking capability can enhance organizational resilience. This study contributed further conceptual clarification of general social resilience as consisting of cognitive, interpersonal and intrapersonal sensemaking competencies, and suggested ways to develop these within an organization.

Chapter 5 suggests the effectiveness of organizational sensemaking may improve by collectively enhancing the three elements that constitute sense of coherence, namely cognition, manageability and purposiveness. These elements represent effective sensemaking dimensions and were quantified in the assessment. The study further indicated

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that these dimensions of coherence can be enhanced by (i) fostering shared mental models of feedbacks and interactions within the complex socio-technical system, in order to enhance big picture insight on systems behaviour; (ii) strengthening social network connectivity to ensure an adequate flow of information, resources and ideas across the network; and (iii) creating conditions for empowerment, agency and commitment to a contribution and purpose that is considered worthwhile.

6.3.2 Methodological contributions: Assessing social resilience

6.3.2.1 Formative versus summative resilience assessments

When I joined Eskom's enterprise resilience program, I knew nothing about resilience assessments. I read widely about the topic, and noticed that the field of education draws a clear distinction between formative assessments - performed on an ongoing basis during the year, to inform how to adapt teaching - and summative assessments, which determine what goes onto the report card for the parents and the school's reporting body. Informed by this insight I clarified that my role in Eskom was summative, but was not satisfied with that answer as it would not solve problem; instead it simply reports on them.

This dissertation highlights the need to explicitly draw a distinction between resilience assessments based on the primary purpose and required outcome. The purpose of summative assessments are to give an account *of* resilience in place currently, while formative assessments seek to inform interventions *for* resilience enhancements to strengthen future resilience outcomes (Bloom *et al.*, 1971).

This study piloted two methods for assessing and building social resilience. The assessment in Chapter 3 adopted a formative approach, while the sensemaking assessment in Chapter 5 was conducted summatively. The formative assessment focused exclusively on building resilience in the top right hand domain of the framework proposed in Chapter 2, while the summative assessment served to distinguish and distil systems-level usage patterns between specified and general social resilience resources – the top two quadrants of the framework (Figure 6-1). Both types of resilience assessments are essential, as their respective contributions add fundamentally different perspectives and benefits.

A novel contribution of the study is to highlight SenseMaker as a feasible method for resilience assessments. The SenseMaker method is well capable of supporting formative assessments through its collective sensemaking phase, designed to directly engage key stakeholders on the meaning and interpretation of patterns from the data, as described in Chapter 4. It was contextual circumstances and key stakeholder choice that prevented the

SenseMaker results to be utilised formatively in the reported study. The exercise coordinator did not want to be influenced by the SenseMaker findings, until completion of conventional analysis and reporting on the exercise execution. In a similar fashion, appreciative inquiry can be applied to enhance specified social resilience objectives if applied to specified resilience capabilities against specified threats. Thus both the appreciative inquiry and SenseMaker methods can be utilised formatively to enhance social resilience, whether specified or general.

Furthermore, a distinction can be made on the temporal focus of these types of assessments: summative assessments look at what resilience capacities have been built in the past to report on what is currently in place; simulation exercises test response in the present; while formative assessments establish what capabilities should be built for the future (Table 6-5). This confirms Sharifi's (2016) observation that formative assessments involve ex-ante evaluations, while summative assessments are ex-post measures. This temporal distinction in assessments between looking at what has been done in the past, what is being done in the present, and what can be done for the future has been expanded in Table 6-5.

Table 6-5 Temporal focus of resilience assessments.

Looking back over time to assess what has been accomplished in the past	Look at present action to assess response in the present	Looking forward in time to assess what needs to be done in future
Retrospectively reflect on and learn from the past	*React* and respond to change or disruption in the present	*Proactively* anticipate and adapt to prepare for the future
Summative assessments can be scheduled periodically *of* resilience against standardized indicators decided top-down, for the purpose of producing a report for a third party, to give an account of what has been achieved, for comparison, aggregation or benchmarking (Van der Merwe, Biggs and Preiser, 2018).	Disruption may come as an abrupt and *brutal audit*, which might serve as the litmus test of resilience, and where failure may be the momentary inability to cope effectively with complexity (Lagadec, 1993; Woods, 2012).	*Formative assessments* can be an ongoing process *for* a resilience outcome, to facilitate a bottom-up dialogue among actors in the system, to diagnose where the system is at in its levels of resilience, to agree where resilience should be strengthened, through collective action towards shared resilience goals (Van der Merwe, Biggs and Preiser, 2018).
Resilience capacities are finite resources that is available and can be measured to establish the current ability (capacity) to perform, or the measure that can	*Resilience competencies* determine the effectiveness or adequacy of response to disruption or change (based on Vincent, 2008).	*Resilience capabilities* are aptitudes, abilities, or processes which can be developed or improved that contribute to resilience in a system (based on

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Looking back over time to assess what has been accomplished in the past	Look at present action to assess response in the present	Looking forward in time to assess what needs to be done in future
be contained (based on Vincent, 2008).		Vincent, 2008).
Summative assessments are used to measure or assess resilience capacities established *to date*.	Emergency simulation exercises are used to assess *current* response to disruption (Wybo, 2008).	Formative assessments are used to establish resilience capabilities to cultivate for the *future*.

While many assessments measure resilience established or displayed in the past, this study points to how formative assessments can enhance future resilience outcomes. General social resilience offers a distinctive resilience advantage, as the unique human strength to improvise, tinker and adjust enhances the adaptability and transformability of complex socio-technical systems (Dekker, 2005; Heese, Kallus and Kolodej, 2013; Van der Merwe, Biggs and Preiser, 2018). Formative resilience assessments form part of a continuous improvement process to assess and build resilience that will contribute to a system's ability to survive and thrive under a range of expected and unexpected conditions. The formative assessment approach developed in this study (Chapter 3) offers a no-regret general social resilience investment, as it embeds the resilience building principles into the sensemaking repertoire of the organization.

6.3.2.2 Operationalizing the 7 Resilience building Principles

This study operationalised the seven resilience building principles to resilience assessments as suggested by Schlüter et al (2015) and Quinlan et al (2015). The approach may be compared to the "Design innovative strategies for change" phase in Wayfinder (Stockholm Resilience Centre, 2018), but where Wayfinder overall describe an elaborate process to be conducted with a manageable team; this approach constitute short rapid assessments, that can be replicated many times to expose a large number of participants to the learning intervention. Participants don't need to know about or be involved in resilience before as the principles and capabilities speak for themselves.

The formative principle-based assessment process catalyses social innovation and is replicable in different contexts. In this case the assessment was performed relative to the agreed upon Eskom resilience capabilities. These can be replaced with a generically defined set. The workshop process developed offers a practical and participative approach to perform resilience assessments *for* enhancing resilience and *as* collective learning within the general social resilience domain of the framework. Besides essential service organizations, it may potentially be utilised in communities to enhance climate or disaster resilience, cities

towards urban resilience, or in social-ecological systems involving multiple stakeholders from many different organizations.

6.3.2.3 SenseMaker

This study introduced the SenseMaker tool as an approach to assess social resilience. A particular value of the narrative-based sensemaking assessment approach is the ability to distinguish, quantify and compare specified and general social resilience resources utilised by people. Although this was not the first SenseMaker based resilience assessment, as mentioned in Chapter 4, Table 4-1, it was the first assessment of social resilience collectively – as participants constitute employees whose role switch to emergency responders, tasked to maintain and restore service delivery in case of disruption, and who would need to respond in concert to accomplish this objective. Since assessing social resilience as a collective construct is difficult to do, there is scope for SenseMaker to be taken up further in this regard. SenseMaker can be applied to both summative and formative resilience assessments, as well as for extracting learning to enhance resilience.

Since SenseMaker is a mixed-method increasingly utilised for research, this study contributes to inform selection and utilisation considerations, if the SenseMaker tool is considered. The article might even draw further researcher attention to it than would have been the case otherwise.

6.3.3 Empirical contributions: Social resilience of electricity supply in South Africa and implications for building social resilience in Eskom

In the course of this study we gained a number of insights about the resilience of electricity supply, particularly of the social dimensions of resilience in Eskom. This in turn constitutes a significant aspect of the social dimension of electricity supply in South Africa, with direct implications for the resilience of electricity supply in South Africa.

While Eskom's Enterprise Resilience Programme has focused on specified resilience objectives, this study highlights the need to also explore general social resilience as a key priority, as people can be a source of vulnerability or contribute breakthrough strength in the face of the unexpected.

Based on the two resilience assessment approaches developed and piloted in this study, we found that Eskom's general social resilience is quite low. A key common theme that emerged across the formative resilience building workshops from Chapter 3, is the need for Eskom to apply the principles relating to governance (i.e. the principles of learning, participation and polycentricity) to proactively adapt to threats and opportunities within the

organization as well as in the national and international context, and to deliberately evolve resilience through learning in response to incidents. Findings from Chapter 5 indicate that the organization overall relies too heavily on specified resilience during extreme incidents. However, the responders generally had high levels of sense of coherence, which enables effective sensemaking and contributes to general social resilience.

Based on the quality of the dialogues in the resilience building workshops developed for Chapter 3, I suggest that these continue to be held across the organization. Using the resilience building principles more widely will contribute to build resilience thinking across the organization. However in an organization there is a point where bottom-up change needs to meet top-down transformation. We alluded to signs that the current organizational culture seem to inhibit social resilience, and highlighted the need for institutional transformation in the organization to create the environment where general social resilience can flourish. Therefore it would be good to find ways to infuse the principles speaking to governance of the system deeper into, and higher up into the organization. The Eskom Risk & Resilience plan may present such an opportunity.

I further suggest that the recommendations from the sensemaking assessment be incorporated into how preparation for disaster management is established to facilitate development of cognitive, connective and purposive competencies, and to enhance collective sensemaking through deeper understanding and better interpretation frameworks.

6.4   Limitations of the study

The system assessed is strongly influenced by internal dynamics as well as external drivers. A limitation of this study is that external drivers and linkages to containing systems were excluded from the scope of the study. These external drivers constrain the focal system and may expose it to shocks, such as the containing ecosystem, the national political system, global technological trends, or green energy transitions.

This study was conducted in the context of an electrical utility. Although I suggest that the findings and recommendations can be extended to essential services in general, the application of especially the two resilience assessment approaches developed and piloted in this study would need to be adapted and tested for those contexts.

Similarly, the South African context is quite particular, and the approaches developed in this study may not be readily transferable to utilities in other countries. The South African electricity industry is dominated by a single large player, Eskom. This is unlike many other countries where the industry was deregulated and multiple companies are involved in the

electric supply value chain. The assessment conducted here could thus cover the full value chain, which may be much more challenging to achieve working across and among multiple companies. On the other hand, however, it may be simpler to affect change in smaller, more agile companies.

In the South African context, even if all the recommendations from this study were implemented in Eskom, it would still not ensure resilient electricity provision, since most of the metropolitan and other large municipalities buy electricity from Eskom and sell electricity to their constituents. These role-payers are thus critical in die delivery of electricity to consumers. The whole industry value chain may benefit from a focus on resilience in the national interest.

While sustainability and biosphere resilience require green energy transitions, and resilience provides the capacity to deal with disruption and change, it was not an objective of this study to develop the capacity for change. For example, the sensemaking based assessment was more biased towards dealing with disruption. This emphasis on response to immediate failure is a general characteristic of current utility resilience initiatives.

While utility resilience often has a dominant focus on technology, this study did not address technological resilience, other than to distinguish it from social resilience. Furthermore, no explicit consideration was given to the interplay between social and technology resilience. The choice to focus on social resilience was on account of the fact that most current initiatives focus largely on technological resilience, and consideration of social resilience is a major gap.

Replicability of the study may be limited if key competencies are lacking. The resilience assessment approaches developed and piloted in this study require an understanding of complexity. The ability to replicate the formative assessment described in Chapter 3 requires facilitation skills and some comfort with the appreciative inquiry method. Similarly, to execute the sensemaking based assessment requires an understanding of complexity, an appreciation of sensemaking as a capacity, as well as expertise in the use of SenseMaker. Chapter 4 may contribute to overcoming these limitations to an extent.

6.5 Future research directions

Based on the distinction between types of problem contexts and types of resilience applicable to each (Table 6-3), I propose that further work is needed to explore the ontological and epistemological implications of specified and general resilience development. The fundamental difference in type of problem context to which these two approaches apply

suggest that resilience thinking cannot be understood as one unified concept. Moreover, clarification of the difference between these types of resilience could help mitigate some of the confusion in definitions and approaches often referred to in the literature.

It is critical to distinguish between complicated and complex contexts, how to prepare for these, how to make sense in each, and how to share the knowledge required for an informed response, as these respective methods have bounded applicability. However, more work is required to understand how to establish both capabilities, and especially how to develop the intuition to know which type of resilience resources to draw on in a particular context to ensure an appropriate response and enhance resilience.

Social resilience that contributes to resilient essential services cannot be strengthened in isolation of the wider society they are embedded in. Individual, community and societal resilience are interdependent with the technical networks and layers of critical infrastructure they are intertwined in. Ultimately conducive conditions need to be catalysed for resilience to emerge across the overall CAS.

Sense of coherence is an effective indicator of a long term orientation towards psychological resilience of individuals, communities or societies. Therefore we propose conceptually extending the concepts and its three elements systemically. Developing these respective cognitive, connective and contribution competencies may contribute new approaches to foster and nurture general social resilience across social systems.

Since resilience is the capacity to deal with both disruption and change, given the number of disruptive changes looming for electrical utilities in particular, it would be prudent to advance resilience for dealing with transformative change. Resilience may offer adaptability and transformability, which may be seen as a strategic advantage to organizations, other than for dealing with disruption. Further research is required to operationalise interventions to establish adaptability and transformability within the general social resilience domain.

Any transformation of socio-technical systems needs explicit attention to social dimensions. Whether it is the strong social opposition from Mpumalanga to closing the highest polluting power stations or the refusal to sign contracts with more Independent Power Producers, resistance to change is social. Further research is required to understand the social dimensions and associated power and politics of the green energy transition.

6.6 Parting reflection

Personally I have found it rewarding to notice how my thinking, and therefore my practise, has been challenged and influenced through the journey of conducting this study. Better yet

is that the office dialogue in the resilience department has also been infused with concepts introduced from my journey. The resilience manager read and commented on all the articles I have produced. It has been rewarding to see new approaches and practices adaptively experimented with in the organization as a direct result.

However, recent events that tested Eskom's resilience highlighted key questions not considered at the start of my dissertation. In the last 10 years Eskom went through 10 Chief Executive Officers and 6 different Boards of Directors, they need to shut down dirty power stations that exceeded air quality limits, and government is again talking about restructuring (de Villiers, 2018; Gibbs, 2018). These changes bring anxiety among the workforce, the unions and various stakeholders, which expose the organization to internal and external social volatility. Then, Eskom announced in March 2018 that based on unaudited financial results, they are technically insolvent (NUM, 2018). At the wage negotiation table with organised labour late in May 2018, and due to the Eskom's deep financial challenges, management tabled a 0% annual increase, insisting that the company cannot afford increases on its manpower expenditure. Labour unions called for a strike early in June 2018. Eskom issued a statement saying "we have plans in place and we are ready", but within three days of industrial action the whole country got affected when national rotational load shedding commenced, as "striking workers pulled the plug on national electricity utility" (Hlatshaneni, 2018; Paton, 2018). Hadebe, the new Eskom chief executive, completely misjudged the situation at Eskom, and said the sabotage and the lengths to which people were prepared to go shocked him (Paton, 2018). Unfortunately power, politics and participation contribute significantly to situations of uncertainty and surprise (Keck and Sakdapolrak, 2013). Eskom's contingency measures failed, the power system remained constrained for up to ten days after the June strike and a few weeks after the July to recover from the effects of the damage, while the load shedding impacted South Africa's economy negatively (Alex News Staff Reporter, 2018; CBN, 2018; News24Wire, 2018).

The confrontation between Eskom and trade unions, in June and July 2018, surfaced an uncomfortable dissonance in the target of the enterprise resilience programme. Resilience literature has highlighted that "resilience for whom?" is a difficult ethical question that requires explicit consideration (Swanstrom, 2008; Keck and Sakdapolrak, 2013; Fjäder, 2014). The question "resilience for whom?" may refer to whose interest gets protected, or who should be the target to be strengthened. The Eskom incident showed that this distinction matter. If we assume "resilience for whom?" focuses on whose interests should be protected, then in the light of essential service delivery the recipients of the resilience benefit may be the recipients of the service (in this case 95% of all electricity consumers in South Africa). Those who consume essential services should benefit from resilient service

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delivery. When the electricity supply service was disrupted due to rotational loadshedding, the well-being of electricity consumers across the country was affected in the short term, and in the long run possibly impact economic well-being, as labour volatility eroded investor confidence and potentially weakened the economy. On the other hand, it is widely accepted that unions contribute to workers well-being. Hall & Lamont (2013) showed that nations with strong trade unions have better levels of social resilience, which they define as well-being in a broad sense, due to the political role of trade unions as advocates for people in the lower socioeconomic strata. Looking at it from that perspective "resilience for whom?" may advance the general social resilience of the workers through increasing their standard of living if they participate with the trade unions in industrial action. Unions fight for the interest of the working class, if need be at the expense of national interest (Workers Solidarity Movement, 2005). Here we have two very different opposing views of resilience, both valid, but simultaneously incompatible. Commenting on the incident, Paton (2018) observed that the unions are too strong and that violence is historically too embedded in protest and political culture in South Africa.

While the original question asks "resilience for whom?" the highlighted dilemma between who should benefit from resilience, raises a fundamentally different question: "resilience of whom?" In order to ask "resilience of whom?" you first need to clarify which interest should be protected. For example, is it the interest of the employees who are part of the working class or of customers who consume the service? These are questions of power, which makes them questions of politics, even if they are also questions about resilience (Ancelovici, 2012). It does not seem possible to establish resilience without considering power and politics, a notion supported by Leach, Raworth, & Rockström (2013), who warned that questions of social equity and social justice has to be explicitly considered, as resilience interventions hold social and political implications.

The national industrial action incident of June 2018 highlighted uncomfortable us-versus-them lines among the employees entrusted with the duty of care to maintain resilient essential service delivery. Whose interests get protected? If it is the interest of recipients of essential services, which may be equated to national interest, then those whom should be made resilient will be workers not belonging to unions as they are less likely to strike, which unfortunately is the difference between managers and workers in this case since managers are excluded from union membership. Who should be included in the "whom to be resilient" in order to achieve resilient service delivery? In order to answer the question "resilience for whom?" becomes a matter of identifying those that may be trusted, those who are committed, who might have an allegiance to keep the system running. But how do you know who can be trusted? What affects an employee's allegiance? While this incident was about money, it

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may just as well have been on convictions of green energy options over coal, or a preference to keep the old coal-fired power stations running for the sake of job security over integration of independent power producers. What interests are currently protecting? And how much does it take for individuals or groups to change their mind?

When a disruption can be caused by potential clashes in benefits, interests and values, resilience endeavours have to carefully consider aspects of social justice, human rights and matters of dignity and respect, especially if response is required against the employees of the organization in order to protect the power system and associated infrastructure. This raises questions and implications of ethics, human agency, respect and human dignity into the pursuit to build resilience. I had no stance on this in this study, as these incidents occurred after the conclusion of my empirical work and as I was reflecting on the journey. These events opened up new ways of reflecting on resilience and point to new avenues through which building resilience can be engendered. However, further work is required to better understand the impact of power and the effect of choice, especially of labour within essential service organizations.

To build resilience is to bestow power to persist, adapt and transform. Eskom, as a predominantly coal fired utility, negatively impact on the natural and social-ecological systems it is embedded in. It would be unfortunate if the process to enhance the resilience of the essential service stymie the required green energy transition and so contribute to further vulnerability in the broader South African context. Similar to how Japanese kintsugi artists consider breaking ceramics to enable a creative rebirth; resilience scholars may consider eroding resilience to enable transformation towards beneficial futures.

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