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Conceptualising the link between information systems and resilience: A developing country field study

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Abstract

Resilience—the ability of systems to cope with external shocks and trends—is a topic of increasing interest to research and practice. That growing interest is reflected within information systems (IS), but a structured review of IS literature shows a number of knowledge gaps around the conceptual and empirical application of resilience. This paper investigates what the subdiscipline of information and communication technologies for development (ICT4D) can contribute; finding that it offers the IS discipline fresh insights that can be built into a new framework of resilience, and an arena within which this new framework can appropriately be field tested. Application of the resilience framework was undertaken through interviews and a survey in an urban community in Costa Rica; benchmarking both community resilience and "e-resilience" (understood here as the contribution of ICTs to community resilience), and developing from these a set of action priorities. The paper reflects on what can be learned generally from this conceptualisation and operationalisation of resilience. It also reflects on what ICTs contribute to resilience in developing countries and on what this ICT4D-based research specifically contributes to the identified IS knowledge gaps. This includes identification of a future research agenda on information systems and resilience.

KEYWORDS

adaptation, Costa Rica, ICT4D, resilience

1 | INTRODUCTION

It is predicted that, as the 21st century progresses, the frequency and/or severity of shocks—environmental disasters, economic crises, social and political upheavals—will increase (WEF, 2013). Breadth and depth of impact of these shocks is predicted to increase with growing complexity and interconnection of global systems (Zolli & Healy, 2012). Thus longer-term trends of economic globalisation and digitisation—plus others such as climate change and

urbanisation—sit alongside, and interact with, the short-term phenomena. Systems of all kinds—from individual households through communities and organisations and nations to the whole planet—will have to cope with these shocks and trends. Resilience is central to this coping; indeed, resilience can be understood as the ability of systems to cope with external shocks and trends. Resilience is therefore essential to future survival of all these systems, and they must strengthen their resilience in order to endure (UNDP, 2011).

The heightened reality and perception of shocks, and the related need for systems to become more resilient, has pushed resilience up both research and practice agendas across a range of domains. Research programmes and journal special issues on resilience have emerged in many areas, for example, small and medium enterprises (Bhamra & Dani, 2011), security policy (Cavelty, Kaufmann, & Kristensen, 2015), and civil engineering (Jowitt & Milke, 2015). Practical guides and initiatives have also emerged, seeking to build the resilience of a variety of systems, for example, strengthening business resilience (IBM, 2009), community resilience (Mguni & Bacon, 2010), and public sector resilience (Cho, Willis, & Stewart-Weeks, 2011).

The growing presence of resilience has also been felt in the information systems (IS) domain with, again, special issues (Donnellan, Larsen, & Levine, 2007; Zhang, 2010) and practical guides (eg, DCLG, 2015; ENISA, 2011) on information systems and resilience. However, as will be argued in greater detail below, there have been lacunae in the resilience research undertaken within the information systems discipline: limited conceptualisation of resilience in relation to information systems, and limited testing of concepts in practice.

This creates a knowledge gap within IS; space for an improved conceptualisation of resilience, and space for practical operationalisation of such concepts. Our aim in this paper is to address this knowledge gap, seeking to provide a better-founded conceptualisation of resilience, to test out that framework in the field and to reflect on our findings. We follow this aim by drawing on the subdiscipline of ICT4D—information and communication technologies for development—which sits at the intersection of IS and development studies. Our guiding question was therefore the following: "What can be learned for information systems and resilience from research and practice in ICT4D?" Although work on resilience within the ICT4D field has been limited, we find that it adds some specific conceptual insights and has also been the locus for development of a full resilience framework, used here. ICT4D also provides a priority arena for implementation of resilience research because of its importance: developing countries are on the "front line" of many shocks and therefore in especial need of deepening their resilience (Bene, Wood, Newsham, & Davies, 2012). ICT4D can therefore help the wider IS discipline develop both conceptual and practical knowledge about resilience.

To realise its aim, this paper next undertakes a review of resilience within the information systems literature and within the ICT4D literature. Drawing not only on both but also on deeper roots, it conceptualises resilience as a systemic property with nine attributes: a mix of primary foundations and secondary enablers. We present field application of this framework in a developing country community—Barrio Lujan in San Jose, Costa Rica—with three goals: benchmarking the general resilience of the community, benchmarking its "e-resilience" (the contribution ICTs make to community resilience), and deducing some future action priorities. We end by discussing conceptual and practical conclusions that can be drawn from this field study.

2 | LITERATURE REVIEW

Research literature on resilience has grown in leaps and bounds in recent years: a Google Scholar search for English-language items containing "resilience" in the title shows 1311 items in the years to 2000, 7940 items for 2001 to 2010, and 19200 items for the seven years 2011 to 2017. Emergence of work on information systems and resilience has been one—very small—part of this trend, as discussed next.

2.1 | Information systems and resilience

Our literature review on information systems and resilience (for details, see Section 3) identified 30 relevant papers, all published from 2003 onwards. A number of these papers provide no definition of resilience, but those that do almost

all see it as the capacity of a system to cope with changes in its external environment. Systems have structure, function, and properties: where defined, then, resilience is largely understood as a system property (eg, Zhang & Lin, 2010). This property is almost always defined in response to short-term stressors, either as continuity of system performance (a robustness to withstand external stressors) and/or as recovery of system performance ("bounce back" after damage by external stressors). What the IS literature generally does not see resilience as is a response to longer-term trends: only three papers mentioned ideas of resilience as the "bounce forward" of adaptation to those trends, or even more substantial reconfiguration in the form of system transformation (eg, Muller, Koslowski, & Accorsi, 2013).

If the IS literature has a constrained but fairly consistent notion of "what is resilience," the same is also true in its approach to "resilience of what." Resilience is a system property, but IS research papers—as summarised in Figure 1—take three different positions on the identity of the system that is to be resilient, with a significant skew towards just one position:

- Resilience of an information system input system (RISIS): in this case, resilience is the property of some precursor system that acts as an input to the information system; typically a human system inputting to IS implementation and/or operation. Only four papers take this view; for example, Cho, Mathiassen, and Robey (2007) consider how the resilience of key stakeholders impacted adoption of a health care information system.
- Resilience of an information system (RIS): the information system itself and its resilience are here the focus for analysis. Most of the IS literature—22 of the 30 papers—takes this approach, with a particular interest in the resilience of ICT infrastructure such as digital networks (eg, Smith et al., 2011).
- Resilience of an information system outcome system (RISOS): this research looks at the impact of information systems on the resilience of other, wider systems that the IS supports. Only two research papers explicitly engage with RISOS, both reviewing the potential for digital information systems to impact the resilience of the private enterprises in which they were operating (Erol, Sauser, & Mansouri, 2010; Ignatiadis & Nandhakumar, 2007).

While resilience may be understood as a property, typically of information systems, further depth of conceptualisation within the IS literature has been limited. In most papers, resilience is either an undefined descriptor or defined but without additional depth beyond the definition. A few researchers go further to propose measurement of defined resilience, most often in terms of the negative impact of an external stressor on system performance combined with time to recover to normal performance (eg, Zobel & Khansa, 2012). Although explicit declaration of their ontological or epistemological stance is generally absent, these papers can be inferred as taking a positivist perspective, seeing resilience as the real and directly measurable property of an information system (eg, Wang, Gao, & Ip, 2010).

Very few papers move beyond this. In ontological terms, no paper takes a clearly realist approach and no paper directly and interpretively researches the discourse and meaning of resilience or challenges the idea of it as a real systemic property. In conceptual terms, a few sources acknowledge foundations that can provide a rationale for resilience, such as normal accident theory or the notion of high-reliability organisations (eg, Hyslop, 2007; Muller et al., 2013), but these are not developed further. Only two papers propose a clear model or framework: Erol et al. (2010) who propose a model of organisational resilience combining capabilities of flexibility, adaptability, and agility

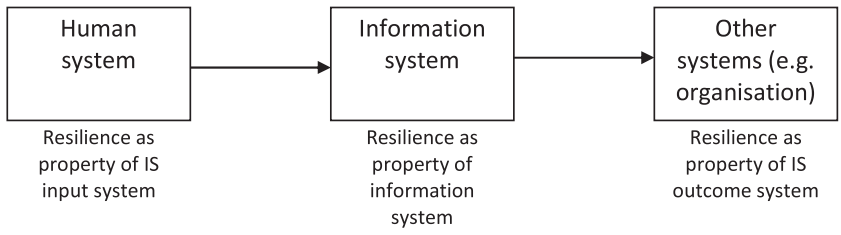

FIGURE 1 Resilience of what: different identities of resilient systems in information systems literature

and Sterbenz et al. (2013) who model strategic behaviours underlying resilience (but do not model resilience itself). The IS literature to date therefore offers only a narrow and shallow understanding of resilience.

These limitations continue into empirics. As might be expected, given the relative novelty of resilience within the IS field, there is limited empirical investigation: most papers are setting out positions and propositions for potential future operationalisation. Only five papers contain empirical work in which resilience is a focus for investigation. For example, Park, Sharman, and Rao (2015) research the strength of correlation between perceived resilience (among other independent variables) of the ICT function in hospitals and perceived usefulness of the hospital's information systems.

In sum, the IS literature to date provides an important foundation for our understanding of the relationship between information systems and resilience, but that foundation is small as yet; less than one paper per year in the leading IS journals. The foundation is also quite limited and quite strongly skewed, leaving gaps that other literatures might help to fill:

- Resilience is a system property but understood almost exclusively in terms of continuity and recovery. The "bounce forward" adaptive role of resilience remains uninvestigated in relation to IS.
- Only one paper offers a model of resilience itself, so opportunities for contestation or aggregation of conceptual ideas within IS have so far been absent.
- The resilience of information systems (RIS) is both important and of direct relevance to the IS domain, but there has been little work to date on the impact of information systems on resilience of wider systems (RISOS) that IS serve.
- There has been little empirical investigation of resilience. In particular, viewing across the categorisations, there has been no work that proposes a conceptual framework for resilience and then empirically tests it. And there has been no work that empirically investigates the impact of information systems on wider systems' resilience (RISOS).

2.2 | ICT4D and resilience

The information systems literature has created a foundation of knowledge on the relation between digital systems and resilience, but still leaving some knowledge gaps to fill. What can the ICT4D subdomain offer? To assess this, we first undertook a review of ICT4D literature (for details, see Section 3) and identified 15 papers of relevance. Seven were linked to the framework presented in the next section, which can be seen as the key conceptual contribution of the ICT4D literature: they were either outputs of the Nexus for ICTs, Climate Change and Development (NICCD) project from which the framework emanated, or they cited the framework. From analysis of the remaining eight ICT4D papers, we draw a number of conclusions.

In some ways, the ICT4D literature reflects the findings from the IS review: a paucity of research creating a general knowledge gap and a need for work on resilience given the importance of the subject; a lack of conceptualisation other than our own framework discussed below; a lack of empirical work; and a lack of ontological clarity. However, the ICT4D literature does provide findings and ideas that address the lacunae identified in the IS review. In particular, the ICT4D literature offers and argues for a wider view of resilience than has to date been taken by the IS literature in three ways.

Firstly, in terms of system identity, ICT4D looks mainly at RISOS—that is, more at the resilience of wider systems impacted by ICT than at the resilience of ICT4D systems themselves. Six of the eight papers look at resilience of various levels of wider system: livelihoods, communities, and broader socio-economic systems. This likely stems from the growing importance of resilience within international development, given that ICT4D is significantly shaped by the development agenda. That importance in turn arises bottom-up from vulnerable communities in developing countries, which are seen to suffer an increasing frequency and severity of shocks: natural disasters, economic crises, violence, etc (DPA, 2015; Srivastava, 2012). These communities must become more resilient if they are to survive these shocks. Such experiences are shaping the international development agenda: while it retains its progressive component that

assumes positive developments such as economic growth or increasing lifespans, it now adds a "nonregressive" component that seeks not to move backwards on key development indicators in light of the perceived growth in impact of external shocks (UNDP, 2011). One outcome is a strong representation for resilience in formal agendas: unmentioned in the 2001 Millennium Development Goals, resilience is included 10 times—in two goals and eight targets—in the post-2015 Sustainable Development Goals that succeeded the MDGs.

The growing prioritisation of resilience—community resilience especially (World Bank, 2013)—has filtered into the ICT4D field given its continuous emphasis on technology being a means not an end, and its focus on the wider development goals that ICT serves (eg, Anderson, Crowder, & Dion, 1999; Heeks, 2008). All this acts as a reminder for IS more generally that the *raison d'etre* of information systems is to support wider systems. It serves to question the lack of RISOS work in the IS literature to date. And it serves as the basis for arguing that IS research on resilience should give greater weight to the way in which information systems impact the resilience of those wider systems: be they organisations, supply chains, communities, etc.

A wider view of resilience is secondly encouraged through the ICT4D literature's definitions. Unlike those derived from the IS literature, the ICT4D definitions expand beyond continuity + recovery to also encompass adaptation. This arises from the connection between resilience and sustainability: the latter a dominant theme for the current international development agenda (Heeks, 2014). Resilience can be seen as a necessary property for a system to sustain, and more specifically as a means to operationalise the rather broad and general concept of sustainability (Marais, 2015). Resilience encompasses both short-term continuity/recovery and longer-term adaptation because sustainability is conceived not just in relation to cross-sectional shocks such as disasters but also in relation to longitudinal trends, most obviously climate change but also economic and demographic trends. Deriving from work on IS failure, "green ICT" and IS impact, there is recognition within IS literature of the need for information systems to sustain in the longer-term and in face of external change (eg, Kettinger, Grover, Guha, & Segars, 1994; Korte, Lee, & Fung, 2013; Maruster, Faber, & Peters, 2008). ICT4D's expanded definition of resilience will therefore be relevant to IS although noting it may introduce tensions: where the short-term sense of resilience is about stability, the longer-term sense of resilience is about change.

Thirdly, the ICT4D literature provides a wider view of resilience because it places the concept within a broader normative, even moral, context (Chen, 2015). The development agenda wants systems to change, but there is a danger that a resilience agenda means "poor communities will stay in a resiliently poor state" (Marais, 2015, p. 436). This can be seen as aligning with a more critical perspective on resilience, something that, while alluded to in the IS literature (Wastell, McMaster, & Kawalek, 2007), is not developed. Adding a need for adaptation to the definition of resilience might help, but what the development agenda is looking for is more than adaptation but transformation of systems (Heeks, 2014), something antithetical to the system continuity roots of resilience. An alternative might be to take a very longitudinal and developmental perspective, arguing that systems that are exclusive and inequitable will not sustain in the long run (eg, Wilkinson & Pickett, 2010).

The ICT4D literature reviewed so far therefore encourages IS research to widen its perspective on resilience in three ways: taking greater account of the resilience of the wider systems that IS serve, adding a longer-term adaptational element to resilience, and understanding resilience in a way that avoids perpetuation of systemic inequalities. These three elements will be incorporated into the final contribution from the ICT4D literature found lacking within IS: development and operationalisation of a full conceptualised framework for resilience, as discussed next.

2.3 | Conceptualising resilience

How should resilience be conceptualised to fill the conceptual gap so far found in the IS literature? Following the approach found in multiple IS and ICT4D papers as well as in wider resilience literature (eg, Hollnagel, Woods, & Leveson, 2006; Lorenz, 2013), we understand resilience as a system property. But defining resilience as the property of any system provides limited basis on its own for an operationalisable conceptualisation, noted above as a shortcoming of much of the IS literature. To build towards such a conceptualisation, we follow the lead of the only reviewed IS paper to offer a way forward: Erol et al. (2010). They argue resilience to be a property made up of a set of elements, which they call

"attributes": defined subproperties that together make up the overall property of resilience—in this case, flexibility, adaptability, and agility. This approach to conceptualising resilience through a series of defined subelements can be found throughout resilience literature, albeit those elements may be called "qualities" (Hollnagel & Woods, 2006), "subproperties" (De Florio, 2013), or "characteristics" (Attoh-Okine, 2015) as well as attributes.

We could have just reused the Erol et al. (2010) framework of three resilience attributes. However, from review of other IS sources we could identify other implicit attributes—eg, redundancy (Smith et al., 2011) and self-organisation (Sterbenz et al., 2013)—which suggest the Erol et al. (2010) framework to be incomplete. The general lack of discussion of resilience attributes within the IS and ICT4D literature, though, meant this could not provide the necessary foundation for a comprehensive decomposition of resilience into constituent parts. We therefore needed to look at wider resilience literature.

Resilience has three distinct though interrelated disciplinary roots (Alexander, 2013), each of which contains literature on resilience as a system property with multiple attributes: ecology (eg, Holling, 1973), engineering (eg, Hollnagel et al., 2006), and psychology (eg, Richardson, 2002). We decided to derive resilience attributes from the ecological literature for two reasons. First because that literature adhered to the lessons drawn above from ICT4D: a focus on resilience in broader social rather than narrowly technical systems; a broader conception of resilience beyond just system continuity and recovery that allows for system adaptation to longer-term trends, and a concern to address factors such as inequality that can undermine long-term system survival. Second because ecological conceptions of resilience have been demonstrably applicable in global South settings, particularly in relation to socio-ecological systems (eg, Folke et al., 2002; Walker, Sayer, Andrew, & Campbell, 2010).

The conceptualisation outlined here was based on a saturation review of the ecological (including environmental and socio-ecological) literature that continued until no additional attributes of relevance could be identified. From this, we confirmed our ICT4D literature–derived definition of resilience as the ability of a system to withstand, recover from, and adapt to short-term shocks and longer-term change.

Within the set of possible attributes identified by the review of literature on ecological resilience, there was a differentiation. Some of the attributes were portrayed as inherent constituents of resilience, integral to the conceptualisation of a resilient system and almost always present within any decomposition of resilience as a system property (eg, Miller et al., 2010; Nelson, Adger, & Brown, 2007; Plummer & Armitage, 2007; Walker, Holling, Carpenter, & Kinzig, 2004). These foundational attributes could be related to each component of the definition of resilience just given. The ability of a system to withstand is represented by the attribute of *robustness*, which is specifically explained as the ability of the system to maintain its characteristics and performance in the face of external fluctuations, including shocks (Carlson & Doyle, 2002; Janssen & Anderies, 2007). Illustrative elements for a social system include not only physical barriers, eg, to climate shocks, but also strength of social institutions. The ability of the system to recover is represented by the attribute of *self-organisation*, which is explained as the system's ability to independently rearrange its functions and processes in the face of external disturbances, without being forced by the influence of other external drivers (Carpenter, Walker, Anderies, & Abel, 2001). This is illustrated not only by collective social processes within the system but also by enablers of those processes such as social capital and trust (Fuchs, 2004). Self-organisation is not just associated with recovery but is also seen as necessary for longer-term adaptation, which is also associated with a third attribute: *learning*. This is understood as the capacity of the system to generate feedback with which to gain or create knowledge and build the skills, attitudes, and other competences required to experiment and innovate (Folke et al., 2010). Although strongly linked to internal processes of knowledge-generation, this attribute is also seen to require inputs of new, external knowledge (Folke, Colding, & Berkes, 2003).

Alongside these three foundational attributes, we identified from the review of ecological literature six other attributes. While not universally discussed, these appeared in multiple sources and were seen to facilitate operation of the foundational attributes (eg, Callaghan & Colton, 2008; Cutter et al., 2008; Marshall & Marshall, 2007; Peterson, Allen, & Holling, 1998). *Redundancy* is the extent to which components within a system are substitutable, for example, in the event of disruption or degradation (Folke et al., 2003). This was understood in terms of both an interchangeability of assets such as technology but also processes that could be maintained even during partial failure (Rockefeller

Foundation, 2009). *Rapidity* means how quickly assets can be accessed and mobilised to achieve goals in an efficient manner and is key to ensure the system's ability to respond to external stressors in a timely manner (Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2008). For socio-ecological systems, this was sometimes interpreted in terms of mobilising financial resources, but it could also have a broader understanding as the presence of fast stimulus-response feedback loops across the system (Levin, 1999). *Scale* refers to the breadth of assets and structures a system can access to effectively overcome or bounce back from or adapt to the effects of disturbances and includes access to resources and structures outside the immediate system (Folke et al., 2010). So part of this was illustrated by wider social and institutional networks that would allow resources to flow into the system from outside (Few, Osbahr, Bouwer, Viner, & Sperling, 2006).

Diversity is the availability of a variety of assets (including knowledge), institutions, and institutional functions that enable a range of response options to external stressors, both short- and long-term (Folke, Hahn, Olsson, & Norberg, 2005; Hopkins, 2009). This combined diversity of system elements is seen not only to support continuity in the face of a variety of external shocks but also to provide "the basis for innovation, learning and adaptation to slower, ongoing change" (Biggs et al., 2012, p. 425). Closely linked to diversity and combined into a single attribute for the purposes of what follows, *flexibility* refers to the ability of a system to undertake different sets of actions with the determinants at its disposal, better enabling it to address problems and use opportunities arising from external change (Folke, 2006). It can be read as the variety of system processes that emerges from the variety of system elements described by diversity and, as with diversity, it supports both continuity- and adaptation-oriented views of change (Rockefeller Foundation, 2009). Finally, *equality* is the extent to which the system affords equal access to rights, resources, and opportunities to its members (Magis, 2009). It, for example, makes the case that resilience derives not just from general availability of resources within a system but also from the effective ability of all system members to access and use those resources (Adger & Kelly, 1999).

This framework of foundational (robustness, self-organisation, and learning) and enabling (redundancy, rapidity, scale, diversity and flexibility, and equality) attributes therefore provided our conceptualisation of resilience for application in the ICT4D domain. It built on the idea of resilience as a system property reflected in the IS literature, but—by drawing on the greater depth of treatment in the ecological literature—the framework addressed the conceptual developments advocated from the ICT4D literature review. The framework was directly relevant to the broader social systems that ICT systems serve given its understanding of people and institutions and social networks as parts of a system. The framework encompasses system continuity and recovery: most attributes were described in relation to this aspect of resilience. But there is also an explicit incorporation of system adaptation as discussed, for example, in relation to self-organisation, learning, and diversity and flexibility. Lastly, the danger of resilience perpetuating unjust systems is at least partly addressed by incorporation of equality as an attribute; something that is not found in most resilience frameworks. This directly adds what can be seen as a "development perspective" to resilience, given that addressing inequality is a key part of the current development agenda and given the evidence noted above that more unequal systems are less resilient and less able to adapt over the long term.

It is this resilience framework that we then took for field application in an ICT4D environment in Latin America, characterising the framework and its methods (see next) as the Resilience Assessment Benchmarking and Impact Toolkit (RABIT). In undertaking this application of the framework, we were particularly interested in three things: the extent to which it would deliver on the ICT4D literature's filling of IS literature gaps on resilience; what this would tell us about the conceptualisation of resilience inherent to the framework; and what lessons the developing country fieldwork would offer for putting a resilience framework into action.

3 | METHODOLOGY

The first part of our research for this paper was the two literature reviews. To review the literature on information systems and resilience, we undertook three searches:

- Searching the titles, keywords, and, where feasible, abstracts of the AIS senior scholars' basket of eight IS journals (EJIS, ISJ, ISR, JAIS, JIT, JMIS, JSIS, MISQ) for "resilien*," which identified seven relevant papers.
- Searching the ABI/Inform database for all items with "information system*" in the title and "resilien*" in the title or abstract, which identified two relevant papers.
- Searching Google Scholar using the term—resilience "information systems"—until three consecutive pages produced no new relevant item, which identified 24 relevant papers.

Given overlaps, there were 29 papers in total, with small clusters around two special issues: one in *Journal of Information Technology* in 2007 and one in *Enterprise Information Systems* in 2010. Review of the special issues identified one more paper of relevance to IS and resilience, making an overall total of 30 papers, which are summarised in the review above.

To review the literature on ICT4D and resilience, again, a three-part literature search was undertaken:

- Searching the full text of the three main ICT4D journals (Heeks, 2010): *Information Technology for Development*, *Information Technologies and International Development*, and *The Electronic Journal of Information Systems in Developing Countries* for "resilien*." This produced 23 hits, but all were single instances of the word and had no resilience focus.
- Searching Google Scholar using the term—resilience "ICT4D"—until three consecutive pages produced no new relevant item, which identified 14 papers.
- Searching Google Scholar using the term—resilience "ICTD" —until three consecutive pages produced no new relevant item, which identified one paper.

In total, then, there were 15 relevant papers identified. As noted, eight formed the basis for the analysis in Section 2.2, and seven of these were directly related to the attributes framework described in Section 2.3.

The second part of our research was applying the resilience framework in an empirical setting of relevance to ICT4D. Given the novelty of the framework and lack of prior IS- or ICT4D-based empirical work on resilience, we faced something of a blank slate, with three particular areas in which decisions had to be made: research philosophy, focus, and methodology/methods.

For the first, we diverged from the perspectives to date within the IS literature by essaying a critical realist approach to resilience. Following the general treatment of resilience within the IS literature and also within the ecological literature from which we drew our framework, we regarded resilience and its attributes as the real property of real systems with causal power. Positivist approaches are used in the IS literature where resilience is defined in terms that can be directly measured, eg, as the time from disturbance of a technical system to recover the function of quantified system performance parameters. But a positivist paradigm seems inappropriate when, as in this case, resilience is defined as residing within social or socio-technical systems. The open and complex nature of such systems and the involvement of people—hence their worldviews—in the enactment of resilience within such systems can be argued to render positivism's empirical and objective approach invalid (Dobson, 2001; Smith, 2005). As will be discussed later, an interpretive approach to resilience—although not yet represented in the reviewed literature—would be feasible, but was not seen as appropriate for our work given the ontological reality we ascribed to resilience (and also given the deductive approach we were following).

Aligning the core ideas of critical realism and resilience is challenging. An assumed commensurability between the two can be found in some items of resilience literature (eg, Hatt, 2013; Le Coze & Pettersen, 2008), but in-depth analysis has yet to be undertaken. While a full discussion lies beyond the scope of this paper, here, we address two features: the nature of resilience and the methodology for its study.

What is a system property within critical realism? We understand it to be synonymous with a mechanism: an ontologically real potential or tendency of a social structure that is the causal power behind events; a view supported

by, for example, Bhaskar's (2008, pp. 162, 169) treatment of powers and properties as synonymous. This fits with the description above of resilience attributes, which we can see as potentials of a system which, if enacted, would lead to events that would in turn impact the system. Drawing on Archer's (1995) terminology, this cycle between the real and the actual can be categorised as either morphostatic in relation to the continuity and recovery aspects of resilience, or morphogenetic in relation to the adaptation aspects of resilience.

If we view resilience as lying within the domain of the real, then for research, we need some instrument to connect resilience to the domain of the empirical. This is needed for two reasons: first, for retrodiction, "the application of previously identified mechanisms to the explanation of an outcome in a new setting" (Wynn & Williams, 2012, p. 799). Rather than retroduction, this is the relevant technique here given our pre-hoc construction of a framework of previously retroduced resilience mechanisms that is then applied in a new context. Second, to access the perceptions of those involved in resilience actions within the system under study, given "social structures do not exist independently of agents' conceptions of their own activities set within the structures" (Wynn & Williams, 2012, p. 791). Hence, that the "thoughts and beliefs" of actors must be understood as an integral part of the mechanisms of resilience in any particular context.

As described further below, our field study had a practical orientation. We therefore diverged somewhat from what might be called the more-conventional applications of critical realism within IS and, instead, drew some guidance from work seeking to intersect the paradigms of pragmatism and critical realism (Bechara & Van de Ven, 2007; Johnson & Duberley, 2000). Hence, our interest was less in understanding the application and perceptions of resilience mechanisms for explanatory reasons. We thus do not report here which mechanisms were seen as causally related to which events. Instead, our purpose and findings centre on understanding the instantiated nature and relative extent of the mechanisms for the practical purpose of guiding subsequent action: what we refer to as "benchmarking."

To investigate that empirical experience of resilience within a particular setting and to enable aggregation of field data, we operationalised each of the attributes as a set of three "markers," observable characteristics for each attribute again derived from the ecological literature on resilience (see Table 1, adapted from Ospina, 2013, which can be referred to for fuller detail). By restricting ourselves to just three markers, these were not intended to be comprehensive or authoritative but as illustrative.

Second, we had to decide on a particular focus for enquiry. Following the arguments made above about the wider purpose of information systems, we selected RISOS rather than RIS (or RISIS): by far the main agenda in ICT4D and in international development is resilience of broader social systems. Determination of system scope was then required: what should be the social system whose resilience we would evaluate? We chose to study the resilience of communities. So, for our fieldwork, the system under investigation was a community. Not only does this follow the thread in the ICT4D literature but the community as system has been a relatively common scope for resilience analysis more generally (eg, Callaghan & Colton, 2008; Magis, 2009). It also fitted with the interests of a number of NICCD project stakeholders such as NGOs working on urban or rural development.

In October 2013, we issued a call for partners to help apply the RABIT resilience framework in the field. From the respondents, we selected Sula Batsu, a Costa Rican social enterprise that works on a range of development issues including ICT-based development. With their assistance, we identified Barrio Lujan as the study site; a community of roughly 2000 inhabitants in the southeastern part of Costa Rica's capital city, San Jose. Barrio Lujan was chosen because it met four criteria: prior contacts with Sula Batsu that would facilitate access, a relatively safe environment for research, ample use of ICTs within the community, and known impacts of external stressors including climate events and insecurity making resilience a salient issue for the community. In this last regard, Barrio Lujan reflected broader trends in Costa Rica; trends seen in many developing country urban contexts and which lead to environmental, economic, and social stressors for the community (Parnell & Oldfield, 2014). Costa Rica is recording a growing number of climate change–related phenomena, including a growth in urban flooding (MINAE, 2014), something that has occurred regularly within Barrio Lujan. Economic liberalisation in the country has been associated with growth but also some disruptions to local enterprise (Gwynne & Kay, 2014), and Barrio Lujan saw one of its main firms—the "Dos Pinos" dairy goods production facility—close some 10 years previously. Urbanisation has also been a feature of Costa Rica

TABLE 1 Resilience attributes and illustrative markers

Resilience Attribute	Definition	Illustrative Markers
Foundational attributes		
Robustness	• Ability of the system to maintain its characteristics and performance in the face of contextual shocks and fluctuations.	• Physical preparedness • Institutional capacity • Multilevel governance
Self-organisation	• Ability of the system to independently rearrange its functions and processes in the face of an external disturbance, without being forced by the influence of other external drivers.	• Collaboration and consensus building • Social networks • Local leadership and trust
Learning	• Capacity of the system to generate feedback with which to gain or create knowledge, and strengthen skills and capacities necessary to experiment and innovate.	• Capacity building • New and traditional knowledge • Reflective thinking
Enabling attributes		
Redundancy	• Extent to which components within a system are substitutable; for example, in the event of disruption or degradation.	• Resource spareness • Functional overlaps and interdependency • Resource substitutability
Rapidity	• Speed at which assets can be accessed and mobilised to achieve goals in an efficient manner.	• Rapid resource access • Rapid resource assessment/ coordination • Rapid resource mobilisation
Scale	• Breadth of assets and structures a system can access to effectively overcome or bounce back from or adapt to the effects of disturbances.	• Multilevel networks • Resource access and (intra-/inter-level) partnerships • Cross-level interactions
Diversity and Flexibility	• Ability of the system to undertake different courses of actions with the determinants at its disposal, while enabling them to innovate and use the opportunities that may arise from change.	• Different courses of action/emerging opportunities • Adaptable decision-making • Innovation mechanism
Equality	• Extent to which the system affords equal access to rights, resources and opportunities to its members.	• Strengthened competencies/gap reduction • Inclusiveness • Openness and accountability

with urban population growth of 2.5% per year (Maria, Acero, Aguilera, & Lozano, 2017). Barrio Lujan has reflected this with around 40% of its population being in-migrants according to the 2011 census (INEC, 2014), which also showed housing quality to be generally good although with some pockets of temporary or fragile structures. As will be seen below, these contextual factors all shaped the mechanisms, including perceptions, of resilience in the community.

Given Sula Batsu's practical engagement with its target communities, the main aim of the field study—alongside learning from application of the RABIT framework—was to develop a set of priority actions for future use of ICTs to strengthen the resilience of the Barrio Lujan community. As noted above, this pragmatist orientation led us to take an evaluative more than explanatory approach to the resilience mechanisms. We could have done this just by benchmarking existing use of ICTs to support each of the community's resilience attributes and looking for areas of low usage. However, we decided that there should also be a weighting based on the perceived strength or weakness of those attributes—so, for example, highest priority would be given where ICT usage was reported as low and the community resilience attribute was also seen as weak. We would therefore be assessing perceptions of two things: baseline community resilience and baseline impact of ICTs on community resilience. The latter we called "e-resilience" for short, being synonymous with RISOS: the impact of ICT-based information systems on a wider system; in this case, the community.

Our final area of decision making was methodology and methods. Consistent with the tenets of critical realism, we chose a pluralist research methodology (Mingers, Mutch, & Willcocks, 2013); specifically, one which sought to address the "perceptual limitations" inherent in a critical realist approach through triangulation of both methods

and data sources (Wynn & Williams, 2012). Past resilience research has used a variety of research methods that could have been incorporated into our approach, and we selected two which were implemented during January to March 2014. To benchmark community resilience, we used a set of semistructured interviews with content framed in terms of general community context and then specific discussion of the resilience markers. Our sampling approach was purposive, targeting a variety of key local stakeholders—both individuals and organisations—directly involved in enactment of resilience mechanisms to provide a triangulation of perspectives. Six individual interviews were undertaken with those Sula Batsu identified as community leaders, including official leaders of community organisations. Four group interviews with a further 14 respondents were undertaken: emergency services representatives (police/fire), the local emergency committee ("Risk and Disaster Prevention Group"), the community association ("Local Neighbourhood Association"), and a local women's group ("Entrepreneurial Women's Group").

Interviews were tape recorded and then transcribed and translated. Consistent with norms of critical realist research, we adopted "a hybrid approach combining theory-driven template coding … with inductive code generation methods" (Fletcher, 2017; Williams & Karahanna, 2013). Initial coding began using a template based directly on the attributes and markers within the RABIT framework. Consistent with our retrodictive approach, we then developed codes for the specific instantiations of these mechanisms as linked to events within the community. Applying these codes across the corpus of our data, we were then able to analyse qualitatively to understand the perceived nature of resilience, and quantitatively to assess relative strength and weakness of resilience attributes.

To benchmark e-resilience, we undertook a survey. Following basic demographic and ICT usage questions, this involved specific questions on use of ICTs in relation to resilience markers. The questionnaire was administered by research team members face-to-face with respondents (ie, as a fully-structured interview) and was piloted with nine respondents. This resulted in elimination of some repetitive questions, clarifications to questions and answers that respondents did not understand well, and reduction in the number of questions to ensure the process would not last more than 15 minutes since respondents were unhappy about the length of time required for the initial questionnaire. The revised questionnaire was then administered by going door-to-door in the community until 50 responses had been achieved. To provide for respondent triangulation, selection of homes was random across the community but did have to exclude one area where researcher safety was a concern. The basic demographics of the respondents are summarised in Table 2; some gender, age, and occupation skews can be seen arising from the fact that the survey had to be undertaken during the day to safeguard researcher security. Survey results were subject to basic statistical analysis, which supplemented the evidence already gathered from discussion of ICT usage by interviewees.

In terms of levels of ICT usage, 48 of the 50 survey respondents owned at least one mobile phone (the two who did not said that this was due to lack of money; 18% owned two or more phones), and more than half (56%) used their mobile for Internet access. Approximately 76% of respondents had access to an Internet-connected computer or tablet, almost all at home, although 9% of those with access obtained this via a local cyber-cafe. Social networking and e-mail were the main usage categories. It can be seen that mobile phone and Internet access are widespread within the community. Although ICTs are not ubiquitous, ownership and usage levels reflect the mainly middle-

TABLE 2 Barrio Lujan survey respondent demographics

Gender		Age		Occupation	
Female	60%	16-25 y	36%	Student	26%
Male	40%	26-45 y	20%	Employee	24%
		>46 y	44%	Pensioner	20%
				Homemaker	16%
				Self-employed	12%
				Unemployed	2%

income status of the community, at least of those who were accessible by the survey given the need to avoid data gathering around less-secure areas, which housed lower-income residents.

4 | FINDINGS

Consistent with the critical realist principles outlined above, the findings from fieldwork will be seeking to instantiate the pre-identified mechanisms (resilience attributes) that are connected to particular events experienced by those involved in the particular system (the Barrio Lujan community). Consistent with the pragmatist orientation, this instantiation will seek to assess not just the nature but also the relative extent—presence or absence—of each mechanism within the community, to provide a benchmark to guide subsequent action. As such, and given limitations of space, our focus here will be more on the mechanisms, than on explaining in detail how particular mechanisms are seen to link to particular events (or not in the case of their weakness or absence). The findings are reported in two subsections: one benchmarking the foundational resilience attributes within the community including the contribution of ICTs ("e-resilience") and one similarly benchmarking the enabling resilience attributes. A summary of the derived action recommendations is then provided.

4.1 | Foundational resilience attributes

4.1.1 | Robustness

Interviewees were only able to identify a few examples of the *physical preparedness* of the community: a communal room that could be used for emergency coordination, and some concrete barriers to counteract flooding. More generally, there was a sense of the absence of preparation: only 11% of those surveyed regularly used ICTs to access climate-related information, and most interviewees did not know where they should go in an emergency nor were they aware of local emergency plans or risk-reduction regulations:

> *… the people do not prepare. And when something does happen it is too late, then you have to figure out how to survive. The only ones that practice are the firemen. Otherwise …. We have never seen an [emergency response] simulation here" (I1:6)*[1]

The river Ocloro runs through the community and maintenance of flood protection in one area had been responsibility of the local factory, Dos Pinos. With closure of the factory, "*that infrastructure was abandoned*" and "*the area is flooded during the rainy season*" (I4:35). Physical quality of some housing was also seen as poor. The presence of *institutional capacity* was described in terms of the local fire and police departments, hospitals, and the local Catholic church, all of which were seen as supporting the community in the event of external stressors of various kinds. These—rather than other institutions of government—were also cited as interviewees interpreted the notion of *multilevel governance*. It was the former institutions that had more of a presence in the lives of the community. However, ICTs were broadening this to some extent: around one-third of those surveyed had used them to interact with national emergency organisations—either reporting an emergency or sourcing information about emergencies.

4.1.2 | Self-organisation

Within the community, a number of organisations including those used for group interviews were seen to facilitate *collaboration and consensus*. Alongside the community and women's groups, of most direct relevance was the local "Risk and Disaster Prevention Group". This is a group of community members who, for example at the time of the field study, were undertaking a census to identify areas of infrastructural vulnerability, though a number of interviewees questioned the ability of this group to respond adequately if there were a disaster. Other local participative

associations included the School Association for parents, the Janos cultural group involved with youth training, a "neighbourhood watch" group that met with the police regularly and disseminated security alerts, and a branch of the "Lions Club" that supported community activities. ICTs had, to date, had only a limited impact—less than a quarter of those surveyed reported ever using ICTs to support local activities or projects, and this was mainly just basic communication about group activities among members. These groups were part of a more general strength of *social networks* within the community with a clear perception of belonging and stability:

> *"This is a community in which people have lived for many years … they are all the same neighbours … I have seen ladies that have been living here for 30, 35 or 40 years, that's people that have grown up in the community … If there are no grandparents anymore, the parents or their children continue to live in the same house, so people know each other ever since" (I1:3,5).*
> *"This is a community of few [economic] resources, but there is a lot of 'humanity'. And that … makes the community unite. In an eventuality, I see that neighbours provide support to each other, and are aware of each other"(I8:75).*

There was, though, an awareness of change within the community with perceived threats to its social fabric: in-migration from rural areas, out-migration of younger members of the community, and conversion of residential property into commercial offices. A mixed picture was presented of the impact of ICTs on social networks. Almost all respondents were engaged with social networking, with 88% active on Facebook (and 16% on Instagram). There were formal Facebook pages for many local institutions and enterprises but these were little used. By far the majority of activity was communication with friends and family—either posted content or messaging/chat. Some saw this as strengthening those social relations, but others saw online activity as undermining offline relations. Less than one-third of respondents saw ICT usage contributing to *trust-building* within the community, as one interviewee noted: *"We are 'connected', but only with another world … We don't care about the lives of others unless we meet them through the Internet"* (I2:18). Few interview comments were made about *local leadership and trust*, but there was a concern that presence of the fire station was causing local leadership within the community to atrophy:

> *"… now that they have the Fire Department located in the middle of the neighbourhood, they believe that they are 'the salvation'! … What they don't understand is that the firemen are not there to 'save everybody', but you have to seek protection or take measures on your own". (I1:8).*
> *"I feel that they [the community] are waiting for us [Fire Department] to take the initiative" (I7:68).*

4.1.3 | Learning

There were identifiable *capacity-building* initiatives within the community, but they tended to be rather narrowly focused: skills training in first aid or production of handicrafts, some awareness-raising about environmental issues through local schools, and training for members of the Risk and Disaster Prevention Group. Use of ICTs for personal capacity building had a different focus and was at a relatively formative level: just 21% reported undertaking online training via the Web, mainly for practical and more technical skills linked to actual or potential livelihoods such as mechanics, electronics or health/beauty. These were thus of longer-term value rather than directly relating to shorter-term external shocks or emergencies, and the learning related more to building diversity of potential livelihoods within the community rather than to building an internal feedback capacity. Any integration of *new and traditional knowledge* was solely informal, mainly illustrated in terms of the contribution of older community members in offering their experience and advice to communal activities. More dominant was the impression of deficient mechanisms for *reflective thinking*: a lack of ability to learn from experiences of shocks:

> *"No, no, no [there is no knowledge sharing] … People know that there is a river here, so when it rains, they come just to see what happened to the neighbours, and to say "Poor you" … And then another storm comes, and they do the same: "Poor you", and then they go home. We do not share solutions … We are lacking awareness about that …". (I2:17).*

There were equally few examples of ICTs helping in relation to these other markers of learning: just five respondents reported using ICTs to access *new knowledge* about community improvement ideas, and no evidence emerged of use of ICTs to access *traditional knowledge* or to engage with *reflective thinking*.

4.2 | Enabling resilience attributes

4.2.1 | Redundancy

The markers of *resource substitutability* and *functional overlap* were mainly identified with the multiple institutions operating within the community that, alongside less formal social networks, could provide support in emergency situations even if others of those institutions were no longer functioning. ICTs were seen to potentially help here, with half of respondents using ICTs to access resources from multiple sources in emergency situations, including official government assistance, help from other organisations such as church or NGOs, and networks of family and friends. Given these provided different options for sourcing, they may be equated with resource substitutability. *Resource spareness* was not directly brought up, except that just under one-third of respondents said they had used ICTs to generate additional income via remittances or other financial opportunities. Just how "spare" such financial resources might be was not investigated, and they would need to be set against the loss of income that occurred with removal of economic opportunities, as had happened when the Dos Pinos factory closed, leading to loss of jobs in Barrio Lujan.

4.2.2 | Rapidity

The potential for *rapid resource access*, *assessment*, and *mobilisation* was vested largely in the presence of three relevant institutions: the community's Risk and Disaster Prevention Group, the local emergency services, and the local government's own Emergency Committee. The rapid response of the latter two in relation to recent flooding had been demonstrated in practice, and ICTs were of proven value—half of respondents had used them to contact one or more emergency services, and 70% saw ICT usage providing more rapid access to assistance of any type in case of local emergencies. However, the ability of the community to respond rapidly was seen to be hampered by two things: the absence of any early warning system to detect and analyse threats and to disseminate warnings, and the lack of a clear emergency response plan that could be immediately put into action. While ICTs have potential to act as an early warning system, they currently did not: the nearest existing use was from the one quarter of respondents who used ICTs to get post-hoc news about emergency events such as flooding in the local area.

4.2.3 | Scale

Interviewees saw the location of the community providing access to *multilevel networks* and *cross-level interactions* through formal institutional links; for example, nearby schools and universities that community members attended. More specific to the issue of resilience were the connections to higher-level organisations that responded during emergencies. For example, during flooding in the community, not only had the local government been contacted to respond but assistance had also been sent after contacting the national-level Joint Social Welfare Institute (IMAS) and the National Emergency Commission. These higher-level connections were seen as less effective for any sustained actions such as longer-term development and adaptation, as one organisational representative identified:

"People only call us when there is a situation … But there is no medium, or a leader from the community with whom we can communicate" (I1:5)

There was also a sense of this from the ICT-related responses: around half of respondents reported ICTs as being helpful in contacting higher-level organisations, but few reported the technologies were helping to build true multilevel networks such as those bringing together community and city-wide or nationwide organisations for emergency response or community development. More locally, there was potential for *intralevel partnerships* between the Risk and Disaster Prevention Groups of neighbouring communities but this had been limited to date: attending a joint training workshop and sharing some ideas about disaster prevention. Otherwise, organisational representatives complained that local organisations operated in silos that, on a day-to-day basis, did not share resources and activities, and there was no evidence of ICTs helping cross these boundaries to create new shared structures.

4.2.4 | Diversity and flexibility

It was difficult to uncover much evidence about the strength of these attributes, beyond general expressions of the way in which the community had been able to adapt to changing economic and demographic conditions. The only offered example was finding alternative employment options when the Dos Pinos factory closed, which could be seen to illustrate *adaptable decision making* and *different courses of action*. Rather, the narrative of interviewees was homogeneity and stability of the community, including a lack of *innovative practices*:

"There have been no changes in the community … it continues to be the same. … [In terms of innovation] there is nothing significant." (I6:59).

This was linked not only to the stability arising from the older inhabitants of the community but also to the limited "*youth injection*" (I7:68) that might drive forward alternative ideas. The gap between general and specific was also seen in relation to ICT use. The great majority (85%) of respondents said that they used ICTs to access new information for decisions and to identify different courses of actions and opportunities: economic opportunities, household activities, and wider social activities within the community. However, it was not possible to find evidence of this precursory ICT-enabled activity then materialising into innovative practices relating to livelihood or community improvements.

4.2.5 | Equality

A number of the groups operating within the community were aimed at those who might be relatively marginalised —seniors, youth, and women—and so were seen to foster *inclusiveness*, although a number of respondents felt that young people particularly were not included in many of the more general activities and organisations of the community. In terms of a sense of belonging, only 10% reported ICT usage making a contribution, reflecting concerns around ICTs and community identity and cohesion similar to those expressed around self-organisation. Geographic divisions were also seen within the community with growth in "cuarterias"; areas characterised by dense population, fragile structures including housing, poor sanitation, and instances of homelessness, as one interviewee illustrated:

"The area of "El Vallejo" is divided in two parts. A HORRIBLE [emphasis] part that is known locally as "Agudo Street" … And another part that is where, supposedly, "the decent people" live."(I1:2)[2]

Given their role in training, local groups were seen as helping to *strengthen competencies* of some relatively excluded community members. This was also perceived of digital technologies with around two-thirds of respondents

giving examples of ICT use to build competencies that included training opportunities, expanded access to new livelihoods, and support for those with particular needs such as seniors or persons with physical disabilities. There was a degree of *openness and accountability* in some of these groups where key roles (chair, secretary, etc) were selected via nominations and elections. But others saw them as insular and potentially self-serving, not informing the wider community about activities and opportunities: "I feel that [the Association] has not known how to project itself to the community" (I2:20). And there was no evidence offered that ICTs were being used to make these institutions more open to the community.

4.3 | Priorities for future ICT-related action

Alongside our aim of operationalising the RABIT framework, we were also engaged with the community and wanted to produce a set of ICT-related action priorities that could be used to strengthen resilience in Barrio Lujan. We undertook various quantifications and visualisations of the interview and survey data, only brief details of which are provided here (for further detail, see Ospina et al., 2016). Acknowledging that there are many different ways in which priorities could be identified, we felt it most appropriate to take account of both general resilience and specific e-resilience findings.

The approach we chose was, for each resilience attribute, to subtract the number of mentions of weaknesses in the interviews from the number of mentions of strengths to produce a single score, which could then be used for prioritisation. For example, highest priority for intervention was given to robustness since that had the most negative score. Lowest priority was given to self-organisation, which had the most positive score. We then also scored each attribute in terms of "e-resilience": the extent to which survey responses showed ICTs were currently being used to support that attribute. Highest priority for intervention was given to learning since that had the lowest ICT usage score through to lowest priority for diversity and flexibility since that had the highest ICT usage score.

Ranking the priorities from the two exercises and then combining them, we produced a composite list of priorities, as shown in Table 3. This is a ranking that takes into account both the general need to strengthen particular aspects of resilience and the specific opportunity for greater use of ICTs.

This still left quite a substantial set of first-tier issues: too many to produce a viable list of priority actions. We therefore narrowed this further by just prioritising those markers of the first-tier attributes where current ICT usage levels were lowest. These markers were presented back to the community via a learning event that discussed all findings, held with the community's Risk and Disaster Prevention Group. From this event, action suggestions for each marker were developed, as summarised in Table 4. The focus was particularly on use of ICTs to support resilience to climate change and related environmental issues. "Level of involvement" indicates which of community-, municipality-, and national-level stakeholders were thought likely to be involved.

TABLE 3 E-resilience action priorities by composite index

Resilience Attribute	Average Rank Score	Action Priority
Learning	1.5	First tier
Robustness	2.5	
Equality	3.5	
Scale	3.5	
Diversity and Flexibility	5.5	Second tier
Redundancy	6.0	
Rapidity	6.5	
Self-organisation	7.0	

TABLE 4 Priority actions to improve community e-resilience in Barrio Lujan

Resilience Attribute	Resilience Marker	Potential Intervention	Level of Involvement C	M	M
Learning	Capacity building New and traditional knowledge	• As part of "Green Barrio" activity, produce an awareness-raising and information campaign via social media on environmental issues and impacts (including climate change) in the local community	X		X
		• Develop an interactive e-learning course on climate change, community impact, and adaptive practices	X		X
		• Develop a broader interactive e-learning course on community environmental issues and actions (eg, garbage disposal, pollution, and housing)	X		X
		• Use ICTs to help record, visualise and share a community mapping exercise	X	X	X
		• Use ICTs to develop and support a community of practice on local development actions	X	X	X
Robustness	Physical preparedness	• Use ICTs to provide to the community well-visualised overviews of climate change impacts, and priorities for adaptive actions		X	X
Equality	Inclusiveness	• Investigate development of local youth as "environmental knowledge brokers," using ICTs to access environmental information, to train others, to create environmental awareness within the community, to capture and share traditional knowledge of seniors, and to participate in broader networks	X		
		• Create a Barrio Lujan community Facebook page to foster community identity	X		
Scale	Multilevel networks	• Post an updateable (eg, as wiki) list of relevant community, municipality and national institutions of relevance to environmental and community development: their contacts and responsibilities and resources	X		

5 | DISCUSSION

In this section, we seek to address our guiding question—"What can be learned for information systems and resilience from research and practice in ICT4D?"—by reflecting on what our ICT4D-based findings tell us about information systems and resilience. First, we discuss the extent to which our ICT4D-derived approach addresses the lacunae identified within IS literature on resilience. And, second, we offer some more in-depth thoughts about our conceptualisation of resilience, and about operationalisation of our specific framework.

5.1 | Reflections on IS literature gaps

We start by discussing the resilience-related lacunae in the IS literature: the lack of operationalised conceptualisation, the lack of application to wider systems, and the lack of consideration given to longer-term adaptation and change. Some of these were addressed in theory by ICT4D literature, and we sought to address all through our primary research on resilience applied in the ICT4D domain.

It has been shown feasible to build a conceptual framework for resilience, developing a much more comprehensive understanding than previously offered within the IS literature. And it has been shown feasible to undertake an empirical investigation of that framework using an ICT4D case study, which provided both a qualitative insight into the key mechanisms of systemic resilience as understood by those involved, but also offered some basis for pragmatic quantification and visualisation of resilience. The RABIT framework of attributes enabled an evaluation of the resilience of a wider system—in this case a community—and also an

evaluation of the contribution of ICT-based information systems to that wider system's resilience. This is the "RISOS" that was present in the ICT4D literature but which to date has been given too little consideration within the IS domain.

We can consider what our findings tell us about that wider systemic impact of ICT-based information systems. Typical of the patterns seen in ICT4D contexts, ICT usage can be described as broad but shallow. Use of ICTs was thus quite widespread both within the community and in relation to resilience: examples were provided of ways in which ICTs were involved with every one of the resilience attributes. But the depth of that impact was as yet limited: applications were mainly one- or two-way communications rather than transactions; applications were mainly digitising existing flows and processes rather than using the potential of digital technology to redesign or reengineer those flows and processes; and applications mainly supported links to individual existing institutions rather than helping develop new, multistakeholder networks. At present, then, ICTs were mainly supporting the stability of the wider system rather than its change let alone transformation: symptomatically reflected in the gap between the large number of respondents saying that they obtained new information and ideas via ICTs, and the lack of evidence that these were being put into practice. There were signs of ICT-supported incremental change, but these were a mixed bag of perceived positives (eg, access to additional finance) and negatives (eg, the sense that online links might be undermining relations within the physical community), albeit the balance of assessment was that ICTs were contributing more benefits than disbenefits to the community.

But we can also reflect on what this approach does not tell us about ICT-based information systems. In looking at resilience of the wider system, the digital information systems of the Barrio Lujan community were themselves black boxed: we found out nothing about the resilience of those systems. Had we taken the RIS route—that is, investigating resilience of the information systems—then the black box would have been opened, and the attributes and characteristics of the information system would have been subject to scrutiny. As yet, though, application of the RABIT resilience model to an information system remains part of the future research agenda.

In terms of the roles of resilience, we were guided by the ICT4D literature to relate the definition and conceptualisation of resilience to both stability and change, moving beyond the typical IS approach. Our findings show operationalisation of the attributes and markers to be skewed towards the continuity (withstand and recover) aspects of resilience more than the adaptive aspects. For example, one intention of our work was to understand adaptive resilience to climate change. But Barrio Lujan residents did not readily perceive long-term climate change trends. As a result, the interview, discussion and survey questions were oriented towards short-term emergencies and the continuity aspects of resilience. Robustness, rapidity, and scale were all oriented this way and as just noted, so was much of the discussion of ICT usage. The sense of resilience that therefore materialises is somewhat specific and skewed away from adaptation, rather than being a generic measure of overall resilience to the whole range of external stressors including longer-term trends.

However, this is not an inherent shortcoming of the framework. Institutional capacities, resource usage, and other processes within the community relate equally to longer-term change. And our respondents offered examples that gave insight into the adaptational aspect of resilience: use of ICTs to learn new livelihood skills, use of ICTs to support community development groups, use of ICTs to foster inclusiveness, etc. The RABIT framework therefore did address the concern that earlier IS-based models of resilience did not include an adaptational element: intrinsically so, given its construction from literature dealing with adaptation. Instead, the challenge is more a methodological one of broadening out the discussion and questions to include tangible aspects of adaptation and trends that respondents can relate to their everyday lives; for example, linking climate change to the increase in climate-related events such as flooding, linking demographic change to the perceived composition of the community, and linking economic change to concrete events such as loss of the Dos Pinos factory.

We were also guided by the ICT4D literature to add the equality attribute to our framework of resilience. In practice, this did partly attend to the danger identified earlier that resilience could be viewed negatively if it assists the continuity of systems that are unfair or harmful in some way. The equality-related findings show addition of this attribute enabled some exposure of inequalities within the system: both causes such as distribution of skills and

openness of decision-making, and effects such as perceived exclusion of certain groups. And it enabled assessment of the degree to which ICTs were or were not making a difference.

There could be an argument for extending the consideration of equality. For example, it did not yet cover all the structural and functional elements seen to reproduce inequality (eg, Acker, 2006; Sen, 1992). And there could be an argument for expanding the consideration of transformational attributes of resilience: the weight of the overall framework remains tipped more to system continuity or at most incremental change rather than the type of transformational development that is often called for (UNGA, 2015). However, there would be a risk here. We noted above the risk that our addition of an adaptational aspect might create tensions between the stability and the change orientations to resilience. In practice, neither in analysing the data nor in feeding back results to the community did any strong tensions arise from this combined approach to resilience. But the potential is still there for contradictions to materialise between more stability-oriented attributes such as robustness and redundancy and more change-oriented attributes such as learning, flexibility, and equality. Such contradictions would intensify if we added more transformational change elements to the framework of resilience (Meerow, Newell, & Stults, 2016).

5.2 | Reflections on conceptualisation of resilience

Having considered the particular gaps that we identified earlier, we now discuss what our findings tell us about our conceptualisation of resilience; specifically, two aspects: the ontology and epistemology of resilience and its framing in terms of attributes and markers.

In relation to ontology and epistemology, as argued above, a positivist position seeing resilience as a directly- and quantifiably-measurable system property might be appropriate for an engineering-derived approach to technical system resilience. But it would not be workable for a social or socio-technical system like that encountered in case of Barrio Lujan. We therefore essayed a critical realist position. The relation between resilience and critical realism remains to be fully explored because of the particular nature of our approach: retrodictive rather than retroductive, pragmatist in orientation, and evaluative rather than explanatory. However, we can see in our findings representation of the three domains of critical realism as outlined by Bhaskar (2008). We find the real—underlying structures and mechanisms—reflected, for example, in the formal organisations and informal groupings within and around the community, and in the connections or lack thereof between them. We find the actual—events generated by the real mechanisms—instantiated, for example, in the responses to emergency situations or in the livelihood-related decisions and actions of individual residents. And we find the empirical—observed experiences—in all the responses and perceptions of our respondents.

Stakeholder triangulation and pluralism of methods—as advocated for critical realist studies—helped partly move beyond the individual judgements, biases, and priorities that impinge upon the empirical. Following the ideas of retrodiction, we regarded the resilience attributes as pre-identified mechanisms and then sought through fieldwork to instantiate them as potential bases for the events experienced by respondents. We were thus able to build a picture of what was seen to constitute resilience of this particular system. Guided by pragmatism, our interest was less on how the instantiated mechanisms might explain the experienced events and more to gain an insight into the relative strengths and weaknesses of different attributes. We cannot be said to be directly measuring system resilience in the way some earlier positivist IS studies claim to do. But that does not mean that there was no basis for quantification. The interviews provided indirect measurement of resilience attributes, with analysis of positive and negative perceptions of system resilience attributes allowing a ranking of relative strength or weakness. This also allowed prioritisation, eg, of interventions for those system attributes described as weakest. The survey measures were even more indirect: "e-resilience" in this case was not a measure of resilience but a measure of the extent of use of ICTs in relation to each attribute. However, this still allowed a ranking and prioritisation, eg, of ICT-related interventions for those attributes to which ICTs contributed least at present. We adopted one particular approach to quantification and acknowledge there could have been others. But we do

therefore see validation for this type of realist approach to resilience of social and socio-technical systems not only in intellectual terms but also in pragmatist terms of helping derive an ordered set of action recommendations.

However, we also see limitations of adopting a critical realist approach. In phrasing questions about perceptions of resilience markers, we limit the comparative validity of the RABIT resilience framework. Cross-sectional comparisons of resilience between different systems will be of limited value, at least with the current question set. So one area for future research could be to seek a more portable and comparable model of resilience by (see below) better marker descriptors and thence narrowing to more "objective" questions that seek to triangulate more to the underlying attributes of the system. It is questionable whether this would be commensurate with critical realism's worldview. However, without this, validity will be limited to within-system comparisons, such as longitudinal work to understand how resilience is seen to change over time—for example, in response to particular interventions such as implementation of a new information system in a community.

Secondly, of the general approach of understanding resilience in terms of attributes and then markers, the findings suggest that they do provide insight into aspects of the system (ie, community) that all in some way relate to withstanding or recovering from or adapting to short-term shocks and longer-term change. While—as discussed below—there were some issues with individual markers, in general, the eight attributes illuminated different aspects of resilience. The findings show that each attribute identified at least some element of life within the community and some use of ICTs that was not found by any other attribute. Since all relate to coping with shocks or trends, this suggests all are necessary to a resilience framework. There is some evidence that they are sufficient: the more open-ended group interviews did not throw up anything that could not be related to one of the RABIT framework resilience attributes.

However, we followed a largely deductive design that predetermined the mechanisms of resilience and required retrodiction for their instantiation. One area for future research could thus be a retroductive approach that laid greater emphasis on the empirical as its starting point. Using more open-ended discussion, this would allow additional aspects including alternative potential mechanisms of resilience to emerge. Thus, in concrete terms, this might derive alternative or additional resilience markers—even attributes—from more open-ended interviews about stability and adaptation. This would take research in a contrasting direction to that suggested above on more realist and "objective" assessment of resilience. If one still accepts the intransitive reality of resilience attributes as mechanisms, this would not be synonymous with, but would come closer to a constructionist approach focusing solely on what stakeholders perceive resilience to be. This would fulfil a potential for such work that is so far only hinted at in the IS/ICT4D literature (Wastell et al., 2007) and would allow a more flexible and less constrained investigation of resilience. The downside is that resilience would be constructed differently for each new system, limiting the portability and comparability of knowledge.

5.3 | Reflections on operationalisation

Finally, in these reflections on findings, we turn to two more specific issues around operationalisation of the RABIT framework in Costa Rica: system boundaries, and the selection and assessment of markers.

A generic problem for systems thinking (eg, Cordoba & Midgley, 2006), which also emerged during fieldwork is where to set the boundary of the system. This arose particularly in relation to local institutions: community groups were assuredly part of the community-as-system but fire, police, and local government agencies—partly employing community members but partly not—rather awkwardly straddled the boundary. This raised questions about whether they should be included, for example, in analysing the institutional capacity of the community as part of robustness. A similar problem would arise for research studying the resilience of an information system: would one include within that system all the infrastructure and platforms and devices on which it runs; and what types of people—users, implementers, builders, etc—would be placed within the boundary.

In relation to markers, the field study was particularly helpful in identifying two issues and encouraging revisions. First, there was the issue of marker selection. The three illustrative markers that we derived for each of the attributes led to problems:

- There were overlaps: for example, multilevel networks and cross-level interactions under scale, and multilevel governance under robustness might have potential differences, but they appeared in practice to be very similar.
- There were gaps: the markers for rapidity were narrowly conceived around resources and as a result, did not adequately reflect the need for a fast-acting detection-assessment-response subsystem. The first equality marker was narrowly conceived in terms of human competencies rather than other assets that might be unevenly distributed.
- There were some misallocations: trust belonged with social networks rather than with leadership, and interdependency of system functions relating to robustness rather than redundancy with a requirement that that interdependency be marked by "loose coupling" of subsystems such that damage to one does not cause all others to collapse.
- There were over-broad combinations: where rather different characteristics were combined into a single marker, often leading to only one of them being operationalised; for example, "functional overlaps and interdependency" was only operationalised as "functional overlaps," "resource access and (intra-/inter-level) partnerships" as "intra-level partnerships," etc.

TABLE 5 Revised resilience markers

Resilience Attribute	Markers
Foundational attributes	
Robustness	• Physical preparedness • Institutional capacity • Loose functional coupling
Self-organisation	• Collaboration and consensus-building • Social networks and trust • Local leadership
Learning	• Capacity building • New and traditional knowledge • Reflective thinking
Enabling attributes	
Redundancy	• Resource spareness • Resource substitutability • Functional overlaps
Rapidity	• Rapid issue detection • Rapid issue assessment • Rapid issue response (resource mobilisation)
Scale	• Scale of resource access • Multilevel networks • Intra-level networks
Diversity and Flexibility	• Variety of courses of action • Adaptable decision-making • Innovation mechanism
Equality	• Equality of distribution of assets • Inclusiveness and participation • Openness and accountability

Putting all these findings from the field study together, a revised set of markers is proposed (see Table 5). This revised set of markers would itself require operationalisation, and it would be helpful to develop deductively a set of descriptors and indicators associated with each marker and inductively a set of respondent keywords/key phrases associated with each marker.

Second, there was the issue of marker assessment. Because the resilience model seeks to be comprehensive, it aggregates quite a number of attributes and, hence, even more markers. But this completeness comes at the expense of ease of implementation. As noted, there were too many markers to include all of them in a survey of reasonable length leading a number of them to be dropped for the e-resilience survey. Other than reducing the number of markers, one solution for future application would be to have two different versions of the survey, covering all attributes but different markers, and increasing the number of people surveyed.

6 | CONCLUSIONS

During the course of the 21st century, so far, there has been dramatic growth in the diffusion of ICTs in the countries of the global South (World Bank, 2016). Simultaneously, there has been growth in the importance of resilience to those same countries (World Bank, 2013). Yet, to date, there has been little connection in theory or practice between these two trends. Work undertaken within the NICCD project has sought to make that connection, starting with a conceptualisation of resilience that integrates ideas and schema from a range of resilience literature to produce a single, comprehensive "RABIT" framework. In line with the requirements of an international development context, and guided by the ICT4D literature on resilience, the framework adopts a longer-term frame for resilience than found in most of the IS literature and specifically incorporates elements relevant to an adaptational and developmental perspective.

This framework was then operationalised in a developing country setting with a field application in an urban community. This provided a proof-of-concept for the RABIT resilience framework. It proved to be workable in the sense that data could meaningfully be gathered to instantiate the attributes/mechanisms of resilience. And it had some demonstrable validity in gathering data about phenomena that impinge on the ability of the community to maintain functioning in the face of external stressors (eg, to resist potentially damaging climate events), recover functioning when damaged (eg, through the actions of the emergency services during such events), and to some degree adapting to longer-term trends (eg, in supporting actions to address future change). The framework proved workable in benchmarking community resilience. And it proved workable in benchmarking "e-resilience," albeit finding in this case that—to date—the contribution of digital information systems to community resilience had been relatively limited and has supported stability more than change. From findings on both resilience and e-resilience, actualisation of the framework was able to generate a series of priority recommendations for practice, generated by community representatives and local partners from the visualised results of fieldwork.

The RABIT resilience framework in terms of attributes, definitions, and markers is generic and so should in theory be applicable to all types of system in all types of context. It can be elevated from the ICT4D subdiscipline into its IS cognate discipline and applied to RISOS: assessing ICTs' impact on the resilience not just of communities but also of other systems such as organisations, supply chains, and groups in both global South and global North. For such future work, we recommend some operational revisions to enable more emphasis on the adaptational and perhaps transformational aspects of resilience, and better use of an amended set of markers. Nonetheless, it requires little conceptual extension to see how the framework would fit with other social systems. Applying the framework to RIS—that is, to assess the resilience of specific information systems or of ICT infrastructures—may require more modification. These are technical or socio-technical systems. At the least, such systems will require a different set of markers for each attribute; they may require different attributes to be developed; and a different ontological position on those attributes—positivist rather than critical realist—may be appropriate. We hope that colleagues in IS will take forward this research agenda, using and adapting this framework to evaluate resilience of both information systems and the wider systems that IS serve.

Overall, the research reported in this paper has addressed its central question by demonstrating that ICT4D can be a domain in which to conceptualise models with wider relevance to IS; here, fulfilling a call within IS for more and better conceptualisation of resilience (Muller et al., 2013). Orienting development of the framework to ICT4D, as opposed to some other subarea of IS, has had a particular value because it has instigated a wider view of resilience, helping avoid what might otherwise be an overly circumscribed approach to resilience within IS. This approach has been broader, stressing that digital systems are means that serve wider ends and systems, rather than ends in themselves. And it has been longer-term, stressing that lasting sustainability of systems requires a resilience that not merely survives transient shocks but also adapts to trends and avoids attributes that undermine long-term survival.

The research has also fulfilled a call for field testing of resilience concepts in relation to information systems (Erol et al., 2010). While this could have taken place in any context or system, choice of the ICT4D domain is conceptually logical given the development-related influence on the resilience framework. It is also functionally (even morally) logical given the greater vulnerabilities of communities and other systems in developing countries, and the greater need for them to build resilience (Adger, Huq, Brown, Conway, & Hulme, 2003; UNDP, 2011).

Conveying resilience from ICT4D into the wider IS domain can also bring with it the idea that resilience is a challenge to the mainstream; an argument arising within ICT4D (Marais, 2015) with origins in international development (Brown, 2016). In this light, resilience can be seen as an alternative to mainstream IS perspectives. Resilience in particular can be—indeed must be—an alternative to the dominant focus within IS on efficiency of operations, just as it counterposes with the market-based agenda in development. Systems optimised for efficiency are not optimised for resilience, and designers must at the least recognise the trade-off between these two. Resilience also challenges the conventional "normal operations" view within IS, which—while it may accept total failures that are never implemented, or partial failures that fall short of some objectives—tends to adopt an "inertial" perspective. This inertial perspective assumes that a system, once implemented and adopted, continues to operate at a constant level of performance (Park et al., 2015; Reimers & Johnston, 2008). Just as the development agenda has incorporated a nonregressive element, so too ought the IS agenda, recognising that systems can degrade or fail during operation due to external stressors and that our worldview of information systems must include "abnormal operations." This is not simply an issue for IS designers, to include protective countermeasures, but also an issue for researchers to understand that information systems have a story of uncertainty and variability to tell beyond the technology acceptance model-conceived stage of adoption.

In sum, our application of the resilience framework has shown ICT4D to be a domain of both ideas and practice that can contribute to the IS discipline. In overall terms, that application has suggested the critical realist view of resilience to have potential validity (though also limitations), and the resilience attributes to be appropriate but the specific markers of resilience to require revision. A rich future research agenda on information systems and resilience therefore lies ahead:

- philosophically in taking both more positivist and more interpretivist approaches;
- methodologically in exploring more inductive bases for understanding and measuring resilience;
- in terms of focus, applying the RABIT resilience framework to a wider variety of systems in order to aggregate knowledge: especially researching resilience of information systems themselves, which will likely require some further modifications to the framework; and
- in terms of methods, applying the revised resilience markers—including more generic/adaptive rather than emergency-/climate-oriented application—and building a corpus of descriptors and indicators for those markers.

ENDNOTES

[1] This indicates interviewee no. 1, text from p6 of the consolidated, translated interview transcripts.

[2] Names of locations have been anonymised.

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