Operationalizing Digital Resilience – A Systematic Literature Review on Opportunities and Challenges

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Abstract

Building a digital resilience (i.e., capabilities to design, deploy and use information systems (IS) to adjust to changes caused by external shocks) may prepare individuals, organizations and other institutions for future disruptions caused by global crises. To be able to monitor the emergence and development of digital resilience, one needs to be able to measure it. Currently, there is no consensus in IS literature on how to conceptualize or operationalize resilience. By conducting a systematic literature review, we identify traditional and innovative operationalization approaches. We find scale-based quantitative methods to be most prominent, followed by qualitative analyses of resilience indicators through interviews and case studies. We identify advantages and limitations of each approach and encourage authors to move beyond the boundaries of traditional methods and incorporate innovative approaches – some of which we present in this paper – to operationalize digital resilience in a tailored, context-specific way. Challenges and opportunities are discussed.

Keywords: Digital Resilience, Information System Resilience, Systematic Literature Review, Resilience Scales, Resilience Indicators

1. Introduction

Organizations often have to cope with and adjust to external disruptions such as natural disasters, pandemics, political unrest etc. These disruptions can threaten an organization, as they are mostly unpredictable and outside their control. The Covid-19 pandemic has raised global awareness on the importance of being prepared for future exogenous shocks, which are expected to increase in frequency and severity as the 21st century progresses (Boh et al., 2020; Heeks & Ospina, 2018). This draws organizations' attention to their ability to respond in creative, flexible and resilient ways.

Resilience can be understood as the ability to respond to and recover from disturbances, absorb changes and persist (Holling, 1973). At its core is the capacity to return to a stable state following an adverse event without turning into a qualitatively different state (Holling & Gunderson, 2002). It is connected to a number of related capabilities such as adoptability, agility and innovation (Alharthy et al., 2018) and it has been applied in a broad range of disciplines, including individual and organizational psychology. Only recently this complex concept entered the information systems (IS) literature. In this context, the term digital resilience emerged to describe capabilities to design, deploy and use IS to adapt to changes caused by major external shocks (Boh et al., 2020).

In order to strengthen the digital resilience of individuals, communities, organizations and whole societies, we must have the ability to analytically compare the multiple dimensions of resilient behavior against some baseline values (Zobel & Baghersad, 2020). Resilience is a complex theoretical concept that is hard to operationalize and little empirical work has been done in this area in the IS context. So far, there is no widely accepted approach for organizations to identify the presence or absence of digital resilience prior to its performance in a turbulent time and there is no overview over suitable measurement tools and operationalizations (Linnenluecke, 2017). We conduct a systematic literature review to answer the following research question:

How is resilience operationalized in IS literature and what are related opportunities and challenges?

To this end, we conduct a systematic literature review on research that operationalizes digital resilience. This leads to an overview of the state of research on resilience in IS literature with regards to its operationalization and gives insights into multiple traditional and innovative measurement approaches. To the best of our knowledge, we are the first to assess the state of resilience operationalizations in the IS domain. Considering the domain-specific resilience

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definitions and assessments, this is an important research gap to fill for the IS domain. Our results have implications for organizations and the research community alike, as they help organizations evaluate their current level of resilience and facilitate future studies in this increasingly important area.

Our paper is organized as follows: First, we describe related research on resilience in IS, focusing on how digital resilience can be conceptualized across multiple levels. Next, we provide insights in the operationalization of resilience in other disciplines. Afterwards, we outline the steps of our literature review process, followed by a synthesis and analysis of the identified relevant literature. Finally, we discuss our findings in light of opportunities and challenges for organizations and the IS community.

2. Related research on resilience in IS

Since the concept of resilience was initially introduced as a system's ability to respond to and recover from disturbances (Holling, 1973), it has evolved beyond ecological and engineering applications. Bruneau et al. (2003) describe four dimensions of resilience in the face of adverse events as follows: Technical resilience is a component physical system's ability to maintain functionality, organizational resilience describes how organizations' actions contribute to resilient outcomes, social resilience is the capacity of individuals and groups to persist and recover and economic resilience is about reducing losses related to a disruption.

In the IS context, resilience has been mostly studied from two of the above perspectives: the technical one is mostly equated with robustness and fault tolerance and the organizational one focusses on the role resilience plays in how IS impacts organizational performance (Herrera & Janczewski, 2013). Recently, more research appears from a social perspective, for instance, on how individual digital resilience affects the continuance of technology usage (Liao et al., 2009). Resilience in IS literature is understood as a sociotechnical concept that encompasses "people, information, technology, and facilities that work interdependently for developing strategies and processes for protecting high-value services and associated assets" (Park et al., 2015). We define digital resilience in accordance with Boh et al. (2020) as the capability to design, deploy and use IS to adapt to changes caused by major external shocks. It can be studied on multiple levels, namely as part of IS input systems, as property of the IS itself or within wider IS outcome systems.

Resilience of an IS input system refers to those systems acting as an input to the IS, which is usually a human. Studies in this area, for instance, investigate how the personal resilience of a human influences their adaptation of a specific IS (e.g., Cho et al., 2007). Schemmer et al. (2021) consider backend technology as another IS input system, whose resilience they call cyber resilience. They also confirm that other IS input systems, for instance in the form of artificial intelligence, may exist and influence digital resilience.

IS resilience itself is the second level of analysis and it covers the resilience of IS as a sub-system of a wider system resilience. Erol et al. (2010) define IS resilience through four attributes, namely vulnerability, flexibility, adaptability, and agility. Studies that fall under this level of analysis are especially interested in the resilience of the infrastructure of information and communication technologies (Heeks & Ospina, 2018). It is noteworthy that the term IS resilience is often used interchangeable with digital resilience, which is technically incorrect, considering that it only represents a part of the overall digital resilience as illustrated in Figure 1.

Resilience of an IS outcome system addresses the impact IS has on the resilience of a wider system than the IS itself supports. Such wider systems encompass, for instance, an organization, a community, an economy or society as a whole (Schemmer et al., 2021).

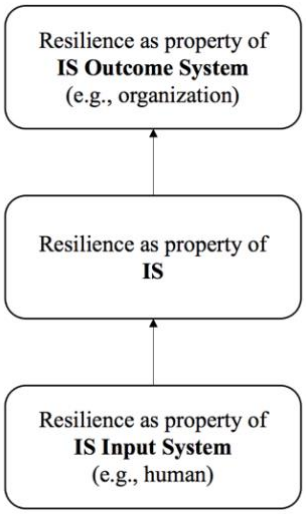

Figure 1. Levels of analysis of digital resilience (following Heeks & Ospina (2018))

Despite the growing research interest in digital resilience, we lack an agreed upon approach to operationalize it. In fact, empirical work that attempts to measure digital resilience is scarce. We, therefore, first outline resilience operationalizations in other

scientific disciplines in the next chapter, before conducting a literature review on resilience operationalizations in the IS space.

3. Operationalizing resilience

While some argue it might be best to treat resilience as an unquantifiable, vague concept (Quinlan et al., 2016), the majority agree that a concrete guidance regarding how to measure and manage resilience in a rigorous and repeatable way is needed to support managers (Garmestani et al., 2013; Spears et al., 2015). A measurement involves conceptualizing an abstract concept (i.e., a phenomenon that is not directly observable such as resilience) with specific characteristics and operationalizing it into measurable observations (Bhandari, 2022). Thus, we refer to operationalization to describe the specification of how (digital) resilience is measured in studies.

Multiple frameworks to operationalize resilience have been proposed in various disciplines to assess the resilience of particular systems and contexts, for example seismic resilience of communities (Bruneau et al., 2003), resilience of infrastructures under system stress (Chang & Shinozuka, 2004) or resilience in transport networks over various factors (Murray-Tuite, 2006). Accurate inputs are essential for the process of quantifying resilience (Umunnakwe et al., 2021). Each quantification approach is based on meta-theoretical assumptions and views of resilience prevalent in the resilience research community (Amir & Kant, 2018). To exemplify this, we will present some operationalization approaches in disaster resilience and ecological literature.

In the disaster resilience literature, Zobel & Baghersad (2020) introduce two approaches to quantify and compare complex resilience behaviors across dimensions: The first approach refers to capacity-based methods such as survey-based methods and index-based methods which measure resilience as an anticipated capacity for resisting disruptions and recovering. The second approach is output-oriented in terms of measuring a system's resilience regarding its functionality after a simulated or actual disaster. Usually, capacity-based methods measure resilience from a multi-dimensional perspective, whereas output-oriented methods evaluate only a single dimension that represents the resilience (Zobel & Baghersad, 2020).

Amongst the qualitative resilience operationalization approaches in the ecological sciences are rapid assessment approaches (Nemec et al., 2014) that focus on surveys and stakeholder knowledge of a system. Some prominent quantitative approaches are spatial approaches that focus on geometric relationships among spatial attributes of a system (Cumming, 2011), functional assessments (Angeler et al., 2014), discontinuity approaches (Sundstrom et al., 2014) and methods focusing on identifying regime shifts through early warning indicators (Lindegren et al., 2012). Angeler & Allen (2016) discuss the strengths and limitations of these approaches and point out several methodological challenges. For instance, resilience assessments are often specific to a certain group and not representative of others. What we can learn from literature on socioecological system resilience is that we must specify which system configuration and disturbances are under investigation to be able to operationalize indicators of a system's resilience (Carpenter et al., 2001). Transferred to the IS context, this means we must specify which of the previously introduced levels of analysis we target in a specific study and which resilience perspective we hold to be able to identify a suitable operationalization. Eljaoued et al. (2021) reviewed research on resilience assessments of sociotechnical systems, which they define as large-scale systems featuring a combination of technological systems and human-intensive organizational systems. Sociotechnical systems are characterized by a high complexity and interconnected components. They find the Functional Resonance Analysis Method (FRAM) to be the most popular approach. It is a qualitative method to provide a functional model of the relationships between sub systems and evaluate the resilience of complex sociotechnical systems. It can be combined with graph theory to quantify sociotechnical system resilience (Wissem Eljaoued et al., 2020). Most studies use graph theory metrics (i.e., connectivity, centrality, modularity, redundancy, diversity) and Bayesian probability metrics to measure resilience properties such as robustness, flexibility, effectiveness and resilience loss.

To summarize, there are diverse approaches to measure and operationalize resilience in various disciplines. However, they lack conceptual theorization of what resilience represents in sociotechnical systems (Amir & Kant, 2018) and in the IS discipline.

4. Structured literature review

For our systematic literature review, we follow the methods by Webster & Watson (2002) and vom Brocke et al. (2009). In the first step we define the review scope and in the second step we conceptualize the resilience construct. Thirdly, we describe the search process and fourthly synthesize and analyze the

identified literature. The fifth step is the proposition of directions for future research.

4.1. Definition of review scope

We draw on the established taxonomy for literature reviews by Cooper (1988) to define the scope of our literature review. Our focus is on research methods as our goal is to identify and summarize central issues around the operationalization of resilience in IS. The structure of our literature review is methodological according to measurement methods as well as conceptual according to levels of analysis. We consider literature of different perspectives and audiences. The degree of coverage we target is a representative coverage for the IS domain.

4.2. Conceptualization of topic

It is recommended to begin a review by stating what is known about the concept under study and in which area more knowledge is needed (vom Brocke et al., 2009). As stated in the related research section, mostly theoretical work exists in the area of digital resilience, in which the authors attempt to conceptualize it by developing resilience models or frameworks (e.g., Erol et al., 2010; Riolli & Savicki, 2003). We defined digital resilience as the capability to design, deploy and use IS to adapt to changes caused by major external shocks (Boh et al., 2020). Potential areas in which more knowledge should be sought are empirical studies as well as methodological ones on how to measure resilience in IS. Thus, our target for this literature review is to identify traditional and innovative approaches for operationalizing resilience in the IS literature.

4.3. Literature search process

In line with the previously specified taxonomy, we did not aim at an exhaustive coverage. We identified the AIS electronic library (AISel) as a suitable source of literature on digital resilience. The AISel is a central repository that provides access to prominent journals in the IS domain as well as leading IS conferences. We searched for the keyword "resilience" in the abstract and got 208 hits. We chose not to specify the keyword further as the resulting number of hits was considered manageable.

We defined a list of inclusion and exclusion criteria to select the literature for our review when scanning the body of text of these articles. Rigor and quality of included literature is guaranteed through our choice of outlet and therefore not mentioned in the criteria. We excluded the following:

- Theoretical papers that neither implemented nor suggested a concrete operationalization for resilience.
- Research in progress in which the authors plan to test a resilience model but do not specify how they plan on measuring resilience.
- Papers that use the term digital resilience in other contexts, such as to describe resilience to extremist grooming online.
- Non-English papers.
- Duplicate papers (only the most recent version of multiple papers by the same author using the same data set and measurement approach is included).

We included the following:

- Papers that contain a digital resilience measurement.
- Papers that measure resilience in general and then link it to IS-related concepts.
- Research in progress in which the authors specify how they plan on operationalizing their resilience concept, even if they so far did not implement it.

By conducting a forward/backward search, we were able to identify five more relevant articles. This led to a total of 37 final hits, which we analyze and synthesize in the following step.

4.4. Literature analysis, synthesis and future research

We identified 37 relevant publications in IS literature that measure resilience in an IS context. This allows us to present an overview over the operationalization of resilience in IS literature in the following section. Based on our research findings, we discuss opportunities and challenges of operationalizing digital resilience and propose directions for future research. These insights are described in the discussion section. We especially encourage non-self-reported approaches of resilience operationalization.

5. Research findings

We analyzed and synthesized the identified literature to answer our research question "*How is*

resilience operationalized in IS literature and what are related opportunities and challenges?". With regard to the three previously introduced levels of analysis, we identified nine research items on resilience of an IS input system, seven on IS resilience and 21 on resilience of an IS outcome system (see Table 1). Among those outcome systems, nine refer to organizational resilience, four to community resilience, three to supply chain resilience, three to health information system resilience, one to economic resilience and one to team resilience. In the following, we will present the methods applied by these studies with regard to their operationalization and related advantages and disadvantages.

Table 1. Overview of identified literature

Methods		Level of Analysis		
		Input	IS	Outcome
Survey / SEM		6	1	11
Survey / Regression		1	0	0
Interview / coding		0	0	2
Survey + interviews		0	0	1
Case study	Single	1	0	1
	Multi	0	0	1
Modeling		0	2	2
Algorithmic		0	2	0
Other		1	2	3

When analyzing the distribution of research items by level of analysis and method, we find that the majority of literature on resilience in IS input and IS outcome systems rely on traditional methods while literature covering IS resilience more often applies other, non-self-report methods. The most popular method is a survey-based data collection with subsequent data analysis through structural equation modeling (SEM), mostly applying partial least square (PLS) regression.

5.1. Resilience scales and SEM

Data for SEM is typically collected in a survey by asking participants to rank statements regarding their perception of resilience. These statements are either taken from established scales, adapted from established scales to better fit the study's context or newly created. The statements are typically operationalized on a Likert scale, asking participants to rank their agreement with each item. For example, Park et al. (2015) measured perceived resilience using the following four items on a seven-point scale from 1 (strongly disagree) to 7 (strongly agree):

1. Our information systems can handle many critical incidents at a time.
2. People in the organization are well prepared to respond during critical incidents.
3. Our organization has business continuity plans to handle unfamiliar situations.
4. Our information systems recover quickly after critical incidents.

Since resilience is a highly context-sensitive concept (Luthar et al., 2000), no one-size fits all established digital resilience scale exists. We find that most authors of our identified literature adapted the items to better fit their studies' contexts. While this increases the amount of information captured on the concept under study, it might decrease the validity and reliability of a scale (Jean Camp et al., 2019). We elaborate on this trade-off in the discussion section. Some authors chose to develop their own items and justify this with the novelty of the concept and the unavailability of a suitable scale in the literature that sufficiently covers their study's context (e.g., Alsalman & Park, 2018; Oh & Teo, 2009; Park et al., 2015). Among the scales adapted in the identified IS literature are:

- Brief resilience scale (Smith et al., 2008) adapted by Bermes et al. (2021) and Kisekka et al. (2015)
- Organizational resilience scale (Park et al., 2015) adapted by Chatterjee et al. (2021)
- Employee resilience scale (Näswall et al., 2015) adapted by Frank & Kohn (2021) and Kohn (2020)
- IT resilience scale (Klesel et al., 2018) adapted by Bermes et al. (2021)
- Supply chain resilience scale (Brandon-Jones et al., 2014) adapted by Mandal (2016)
- Connor- Davidson resilience scale (Connor & Davidson, 2003) used by Westmattelmann et al. (2021)
- Resilience scale (Stephens et al., 2013) used by Wang et al. (2019)

SEM allows constructing interrelationships and simultaneously evaluate a measurements quality (Park et al., 2018). The causal role of resilience related to other concepts in the identified IS literature is shown in Table 2. Within SEMs, resilience is either measured as a first-order or second-order construct comprising of two or more competencies (e.g., anticipatory competence, recovery competence (Oh & Teo, 2009)) or through a set of underlying constructs (e.g., Alharthy et al., 2018).

Table 2. Causal Role of Resilience

Causal role of Resilience in SEMs	Level of Analysis		
	Input	IS	Output
Antecedent	2		1
Moderator		1	1
Mediator	1		4
Outcome	2		4
Multi	1		1

A major advantage of SEM is the flexibility of the measurement instrument which offers the opportunity to investigate unobservable constructs (Nachtigall et al., 2003). Especially when applying PLS-SEM, reliable results can be achieved even with smaller sample sizes and non-normal data (Chatterjee et al., 2021). On the other hand, the relationship between constructs is much more complex in the real world than what can be captured in a SEM. For instance, outcome variables may in fact have an influence on anteceding variables, mediators or moderators (He et al., 2022). Another downside is the trade-off between capturing a complete resilience picture through a lengthy survey versus offering a comprehensive version of the survey at a reasonable length, which attracts more participants (Heeks & Ospina, 2018).

5.2. Case studies, interviews and coding

While we found only two studies operationalizing resilience in IS literature that solely use interviews and subsequent coding (Chewning et al., 2013; Pries-heje & Baskerville, 2021), interviews were also conducted and analyzed in two of the case studies we identified (Cho et al., 2007; Schaffer et al., 2021) as well as in combination with a survey (Heeks & Ospina, 2018). Interviews allow an indirect measurement for resilience attributes by means of coding. For instance, Cho et al. (2007) developed content coding categories to analyze resilience when adapting a telehealth innovation, Pries-heje and Baskerville (2021) used open, axial and selective coding as well as analytic induction coding to deduct information on the degree of resilience from interviews. While surveys usually draw on a larger pool of participants, interviews have the advantage of a higher flexibility and a higher probability of discovering unexpected results. Conducting interviews on-site has the additional advantage of allowing to capture non-verbal data, such as anxious facial expressions, which is useful when studying resilience.

When interviews are conducted as part of a larger case study, the gained information is even richer as it is supplemented by observational and publicly available data such as newspapers articles. Another advantage of case studies is its longitudinal character, which offers a chance to study changes in resilience over time. The downside is that they require a higher time commitment and effort, and its findings might not be generalizable to other cases.

A final self-reported measure identified in our literature search is Q-methodology. On the edge of qualitative and quantitative analysis, Sarkar et al. (2021) apply Q-methodology to identify top management's decision priorities for IS resilience planning. Q-methodology allows measuring subjectivity using quantitative methods without the biases associated with traditional scientific surveys (Amin, 2000; Brown, 1993). It involves inquiring individuals' attitudes and points of views by asking them to position a diverse set of statements on a topic along a pre-defined pattern and conducting a factor analysis on their subjective rankings. Often, open-ended comments or follow-up interviews support the factor interpretation (Watts & Stenner, 2005).

5.3. Non self-report approaches

While case studies already move beyond self-reported approaches to measure and operationalize resilience by combining interviews with the analysis of observations and additional data, the following methods rely solely on data. They include modeling, algorithms and other innovative methods and are mostly used to capture IS resilience (see Table 1).

Fan et al. (2020) model infrastructure systems as networks to be able to quantify IS resilience using network theory. Butler et al. (2014) and Gisladottir et al. (2017) use simulation models to measure the critical functionality of a system in the face of threats and a community's tolerance for non-beneficial content respectively. The later can be considered a virtual experiment. Basavaraj et al. (2020) draw on big data and conduct empirical modeling using algorithms such as the Poisson Count Model to measure the resilience of the U.S. gig economy during the Covid-19 pandemic. Llansó and McNeil (2021) demonstrate how discrete event stochastic simulation can be used to calculate a resilience index that quantifies a system's resilience against cyber threats. Schemmer et al. (2021) apply concept drift detection algorithms to prove the technical feasibility of this approach to enable resilience. Capturing resilience through algorithms and modeling is not limited to the ones mentioned above; they simply serve as examples to show the feasibility of operationalizing resilience in IS using mathematical approaches.

Other non-self-report methods include the analysis of dynamic panel data such as job postings or tweets. Mousavi and Gu (2020) calculate a resilience

score based on the amount of resilience messaging in tweets on Covid-19 by first applying a dictionary-based approach to extract resilience-related keywords from the Connor-Davidson Resilience Scale (Connor & Davidson, 2003) and extending this by applying an algorithm that identifies the nearest neighbors in vocabulary. Kohn (2020b) captures the sentiment scores of tweets regarding the pandemic-induced transition to remote work, arguing that this reflects on employee's digital resilience. Bai et al. (2021) extract data from pre-Covid-19 Job postings and calculate a work from home feasibility index as a measure of a company's resilience to the pandemic. To assess resilience, it is necessary to identify the configuration and disturbances of interest (Carpenter et al., 2001). In this sense, Chowdhury et al. (2012) use Quality Function Deployment (QFD) to identify prioritized vulnerabilities and which resilience capability requirements they correspond to. Other methods applied include intra-day event studies (Chlistalla, 2011).

6. Discussion

As the amount and severity of future crises that involve IS are expected to increase (Heeks & Ospina, 2018), there is a need to further our understanding of digital resilience. Based on our findings, we can identify a number of challenges and opportunities regarding operationalizing digital resilience.

We identified seven articles that incorporate the term digital, IS or similar into the definition of the resilience concept itself. Table 3 exemplifies for these articles how digital resilience is conceptualized. Since we only investigated empirical research, there are even more digital resilience definitions in theoretical papers that are not included in the table. It becomes apparent, that only some describe capabilities to design, deploy and use IS in line with our previously introduced definition (Boh et al., 2020). This inconsistent conceptualization of digital resilience poses the first challenge in operationalizing it. There is a need to clarify what constitutes the digital aspect of digital resilience and how digital resilience is distinct from a generic resilience applied to the IS domain.

Table 2. Variety of digital resilience definitions

Bai et al., 2021	"Digital resilience as measured by ability to work remotely".
Heeks & Ospina, 2018	"e-resilience [is] understood here as the contribution of ICTs [Information and communication technologies] to community resilience".
Kohn, 2020b	"We use the term digital resilience to refer to human's resilience in response to digital disruptions"
Kohn, 2020a	"Digital security resilience is an employee's ability to continuously deliver the intended outcome despite adverse cyber events."
Park et al., 2018	"Employee's perceptions of health information system [HIS] resilience is defined as the belief that the HIS is characterized by the ability to bounce back from negative experiences and by flexible adaptation to certain contexts."
Sarkar et al., 2021	"Information Systems resilience is a function of an organization's overall situation awareness related to Information Systems, management of Information Systems vulnerabilities, and adaptive capacity, risk intelligence, flexibility and agility of Information Systems in a complex, dynamic, and interconnected environment."
Schemmer et al., 2021	"Digital resilience is the property of an IS to increase the resilience of IS output systems while satisfying a sufficient resilience on sub-systems."

It is challenging to recommend a preferred approach to operationalizing digital resilience, as it is a highly context-specific concept that can capture the resilience of various instances to a multitude of disturbances (Carpenter et al., 2001). As a consequence, authors typically modify existing scales, develop their own or identify study-specific resilience indicators. This makes the comparison of findings across studies challenging. We find that some authors only mention the fact that they adapted a method for their study context without indicating the exact changes. To counter the limitation of reduced comparability, we urge authors for transparency about which modifications they make and to provide details on their understanding and operationalization of digital resilience.

When attempting to quantify digital resilience through scales, for instance to analyze data using SEM, there is a trade-off between the validity and reliability of established scales and the ability to capture the specific resilience attributes of a study's context. This on-going discussion on using consistent but less refined versus improved and tested questionnaires makes it even more challenging for authors to identify a suitable approach (Jean Camp et al., 2019). We hope our overview over previously applied scales and alternatives helps guide future work in this regard.

We identify most empirical previous work on resilience in the IS domain to apply a survey-based

approach to measuring digital resilience, which comes with a number of limitations. Most importantly, it captures perceptions of digital resilience, which might not perfectly reflect an objective assessment of the underlying resilience (Setia et al., 2018). As resilience is a complex construct that is hard to observe or fully capture using secondary data, self-reported approaches like questionnaires and interviews allow assessing resilience across various contexts. Drawing on multiple data sources by combining self-reported measures with non-self-reported ones represents an opportunity to capture a more accurate picture of digital resilience. For instance, we found multiple examples of case studies that supplemented semi-formal and informal interviews with direct observations and public data (Cho et al., 2007; Schaffer et al., 2021). So far, we find mostly studies on the IS resilience level of analysis to apply non-self-report measures. We encourage future work on the resilience of input and outcome systems to supplement traditional approaches with non-self-reported ones whenever applicable. We further identify potential in empirically studying digital resilience from multiple levels to demonstrate interaction effects.

Only a small percentage of previous literature conducted a longitudinal study. There is vast potential for future work to incorporate the time dimension in the study of digital resilience as it is usually studied in the context of specific, disruptive events. Considering the time perspective allows studying behaviors and actions taken in different phases to further our understanding of the resilience process. It also might lead to insights into which factors strengthen or hinder the building of a digital resilience as well as how it spreads in a community and across multiple levels (Cho et al., 2007). It might also give insight into to which degree the digital resilience built during one crisis is transferable to the future to serve as an asset for a crises of a different nature.

While an ideal digital resilience operationalization does not exist, we could identify a number of characteristics that a suitable approach should account for. Firstly, it should build on a specification of which components of a system are studied with regard to their resilience and which level of analysis is taken and how this system interacts with its environment (Erol et al., 2010). Secondly, it should include a time factor in a way that both the initial effects of resilience and the effects in the long run are studied. For instance, Cho et al. (2007) showed that resilience might initially facilitate the adoption of an IS innovation, but might be harmful in the long run, for instance by causing tensions. They, therefore, argue to view resilience as a process capability and decouple it from the outcome of a positive adaptation. Moreover, an ideal digital resilience operationalization should find a good balance of being valid and reliable but also have a good fit to the study context. It should reflect the understanding of resilience as creating a new improved trajectory rather than just bouncing back to an old state (Cho et al., 2007). Finally, authors should be transparent about their operationalization to increase comparability.

Taking advantage of the non-exclusive components of existing resilience operationalizations from multiple disciplines to form a novel resilience indication and assessment scheme that can be applied transdisciplinary – including in the IS domain – is needed (Angeler & Allen, 2016). It could enable management and policy decisions to better reflect the dynamics of complex systems in rapidly changing environments. In line with Quinlan et al. (2016) we emphasize the need to use complimentary approaches to operationalize resilience in the IS domain and to build on key principles to enhance resilience that have been identified across disciplines.

7. Conclusion

The Covid-19 pandemic has exemplified the need for understanding and developing digital resilience to overcome disruptions caused by global crises. Digital resilience is further beneficial to facilitate positive change and digital transformation. We identified various approaches on how resilience is operationalized in IS literature so far – ranging from scale-based quantitative analyses to the observation of multi-dimensional indicators for digital resilience to algorithmic calculations and virtual experiments. Some of the main challenges of operationalizing it relate to its unclear conceptualization, the lack of specific reliable scales and the resulting difficulty in comparing results across studies as well as the move beyond self-reported measures. Related opportunities include transparent mixed-methods and longitudinal approaches as well as considering a temporal perspective. Most authors in the identified literature agree on the need for further studies on how to conceptualize and operationalize digital resilience (e.g., Magutshwa & Radianti, 2022). Our literature review represents a first step in this direction.

7. References

Alharthy, A., Sohaib, O., & Hawryszkiewycz, I. (2018). The impact of knowledge creation on organizational resilience towards organizational performance. *Proceedings of the 27th International Conference on Information Systems Development: Designing Digitalization, ISD 2018.*

Alsalman, D., & Park, I. (2018). The determinant of selfless misuse intention and the role of system resilience under the context of disasters. *Americas Conference on Information Systems 2018: Digital Disruption, AMCIS 2018*.

Amin, Z. (2000). Q methodology - A journey into the subjectivity of human mind. *Singapore Medical Journal*, *41*(8), 410–414.

Amir, S., & Kant, V. (2018). Sociotechnical Resilience: A Preliminary Concept. *Risk Analysis*, *38*(1). https://doi.org/10.1111/risa.12816

Angeler, D. G., & Allen, C. R. (2016). EDITORIAL: Quantifying resilience. In *Journal of Applied Ecology* (Vol. 53, Issue 3). https://doi.org/10.1111/1365-2664.12649

Angeler, D. G., Allen, C. R., Birgé, H. E., Drakare, S., McKie, B. G., & Johnson, R. K. (2014). Assessing and managing freshwater ecosystems vulnerable to environmental change. *Ambio*, *43*(1). https://doi.org/10.1007/s13280-014-0566-z

Bai, J., Brynjolfsson, E., Jin, W., Steffen, S., & Wan, C. (2021). Digital Resilience: How Work-From-Home Feasibility Affects Firm Performance. In *Social Science Research Network*. https://doi.org/http://dx.doi.org/10.2139/ssrn.3616893

Basavaraj, N., Foutz, N., & Li, B. (2020). Resilience of the U.S. Gig Economy during the COVID-19 Pandemic: Insights from Location Big Data. *ICIS 2020 Proceedings*.

Bermes, A., Hubert, M., & Eberhardt, T. (2021). Bounce Back and Don't Let Go: The Mitigating Effect of Users' SNS Resilience on SNS Exhaustion and Discontinuous Usage Intention. *ECIS 2021 Proceedings*.

Bhandari, P. (2022, May 6). *Operationalization | A Guide with Examples, Pros & Cons*. https://www.scribbr.com/methodology/operationalization/

Boh, W. F., Padmanabhan, B., & Viswanathan, S. (2020). *Call for Papers MISQ Special Issue on Digital Resilience*. https://doi.org/https://misq.org/skin/frontend/default/misq/pdf/CurrentCalls/DigitalResilience.pdf

Brandon-Jones, E., Squire, B., Autry, C. W., & Petersen, K. J. (2014). A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness. *Journal of Supply Chain Management*, *50*(3). https://doi.org/10.1111/jscm.12050

Brown, S. R. (1993). A Primer on Q Methodology. *Operant Subjectivity*, *16*, 91–138. https://doi.org/10.15133/j.os.1993.002

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., Shinozuka, M., Tierney, K., Wallace, W. A., & Von Winterfeldt, D. (2003). A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities. In *Earthquake Spectra* (Vol. 19, Issue 4). https://doi.org/10.1193/1.1623497

Butler, B. S., Bateman, P. J., Gray, P. H., & Diamant, E. I. (2014). An attraction-selection-attrition theory of online community size and resilience. *MIS Quarterly*, *38*(3), 699–728.

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From Metaphor to Measurement: Resilience of What to What? *Ecosystems*, *4*(8). https://doi.org/10.1007/s10021-001-0045-9

Chang, S. E., & Shinozuka, M. (2004). Measuring improvements in the disaster resilience of communities. *Earthquake Spectra*, *20*(3). https://doi.org/10.1193/1.1775796

Chatterjee, D., Chatterjee, S., & Chatterjee, S. (2021). An Empirical Investigation of the Role of Information Technology in Fostering Organizational Resilience and Effectiveness. *ACIS*.

Chewning, L. V., Lai, C. H., & Doerfel, M. L. (2013). Organizational Resilience and Using Information and Communication Technologies to Rebuild Communication Structures. *Management Communication Quarterly*, *27*(2). https://doi.org/10.1177/0893318912465815

Chlistalla, M. (2011). From minutes to seconds and beyond: Measuring order-book resiliency in fragmented electronic securities markets. *ECIS 2011 Proceedings*.

Cho, S., Mathiassen, L., & Robey, D. (2007). Dialectics of resilience: A multi-level analysis of a telehealth innovation. *Journal of Information Technology*, *22*(1), 24–35. https://doi.org/10.1057/palgrave.jit.2000088

Chowdhury, M. M. H., Dewan, M. N. A., & Quaddus, M. A. (2012). Supply chain resilience to mitigate disruptions: A QFD approach. *Proceedings - Pacific Asia Conference on Information Systems, PACIS 2012*.

Connor, K. M., & Davidson, J. R. T. (2003). Development of a new Resilience scale: The Connor-Davidson Resilience scale (CD-RISC). *Depression and Anxiety*, *18*(2). https://doi.org/10.1002/da.10113

Cooper, H. M. (1988). Organizing knowledge syntheses: A taxonomy of literature reviews. *Knowledge in Society*, *1*(1), 104–126.

Cumming, G. S. (2011). Spatial resilience in social-ecological systems. In *Spatial Resilience in Social-Ecological Systems*. https://doi.org/10.1007-978-94-007-0307-0

Eljaoued, W., Ben Yahia, N., & Bellamine Ben Saoud, N. (2021). Systematic Literature Review on Sociotechnical Systems Resilience Assessment in a Holistic View. In E. Insfran, F. González, S. Abrahão, M. Fernández, C. Barry, H. Linger, M. Lang, & C. Schneider (Eds.), *Information Systems Development: Crossing Boundaries between Development and Operations (DevOps) in Information Systems (ISD2021 Proceedings)*.

Eljaoued, Wissem, Yahia, N. Ben, & Ben Saoud, N. B. (2020). A Qualitative-Quantitative Resilience Assessment Approach for Socio-technical Systems. *Procedia Computer Science*, *176*. https://doi.org/10.1016/j.procs.2020.09.305

Erol, O., Sauser, B. J., & Mansouri, M. (2010). A framework for investigation into extended enterprise

resilience. *Enterprise Information Systems*, *4*(2), 111–136. https://doi.org/10.1080/17517570903474304

Fan, C., Farahmend, H., & Mostafavi, A. (2020). Rethinking infrastructure resilience assessment with human sentiment reactions on social media in disasters. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2020-January*. https://doi.org/10.24251/hicss.2020.205

Frank, M., & Kohn, V. (2021). How to mitigate security-related stress: The role of psychological capital. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2020-January*. https://doi.org/10.24251/hicss.2021.550

Garmestani, A. S., Allen, C. R., & Benson, M. H. (2013). Can law foster social-ecological resilience? In *Ecology and Society* (Vol. 18, Issue 2). https://doi.org/10.5751/ES-05927-180237

Gisladottir, V., Ganin, A. A., Keisler, J. M., Kepner, J., & Linkov, I. (2017). Resilience of Cyber Systems with Over- and Underregulation. *Risk Analysis*, *37*(9). https://doi.org/10.1111/risa.12729

He, Z., Huang, H., Choi, H., & Bilgihan, A. (2022). Building organizational resilience with digital transformation. *Journal of Service Management*. https://doi.org/10.1108/JOSM-06-2021-0216

Heeks, R., & Ospina, A. V. (2018). Conceptualising the link between information systems and resilience: A developing country field study. *Information Systems Journal*, *29*(1), 70–96. https://doi.org/10.1111/isj.12177

Herrera, A., & Janczewski, L. (2013). Modelling organisational resilience in the cloud. *Proceedings - Pacific Asia Conference on Information Systems, PACIS 2013*.

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, *4*(1), 1–23. https://doi.org/10.1146/annurev.es.04.110173.000245

Holling, C. S., & Gunderson, L. H. (2002). Resilience and adaptive cycles. *Panarchy: Understanding Transformations in Human and Natural Systems*.

Jean Camp, L., Grobler, M., Jang-Jaccard, J., Probst, C., Renaud, K., & Watters, P. (2019). Conceptualizing human resilience in the face of the global epidemiology of cyber attacks. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2019-January*.

Kisekka, V., Sharman, R., Rao, H. R., Upadhyaya, S., & Gerber, N. (2015). Investigating the antecedents of healthcare workers' perceptions of organizational resilience in hospitals. *2015 International Conference on Information Systems: Exploring the Information Frontier, ICIS 2015*.

Klesel, M., Narjes, N., & Niehaves, B. (2018). Conceptualizing IT Resilience: An Explorative Approach. *Multikonferenz Wirtschaftsinformatik*, 1008–1019.

Kohn, V. (2020a). How Employees' Digital Resilience Makes Organizations More Secure. *Proceedings of the 24th Pacific Asia Conference on Information Systems*.

Kohn, V. (2020b). How the Coronavirus Pandemic Affects the Digital Resilience of Employees. *Proceedings of the 40th International Conference on Information Systems, ICIS 2020*, 1–17.

Liao, C., Palvia, P., & Chen, J. L. (2009). Information technology adoption behavior life cycle: Toward a Technology Continuance Theory (TCT). *International Journal of Information Management*, *29*(4). https://doi.org/10.1016/j.ijinfomgt.2009.03.004

Lindegren, M., Dakos, V., Gröger, J. P., Gårdmark, A., Kornilovs, G., Otto, S. A., & Möllmann, C. (2012). Early detection of ecosystem regime shifts: A multiple method evaluation for management application. *PLoS ONE*, *7*(7). https://doi.org/10.1371/journal.pone.0038410

Linnenluecke, M. K. (2017). Resilience in Business and Management Research: A Review of Influential Publications and a Research Agenda. *International Journal of Management Reviews*, *19*(1). https://doi.org/10.1111/ijmr.12076

Llansó, T., & McNeil, M. (2021). Towards an organizationally-relevant quantification of cyber resilience. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2020-January*. https://doi.org/10.24251/hicss.2021.849

Luthar, S. S., Cicchetti, D., & Becker, B. (2000). he Construct of Resilience: A Critical Evaluation and Guidelines for Future Work. *Child Development*, *71*(3), 543–562.

Magutshwa, S., & Radianti, J. (2022). Is this Digital Resilience? Insights from Adaptation and Exaptation of a Cyber-Physical-Social System. *Proceedings of the 55th Hawaii International Conference on System Sciences*. https://doi.org/10.24251/hicss.2022.305

Mandal, S. (2016). Influence of Partner Relationship and IT Integration on Supply Chain Capabilities: An Empirical Relational Paradigm. *Pacific Asia Journal of the Association for Information Systems*, *8*(2), 19–48.

Mousavi, R., & Gu, B. (2020). The Effect of Resilience Messaging on Community Conformity to Government Healthcare Guidelines: An Empirical Analysis of Governors' Twitter Use During COVID-19 Pandemic. *ICIS 2020 Proceedings*.

Murray-Tuite, P. M. (2006). A comparison of transportation network resilience under simulated system optimum and user equilibrium conditions. *Proceedings - Winter Simulation Conference*. https://doi.org/10.1109/WSC.2006.323240

Nachtigall, C., Ulf Kroehne, F. F., & Steyer, R. (2003). (Why) Should we use SEM? Pros and cons of structural equation modeling. *MPR-Online*, *8*.

Näswall, K., Kuntz, J., & Malinen, S. (2015). Employee Resilience Scale (EmpRes) Measurement Properties. *Resilient Organisations Research Report*, *August*, 1–4.

Nemec, K. T., Chan, J., Hoffman, C., Spanbauer, T. L., Hamm, J. A., Allen, C. R., Hefley, T., Pan, D., &

Shrestha, P. (2014). Assessing resilience in stressed watersheds. *Ecology and Society*, *19*(1). https://doi.org/10.5751/ES-06156-190134

Oh, L., & Teo, H. (2009). An Empirical Study of IT-enabled Enterprise Risk Management and Organizational Resilience. *CONF-IRM 2009 Proceedings*, *5–2009*.

Park, I., Cho, J., & Rao, H. R. (2018). An Examination of Resilience in Healthcare Information Systems in the Context of Natural Disasters. *Proceedings of the 13th Pre-ICIS Workshop on Information Security and Privacy*.

Park, I., Sharman, R., & Rao, H. R. (2015). Disaster experience and hospital information systems: An examination of perceived information assurance, risk, resilience, and his usefulness. *MIS Quarterly*, *39*(2), 317–344.

Pries-heje, J., & Baskerville, R. (2021). Achieving Resilience through Agility. *42nd ICIS*.

Quinlan, A. E., Berbés-Blázquez, M., Haider, L. J., & Peterson, G. D. (2016). Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives. *Journal of Applied Ecology*, *53*(3). https://doi.org/10.1111/1365-2664.12550

Riolli, L., & Savicki, V. (2003). Information system organizational resilience. *Omega*, *31*(3), 227–233. https://doi.org/10.1016/S0305-0483(03)00023-9

Sarkar, A., Wingreen, S., Ascroft, J., & Sharma, R. (2021). Bouncing back after a crisis: Lessons from senior management team to drive IS resilience. *HICSS*, *2020-January*.

Schaffer, N., Pérez, P. G., & Weking, J. (2021). How business model innovation fosters organizational resilience during COVID-19. *27th Annual Americas Conference on Information Systems, AMCIS 2021*.

Schemmer, M., Heinz, D., Baier, L., Vössing, M., & Kühl, N. (2021). Conceptualizing Digital Resilience for AI-based Information Systems. *ECIS 2021 Research-in-Progress Papers*.

Setia, P., Deng, K., & Jena, R. (2018). Internally or Externally-oriented IT Competencies: A Configuration Theory Perspective on How to Build Demand Management Agility. *ICIS 2017: Transforming Society with Digital Innovation*.

Smith, B. W., Dalen, J., Wiggins, K., Tooley, E., Christopher, P., & Bernard, J. (2008). The brief resilience scale: Assessing the ability to bounce back. *International Journal of Behavioral Medicine*, *15*(3). https://doi.org/10.1080/10705500802222972

Spears, B. M., Ives, S. C., Angeler, D. G., Allen, C. R., Birk, S., Carvalho, L., Cavers, S., Daunt, F., Morton, R. D., Pocock, M. J. O., Rhodes, G., & Thackeray, S. J. (2015). Effective management of ecological resilience - are we there yet? *Journal of Applied Ecology*, *52*(5). https://doi.org/10.1111/1365-2664.12497

Stephens, J. P., Heaphy, E. D., Carmeli, A., Spreitzer, G. M., & Dutton, J. E. (2013). Relationship Quality and Virtuousness: Emotional Carrying Capacity as a Source of Individual and Team Resilience. *Journal of Applied Behavioral Science*, *49*(1). https://doi.org/10.1177/0021886312471193

Sundstrom, S. M., Angeler, D. G., Garmestani, A. S., García, J. H., & Allen, C. R. (2014). Transdisciplinary application of cross-scale resilience. *Sustainability (Switzerland)*, *6*(10). https://doi.org/10.3390/su6106925

Umunnakwe, A., Huang, H., Oikonomou, K., & Davis, K. R. (2021). Quantitative analysis of power systems resilience: Standardization, categorizations, and challenges. In *Renewable and Sustainable Energy Reviews* (Vol. 149). https://doi.org/10.1016/j.rser.2021.111252

vom Brocke, J., Simons, A., Niehaves, B., Riemer, K., Plattfaut, R., & Cleven, A. (2009, January 1). Reconstructing the giant: On the importance of rigour in documenting the literature search process. *Proceedings of the 17th European Conference on Information Systems*. https://aisel.aisnet.org/ecis2009/161

Wang, C. H., Liu, G. H. W., Lee, N. C. A., & Chen, K. J. (2019). Passive leadership and online interaction: The mediating effects of job autonomy and employee resilience. *Proceedings of the 23rd Pacific Asia Conference on Information Systems: Secure ICT Platform for the 4th Industrial Revolution, PACIS 2019*.

Watts, S., & Stenner, P. (2005). Doing Q methodology: theory, method and interpretation. *Qualitative Research in Psychology*, *2*(1), 67–91. https://doi.org/10.1191/1478088705qp022oa

Webster, J., & Watson, R. T. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly*, *26*(2). https://doi.org/10.1.1.104.6570

Westmattelmann, D., Kuen, L., & Schewe, G. (2021). Ehealth Apps in Workplace Health Management – an Analysis of Determinants and Effects on Employee Health. *ECIS 2021 Research-in-Progress Papers*, *May*.

Zobel, C. W., & Baghersad, M. (2020). Analytically comparing disaster resilience across multiple dimensions. *Socio-Economic Planning Sciences*, *69*. https://doi.org/10.1016/j.seps.2018.12.005