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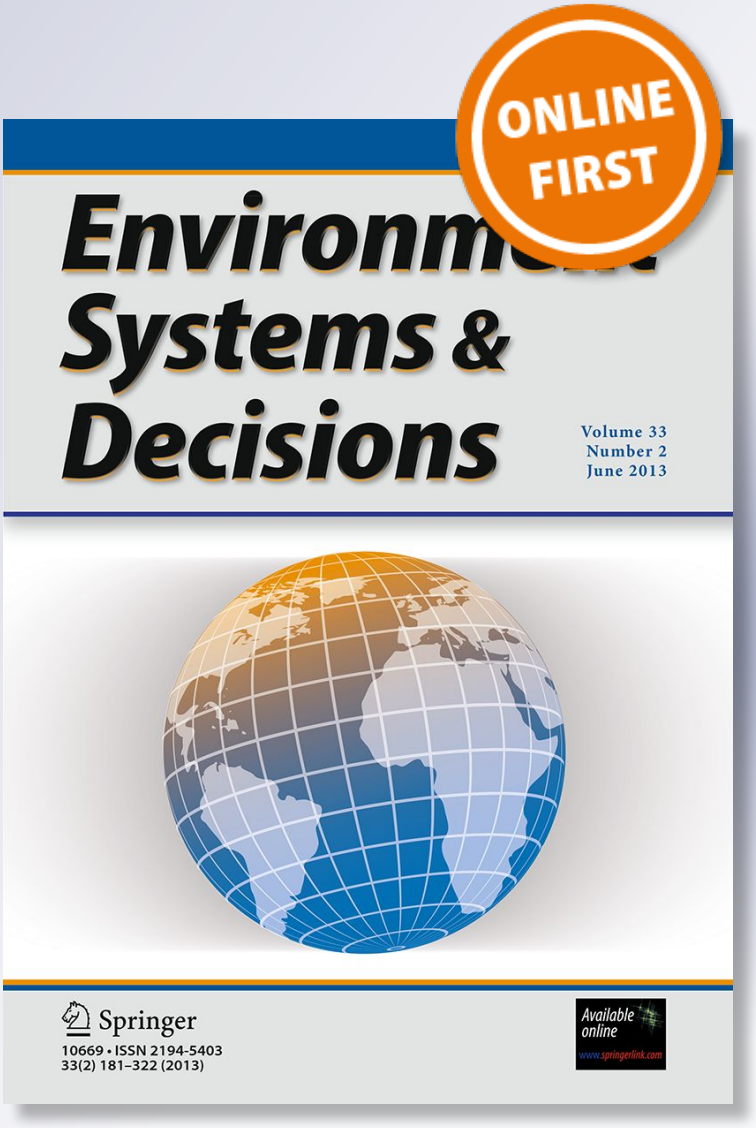

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Sensemaking as an approach for resilience assessment in an Essential Service Organization

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Abstract
Essential service organizations are interested in approaches to assess and build infrastructure resilience to ensure an uninterrupted supply of services, such as electricity or water. This study applied a sensemaking approach to assess the nature of social resilience in a national essential service organization in South Africa. It used the SenseMaker tool to collect and surface patterns from a set of micro-narratives collected in response to a national emergency simulation exercise. Findings show that participants utilized specified resilience resources, such as procedures and protocols, while general social resilience resources, such as social network integration and agency, which would have contributed to the response, did not feature significantly. Participants' sense of coherence—how they comprehend, manage, and find meaning amidst life's challenges—had a positive bearing on preparedness, involvement, and expectation of outcome in the context of the emergency simulation exercise and appear to be the organization's strongest social resilience resource. This study suggests that a sense of coherence can inform resilience-building interventions, and be used as a measure of effective sensemaking towards more resilient outcomes.

Keywords Critical infrastructure resilience · General social resilience · Sensemaking · Sense of coherence · Resilience capacities · Emergency exercise

1 Introduction

This article describes a resilience assessment performed in the critical infrastructure sector to determine the relative composition of specified and general social resilience utilized in response to a specific disruption. The assessment took place in a national electrical utility and utilized a narrative-based sensemaking approach following a national emergency exercise that simulated cascading failure leading to a national blackout. Specified and general resilience offer complimentary, but sometimes contradictory capabilities, which contribute to response-ability in different contexts. If organizations can establish the relative composition of resilience resources drawn upon in a specific context, they might be able to evaluate resource use and latent capacities across the community of responders. This insight may be useful to enhance an organization's resilience repertoire through establishing greater levels of ambidexterity (Van der Merwe 2019).

Resilience is needed to sustain essential service delivery, as complex interdependent critical infrastructure systems are prone to disruption and surprise which tend to erode and disrupt the functioning of these systems (Woods 2012; Dunn et al. 2017). Given the many formulations for resilience, we here define it as the ability to sustain core functions amidst disruption and change and envisage it as an emergent property of complex adaptive systems (Folke et al. 2010; Biggs et al. 2012). The electrical power systems, like all critical infrastructure systems, are complex adaptive systems (Jackson 2010; Johnson and Gheorghe 2013; Kelly 2015). Different infrastructure systems are dependent on and connected to one another resulting in critical infrastructure interdependency (Bloomfield et al. 2017; Furuta and Kanno 2018). Furthermore, critical infrastructure systems are embedded in social, ecological, and economic systems which are all complex adaptive systems (Van der Merwe et al. 2018). These implications necessitate an explicit incorporation of

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complexity thinking towards achieving critical infrastructure resilience objectives.

Resilience scholars highlight the need to assess and build two different types of resilience, being specified and general resilience, to withstand predictable and unpredictable disruption (Walker et al. 2009; Resilience Alliance 2010). Specified resilience aims to ensure that an identified set of components of a system may be able to withstand identified (known) threats, for example, that a particular bridge needs to withstand one-in-one-hundred-year flood events, or that specific time-critical business processes need business continuity to cope with the unavailability of specific human resources (BCI 2010). In contrast, general resilience establishes systems-level flexibility to enhance coping capacity amidst unpredictable (even unknowable) threats and surprises (Carpenter et al. 2001; Folke et al. 2010). Furthermore, both types of resilience are necessary, and an exclusive focus on building one is likely to erode the other (Resilience Alliance 2010).

Essential services are produced by complex adaptive socio-technical systems that consist of critical infrastructure embedded within specific social–cultural–organizational arrangements (Varga 2015; Van der Merwe et al. 2018; Thomas et al. 2019). The socio-technical systems' propensity for resilience should be assessed and enhanced to support continuous operations in the face of disruption, and speedy restoration of essential services following disruption (Zolli and Healy 2012; Folke 2016; Linkov and Trump 2019). Resilient technical infrastructure is not enough to sustain service delivery in the face of extreme events, as the social resilience of these human and institutional processes is likewise a precondition (Omer et al. 2014; Thomas et al. 2019). Technical resilience is well studied, but more research is required to assess and enhance social resilience within essential service organizations, such as among the employees in an electrical utility, as is the focus of this study.

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). Sensemaking is an ongoing action-oriented cycle of acquisition and reflection that people go through to integrate experiences into their understanding of the world, and which furthermore informs their action (Kolko 2010; Maitlis et al. 2013). Naturalistic sensemaking studies use self-signified narratives to reveal how people make sense of experiences in their natural contexts (Kurtz and Snowden 2007; Snowden 2011). In any given situation, individuals have access to an array of resilience resources to draw upon. Which resources they use is influenced by their sensemaking, i.e., interpretation and understanding of the context and mindfulness of a desired outcome. Probing the way in which individuals, and organizations as a whole, respond under pressure can uncover the interpretations they make in individual or collective sensemaking, which can reveal prevalent mind-sets that inform action. Insights from such an assessment can be used to enhance resilience through ensuring the group has access, in their collective culture, to a balanced repertoire of specified and general resilience resources.

The aim of this article is to assess the composition of specified and general social resilience within an essential service organization using a naturalistic sensemaking approach. This is done using the SenseMaker tool, a software solution developed by Cognitive Edge, that analyzes 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 participants' reflections on a countrywide 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. The assessment informed 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 participants utilized 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, alternative perspectives on resilience are introduced, with an emphasis on social resilience, and factors that influence sensemaking and contribute to specified and general social resilience. An understanding of these factors was used to design the SenseMaker survey instrument used in this study.

2 Alternative perspectives on resilience

2.1 Complicated and complex approaches to resilience

While the presence of complexity is widely acknowledged in the ontology of critical infrastructure resilience (Seager et al. 2017; Collier et al. 2018; Kete et al. 2018; Mian et al. 2018; Keele and Coenen 2019), it is rare to find the precautionary

implications of complexity thinking coherently applied to the epistemology and methodology of these problems (Kupers and Foden 2017; Pearson et al. 2018). While Kupers and Foden (2017) hold that resilience engineering concepts are firmly established in complexity thinking, they observe that the resilience engineering discipline is not yet close to mainstream in engineering schools globally. Complicated problems are well suited to Newtonian and reductionist approaches, like those employed by classic engineering that builds robustness to dynamic stresses. Yet, Poli (2013) explain that complicated and complex problems are different in type, not different by degree. Poli (2013), furthermore, provided a golden rule to distinguish between these problem contexts: complicated problem causes can be individually distinguished, while complex problems result from networks of interacting and vague causes; complicated problems can be solved piece by piece, while complex problems must be addressed for entire systems, not in a piecemeal fashion; in complicated systems, input results in a proportionate output, while small input in complex problems may result in disproportionate and non-linear effects; complicated problems admit permanent solutions, while complex problems cannot be solved once and for all—interventions typically merge into new problems as a result of the interventions undertaken to deal with them; and, unlike complex problems, complicated systems can be controlled, although complex systems is susceptible to influence (Poli 2013). For this reason, a complexity philosophy entails holism, uncertainty, and subjectivity (Heylighen et al. 2007; Cilliers 2016). Newtonian reductionism has proven very useful to accomplish the technological breakthroughs and levels of technological sophistication in modern society, but it is insufficient to address the intractable complex problems that remain (Dekker et al. 2011; Rogers et al. 2013). Key implications of complex adaptive systems are that they are relationally constituted; context dependent and radically open; systems behaviors emerge adaptively in response to interactions and change; and change is dynamic and non-linear (Preiser et al. 2018). Furthermore, to acknowledge complex adaptive systems is to recognize that complex problems are intractable and cannot be solved once and for all (Poli 2013); accept that there are inherent limitations to predictability, controllability, and manageability (Dunn et al. 2017); uncertainty is irreducible (Wilkinson et al. 2013); once a system crosses a critical threshold, irreversible regime shifts take place (Gunderson et al. 2017); power–law relationships exist and fat-tail incidents are inevitable (Dahlberg 2015); and, due to tight interdependencies, failure may rapidly cascade across loosely coupled connections (Kelly 2015). Since engineering solutions are always embedded in complex adaptive systems (Allenby and Sarewitz 2011), it becomes essential to incorporate the implications of complexity in pursuit of resilience.

Fig. 1 A conceptual framework differentiates between four domains of resilience to consider in assessing and enhancing resilience of essential services produced by socio-technical systems (Van der Merwe et al. 2018). While critical infrastructure resilience often emphasizes aspects of the bottom technical resilience quadrants, considerations from the top can dynamically contribute or actively detract from resilient essential service delivery amidst disruption and change. Quadrants on the left and right of the framework are distinguished based on the type of problem context and planning paradigm, respectively, requiring complicated and complex approaches

2.2 Domains of resilience

There is a growing call for a holistic approach to resilience in critical infrastructure systems (The White House 2013; Abi-Samra et al. 2014; Aivalioti 2015; Labaka et al. 2015; Clarke et al. 2016; Pearson et al. 2018; Thomas et al. 2018, 2019). A recent framework for resilient essential services serve as the basis of assessing and building among respective domains of resilience, based on a focus on social or technical resilience as well as on the distinction between specified and general resilience (Van der Merwe et al. 2018) (Fig. 1). An interdisciplinary approach was applied to synthesize approaches from different disciplines, combined with experience attempting to apply these principles in practice, while conducting enterprise resilience assessments in a national electrical utility. Building the different types of resilience, specified and general, respectively, utilized complicated and complexity approaches. While specified resilience supports persistence and returning to a pre-defined equilibrium based on a complicated paradigm, general resilience enables emergent adaptability and transformability across multiple equilibria and utilizes a complexity paradigm (Van der Merwe et al. 2018). In that sense, the framework highlights multiple partial

perspectives that are required for a holistic consideration of critical infrastructure resilience.

- *Specified technical resilience* focuses on robust technical infrastructure, where specified resilience levels should be known, and built into components, to ensure that it is adequate, reliable and secure.
- *Specified social resilience* focuses on specific skills, response capabilities, and preparedness, where specified resilience should be known, and is established, in people in the essential service system through processes and institutions.
- *General technical resilience* focuses on systems-level flexibility and adaptability, where the resilience of the overall system should be understood, and strengthened, through adaptive technologies and tools that offer systems-level flexibility to support and enable effective response in dealing with uncertainty.
- *General social resilience* focuses on collective human agency, agility, and volition, where resilience of people and processes should be understood and established to withstand unknown hazards.

By blending different resilience domains and alternative resilience emphasis across the organization, the framework offers a rich view to assess and build resilience for essential service delivery. Since the focus of this article is on the social considerations of critical infrastructure resilience, the objective in this assessment is to distinguish between the top left and top right quadrants of Fig. 1.

2.3 Social resilience

Social resilience entails proactive, adaptive, and transformative capacities to navigate change and disruption (Keck and Sakdapolrak 2013). The community targeted through this research is employees of a national utility who need to respond to disruption to safeguard the power system and "keep the lights on." Enhancing the social resilience of employees in essential service organizations may enhance their ability to navigate between normal business and times of disruption (Wybo 2008). According to Thomas et al. (2018) a holistic take on critical infrastructure resilience includes resilience considerations from subjective interior as well as objective exterior viewpoints for individuals and the collective. While literature on critical infrastructure resilience typically views the organization as an inter-objective system from the collective external perspective, Thomas et al. (2018) observe that the implications of culture on resilience is a rare consideration. This article explicitly considers the collective interior perspective of participants by interrogating the way they made sense of the situation, both individually and collectively. This viewpoint is of particular interest as people's interpretations strongly influence their response. Before delving further into specified and general social resilience, a brief introduction is given of the subjective constructs of sensemaking and sense of coherence as an effective sensemaking measure for a resilient outcome.

2.4 Sensemaking for resilience

How people make sense of their surroundings determine how they respond (Weick et al. 2005; Weick and Sutcliffe 2015). We refer to sensemaking as a human capacity and a subjective psychological process (Klein et al. 2006; Thomas et al. 2018), which is different from sensing in the resilience cycle, described by Park et al. (2013), which refers to an objective process for collecting intelligence and incorporating that into an understanding of the system. Individual sensemaking involves an initial awareness of cues from the environment (or if it is missed), how these signals are interpreted (or misinterpreted), and how individuals enact their interpretation (Kudesia 2017). Sensemaking is a continuous process to establish situational awareness, which is especially crucial under conditions of uncertainty and complexity (VanPatter and Pastor 2016). Effective sensemaking, i.e., comprehension in a crisis, from the individual to the collective, is a prerequisite for effective emergency response (Dekker et al. 2008; Casto 2014). Effective collective sensemaking is, therefore, of particular importance to the resilience objective to maintain continuity amidst disruption without loss of critical systems function (Folke et al. 2010; Maitlis et al. 2013; Kudesia 2017).

Although sensemaking is primarily subconscious, the quality of collective sensemaking can be enhanced to improve the outcome through mutual understanding towards collective action strategies from group norms, shared mental models, and team reflection (Wolf et al. 2017; Szijarto 2019). Approaches to enhance resilience through improved effectiveness of individual and collective sensemaking include Weick and Sutcliffe's (2001, 2015) mindfulness practices from high reliability organizations to enhance the safety and reliability of critical socio-technical functions, and Boyd's OODA loop with strategies to improve the speed and effectiveness of the observation, orientation, decision, and action cycles (Osinga 2005). While these theories describe effective sensemaking strategies, this study assesses how sense is made naturalistically.

Organizations perform emergency exercises that simulate disruption to enhance collective sensemaking and to provide exposure to rarely used procedures. Exercises can confirm the validity of response plans and the readiness of formalized structures to coordinate response and recovery (Wybo 2008). Emergency simulation exercises 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). On the one hand, this exposure builds up the required intuitive capacity to deal with foreseeable events, and also allows participants to expand their repertoires as they engage with complexity, instability, and uncertainty. Thus, they offer safe-to-fail opportunities to advance collective sensemaking and infuse social resilience into the organizational fabric.

2.5 Sense of coherence as social resilience measure

A worldview with high levels of sense of coherence (SOC) gives innate strength to individuals and communities that is coherent with the demands of the external environment, and an aptitude for adapting to changing risk contexts (Lindström and Eriksson 2006; Zaidi et al. 2015). SOC is a measure of general resilience that points towards people's subjective ability to cope and recover from crisis (Antonovsky 1987b). It reflects an internal viewpoint that affects perception (i.e., sensemaking) and coping behavior that alleviates stress (Almedom et al. 2007; Muller and Rothmann 2009; Eriksson 2016). SOC is core to the 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; Bíró et al. 2014). SOC consists of three interwoven dimensions of comprehensibility, manageability, and meaningfulness (Antonovsky 1987b; Lindström and Eriksson 2006). Meaningfulness, i.e., the ability to perceive challenges as worthwhile to engage in, is the strongest subjective contributor to resilience (Antonovsky 1987a; Harrop et al. 2006; Lindström and Eriksson 2006).

SOC has been used to reflect a subjective propensity for 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 collective SOC 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).

2.6 Types of social resilience

An organization's capacity for resilience arises from a combination of well-practiced responses and the ingenuity to deliver creative solutions in novel or surprising contexts (Lengnick-Hall et al. 2011). These particular responses arise from specified and general resilience, respectively. 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 an emergent and dynamic capacity to maintain continuity or rapidly restore service delivery amidst unknown and unforeseen disruption (represented by the top left and top right quadrants of Fig. 1). Lee et al. (2013) refer to these respective types of resilience as first-order and second-order adaptive capacities. Specified social resilience enables bounce-back ability and can be built by inculcating well-practiced responses through adherence to good practice disciplines, whereas general social resilience is the ability to improvise, even capitalize, on unexpected challenges and change, which enables transformability, and which emerges from wide-ranging subjective, cultural, and educational competencies (Lengnick-Hall et al. 2011; Van der Merwe et al. 2018). Fostering general social resilience is therefore a strategy to survive and thrive amidst uncertainty and complexity.

A consistent distinction is made between the ability to deal with foreseen and unforeseen situations in the resilience, sensemaking, and salutogenic bodies of literature referred to thus far (Table 1). Since this distinction between foreseen and unforeseen situations, respectively, points to the need for specified and general resilience, these multi-disciplinary perspectives shed further light on the difference between these types of resilience. Specified and general social resilience resources are built and strengthened differently (Resilience Alliance 2010; Sagy 2016) (Table 1). Literature on sensemaking points out that these different contexts require distinct forms of organizational sensemaking and fundamentally different types of organizational coordination of action; while the salutogenic literature points out different types of social resources that contribute to strong SOC to prevent these respective contexts from causing undue stress.

Holling (1986) describes resilience as the science to deal with surprise. Specified and general social resilience may assist in dealing with situational and fundamental surprises. Situational surprises arise from startling situations and are due to frequently occurring intelligence failures on known phenomena; while fundamental surprises arise from astonishing situations that are rare, but inevitable, and are due to profound misunderstandings, inappropriate mind-sets, or incongruence between perceived and actual reality (Lanir 1983; Marston 2015; Elgersma 2018). Fundamental surprises occur when people were not looking for or did not recognize warning signs, saw a façade, or held viewpoints that became obsolete (Elgersma 2018). Effective response to the latter rest on the ability to reinterpret available information, collectively construct transformed understanding, and attain fundamental learning (Lanir 1983).

Table 1 A general theme emerge that distinguish between formal arrangements and informal capacities when comparing types of resilience, types of resources that contribute to sense of coherence, and types of sensemaking contexts organizations need to respond to in order to coordinate action

	Foreseen situations	Unforeseen situations
Types of resilience	Specified resilience • Resilience of specified parts to identified disruptions • Required for response to foreseeable eventualities unfolding roughly as predicted by experts to return performance to the baseline • Verifiable capacities are established through the adoption of good practice guidelines, leading to specified preparedness and formalized in pre-approved plans and procedures • Often produced to fulfill governance and compliance obligations (Van der Merwe et al. 2018)	General resilience • System's ability to absorb any disturbance and retain its core function • Required to deal with unexpected eventualities, especially in maintaining essential functions amidst uncertainty of unpredictable disruption, including the possibility of a new equilibrium created through the incident • Emerges from an intangible capacity to withstand any hazards, including novel and unforeseen ones (Walker and Salt 2012) • Tightly intertwined with adaptive capacity and the ability to self-organize (Carpenter et al. 2001)
Types of sensemaking contexts	• In routine situations, characterized by an ongoing flow of events; experience meeting expectations • Respondents need to focus on established structure, where control and coordination exerted to improve organization (Bakken and Hernes 2010) • Subjective understanding used generically to establish structural mechanisms (rules, habits, and routines) for effective coordination of action, independent of those involved (Weick 1995; Kudesia 2017)	• In contingent situations, equivocal cues from the environment require sensemaking to interpret its nature and meaning • Respondents need to focus on ongoing relational processes (Bakken and Hernes 2010) • Need to develop innovative new intersubjective understandings to deal with the crisis at hand, which is uniquely constituted by the actual people involved (Weick 1995; Kudesia 2017)
Types of social resources that influence SOC	• Particular resources for dealing with specific situations or stressors, typically only drawn upon when required (Mittelmark et al. 2016), e.g., having a specific helpline number • Resources consist of services, structures or capacities established through societal action (Mittelmark et al. 2016)	• Characteristics with wide-ranging utility and regularly accessed. • Enable people to cope effectively with stress (Idan et al. 2016), e.g., having a social network to draw on • Characteristics arise from cultural, social, and environmental conditions and socialization experiences (Eriksson 2016; Sagy 2016)

2.7 Specified social resilience resources

Resilience objectives, described as the ability to 'bounce-back,' seek to return a system from any deviation towards a pre-defined equilibrium, or safe-operating envelope (Holling 1996; Pendall et al. 2007). A combination of engineering standards, best practice, or good practice disciplines may be employed to strengthen specified components against specified threats, while reducing uncertainty (Van der Merwe et al. 2018). In this context, resilience management seeks to enhance the capabilities of a system to plan and prepare for, absorb, recover from, and adapt to change (Committee on Increasing National Resilience to Hazards and Disasters 2012; Linkov and Trump 2019). Specified resilience applied to the social dimension of an organization would enable predictable response to a disruptive event. Specified social resilience resources utilized in this assessment include adherence to an organizational mandate; technical expertise; rules and procedures; and response plans to follow. Inherent limitations of these resources are also highlighted.

- 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). Pre-approved response plans and contingency arrangements formalize 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, planning 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, the context of a disruption is, nonetheless, often different to that envisaged. Disasters can disable structures, leaving plans and procedures inappropriate (Kendra and Wachtendorf 2003). When unforeseen crises threaten to overwhelm and destabilize organizations, general resilience becomes essential.

2.8 General social resilience resources

Resilience objectives, described as the ability to 'bounce-forward,' seek to enhance the adaptive capacity and transformability of a system across multiple equilibria, while sustaining core systems functions (Polhill et al. 2016; Dunn et al. 2017). Change and surprise can be a source of opportunity, but to seize opportunity, organizations need to enlarge their capacity for adaptability and transformability. To foster general social resilience requires a diverse portfolio of safe-to-fail interventions based on complexity thinking and resilience thinking (Van der Merwe et al. 2018). Complexity methods to cultivate resilience include creating adaptive spaces and engaging with emergence (Holman 2010; Dickens 2012; Uhl-Bien and Arena 2017). Lengnick-Hall et al. (2011) highlight cognitive, behavioral, and contextual capabilities that can be developed through strategic human resource management. General social resilience resources are intangible assets which may contribute to a better than expected outcome (Lengnick-Hall et al. 2011). General social resilience resources utilized in this assessment include social networks, individual agency, understanding the big picture, and the ability to apply new thinking in crisis.

- Social networks are a key source of general social resilience (Moore and Westley 2011). When these networks are characterized by sufficient levels of mutual trust and social capital, they enable the flow of resources, ideas, and people across boundaries (Lengnick-Hall et al. 2011; Dakos et al. 2015). On the contrary, lack of communication and cooperation among loosely connected functions in a system, have been at the root of multiple industrial accidents (Jackson 2010). Appropriate connectivity provides invaluable innovation, problem solving, and col-

laboration 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, which constitutes agency as a vital contributor to social resilience (Bohle et al. 2009; Naderpajouh et al. 2018). Agency promotes the 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 serve as an informal institution that constrain collective action (North 1992). Shared mental models of the systems context should be established prior to an incident in order to increase the validity of the understanding that informs response. 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 reflects an innovative and emergent adaptive capacity of learning-by-doing (Resilience Alliance 2010; Cundill et al. 2015). "Out-of-the-box" thinking in the heat of the moment requires deep expertise and the ability to rapidly act on decisions based on pattern recognition and appropriate mental models (Doyle et al. 2015; Schön 2016). Highly tuned experts take years to develop the ability to perform "reflection-in-action," and to respond and lead in ill-defined situations of extreme pressure. Furthermore, social learning and multi-loop learning is essential to recover from fundamental surprise, develop new response capabilities, or open up new opportunities in crisis (Lanir 1983; Stephenson 2010; Lengnick-Hall et al. 2011; Lee et al. 2013).

3 Method

3.1 Case study

This case study draws on Eskom's Enterprise Resilience programme which was initiated in 2013. The objective was to establish specified resilience capabilities across the national electricity utility. Wholly owned by the South African government, Eskom delivers 95% of the electricity consumed in South Africa (Eskom 2018). Initially the programme utilized quantitative resilience assessments to monitor and report on progress regarding specified resilience targets; however, assessments of general social resilience were ad hoc. The Eskom Resilience Team wanted to explore the extent to which general social resilience has emerged across the organization and to formatively identify the resilience capacities to be enhanced. The set of resilience resources identified for inclusion in this study were drawn from literature across multiple disciplines, and narrowed down to a practical set of indicators through iterations of interviews with the utility resilience manager and exercise coordinator.

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 October 3, 2017 that simulated a major systems failure after an undetected infiltration of the IT network 2 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 damaged infrastructure, and stakeholders were dissatisfied with subsequent delays in restoration. The simulated scenario was believable, but unprecedented in terms of organizational experience and, thus, characterized by equivocality.

This type of context typically triggers sensemaking, and requires a combination of both specified and 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 centralized service functions anticipated their support needs and delivered the required services. Having all supporting services centralized can improve business efficiency and yield global optimization. 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).

3.2 Data collection

Participation in the emergency exercise was based on predefined roles and responsibilities of employees related to emergency response structures in the various divisions across the vertically integrated 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 1 month, 87 entries were received—a response rate of 17.4%, leading to a confidence level of 85% with a 7% margin of error.

Data collection was only initiated a few days after the exercise to draw on retrospective sensemaking that emanates from reflection-on-action (Kolko 2010). Reflection-in-action is characterized 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 a higher response rate, but responses appeared shallow and optimistic compared to those from reflection-on-action. Allowing participants to cool down before inviting their participation poses the risk of fewer participants but can lead to potentially more thoughtful observations.

3.3 SenseMaker as resilience assessment tool

Methods for social resilience assessments are still emerging (Lavelle et al. 2015). Approaches employed include assessments of collaboration and adaptive management outcomes (Plummer and Armitage 2007); adaptive capacity, and the nature of 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 et al. 2014). All these approaches require expert exploration and analysis into specific areas of interest. In contrast, a sensemaking research approach can reveal patterns in a system relative to signifiers based on participant perception, without the need for expert re-interpretation (or potential distortion) (Van der Merwe et al. 2019).

SenseMaker[1] 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 et al. 2012; Van der Merwe et al. 2019). This method can reveal the "evolutionary potential of the present" which can be used to nudge the system towards beneficial adjacent possibilities (Snowden 2011; Mark and Snowden 2017; Van der Merwe et al. 2019).

SenseMaker has been employed for resilience assessments in contexts such as airline flight operations using engineering resilience principles (Dijkstra 2013); economic development and upliftment programmes that establish capacities for coping, adaptation, and transformation (Will 2016; Gottret 2017); and planned for training people serving on the frontline using neuroscience and performance psychology principles (personal Skype conversation with Dr Ian Snape from Frontline Mind, July 2017).

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 invited 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 et al. 2012). The SenseMaker process involves greater cognitive load than a survey, thereby enhancing the depth and accuracy of the responses.

3.4 Instrument design

The web-based instrument consisted of a prompting question that solicited a short observation from the participants after the simulation exercise regarding the organization's ability to respond to challenges. This was followed by various questions that asked respondents to signify meaning against their

[1] 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).

Table 2 Social resilience indicators employed in the assessment

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

observation relative to resilience resources incorporated into the signification framework. The resilience resources utilized as indicators in the signification framework are summarized in Table 2.

The signification framework was designed to capture the aspects in Table 3, using triads, dyads, stones, and multiple-choice questions. Triads invite participants to indicate relative weight among three equally balanced concepts (Deprez et al. 2012). Balanced concepts reduce incidences of response bias—as there are no right or wrong answers. In the center 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 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. Triads were used to establish behavioral patterns across the system by asking participants 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 et al. 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 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 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 from centralized service functions in the organization during the execution of the exercise.

Multiple-choice questions are used to collect demographic data and allow for the visualization 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 distinguish between reported emotion; perceived preparedness; and for how long respondents will remember the incident. (Aspects 1 and 5 from Table 3 employed multiple-choice questions.) (Refer to Fig. 4 in Results section.)

While Antonovsky (1993) motivates the usefulness of SOC in dealing with complexity and conflict, his SOC scale equates comprehension with predictability—a correlation criticized by Flensborg-Madsen, Ventegodt, and Merrick (Flensborg-Madsen et al. 2005) as being too narrow an interpretation to do justice to complexity. Since we recognize the value of SOC as a resilience measure, and resilience is required to deal with complexity (Plummer and Armitage 2007; Folke 2016), we operationalize SOC's comprehensibility dimension as the ability to make sense amidst uncertainty, in line with Lengnick-Hall et al. (2011) decisiveness despite uncertainty.

3.5 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 participants' interpretation of the relative utilization of respective resources to the emergency response. The resilience assessment was based on systems-level usage patterns of participants' reliance upon specified versus

Table 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 utilized in the instrument design
1. Participants' response	Think back to an experience in the exercise that either: (choose one) • scared you, OR • 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? • Trivial, will forget soon • For some time • For a long time • For a lifetime
2. Specified or general resilience resources participants employed during their response.	Drag the ball in each triangle to a position that best describes the experience shared. The closer the ball to any one corner, the stronger that quality is in the context of the experience. Triad 1:  Triad 2:  Triad 3:

Table 3 (continued)

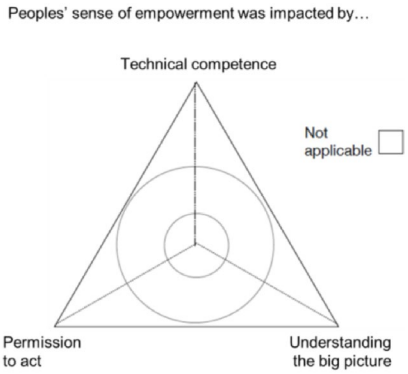
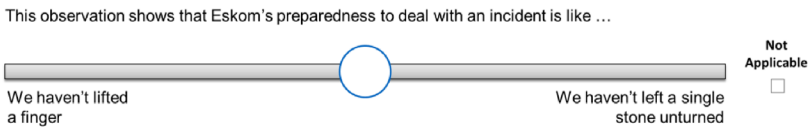
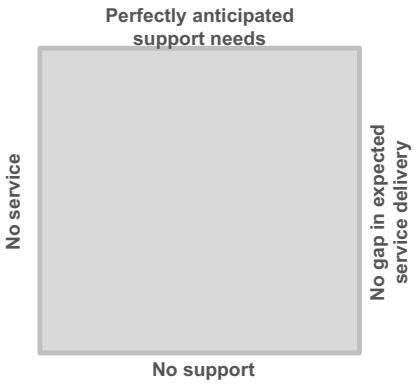
Aspect to evaluate	Signifiers utilized in the instrument design
	
3. Views on levels of preparedness in the organization to effectively deal with the scenario encountered.	
4. Indicators for: the strength of social networks: cooperation within teams; coordination with teams from other areas; and connectedness 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 color 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. • Commercial • Human Resources • Information Technology • Real Estate • Security • Telecommunications • N/A 
5. Participants' perceptions of 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) • Total confusion • Successful recovery • Site shut down • Survival of Eskom • Loss of governance • Survival of SA • Complete disintegration • Eskom seizing opportunities and thriving • Collapse of Eskom • Don't know • End of SA
6. Sense of coherence as	To give us a glimpse on the overall manner in which you deal with tension and

Table 3 (continued)

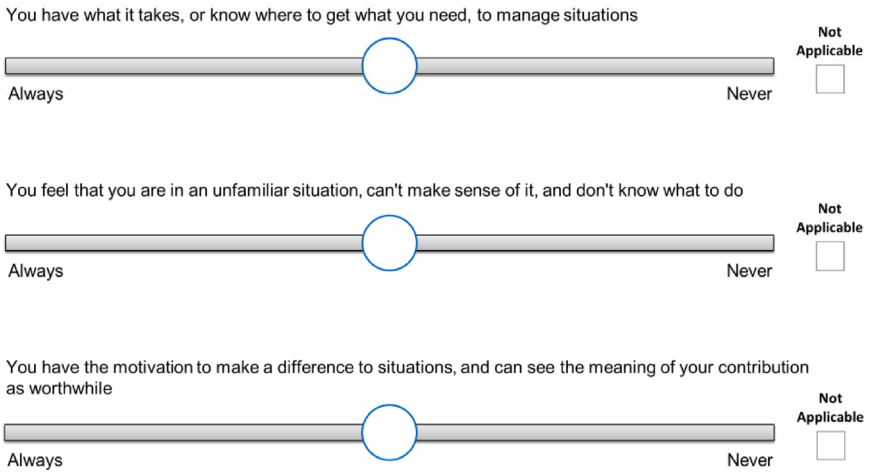
Aspect to evaluate	Signifiers utilized in the instrument design
Participants' assessment of how they normally cope with stress and disruption	stressful situations, please indicate your general approach to life's challenges along these sliders: 

Table 4 Among the triad-derived resilience indicators (color coded from lowest value in red to highest in green) specified social resilience resource was, on average, drawn upon more readily 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***

general social resilience resources. Patterns across the library of micro-narratives were visualized 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).

4 Results

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

4.1 Reliance on specified versus general social resilience resources

The results show that participants utilized specified social resilience resources more than general resilience resources (Table 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, especially among participants working at local sites, for example power station operations, at the expense of *direction from a mandate*.

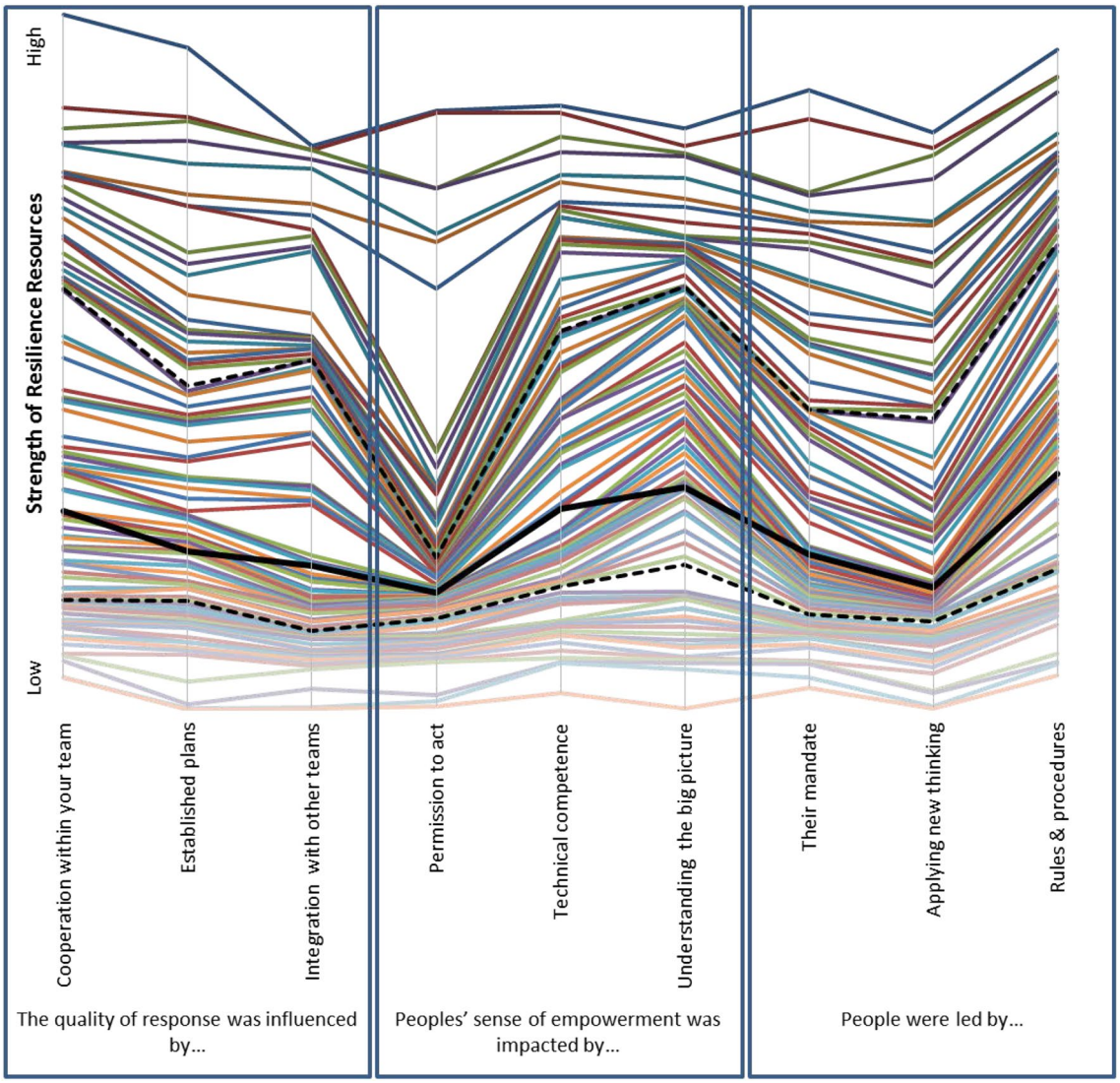


Fig. 2 Data points for all triad variables were joined within and across the three triads (each triad is delineated in a box) to highlight distribution patterns and clustering of the relative weights assigned by participants for the respective resilience resources. The lighter color lines at the bottom reflect resources indicated as low contributors, up to the darkest lines indicated as strongest contributors in response to triads. The solid black line represents the geometric mean, and the dotted black lines connect the 25th and 75th percentile for each variable

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 (Fig. 2). While resources such as *rules & procedures* and *cooperation within your team* have a good spread, 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*.

4.2 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 achieved beforehand,

Table 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	74.9
		Manageability	73.7
		Meaningfulness	77.5
	55.4		75.4

and sense of coherence refers 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). *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 ($x=80$, $n=26$, $p=0.034$).

No relationship was observed between people's overall SOC and their preference for specified or general resilience resources. Nevertheless, micro-narratives 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 (Fig. 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 (Fig. 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, hence, lacked emergency response capacity.

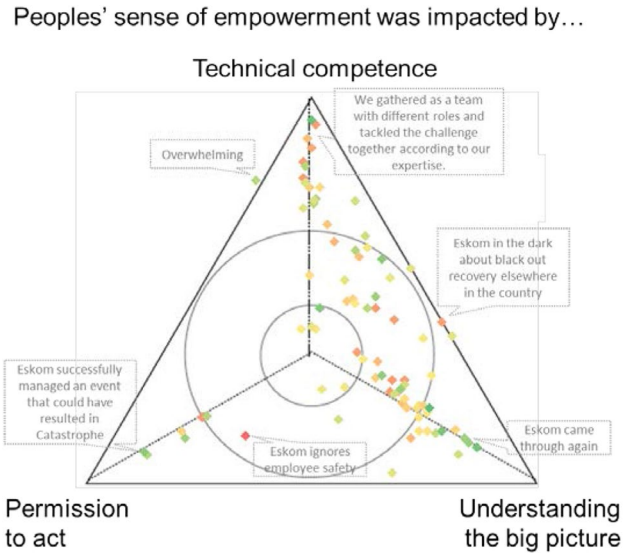


Fig. 3 In this triad, participants were asked to consider the contributors to a sense of empowerment based on their observations. They indicated a position that correlates with the relative strength of the three constructs. The overall pattern illustrates that few people picked up on permission to act. Some micro-narratives are shown as each data point is associated to a micro-narrative along with the results from the signification framework. Furthermore, the points are color coded by participants' levels of sense of coherence from red (low) to green (high). A color gradient (from orange to green) can be distinguished towards the corner of understanding the big picture. It would appear that participants, increasingly comfortable in their understanding of the big picture, also reported increasing levels of SOC

5 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), as in the case of electricity when an extended interruption of supply often affects customers beyond the initial area of impact, as illustrated by remote customer outages of up to 3 weeks after Superstorm Sandy (Lacey 2014). The assessment was based on an emergency simulation exercise, which tested response preparedness and provided an opportunity for assessing resilience resources relied upon in extreme events. The approach developed in this study may prove useful for assessing resilience in essential service systems and other organizations interested in understanding the balance of specified and general social resilience resources utilized in response to extreme events.

5.1 Reliance on specified versus general social resilience resources

As far as could be established, 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 et al. 2009; Frazier et al. 2013; Lee et al. 2013). However, the

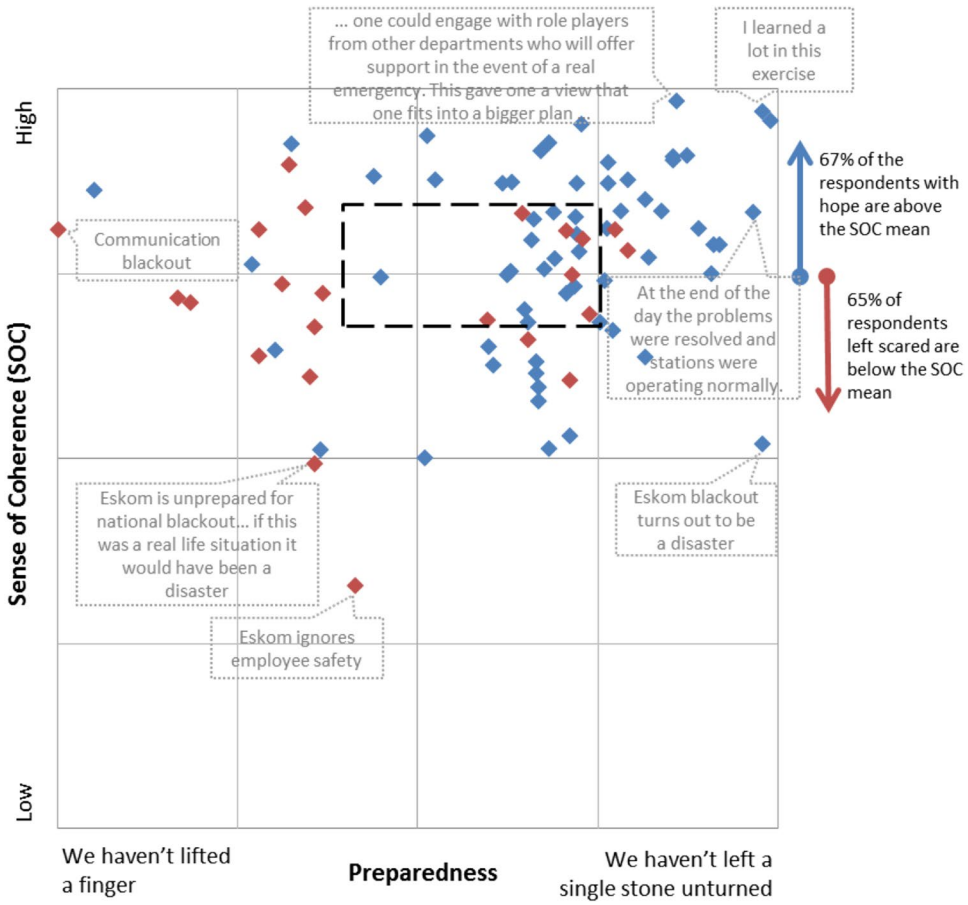


Fig. 4 Scatter plot of levels of preparedness relative to levels of sense of coherence. Data points are color coded by the emotion participants felt based on what they saw: red if scared and blue if they have hope. The black dotted line box on the graph indicates the area between the 25th and 75th percentile of both axes. Micro-narratives are shown at selected data points to illustrate the stories behind the data

social components of complex systems are not reducible to resilience metrics (Walker et al. 2004). This study used a novel sensemaking approach to distill social resilience indicators, indicative of the type of social resilience resources drawn upon in a particular context. This 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. This approach prompted participants to interpret the type of resilience resources enacted in their response. Systems-level 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.

The study recognizes that the equivocality of the scenario in the emergency simulation called for a combination of social resilience resources to be drawn upon, while the results suggest that participants relied more on specified social resilience resources than general social resilience resources (Table 4). Weick et al. (1999) advocate that organizations deliberately create and maintain multiple modes of paradoxical response and decision-making capacities to contribute to problem solving. Although specified resilience competencies are easier to establish than those of general resilience, they may have limited usefulness in confronting the unknowns of extreme events. Reliance on specified resilience resources possibly led to the underutilization of general resilience resource, which may have been more appropriate in dealing with the equivocality of this scenario.

It is essential that an organization has the flexibility to shift between the two sensemaking modes identified by Weick (1995) to enable utilization of the different types of resilience. Despite 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 despite uncertainty (Wybo 2008; Lengnick-Hall et al. 2011; 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* (Table 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 1). Strong institutional rules result in habitual responses that lack deliberate intent (Fleetwood 2008). This situation can be described as "lock-in" as it stifles adaptability and effective responses to complexity (Uhl-Bien and Arena 2017). Unfortunately, rote rule following, especially in periods of crisis and 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 may even encourage positive deviance in certain contexts, which contributes to improving performance and achieving goals on an ongoing basis (Mertens and Recker 2017). Yet, given the current results, expecting this level of agility from Eskom, 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 realized that standard procedures were inadequate for the challenges of the scenario; yet, they failed to take *direction from their mandate* to self-organize. Adaptive action that results from the ability to self-organize is a crucial resilience enabler (Bohle et al. 2009; Brown and Westaway 2011; Zolli and Healy 2012). 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.

The response in the exercise scenario seems to lack quality *integration across functions*, as there were 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 and Archer (2002) to downward causation. However, it is known that systems-level safety does not improve by blaming those at the sharp end for failure (Flin et al. 2017; Weber and Dekker 2016). A just culture focuses on empowering people to learn from failure and emphasizes restorative justice rather than retributive justice (Dekker 2007; Dekker and Breakey 2016). Inayatullah (1998, 2005), Milojević and Inayatullah (2015) propose 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.

The results of this study 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 organization-level issues, interventions aimed at individual-level factors are likely to increase frustration and feelings of powerlessness (Wallerstein 1992). The organizational culture and sociopolitical 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 engage in enhancing 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.

5.2 Effect of sense of coherence on response

The findings of this study suggest that sense of coherence (SOC) influences participants' responses to the emergency simulation. These results confirmed previous field studies to assess resilience using SenseMaker in the same organization, and established results in the literature, that effective sensemaking in the moment of crisis is necessary for

a specific resilient outcome (Weick 1988, 2010); and that sense of coherence is a measure that predicts a general resilient outcome (Antonovsky 1987a, b).

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 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 (Fig. 3). 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 (Basińska et al. 2011). Besides, high SOC levels enable individuals to cope with difficulty and to effectively use mental models and competences (Harrop et al. 2006). 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 behavior, stress, and professional burn-out (Antonovsky 1987a; Basińska et al. 2011).

Although the relative use of specified social resilience resources dominated among the triads, the high levels of individual sense of coherence from the dyads suggest the latter may contribute substantially to the levels of social resilience in the organization (Tables 4 and 5). Thus, emergency response role allocation should consider individual SOC, and collective SOC should be cultivated throughout the organization. This proposal aligns with past studies in essential service organizations conducted among nurses and social workers which aimed to carry out intervention strategies to advance individual and collective SOC. The researchers recognized 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 et al. 2011; Idan et al. 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. 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 this organization. But, this intervention requires enhancing the levels of empowerment that is essential to an individual's sense of meaningfulness (Feldt et al. 2000).

5.3 Limitations of the study

The results of this study focus on the 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. Furthermore, due to the small number of collected narratives, the results of this study cannot be generalized. As the magnitude of an incident determines response, the results cannot be extrapolated to smaller-scale incidents, where a clearer operational mandate and stronger local social networks is likely to reflect as increased agency. Also, this assessment reflects a single snapshot as it was performed on a 1-day exercise. Valuable insight may be gained in monitoring change in sensemaking and meaning-making over time during multi-day exercises or even multi-day response to real emergencies, through ongoing narrative capture. Daily incident debriefing sessions may provide such an opportunity where responders can be prompted to reflect on and share an observation from the day.

Collective sensemaking is considered by Deprez et al. (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. Although SenseMaker analyses use statistics and visualization to bring patterns to light, the data remain subjective in nature. For this reason, Goertz and Mahoney (2012) warn that these patterns or propositions are indicative at best, and should be verified. However, reported results were not subjected to verification among members of the participant community, to not influence the compilation of the normal exercise report required as part of Eskom procedures.

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

5.4 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. 2017). More work is required to understand how collective SOC influences organizational sensemaking and response to disruption and ongoing change. This could emerge from application to more exercises and post-incident assessments after actual events.

6 Conclusion

This article makes 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 use to understand the composition of these types of resilience resource utilized in organizational response to an extreme event and to adaptively stimulate latent resilience capacities.

The study linked a resilient outcome under conditions of equivocality, with effective sensemaking at the individual- and organizational level and utilized sense of coherence (SOC), which reflects aspects of resilience and sensemaking, as a measure of general social resilience. The results of the study suggest a correlation between SOC and a resilient disposition in 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. Moreover, this study underscored that cultivating a strong SOC appears to be a crucial enabler to enhance social resilience. 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 and the economy.

The people embedded in the socio-technical system contribute inherent strengths and vulnerabilities to how the system behaves and evolves. A defining difference between these types of resilience capabilities is that specified resilience can be built top-down through formalized mechanisms to increase managerial control over periods of deviation, while general resilience can be cultivated to grow organically from cultural ingredients such as shared purpose, agency, and mutual trust, but bottom-up emergence contribute to novelty. Organizations who seek to build both capabilities need to know when to let go of control and predictability in order to embrace the opportunity in novelty and ambiguity. Such ambidexterity may be contrary to current organizational norms, but is increasingly essential to navigate unforeseen surprises from change and disruption.

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Compliance with ethical standards

Conflict of interest Susara E. van der Merwe, Reinette Biggs, and Rika Preiser declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

Abi-Samra N, McConnach J, Mukhopadhyay S, Wojszczyk B (2014) When the bough breaks, managing extreme weather events affecting electrical power grids. IEEE Power Energy Mag 12:61–65. https://doi.org/10.1109/MPE.2014.2331899

Abrams AL (2015) Legal strategies—crisis management and accident investigation. In: ASSE professional development conference and exposition. American Society of Safety Engineers

Aivalioti S (2015) Electricity sector adaptation to heat waves. Sabin Center for Climate Change Law, Columbia Law School, New York, NY

Allenby BR, Sarewitz DR (2011) The techno-human condition. Massachusetts Institute of Technology, Cambridge

Almedom AM, Tesfamichael B, Mohammed ZS et al (2007) Use of 'sense of coherence (SOC)' scale to measure resilience in Eritrea: interrogating both the data and the scale. J Biosoc Sci 39:91–107. https://doi.org/10.1017/S0021932005001112

Antonovsky A (1987a) Health promoting factors at work: the sense of coherence. In: Kalimo R, El-Batawi MA, Cooper CL (eds) Psychosocial factors at work and their relation to health. World Health Organisation, Geneva, pp 153–167

Antonovsky A (1987b) Unraveling the mystery of health: how people manage stress and stay well. Jossey-Bass, San Francisco

Antonovsky A (1993) Complexity, conflict, chaos, coherence, coercion and civility. Soc Sci Med 37:969–974. https://doi.org/10.1016/0277-9536(93)90427-6

Bakken T, Hernes T (2010) Organizing is both a verb and a noun. In: Clegg SR (ed) SAGE directions in organization studies, vol II. SAGE, Los Angeles, pp 19–38

Basińska MA, Andruszkiewicz A, Grabowska M (2011) Nurses' sense of coherence and their work related patterns of behaviour. Int J Occup Med Environ Health 24:256–266. https://doi.org/10.2478/S13382-011-0031-1

BCI (2010) Good Practice Guideline 2010, a management guide to implementing global good practice in Business Continuity Management. Global Business Continuity Institute

Biggs R, Schlüter M, Biggs D et al (2012) Toward principles for enhancing the resilience of ecosystem services. Annu Rev Environ Resour 37:421–448. https://doi.org/10.1146/annurev-environ-051211-123836

Bíró É, Veres-Balajti I, Ádány R, Kósa K (2014) Social cognitive intervention reduces stress in Hungarian university students. Health Promot Int 32:73–78. https://doi.org/10.1093/heapro/dau006

Bloomfield RE, Popov P, Salako K et al (2017) Preliminary interdependency analysis: an approach to support critical-infrastructure risk-assessment. Reliab Eng Syst Saf 167:198–217. https://doi.org/10.1016/j.ress.2017.05.030

Bohle H-G, Etzold B, Keck M (2009) Resilience as Agency. IHDP Updat. 8–13

Braun-Lewensohn O, Sagy S (2014) Community resilience and sense of coherence as protective factors in explaining stress reactions: comparing cities and rural communities during missiles attacks. Community Ment Health J 50:229–234. https://doi.org/10.1007/s10597-013-9623-5

Brown K, Westaway E (2011) Agency, capacity, and resilience to environmental change: lessons from human development, well-being, and disasters. Annu Rev Environ Resour 36:321–342. https://doi.org/10.1146/annurev-environ-052610-092905

Carpenter SR, Walker BH, Anderies JM, Abel N (2001) From metaphor to measurement: resilience of what to what? Ecosystems 4:765–781. https://doi.org/10.1007/s10021-001-0045-9

Casto CA (2014) Crisis management: a qualitative study of extreme event leadership. Dissertation, Kennesaw State University

Cilliers P (2016) Critical complexity: collected essays. De Gruyter, Berlin

Clarke J, Coaffee J, Rob R, et al (2016) Resilience evaluation and SOTA summary report. RESILENS, Horizon 2020 Programme, Dublin, Ireland

Cognitive Edge (2017) Realtime situational assessment with MassSense, Potential disruption on the Korean Peninsula, A SenseMaker & BBC Monitor case study

Cognitive Edge (2018) Cognitive Edge landing page. In: Cogn. Edge. http://cognitive-edge.com/. Accessed 4 Feb 2018

Collier ZA, Lambert JH, Linkov I (2018) Resilience, sustainability, and complexity in social, environmental, and technical systems. Environ Syst Decis 38:1–2. https://doi.org/10.1007/s10669-018-9679-4

Committee on Increasing National Resilience to Hazards and Disasters (2012) Disaster resilience: a national imperative. The National Academies Press, Washington, D.C.

Correia AJ, Koch R, Van der Merwe SE, Mahomed S (2017) Addressing emergency decision making in complex incidents: implementation of advanced incident command system in Eskom. In: 8th Southern Africa Regional Cigre Conference. Cigre, Paris, France

Cundill G, Leitch AM, Schultz L et al (2015) Principle 5: encourage learning. In: Biggs R, Schlüter M, Schoon ML (eds) Principles for building resilience, sustaining ecosystem services in social-ecological systems. Cambridge University Press, Cambridge, pp 174–200

Dahlberg R (2015) Resilience and complexity: conjoining the discourses of two contested concepts. Cult Unbound J Curr Cult Res 7:541–557. https://doi.org/10.3384/cu.2000.1525.1572541

Dakos V, Quinlan A, Baggio JA et al (2015) Principle 2: manage connectivity. In: Biggs R, Schlüter M, Schoon MLE (eds) Principles for building resilience: sustaining ecosystem services in social-ecological systems. Cambridge University Press, Cambridge, pp 80–104

Dekker SWA (2007) Just culture, balancing safety and accountability. Ashgate Publishing Limited, London, England

Dekker SWA (2015) Safety differently, 2nd edn. CRC Press, Boca Raton

Dekker SWA, Breakey H (2016) 'Just culture:' improving safety by achieving substantive, procedural and restorative justice. Saf Sci 85:187–193. https://doi.org/10.1016/j.ssci.2016.01.018

Dekker SWA, Hollnagel E, Woods D, Cook R (2008) Resilience engineering: new directions for measuring and maintaining safety in complex systems. Lund University School of Aviation, Lund

Dekker SWA, Cilliers P, Hofmeyr J-H (2011) The complexity of failure: implications of complexity theory for safety investigations. Saf Sci 49:939–945. https://doi.org/10.1016/j.ssci.2011.01.008

DeLong S (2016) Statistics in the Triad. In: QED insight, Res. sensemaking action. http://qedinsight.com/tag/statistics/. Accessed 2 July 2017

Deprez S, Huyghe C, Van Gool Maldonado C (2012) Using Sensemaker to measure, learn and communicate about smallholder farmer inclusion, thematic learning programme on planning, monitoring and evaluation of complex processes of social change. VECO, Vredeseilanden, Eerbeek

Dickens PM (2012) Facilitating emergence: complex, adaptive systems theory and the shape of change. Dissertation, Antioch University

Dijkstra A (2013) Understanding Resilience in Flight Operations "Find the story behind flight safety reports and learn from successes." In: Herrera I, Schraagen JM, Van der Vorm J, Woods D (eds) Resilience Engineering Symposium 2013. Resilience Engineering Association, Soesterberg, The Netherlands

Doyle EEH, Paton D, Johnston DM (2015) Enhancing scientific response in a crisis: evidence-based approaches from emergency management in New Zealand. J Appl Volcanol. https://doi.org/10.1186/s13617-014-0020-8

Duman L (2017) Developing a resilience-thinking leadership mindset scale. Dissertation, Antioch University

Dunn G, Brown RR, Bos JJ, Bakker K (2017) Standing on the shoulders of giants: understanding changes in urban water practice through the lens of complexity science. Urban Water J 14:758–767. https://doi.org/10.1080/1573062X.2016.1241284

Elfassi Y, Braun-Lewensohn O, Krumer-Nevo M, Sagy S (2016) Community sense of coherence among adolescents as related to their involvement in risk behaviors. J Commun Psychol 44:22–37. https://doi.org/10.1002/jcop.21739

Elgersma DS (2018) Airpower's Response to Fundamental Surprise. US Army Command and General Staff College Fort Leavenworth, KS

Engle NL (2011) Adaptive capacity and its assessment. Glob Environ Chang. https://doi.org/10.1016/j.gloenvcha.2011.01.019

Eriksson M (2016) The sense of coherence in the salutogenic model of health. In: Mittelmark MB, Sagy S, Eriksson M et al (eds) the handbook of salutogenesis. Springer, Cham, pp 91–96

Eriksson M, Lindström B (2005) Validity of Antonovsky's sense of coherence scale: a systematic review. J Epidemiol Commun Health 59:460–466. https://doi.org/10.1136/jech.2003.018085

Eriksson M, Mittelmark MB (2016) The sense of coherence and its measurement. In: Mittelmark MB, Sagy S, Eriksson M et al (eds) The handbook of salutogenesis. Springer, Cham, pp 97–106

Eskom (2016) Eskom Holdings Corporate Plan, Financial years 2016/16-2020/21, towards surplus capacity. Eskom, Johannesburg, South Africa

Eskom (2018) Eskom Holdings Corporate Plan FY2018/19—FY2022/23, 8th edn. Eskom Holdings, Johannesburg, South Africa

Feldt T, Kinnunen U, Mauno S (2000) A mediational model of sense of coherence in the work context: a one year follow up study. J

Organ Behav 21:461–476. https://doi.org/10.1002/(SICI)1099-1379(200006)21:4%3c461:AID-JOB11%3e3.0.CO;2-T
Fleetwood S (2008) Structure, institution, agency, habit and reflexive deliberation. J Inst Econ 4:183–203
Flin R, O'Connor P, Crichton M (2017) Safety at the sharp end: a guide to non-technical skills. CRC Press, Taylor & Francis Group, London, England
Flensborg-Madsen T, Ventegodt S, Merrick J (2005) Why is Antonovsky's sense of coherence not correlated to physical health? Analysing Antonovsky's 29-item sense of coherence scale (SOC-29). Sci World J 5:767–776. https://doi.org/10.1100/tsw.2005.89
Folke C (2016) Resilience. Oxford Res Encycl Environ Sci
Folke C, Carpenter SR, Walker BH et al (2010) Resilience thinking: integrating resilience, adaptability and transformability. Ecol Soc. https://doi.org/10.5751/ES-03610-150420
Frazier TG, Thompson CM, Dezzani RJ, Butsick D (2013) Spatial and temporal quantification of resilience at the community scale. Appl Geogr 42:95–107. https://doi.org/10.1016/j.apgeog.2013.05.004
Furuta K, Kanno T (2018) Resilience analysis of urban critical infrastructure: a human-centred view of resilience. In: Trump BD, Florin M-V, Linkov I (eds) IRGC resource guide on resilience: domains of resilience for complex interconnected systems. EPFL International Risk Governance Center, Lausanne
Goertz G, Mahoney J (2012) A tale of two cultures: qualitative and quantitative research in the social sciences. Princeton University Press, Princeton
Gottret MV (2017) Understanding and assessing resilience: a sensemaker-based methodology. Baltimore, MD, USA
Guijt I (2012) Voices in the room: stories, statistics & systemic change. In: Int. Progr. Dev. Eval. Train. [IPDET], Guest Lect. Carlet. Univ. https://www.youtube.com/watch?v=gOQGMlZSARc. Accessed 29 May 2017
Gunderson L, Cosens BA, Chaffin BC et al (2017) Regime shifts and panarchies in regional scale social-ecological water systems. Ecol Soc. https://doi.org/10.5751/ES-08879-220131
Harrop E, Addis S, Elliott E, Williams G (2006) Resilience, coping and salutogenic approaches to maintaining and generating health: a review. Cardiff University, Cardiff Institute of Society Health and Ethics (CISHE), Cardiff
Herbane B (2010) The evolution of business continuity management: a historical review of practices and drivers. Bus Hist 52:978–1002. https://doi.org/10.1080/00076791.2010.511185
Heylighen F, Cilliers P, Gershenson C (2007) Complexity and philosophy. In: Bogg J, Geyer R (eds) Complexity, science and society. Radcliff Publishing, Oxford, pp 117–134
Himmelstrand U, Archer MS (2002) Being human: the problem of agency. Contemp Sociol 31:359. https://doi.org/10.2307/3089723
Holling CS (1986) The resilience of terrestrial ecosystems; local surprise and global change. In: Clark WC, Munn RE (eds) Sustainable development of the biosphere. Cambridge University Press, Cambridge, pp 292–317
Holling CS (1996) Engineering resilience versus ecological resilience, National Academy of Engineering. In: Schulze P (ed) Engineering within ecological constraints. National Academies Press, Washington, DC, pp 31–44
Hollnagel E (2009) The four cornerstones of resilience engineering. In: Nemeth CP, Hollnagel E, Dekker S (eds) Resilience engineering perspectives. Volume 2: preparation and restoration. CRC Press, Boca Raton, pp 117–134
Holman P (2010) Engaging emergence, turning upheaval into opportunity. Berret-Koehler Publishers, San Francisco
Idan O, Braun-Lewensohn O, Sagy S (2013) Qualitative, sense of coherence-based assessment of working conditions in a psychiatric in-patient unit to guide salutogenic interventions. In: Bauer GF, Jenny GJ (eds) Salutogenic organizations and change: the concepts behind organizational health intervention research. Springer, Dordrecht, pp 55–74
Idan O, Eriksson M, Al-Yagon M (2016) The salutogenic model: the role of generalized resistance resources. In: Mittelmark MB, Sagy S, Eriksson M et al (eds) The handbook of salutogenesis. Cham, Switzerland, pp 57–69
Inayatullah S (1998) Causal layered analysis: poststructuralism as method. Futures 30:815–829. https://doi.org/10.1016/S0016-3287(98)00086-X
Inayatullah S (2005) From organizational to institutional change. Horiz 13:46–53. https://doi.org/10.1108/10748120510601662
Jackson S (2010) Architecting resilient systems: accident avoidance and survival and recovery from disruptions. Wiley, Hoboken
Johnson J, Gheorghe AV (2013) Antifragility analysis and measurement framework for systems of systems. Int J Disaster Risk Sci 4:159–168. https://doi.org/10.1007/s13753-013-0017-7
Jones H (2011) When is a policy problem complex, why does it matter, and how can it be tackled? In: Jones H (ed) Taking responsibility for complexity. Overseas Development Institute, London
Keck M, Sakdapolrak P (2013) What is social resilience? Lessons learned and ways forward. Erdkunde 67:5–19. https://doi.org/10.3112/erdkunde.2013.01.02
Keele S, Coenen L (2019) The role of public policy in critical infrastructure resilience. The Resilience Shift, London
Kelly S (2015) Estimating economic loss from cascading infrastructure failure: a perspective on modelling interdependency. Infrastruct Complex. https://doi.org/10.1186/s40551-015-0010-y
Kendra JM, Wachtendorf T (2003) Elements of resilience after the world trade center disaster: reconstituting New York City's Emergency Operations Centre. Disasters 27:37–53
Kete N, Punzo G, Linkov I (2018) Enhancing resilience within and between critical infrastructure systems. Environ Syst Decis 38:275–277. https://doi.org/10.1007/s10669-018-9706-5
Klein G, Moon B, Hoffman RR (2006) Making sense of sensemaking 1: alternative perspectives. IEEE Intell Syst 21:70–73. https://doi.org/10.1109/MIS.2006.75
Kolko J (2010) Abductive thinking and sensemaking: the drivers of design synthesis. Des Issues 26:15–28. https://doi.org/10.1162/desi.2010.26.1.15
Kudesia RS (2017) Organizational sensemaking. Oxford University Press, New York
Kunreuther H, Slovic P, Olson KG (2014) Fast and slow thinking in the face of catastrophic risk. In: Wharton Working Paper, Risk Management and Decision Processes Center. The Wharton School, University of Pennsylvania, Philadelphia, PA
Kupers R, Foden M (2017) Learning for resilience and complex systems thinking. The Resilience Shift, London
Kurtz CF, Snowden DJ (2007) Bramble bushes in a thicket narrative and the intangibles of learning networks. In: Gibbert M, Durand T (eds) Strategic networks: learning to compete (Strategic Management Society). Blackwell Publishing, Malden, pp 121–150
Labaka L, Hernantes J, Sarriegi JM (2015) Resilience framework for critical infrastructures: an empirical study in a nuclear plant. Reliab Eng Syst Saf 141:92–105. https://doi.org/10.1016/j.ress.2015.03.009
Lacey S (2014) Resiliency: how Superstorm Sandy changed America's grid. Greentech Media Inc., Boston
Lanir Z (1983) Fundamental surprises. Center for Strategic Studies, Tel Aviv
Lavelle FM, Ritchie LA, Kwasinski A, Wolshon B (2015) Critical assessment of existing methodologies for measuring or representing community resilience of social and physical systems, NIST GCR 15-1010. Gaithersburg, MD, USA
Lee AV, Vargo J, Seville E (2013) Developing a tool to measure and compare organizations' resilience. Nat Hazards Rev 14:29–41. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000075

Lengnick-Hall CA, Beck TE, Lengnick-Hall ML (2011) Developing a capacity for organizational resilience through strategic human resource management. Hum Resour Manag Rev 21:243–255. https://doi.org/10.1016/j.hrmr.2010.07.001

Lindbert C, Schneider M (2012) Leadership in a complex adaptive system: insights from positive deviance. In: Acad. Manag. Best Pap. Proc

Lindström B, Eriksson M (2006) Contextualizing salutogenesis and Antonovsky in public health development. Health Promot Int 21:238–244. https://doi.org/10.1093/heapro/dal016

Linkov I, Trump BD (2019) The science and practice of resilience. Springer, Cham

Lundberg O, Peck MN (1995) A simplified way of measuring sense of coherence: experiences from a population survey in Sweden. Eur J Public Health 5:56–59. https://doi.org/10.1093/eurpub/5.1.56

Maitlis S, Vogus TJ, Lawrence TB (2013) Sensemaking and emotion in organizations. Organ Psychol Rev 3:222–247. https://doi.org/10.1177/2041386613489062

Mark A, Snowden DJ (2017) Cynefin: a tool for situating the problem in a sense-making framework. In: de Savigny D, Blanchet K, Adam T (eds) Applied systems thinking for health systems research, a methodological handbook. McGraw-Hill Education, Open University Press, London, pp 76–96

Marston AL (2015) The efficacy of cognitive shock. U.S. Army Command and General Staff College Fort Leavenworth, KS

Mertens W, Recker J (2017) Positive deviance and leadership: an exploratory field study. In: 50th Hawaii international conference on system sciences (HISCC 2017), January 4-7. Hawaii International Conference on System Sciences, Waikoloa Village, Hawaii

Mian J, Da Silva J, Kete N, et al (2018) Critical infrastructure resilience: understanding the landscape. The Resilience Shift

Militello LG, Patterson ES, Bowman L, Wears R (2007) Information flow during crisis management: challenges to coordination in the emergency operations center. Cogn Technol Work 9:25–31. https://doi.org/10.1007/s10111-006-0059-3

Milne KMG (2015) Can sense-making tools inform adaptation policy? A practitioner's perspective. Ecol Soc. https://doi.org/10.5751/ES-06791-200166

Milojević I, Inayatullah S (2015) Narrative foresight. Futures 73:151–162. https://doi.org/10.1016/j.futures.2015.08.007

Mittelmark MB, Bull T, Daniel M, Urke H (2016) Specific resistance resources in the salutogenic model of health. In: Mittelmark MB, Sagy S, Eriksson M et al (eds) The handbook of salutogenesis. Springer, Cham, pp 71–76

Moore ML, Westley F (2011) Surmountable chasms: networks and social innovation for resilient systems. Ecol Soc. https://doi.org/10.5751/ES-03812-160105

Mullainathan S, Shafir E (2013) Scarcity: why having too little means so much. Penguin Books, London

Muller Y, Rothmann S (2009) Sense of coherence and employees' perceptions of helping and restraining factors in an organisation. SA J Ind Psychol 35:89–99. https://doi.org/10.4102/sajip.v35i1.731

Naderpajouh N, Yu DJ, Aldrich DP et al (2018) Engineering meets institutions: an interdisciplinary approach to the management of resilience. Environ Syst Decis 38:306–317. https://doi.org/10.1007/s10669-018-9704-7

Nickerson J, Sanders RP (2014) Tackling wicked government problems: a practical guide for developing enterprise leaders. Brookings Institution Press, Washington, D.C.

Nofi AA (2000) Situational awareness, defining and measuring shared situational awareness. Center for Naval Analyses, Defense Advanced Research Projects Agency, Alexandria

North DC (1991) Institutions, institutional change, and economic performance. J Econ Perspect 5:97–112. https://doi.org/10.2307/2234910

North DC (1992) Institutions and economic theory. Am Econ 36:3–6. https://doi.org/10.1177/056943459203600101

Omer M, Mostashari A, Lindeman U (2014) Resilience analysis of soft infrastructure systems. Procedia Comput Sci 28:873–882. https://doi.org/10.1016/j.procs.2014.03.104

Osinga F (2005) Science, strategy, and war: the strategic theory of John Boyd. Eburon Acadmic Publishers, Delft

Park J, Seager TP, Rao PSC et al (2013) Integrating risk and resilience approaches to catastrophe management in engineering systems. Risk Anal 33:356–367. https://doi.org/10.1111/j.1539-6924.2012.01885.x

Pearson J, Punzo G, Mayfield M et al (2018) Flood resilience: consolidating knowledge between and within critical infrastructure sectors. Environ Syst Decis 38:318–329. https://doi.org/10.1007/s10669-018-9709-2

Pendall R, Foster KA, Cowell M (2007) Resilience and regions: building understanding of the metaphor. Institute of Urban and Regional Development, Berkeley

Plummer R, Armitage DR (2007) A resilience-based framework for evaluating adaptive co-management: linking ecology, economics and society in a complex world. Ecol Econ. https://doi.org/10.1016/j.ecolecon.2006.09.025

Polhill JG, Filatova T, Schlüter M, Voinov A (2016) Modelling systemic change in coupled socio-environmental systems. Environ Model Softw 75:318–332. https://doi.org/10.1016/j.envsoft.2015.10.017

Poli R (2013) A note on the difference between complicated and complex social systems. Cadmus 2:142–147

Preiser R, Biggs R, De Vos A, Folke C (2018) Social-ecological systems as complex adaptive systems: organizing principles for advancing research methods and approaches. Ecol Soc. https://doi.org/10.5751/ES-10558-230446

Quinlan AE, Berbes-Blazquez M, Haider LJ, Peterson GD (2015) Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives. J Appl Ecol 53:677–687. https://doi.org/10.1111/1365-2664.12550

Reed DA, Kapur KC, Christie RD (2009) Methodology for assessing the resilience of networked infrastructure. IEEE Syst J 3:174–180

Resilience Alliance (2010) Assessing resilience in social-ecological systems: workbook for practitioners. Version 2.0. http://www.resalliance.org/3871.php. Accessed 29 June 2016

Rogers KH, Luton R, Biggs HC et al (2013) Fostering complexity thinking in action research for change in social- ecological systems. Ecol Soc. https://doi.org/10.5751/ES-05330-180231

Sagy S (2016) Salutogenesis in the era after antonovsky. In: Mittelmark MB, Sagy S, Eriksson M et al (eds) The handbook of salutogenesis. Springer, Cham, pp 43–44

Schön DA (2016) The reflective practitioner, how professionals think in action. Routledge Taylor & Francis Group. First published 1983 by Basic Books, Abingdon, Oxon & New York, NY

Schumann A, Hapke U, Meyer C et al (2003) Measuring sense of coherence with only three items: a useful tool for population surveys. Br J Health Psychol 8:409–421. https://doi.org/10.1348/135910703770238275

Seager TP, Clark SS, Eisenberg DA et al (2017) Redesigning resilient infrastructure research. In: Linkov I, Palma-Oliveira J (eds) Resilience and risk: methods and application in environment. Cyber and Social Domains, Springer

Snowden DJ (2011) Naturalizing sensemaking. In: Mosier KL, Fischer UM (eds) Informed by knowledge: expert performance in complex situations. Taylor & Francis, New York, pp 223–234

Stephenson A (2010) Benchmarking the resilience of organisations. Dissertation, University of Canterbury

Szijarto B (2019) Mediating social change: building adaptive learning systems through developmental evaluation. Dissertation, University of Ottawa

Tappolet C (2016) Emotions, values, and agency. Oxford University Press, Oxford

The White House (2013) Presidential Policy Directive 21: Critical Infrastructure Security and Resilience. Pres Policy Dir 9

Thomas J, Eisenberg D, Seager T (2018) Holistic infrastructure resilience research requires multiple perspectives, not just multiple disciplines. Infrastructures 3:30. https://doi.org/10.3390/infrastructures3030030

Thomas JE, Eisenberg DA, Seager TP, Fisher E (2019) A resilience engineering approach to integrating human and socio-technical system capacities and processes for national infrastructure resilience. J Homel Secur Emerg Manag. https://doi.org/10.1515/jhsem-2017-0019

Uhl-Bien M, Arena M (2017) Complexity leadership: enabling people and organizations for adaptability. Organ Dyn 46:9–20. https://doi.org/10.1016/j.orgdyn.2016.12.001

Van der Merwe SE (2019) Advancing resilience assessments: the social dimensions of electricity supply in South Africa. Dissertation, Stellenbosch University

Van der Merwe SE, Biggs R, Preiser R (2018) A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems. Ecol Soc. https://doi.org/10.5751/ES-09623-230212

Van der Merwe SE, Biggs R, Preiser R et al (2019) Making sense of complexity: using SenseMaker as a research tool. Systems. https://doi.org/10.3390/systems7020025

VanPatter G, Pastor E (2016) Innovation methods mapping: de-mystifying 80+ years of innovation process design. Humantific Publishing, New York

Varga L (2015) Complexity and sustainable utility services. Emerg Complex Organ. 17:F1–F4

Walker BH, Salt D (2012) Resilience practice: building capacity to absorb disturbance and maintain function. Island Press, Washington, DC

Walker BH, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability in social-ecological systems. Ecol Soc 9

Walker BH, Gunderson L, Kinzig A, et al (2006) A handful of heuristics and some propositions for understanding resilience in social-ecological systems. In: Ecol. Soc. http://www.ecologyandsociety.org/vol11/iss1/art13/

Walker BH, Abel N, Anderies JM, Ryan P (2009) Resilience, adaptability, and transformability in the Goulburn-Broken Catchment, Australia. Ecol Soc 14

Wallerstein N (1992) Powerlessness, empowerment, and health: implications for health promotion programs. Am J Heal Promot 6:197–205

Walsh-Dilley M, Wolford W (2015) (Un)Defining resilience: subjective understandings of 'resilience' from the field. Resilience 3:173–182. https://doi.org/10.1080/21693293.2015.1072310

Weber DE, Dekker SWA (2016) Assessing the sharp end: reflections on pilot performance assessment in the light of safety differently. Theor Issues Ergon Sci 18(1):59–78. https://doi.org/10.1080/1463922X.2016.1149253

Weick KE (1988) Enacted sensemaking in crisis situations. J Manag Stud 25:305–317. https://doi.org/10.1111/j.1467-6486.1988.tb00039.x

Weick KE (1995) Sensemaking in organizations. Sage Publications, Thousand Oaks

Weick KE (2010) Reflections on enacted sensemaking in the Bhopal disaster. J Manag Stud 47:537–550. https://doi.org/10.1111/j.1467-6486.2010.00900.x

Weick KE, Sutcliffe KM (2001) Managing the unexpected, what business can learn from High Reliability Organizations. In: Managing the unexpected: assuring high performance in an age of uncertainty. pp 1–24

Weick KE, Sutcliffe KM (2015) Managing the unexpected: sustained performance in a complex world, 3rd edn. Wiley, Hoboken

Weick KE, Sutcliffe KM, Obstfeld D (1999) Organizing for high reliability: processes of collective mindfulness. In: Sutton RS, Staw BM (eds) Research in organizational behavior. Jai Press, Stamford, pp 81–123

Weick KE, Sutcliffe KM, Obstfeld D (2005) Organizing and the process of sensemaking. Organ Sci 16:327–451. https://doi.org/10.1287/orsc.1050.0133

Wilkinson DJ (2006) The ambiguity advantage, what great leaders are great at. Palgrave McMillan, New York

Wilkinson A, Kupers R, Mangalagiu D (2013) How plausibility-based scenario practices are grappling with complexity to appreciate and address 21st century challenges. Technol Forecast Soc Change 80:699–710. https://doi.org/10.1016/j.techfore.2012.10.031

Will MS (2016) Making sense of complexity: review of sensemaker for development. In: Flourishing Disadv. https://flourishingandisadvantage.com/2016/12/08/making-sense-of-complexity-review-of-sensemaker-for-development/. Accessed 11 Nov 2017

Wolf A, Jan S, Schraagen M, Siegel AW (2017) Team reflection makes resilience-related knowledge explicit through collaborative sensemaking: observation study at a rail post. Cogn Technol Work 19:127–142. https://doi.org/10.1007/s10111-016-0400-4

Woods DD (2012) Resilience engineering: concepts and precepts. Ashgate Publishing, originally published 2006, Aldershot, UK

Wybo J-L (2008) The role of simulation exercises in the assessment of robustness and resilience of private or public organizations. In: Pasman HJ, Kirillov. IA (eds) Resilience of cities to terrorist and other threats, learning from 9/11 and further research. Springer-Verlag, NATO Science for Peace and Security Series, vol 6, pp 491–507

Zaidi Z, Pescaroli G, Dien I, et al (2015) Report on the interaction between resilience and vulnerability in cascading crisis situations, Deliverable D2.3. FORTRESS project, European Commission

Zobel CW, Cook D (2008) A decision support framework to assess supply chain resilience. 5th International ISCRAM Conference, May 2008. Information Systems for Crisis Response and Management, Washington, DC, pp 596–605

Zolli A, Healy AM (2012) Resilience: why things bounce back?. Simon and Schuster, New York