A New Policy Narrative for Pastoralism? Pastoralists as Reliability Professionals and Pastoralist Systems as Infrastructure

Emery Roe

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The project's case studies are in pastoral areas of China (Qinghai), Italy (Sardinia) and Kenya (Isiolo). PASTRES is supported by an Advanced Grant from the European Research Council (ERC).

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Glossary

Controlling (Tables 3.5–3.6): The operational approach of reliability professionals when low and stable output variance is rendered and maintained through keeping input variance and process variance low and stable.

Coping (Tables 3.5–3.6): The operational approach of reliability professionals under conditions of high and unstable output variance and/or inadequate process variance to match input variance.

Critical infrastructure(s): Assets or systems deemed essential for the provision of vital societal services, which conventionally include, but are not limited to, large sociotechnical systems for the supply of water, electricity, transportation and financial services**.**

Domain of competence (Figure 3.2): The unique knowledge base that reliability professionals and their networks have with respect to managing a critical service reliably and system-wide. It is bounded by the skills of the networked professionals in terms of their ability to recognise system-wide patterns and practices and their ability to formulate contingency scenarios based on the local application of broader principles and precepts. In that domain, professionals manage by moving across performance modes (see below) as task environment and resource conditions change to achieve and maintain the reliability of a critical service.

Macro-design (node/hub): The position in the reliability space (Figure 3.2) from which formal principles are applied at the system-wide level to govern the achievement and maintenance of a variety of processes for critical service provision.

Managing (Tables 3.5–3.6): The operational approach of reliability professionals when high input variance matched by high process variance (see *options variety*) achieves low and stable output variance.

Micro-operations, reactive (node/hub)*:* The position in the reliability space (Figure 3.2) from which individual operators and managers with the tacit knowledge and experience achieve and maintain reliability of a critical service, albeit in a reactive fashion.

Options variety: The number and variety of different resources that reliability professionals have with which to respond to the system volatility they face in real time. Such resources might be monetary or consist of personnel and/or strategies one of the two dimensions of Table 3.2).

Pattern recognition, system-wide (node/hub)*:* The position in the reliability space (Figure 3.2) from which trends, configurations and generalisations emerge across a run of micro-cases, which network professionals use as the basis for anticipations and, where evident, better practices to achieve and maintain reliable critical service provision.

Performance mode, just-for-now (Table 3.2): Activities undertaken by reliability professionals when system volatility remains high, but network options have become considerably less various with which to respond. This performance is unstable and not to be prolonged, since its firefighting, band-aids and quick fixes mean operators end up doing one thing to achieve and maintain reliability, just for now, that may in fact make other things worse off.

Performance mode, just-in-case (Table 3.2): Activities undertaken by reliability professionals when system volatility is low and when network options to respond to any volatility are many and varied. This performance is characterised by many resources (including strategies) held in reserve, just-in-case they are needed to achieve and maintain reliability if something bad happens.

Performance mode, just-on-time (Table 3.2): Activities undertaken by reliability professionals when system volatility is high but when network options to respond to that volatility remain many and varied. This performance is characterised by operator flexibility in assembling different options up to the last moment in achieving and maintaining reliability, just on time.

Performance mode, just-this-way (Table 3.2): Activities undertaken by reliability professionals to ensure system volatility remains low when network options to respond remain few and less varied. This performance mode is characterised by command-and-control measures such as emergency declarations, which are to be complied with, just this way, to reduce the task environment volatility so that reliability can be achieved and maintained with the few options at hand.

Reliability, high: The safe and continuous provision of a critical service, even during (especially during) peak demand or turbulent times.

Reliability professionals (Figure 3.2 and *passim*): Operators or managers working in a network with other such professionals and who are skilled in (1) recognising patterns (including practices) emerging system-wide across a run of cases; (2) formulating contingency scenarios based on design principles but localised to the case at hand; and (3) translating the system-wide patterns recognised and the localised scenarios formulated into the reliable provision of a critical service.

Reliability space (Figure 3.2): The cognitive field in which reliability in critical service provision is known and across which it is to be realised. It has two dimensions: (1) the type of knowledge brought to bear on efforts to make the service reliable; and (2) the scope (or scale) of attention of those reliability efforts.

The two dimensions of knowledge and scope create a cognitive space in which four nodes (primary hubs, or positions) are identified for achieving reliability: (1) macro-design (principles at the system level); (2) scenario formulation (contingency scenarios at the case level based on the localised modification of macro-principles); (3) pattern recognition (including system-wide anticipations and practices emerging from the identified patterns of behaviour and experience); and (4) micro-operations (reactive behaviour or experience at the case level).

Reliability standards: Three standards were found for ensuring system-wide reliability within systems operationally bounded: those with mandates to preclude certain events from ever happening; those with mandates to avoid events that should not happen; and those with mandates to maintain services in the face of events that inevitably happen.

A *precluded-event standard* identifies disturbances that 'must never happen ever' for the system in question, where reliability professionals work to prevent such an occurrence (think here of a nuclear reactor explosion). Reliability professionals operating to an *avoided events standard* recognise that certain disturbances should be avoided (a leak on a natural gas line), even though that may not always be possible. The *inevitable events standard* recognises that some disturbances, like earthquakes or lightning-induced fires, must be expected in certain localities, and the reliability professionals are to manage their systems reliably recognising and accommodating these contingencies for those times.

Risk (Tables 3.3–3.5): The product of known or estimated probability of failure and the consequences of that failure.

Scenario formulation, localised (node/hub): The position in the reliability space (Figure 3.2) from which macro-principles are contextualised by networked professionals to the local case, thereby formulating scenarios and protocols that embrace a wider range of contingencies when achieving and maintaining reliability in critical service provision.

Uncertainty (Tables 3.3–3.5): Either the probability of failure or the consequences of failure are not known or estimated.

Unknown-unknowns/unstudied conditions (Tables 3.3–3.5): Neither the probability of failure nor the consequences of failure are known for estimating.

Volatility, system: The degree to which the networked professionals managing for reliability face uncontrollable changes and/or unpredictable conditions in the task environment that threaten the provision of the critical service (one of the two dimensions of Table 3.2).

Abstract

This paper proposes that pastoralist systems are better treated, in aggregate, as a global critical infrastructure. The policy and management implications that follow are significant and differ importantly from current pastoralist policies and recommendations.

A multi-typology framework is presented, identifying the conditions under which pastoralists can be considered real-time reliability professionals in systems with mandates preventing or otherwise avoiding key events from happening. The framework leads to a different policy-relevant counternarrative to pastoralism as understood today. Some features of the counternarrative are already known or have been researched. The paper's aim is to provoke further work (including case research and interactions with decisionmakers) on how robust the counternarrative is as a policy narrative for recasting today's pastoralist policy and management interventions.

Based in the framework, the proposed counternarrative has six interrelated lines of argument:

- Water and energy infrastructures, among others, seek to provide the safe and continuous supply of their respective vital services to participants, even during (especially during) turbulent times. This is called their high reliability mandate. Pastoralist systems also seek to reliably provide outputs and services vital to their respective participants.

- Pastoralist systems also share a number of specific features that characterise the large-scale sociotechnical systems called critical infrastructures. These features are fleshed out by the framework typologies. The key feature is the role, practices and processes of real-time operators in managing for system-wide reliability. Reliability professionals are to be found—critically so, the counternarrative argues—in pastoralist systems, today and in the past.

- Since it is well-established that pastoralist systems are found across the world, it is appropriate to view pastoralism on the whole as a global infrastructure with its own reliability professionals. Further, pastoralism-as-infrastructure-with-reliability-professionals provides a worldwide critical service. To put it formally: as with other major globalised or globalising infrastructures, and not just for energy, pastoralist systems seek to increase process variance—think, real-time management strategies and options—in the face of high but unpredictable or uncontrollable input variance so as to achieve low and stable output variance.

- In less formal terms, this means that, to provide stable supplies of services that are vital to society, critical infrastructures have had to enlarge their portfolio of management strategies and options to respond effectively to increasing and changing variability in their inputs brought about by, among other factors, globalisation, increased competition, and expansion of markets and commodification. These key pressures are also at major work in and on pastoralist systems.

- It is this logic of high input variance matched by high process variance to ensure low and stable output variance that characterises what reliability professionals do. One may ask: 'What is "pastoralist" when the herding family's pot would not exist without the support of urban or out-of-country members?' In answer, what has not changed—so argues the counternarrative—is the logic of the reliability management in terms of input, process and output variance.

- As this counternarrative goes on to argue, this international key service—boosting and amplifying process variance with real-time management strategies and options—is foundational for world economic development in times of high uncertainty and complexity. It becomes key when infrastructures with this capability and in the face of their high reliability mandates are better able to withstand the downsides of that uncertainty and complexity, as well as exploit the upsides of new possibilities and opportunities that emerge *in real time*.

Keywords: pastoralism, critical infrastructures, high reliability, reliability professionals, uncertainty, risk

1 Introduction

I start with a confession. Two decades ago, I had the good fortune to co-author 'High Reliability Pastoralism' (Roe *et al*. 1998), which applied a then-new framework for recasting pastoralist behaviour. Pastoralists had been described as highly risk-averse in much of the literature; the 1998 article argued that the same literature demonstrated pastoralists were reliability-seeking, not risk-averting. The shift from a risk-averse to a reliability-seeking framework entailed rethinking major policy and management recommendations at that point.[1]

The 1998 article may, however, have left some readers with the impression that pastoralist systems were relatively static or standalone at the time of research. I would like to credit this to the anthropological literature, but I may have seen stasis in some of case material where none was reported. Pastoralist systems have always had to respond to high input variability due to weather or such, and even in 1998 this was not news.

In order not to make the same mistake here, this working paper does not purport to be anything like a thorough review of the literature or an exhaustive analysis of available research. In fact, I refrain from citing and discussing those who should be cited, opting instead to spend my time in provoking readers to reconsider what they may well think about pastoralism. My defence is that this lapse on my part frees up space to demonstrate how the changes in high reliability theory and practice over the last twenty years, about which I know, inform and recast already well-established changes that pastoralists systems have undergone, including but not limited to land fragmentation, encroachment and conversion across rangelands and grazing areas (see Nori 2019a for the PASTRES review of the literature on these and other factors).

Those documented changes, in turn, have been credited to the wider forces of globalisation, marketisation, and commodification—which are among the same forces that have transformed the 'high reliability organisations' (HROs) described by first-generation researchers. To cut to the point, high reliability systems, like water and energy infrastructures, have—increasingly so for the last two decades—faced high input variability as well.

Accordingly, the field of 'high reliability theory and practice' differs considerably from what it did in the 1980s. The earlier research had a taxonomic focus by identifying the relatively stable, chief features or principal characteristics of HROs. Such features included high system complexity, high technical competence and the constant search for improvement (which the 1998 article also found in its review of the pastoralism literature). In contrast, and more importantly for the purposes of this paper, contemporary high reliability research has widened the landscape of systems researched to include a variety of critical infrastructures and has focused attention on the skills, practices and processes that drive reliability-seeking behaviour in the face of altogether more dynamic and interconnected environments. This paper is devoted to demonstrating how this better informs understanding of what has always been a high input variability pastoralism.

Before we get to the details, the paper's framework is described and summarised. Afterwards, we turn to a more detailed discussion of the specific findings and typologies underlying the framework and its new counternarrative.

[1] This reliability-seeking framework was based on 1980s research by Todd LaPorte (1996), Gene Rochlin (1993), Karlene Roberts (1993) and Paul Schulman (1993), who found a small set of large systems—namely, nuclear power plants, air traffic control, naval aircraft carriers—were more reliable and safer than one would expect from their sociotechnical complexity and multiple pathways to failure.

2 The reliability professionals framework in brief

Nothing seems further away from arid and semi-arid pastoralists and montane herders than the control room operators of a large electric power plant—that is, until we centre our attention on the real-time skills, practices and processes of both operators and pastoralists. In so doing, it becomes clearer why both can be viewed as complex sociotechnical systems mandated for reliability in service provision.

This paper asks you to think of the critical services provided by pastoralist systems as analogous to (formally, isomorphic with) those tendered by electricity or natural gas systems. The pastoralist service in question could be that longstanding notion of 'the herd as a store of wealth', or—more specifically—stable herd composition, livestock numbers and/or supply of offtake such as wool, meat, blood or milk; it could be certain ecosystem services; or it could be new services altogether (e.g. export cheese production); and so on. (Pastoralists, not the reader, decide whether cheese or meat or whatever is a critical system output.)

What drives a service to be treated as so critical that it requires highly reliable provision is the community-specific or society-specific dread of losing the service(s) in question, e.g. the shared fear of suffering loss of the entire herd under extended dire conditions. Social dread means that system failure—the system-wide collapse of service provision, whether the system be a large electricity grid or a pastoralist system and its critical service(s)—is an ever-present reality that has to be managed against. Those who perform high reliability management in real time are the system's reliability professionals.

Central to managing the system outputs reliably would be pastoralists as reliability professionals, who by virtue of their skills in pattern recognition and scenario formulation (described below) translate the system patterns they see and the local scenarios they face into real-time service reliability—again, defined as the safe and continuous provision of the critical service(s) in real time and over time. This is even true when (and perhaps especially when) impinged upon by changes in climate, environment, politics or policy more generally. A glossary of these and other new terms is provided for ease of reference.

To telegraph ahead and in terms to be explained, we see other ways to identify pastoralist systems' reliability professionals, where present, including the following: their knowing (1) the differences between controlling, managing and coping with risks, uncertainties and unknown-unknowns; (2) the system boundaries and reliability standards to be managed to in real time; (3) the real-time system-wide risks that then have to be managed for, given the system boundaries and standards; (4) the multiple performance modes that they have to manoeuvre across to ensure normal operations; and (5) the options and strategies it takes to match high or changing input variance with a high or changing process variance to ensure low and steady output variance (in other words, that reliable service provision of interest in the face of dynamic external forces and initial conditions). One highly consequential upshot is that reliability professionals manage non-measurable uncertainties well beyond the capability of formal risk methodologies.

In ways that will also be detailed, reliability professionals have unique knowledge of the system as it is actually managed. For the moment, think of what is now called 'real-time team situation awareness' applied to herder behaviour, i.e. a group or networks of pastoralists with real-time understanding of both the system and the case of grazing or herding at hand, right now.

To avoid misunderstanding, this paper does not argue that all pastoralists are reliability professionals or that all pastoralists should be or can be such professionals. Nor am I arguing that reliability professionals have been found in all pastoralist systems. I am claiming something more modest: that there are pastoralists whose current skills, practices and system processes match what we find in high reliability management of other complex sociotechnical systems.

I am suggesting that current perspectives on pastoralism may be true as far as they go, but that they do not go far enough. They do not go far enough because the policy and management implications differ considerably from the ones commonly supposed. This is why a new counternarrative to the current views about pastoralists and their systems is needed.

3 The reliability professionals framework in detail

The pivot of this working paper's framework—reliability professionals—has emerged and developed through some two decades of research on highly reliable control centres of large critical infrastructures, including those for water, electricity, natural gas, telecommunications and hazardous liquids (Roe and Schulman 2008; 2016; 2017). This framework is described through multiple typologies arising out of that research. The typologies are a mix of two-by-two tables, lists of key features or questions and figures. The new terminology introduced by these typologies is set out in the glossary.

A two-by-two table is easily criticised for simplifying a complex reality, but this misses what has always been the latent methodological function of typologies: to remind us that reality is indeed more complex than lines, boxes and lists can ever portray. In like fashion, the typologies below—one after another, new terms following upon new terms—are directed to making the pastoralism's system complexity more visible and granular, without which policy and management implications would not be possible. While it does not make for easy reading, the sequence of typologies that follows provides multiple ways to triangulate on reliability professionals and increase one's confidence in the notion. The additional payoff is that the reader need not subscribe to all the typologies to use one or more in their own work or practice.

For ease of reading, the policy and management implications of each typology are drawn section by section. The overall conclusion when it comes to pastoralist policy and management is this: policy leaders who do not understand the unique orientation and role of reliability professionals are apt not only to confuse their own views about the future with the views that reliability professionals actually hold, but also to commit highly consequential policy and management errors because they ignore the special skills and unique knowledge domain and competencies of reliability professionals.

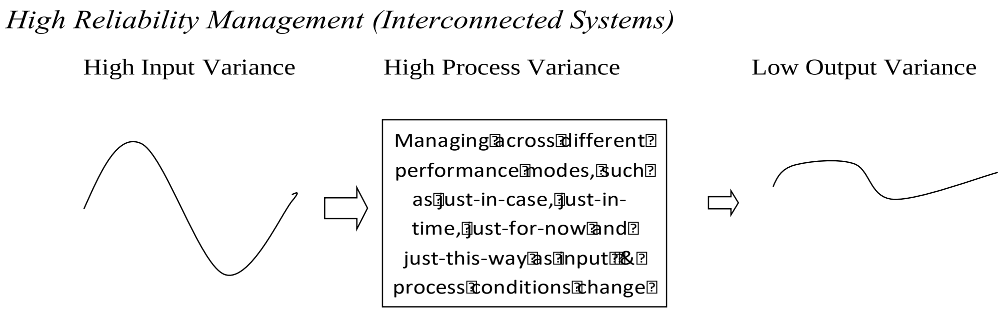
3.1 Core typology: input, process and output variance

In the handful of HROs studied by US researchers in the 1980s, input variance had to be low for output variance to be low. The older public utility for electricity, by example, integrated its generation, transmission and distribution operations such that a problem in generation could be compensated for by way of adjustments in the follow-on transmission and distribution. A nuclear power plant even today must rely on a version of 'guns, guards and gates' to ensure its overall task environment is stable and highly controlled. Further, low output variance—steady and safe nuclear energy—requires strict conformance to a set of highly regulated processes and procedures with few if any deviations permitted. Nuclear plants, for instance, are prohibited to operate 'outside analysis'.

Integrated utilities, however, by and large no longer exist. Electricity generation, transmission and distribution have been privatised, with separate and different entities owning (if not managing) each under competitive market conditions. Other infrastructures formerly regulated to ensure high reliability in service provision—most prominently, in the US, transportation, telecommunications and financial services—have also been privatised and marketised. All this in turn has occurred under conditions where critical infrastructures have become more interconnected in terms of their respective inputs and outputs (natural gas is integral to producing electricity; water is integral to producing both; and so on).

As a result, when it comes to the critical infrastructures we studied over the last 20 years, input variance has become much more volatile and mutable, yet low and stable output variance—service reliability—is still demanded and mandated—if not by regulation, then often by organisational or government mission. The range and mix of management strategies and options in response—what we call process variance—has had to increase to transform what is now a longstanding high input variance into low output variance: the so-called law of requisite variety. Figure 3.1 seeks to capture this current situation.

Figure 3.1. Today's high reliability management of infrastructures in terms of input, process and output variance



Think of process variance specifically as the management strategies, options and resources real-time system operators have with which to maintain normal operations in the face of changing and changeable inputs. (The performance modes to achieve this are discussed in Section 3.3.) Those in the infrastructures managing the real-time process variance are reliability professionals.

Part and parcel of the professionals' process variance is their ability to manage system control variables. These are a relatively small set of variables for which immediate action can be taken by reliability professionals and whose changes in value are central to managing the safe and continuous provision of real-time service at the system level. If the electric grid is to remain reliable, real-time adjustments will have to be made in or around the grid's voltage and frequency; changes in water releases from reservoirs have to be adjusted to ensure real-time water reliability across that system; and the maximum allowable operating pressure will have to varied within proscribed bandwidths to maintain reliable natural gas flows through the transmission pipelines. The principal feature of system control variables is that they are actionable in real time by the reliability professionals in order to ensure system-wide reliability.

Shift now to contemporary pastoralist systems and parse their activities through the Figure 3.1 optic. Since input variability has always been high, albeit changing, over time, the input side of Figure 3.1 can serve as the starting point of analysis. Those more recent changes in land tenure, fragmentation, conversion and encroachment have further increased uncertainty and insecurity of pastoralists. The list grows longer if you had those factors of regulation or privatisation, which have increased the uncertainty of other inputs (e.g. access to credit) for these systems.

But to phrase the issue of high uncertainty this way is misleading. From the perspective of the reliability professionals framework, you have to ask what is happening to *process variance* in response to increased input variability. The empirical question is whether process variance—pastoralist management strategies, resources and options—has expanded and/or diversified to match the increased input variance to ensure reliable provision of the pastoralist critical service(s) in question.

It has long been documented that herding households diversify, where possible, their economic and employment strategies, including changing herd compositions, adopting new forms of mobility (including but not limited to mechanised transport), hiring outside labour and having household members in non-herding employment. We have also long known that herd owners (often urban and off-site) differ from the actual herd managers (often rural and on-site), just as we have long recognised that the owners of modern-day critical infrastructures are almost uniformly not the actual real-time managers of these systems.

Moreover, when it comes to process variance, it has also long been known that herd and herder seasonal mobility was not the only management strategy in response to input uncertainty regarding climate and such; think here of those management strategies of opportunistic grazing strategies involving micro-niches when wet season grazing has become more confined. The use of special or privatised fodder provision (and not just feedlots) is another example of a grazing alternative (Ian Scoones, personal communication; Saverio Krätli, personal communication).

There is even a rough analogue to the infrastructure system control variable (e.g. the frequency for the electricity grid and the pipeline pressure for the natural gas transmission system): the time-sensitive herding and grazing itinerary.[2] Further, while marketisation has indeed increased input variance, it is just as clear in the systems we study that the market also increases real-time options to be reliable for many people; think of the expansion of mobile phone utilisation by dryland herders for their real-time marketing purposes or the use of snowmobiles and four-wheelers by Lapland herders. (For much more on the importance and details of diversification, intensification, specialisation and improvisation in pastoralist systems and their various permutations, see the literature reviews in Nori 2019a; 2019b.)

Readers may well object by this point: ‘But these “options” have been forced upon pastoralists. This is not management; it is last-resort coping.’ In fact, many of the management strategies are evaluated negatively in contemporary pastoralist literature (consider the ubiquitous use of that ‘having to cope with’ phrasing), as if conditions prior to giving rise to current behaviour were, on net, better. Yesterday, there was good wet season grazing; today, these areas are no longer accessible. Yesterday, pastoralists were not as constrained as they are today; today, you need money to unlock all those market opportunities. Pastoralists were better off before; now, not so much.

Such evaluations are always liable to be made, but surely one criterion for assessing what is ‘better’ is whether management strategies—changing herd composition; use of alternative fodder; ‘off-farm’ employment and remittances; opportunistic grazing; and more—match the input variance that has come with that land encroachment, fragmentation, conversion, marketisation and so on. Even if managing to make the match is called coping, it is of a different kind than commonly supposed (Section 3.6.)

Now to shift to output side of Figure 3.1. Considerable rethinking of process variance respecting the outputs of pastoralist systems is also needed. It is well-documented that the basket of old-time outputs—the blood, meat and milk of the anthropologists of the 1950s—has also changed for pastoralist systems. We now talk about ‘conservation beef,’ a variety of ecosystem services (e.g. solar and wind energy) and value-added livestock products. We must also not forget irrigated crop-livestock systems and wildlife tourism/hunting services. Many would view some of these production changes as movements out of pastoralism.

[2] Saverio Krätli (2015: 43) writes: ‘Herding itineraries are chosen with care to keep for last those areas where prevailing plant species or climatic conditions mean that green fodder is available even after the setting in of the dry season. Light grazing might be followed by a second wave of grazing, once the plant has produced new buds. This can be done by the same group of herders, or by different groups following complementary strategies.’

Nevertheless, our framework's unit of analysis is *not the output but the variance* around whatever the output services now provided. So what if the composition of the output has changed? That is not the question. A better one is: has the variance around the changed composition of the output remained low and stable?

The critical infrastructures we study have changed and are changing their outputs. It is no news that present-day critical infrastructures provide reliable services unheard of before: electricity grids routinely provide broadband services and the telecommunications infrastructure regularly provides financial transactions (and more). Even older infrastructures, like the US rail system, can become the 'new pipeline' for shipping crude oil and related products. Furthermore, mobiles have in less time become so much more than yester-year's phone, and reliably so. The same can be said for pastoralist systems: their outputs have changed and this change is no more presumptively or dispositively 'negative' than those changes in other infrastructure outputs. Changing the output mix of a critical system repurposes that system; changes do not by definition kill it.[3]

Has the variance around whatever is the output increased or decreased for the pastoralist system in question? This is an empirical question, not an issue to be settled in the absence of case-by-case research, but the broader point holds. A pastoralist system is dying only where today's input variance is not transformed into low and stable output variance by means of requisite process variance for the systems in question. It is the logic of high input variance matched by high process variance to ensure low and stable output variance that characterises what reliability professionals are involved in. You may then ask: 'What is "pastoralist" when the herding family's pot would not exist without the support of urban or out-of-country members?' In answer, what has not changed—at least in terms of this working paper's framework—is the logic of the reliability management in terms of input, process and output variance.

Return then to the process elements of Figure 3.1. It is all well and good to centre discussion on the issue of 'herd productivity' *as long as you do not forget* that the productivity you are talking about does not reside with the output but rather in how well process variance matches input variance in meeting the overall reliability mandates on the output side. This focus on different types of variance also means that, yes, it is important to document the growing inequalities within pastoralist systems, but this begs a larger question: to what extent is insisting on more equal pastoralist systems—in terms of *inputs, processes and outputs*—a mandate for realising altogether different production systems?

3.2. Core system questions

Before answering the question of 'are there pastoralists who act as reliability professionals in their respective systems?', we must identify their core behaviour, practices and skills along with what we have been calling 'their system'. Recent pastoralist research has been doing just that, but for clarity's sake Table 3.1 sets out the issues in framework terms.

[3] One affiliated PASTRES research area (Gingembre 2019) has archaeological evidence indicating a long history of grazing and watered areas developed, abandoned and later reused; the addition of new activities along the way, like 'dairying' and evidence of trade networks and flint mining (read: 'non-farm employment'). There was also evidence over time of ('non-pastoralist') intermediate hunting-foraging-herding, subsistence ('rainfed') agriculture and what we would now call town/urban (read: 'off-farm') activities (Meister *et al*. 2019; Meister 2016).

Table 3.1. Three sequenced questions to identify reliability professionals

Q1. What is the system that is operated and managed on the ground?

This does not refer to the large sociotechnical system as planned or designed but to the way it actually operates in real time, with all the elements and factors that consistently impinge on it (e.g. the natural gas physical system as managed by its control operators and not in terms of its official procedures only; equally, the pastoralist system as managed in real time and not in terms of, for example, written tenure rules or stated government policy).

Q2. What is (are) the standard(s) of reliability and safety to which this system is to be managed (e.g., if it is managed to a precluded-event standard, what are the events that must never happen—for instance, the loss of strategic water points when needed in the overall water use system for herders)?

Q3. Once Q1 and Q2 have been answered, what are the risks, uncertainties and unstudied conditions to be managed (against) that follow from meeting these standards for that system as it operates in real time?

Reliability professionals manage the system in real time according to the standard(s) of reliability being managed to and in such ways as to manage the kinds of unpredictabilities that follow from standard and system definition in place (for more on these different types of unpredictability, see Section 3.5). That behaviour is the core of their professionalism, uncertified as it is by the techno-managerial elite in town and capitol.

We return briefly at the end of this section to what is meant by 'reliability standards' and the risks that follow from the operative system definition and standard(s). Note first why the sequence of the key questions is so critical.

Much of the critical infrastructure literature starts with a version of Q3—what are the risks to be managed (let alone other unpredictabilities)?—without answering the two prior questions. Ignoring questions about operational boundaries and standards and starting instead with the third serves to import economic and engineering assumptions about optimal reliability into the analysis that are not empirically correct. When spatial boundaries and reliability standards are not addressed first, it is too easy to reduce 'management' to an altogether unrealistic choice: do I, the decisionmaker, take on more or less risk in light of my optimality criteria?

Without answers first to Q1 and Q2, one might erroneously conclude that, because the pastoralist system no longer has the physical boundaries within which it operated and because it can no longer manage to the 'must never happen' event of losing the entire herd, the system is therefore vulnerable to all manner of risks it never had to address before.

In a world where Q1 and Q2 are answered *before* answering Q3, you could still find reliability professionals—groups or networks of herders and associates—operating to different reliability standards and reconfigured system boundaries. Changing boundaries and system definitions, like changing the composition of system outputs, does *not* mean boundaries and standards disappear altogether. The crisis from the perspective of the framework applied here would be the disappearance of reliability professionals who no longer can ensure reliability of the critical service(s), even when system boundaries change (but do not disappear), when reliability standards change (but here too do not disappear), or when the risks requirements change (but do not disappear just because physical boundaries and regulative standards shift).

To put the point differently, operational boundaries, reliability standards and the risks/ unpredictabilities to be managed by reliability professionals are always under pressure to change, if they are not actually changing—without, however, the reliability professionals evaporating away as a result. Their work gets harder, they do not vanish and their hardships may look very different from their perspective than what others outside consider to be 'the crisis.'

Return to lastly to Q2 standards and their importance for Q3 risks, uncertainties and unstudied conditions to be managed or managed against.

Three standards we found in our reading and research for ensuring service reliability are (1) mandates to preclude certain events from ever happening; (2) mandates to avoid events that should not happen; and (3) mandates to maintain services in the face of events that inevitably happen at some time or other. A precluded-event standard identifies disturbances that 'must never happen ever' for the system in question, where its reliability professionals prevent such (think here the loss of containment at a nuclear reactor). Reliability professionals operating to an avoided events standard recognise that certain disturbances should always be avoided (a leak on a natural gas line), even though this may not be possible. The inevitable events standard recognises that some disturbances, like earthquakes or lightning-induced fires, must be expected to happen, and the reliability professionals are to manage their systems reliably recognising and accommodating these contingencies.

Apply these distinctions to pastoralism. Just because the pastoralist system in question no longer operates to a precluded-event standard—'never must we lose the entire herd'—does not mean it has ceased to be managed reliably. The prospective loss of the herd may now be an event to be avoided, one that should be avoided but cannot always be. Changing the standard does not mean there is no regulative standard. In the past, a pastoralist society may have been herders only, and the precluded-event standard made sense; presently, herders may be only one, not even dominant, social or productive grouping in the arid and semi-arid lands, where the dreaded event may now be shared only by the remaining pastoralists but not by other resident groups.

Why do these distinctions matter? Because readers may assume, mistakenly, that the operative standard when it comes to most of pastoralism is that of inevitable events. Drought, we tell ourselves and others, is inevitable; so too is the herd loss induced by the drought. For us, droughts are inescapable.

But even if the pastoralists recognise drought as inevitable, does this mean they are by definition managing to the inevitable events standard? No. What you take to be 'loss of the herd' that you say comes inevitably with drought may instead be perceived and treated by the pastoralists as a temporary disruption under their avoided-event standard, which mandates that, regardless of drought, the basket of pastoralist outputs (including but now not limited to herd-related) should not empty to zero. An inevitable events standard focuses on the herd; an avoided-event standard focuses on the pastoralist bundle of critical service outputs, the variance of which is to be kept low and stable.

Such distinctions matter profoundly, because different standards entail different sets of risks and uncertainties that must be managed to meet said standard and because the cadre of pastoralists that best understands what these differences and requirements mean for real time are those acting as reliability professionals in their respective systems. All too often this complexity is closed down by policy types—and perhaps by some researchers—to pastoralists 'having to face trade-offs'.[4]

[4] The assumption entrenched in economics, engineering and policy analysis that 'everyone necessarily faces trade-offs'—just like the assumption that we can start the analysis of pastoralist systems by focusing on the risks they face—is very misleading in the absence of the hard, empirical work needed to determine *first* the standards of reliability management on the ground. A precluded events standard mandates a point beyond which system reliability or safety cannot be traded off against some other attribute, like cost. As our 1998 article tried to make

3.3 Core typology: risks follow from the reliability standard and system definition

Reliability professionals manage all manner of real-time unpredictabilities (a topic to which we turn in Section 3.5 with an adaptation of the Stirling incertitudes typology). That said, a central point of the reliability professional framework focuses on risks—the chief system-wide risks to be managed follow from, but do not precede, system definition and system reliability standards. This is an incredibly important point, and we have space for only one illustration of how this works and why it matters (Table 3.2).

Table 3.2. Four performance modes and associated system-wide management risks in normal operations under a precluded events standard for reliability

		System Volatility	
		High	*Low*
Options Variety	*High*	Just-in-time performance Risk of misjudgement with too many variables at play	Just-in-case performance Risk of inattention & complacency
	Low	Just-for-now performance Risk of losing options, with lack of manoeuvrability and cascading error	Just-this-way performance Risk of failure in complying with command & control requirements

Assume the precluded event is 'must never lose the entire herd' (the standard can be relaxed to one of an avoided 'should never lose'). If our critical infrastructure research is the guide, pastoralists as reliability professionals require the ability to manoeuvre across four performance modes to maintain normal operations. Normal does not mean static or invariant; if it did, the system could never be highly reliable in the face of change. In this way, 'normal' is not restricted to what happens when there are no shocks to the system. Surprises and setbacks happen all the time, and normal operations are all about responding to them and adjusting to ensure the shocks do not lead to system disruption or outright failure. The four modes in Table 3.2 range from anticipatory exploration of options (just-in-case) when operations are routine and many management strategies and options are available, to a real-time (just-in-time) improvisation of options and strategies when task conditions are more unstable. Reliability professionals may have to operate temporarily in a high-risk mode, just for now, when system instability is high and options are few. They may also be able, in emergencies when options have dwindled, to impose a single emergency scenario (just this way) onto their members to stabilise the situation. These alternative but related performance modes are part of an overall requisite variety—the process variance—needed to match the full range of input variance that operators can encounter and constantly do impinge on their systems, all for the purposes of reliable output/service management.

But—and this is essential to understand—each performance mode has its own major system-wide risk from the reliability professionals perspective.

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clear—and what still holds—is that money is not everywhere interchangeable with high reliability; they cannot substitute for it. High reliability is at some critical point non-fungible and, as such, not to be traded off.

The big risk in just-in-case performance is that professionals are not paying attention and being complacent—reliability professionals have let their guard down and ceased to be as vigilant—when it comes to sudden or emerging changes in system volatility or network options variety; think of system volatility as the degree to which the pastoralist task environment is unpredictable or uncontrollable. When it comes to just-in-time performance, the risk is misjudgement by the professionals with so many balls in the air at one time. The great risk in just-this-way performance is that not everyone who must comply will comply with the emergency measures to reduce system volatility.

Last, just-for-now performance ('just do that right now!') is the most unstable performance mode of the four and the one managers want most to avoid or exit from as soon as they can. Here the risk is tunnelling into a course of action without default options. What you do now could well increase the risks in the next step or steps ahead—effectively, options and volatility are no longer independent dimensions. To use one of the last options available runs the risk of increasing volatility (in other words, unpredictability or uncontrollability) elsewhere in the infrastructure system.

The take-home point regarding risks following from standards is this: (1) the risks that matter are in real time: if you don't have a track record of managing in real time, why would we believe your promises to do better at some indefinite point later on? and (2) those risks regard the system-as-a-system, not as a set or ensemble of assets (whether these are individual herds, single herders, specific grazing areas or browsing/grazing here versus there).

We found that if the chief management risks of complacency, misjudgement, loss of alternatives and noncompliance are not actively addressed by the reliability professionals, it is next to impossible to expect reliability in terms of safe and continuous provision of the critical service(s) in question at the system level.

While uncontrollable or unpredictable weather, for instance, poses risks that vary at the asset level (i.e. the weather *here* affects *that* cattle herd and *this* grazing area), the risks focused on by the framework are decidedly management risks and decidedly, to repeat, at the system-wide level—not at the asset level.[5] Further, we can talk about 'the system' coherently if—and it is a big 'if'—the system has been bounded and the reliability standard to which it is being managed has been identified beforehand, such that the identification of the chief risks that follow can be done for real-time management purposes by the pastoralists concerned.

Just who would these pastoralists as reliability professionals be? Table 3.2 suggests that if you want to identify reliability professionals in pastoralist systems, you are looking for networks of pastoralists characterised by their real-time manoeuvrability across different performance modes and their different chief risks to be managed, when it comes to precluding or preventing what are broadly considered 'must never happen' events in the pastoralist system. More broadly, these pastoralists would be the ones who know system boundaries and standards to be managed to in real time; the chief system-wide management risks that then have to be addressed; the multiple performance modes that have to manoeuvre across to ensure even 'normal operations'; and the options and strategies it takes

[5] To start any analysis with assets is as if in talking about water, you are asked to immediately think 'H_2O' (or, when it comes to a pastoralist system, of 'herds'). Then you are expected to separate out oxygen and hydrogen from each other (separate the herds into goats, sheep, cattle or the like) and thereafter undertake how to measure each (e.g. browsers versus grazers), while all along assuming that this reductionism enables you to talk about water as having the property of 'wetness' (or talking about herd types and their measurable requirements as if they framed the property called 'pastoralist'). One implication is that it may be a grave error to reduce pastoralist systems to 'livestock production sectors' or 'dairy sectors' or 'smallstock sectors', when in fact infrastructures (roads, energy and now pastoralism) are the foundations without such economic sectors would not be possible.

to match high or changing input variance with a high or changing process variance that still can ensure low and steady output variance.

It takes exceptional and, the framework argues, special skills to undertake these tasks and ride out the turbulence, and the skills of reliability professionals set them apart from others and indeed provide them with unique knowledge about what it takes to manage reliability. To put it from the other direction, reliability professionals have special institutional knowledge about the system they manage because of the distinct skills they have and on which they rely.

3.4. Core typology: unique reliability domain and special skills of reliability professionals

What are the special skills and domain of action of reliability professionals? What follows is the longest section of the paper because we have to move step by step from more abstract theory and only then to important implications for the reliability professionals in pastoralist systems.

3.4.1 Theory

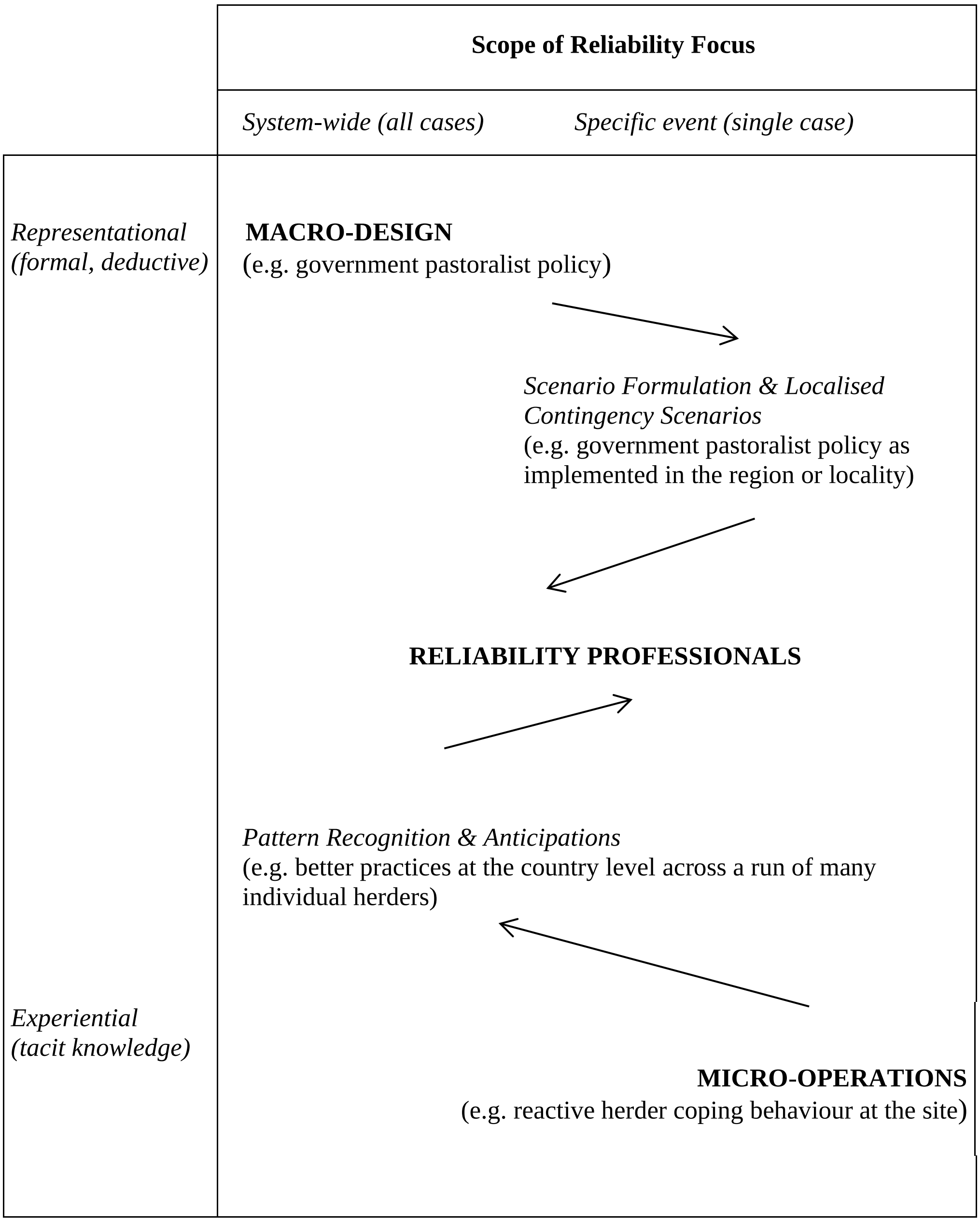
The wider organisational literature from which this paper's framework is drawn tells us that the drive to highly reliable management in complex sociotechnical systems can be, for heuristic purposes, sketched along two dimensions: (1) the type of knowledge used in activities to make system services reliable, and (2) the scope or focus of attention for those reliability activities.

Reliability management is grounded in knowledge that ranges from experience, based on informal tacit understanding of the activities, to formal or representational knowledge, where abstract principles and deductive models (e.g. official laws and government policy) are also part of the understanding. The overall knowledge base blends induction and deduction through the assembly of different arguments and scenarios related to reliability, again defined as the continuous and safe provision of a critical service though time.

The scope of those managing for reliability ranges from a position that assumes reliability is an entire system output, encompassing many variables and elements, to a position that treats each case of reliability as a particular event with its own distinct properties or features. Typically, scope refers to the different scales, ranging from general to specific, that professionals must take into account when reliability matters. Knowledge and scope define a cognitive space for managers, where reliability is to be pursued.

In this cognitive space, there are four nodal activities (Figure 3.2), each position being a different mix of perspectives along the two continua. The nodes—principal positions or hubs from which to manage reliably—are macro-design, micro-operations, pattern recognition along with anticipation and local contingency scenario formulation. To telegraph ahead, reliability professionals operate in the domain bound by the latter two hubs.

Figure 3.2. The cognitive space for reliability professionals (adapted for pastoralism; originally in Roe and Schulman 2008)



At the extreme of scope and formal principles is the macro-design approach to reliable critical services ('macro-design hub'). Design—whether in the form of policy, law, mission statement or blueprint—asserts that formal principles applied at the system-wide level govern a wide variety of critical processes for service provision. In this corner of the world, design is meant to cover the operation of an entire system, including every last case relevant to providing system services. At the other extreme in this cognitive space is reactive behaviour in the face of real-time challenges at the micro-level ('micro-operations hub'). Here, reliability depends on the immediate response of individual system operators working at the event level rather than from pre-existing designs at the system level.

Designers, however, cannot anticipate every eventuality. Also, the more 'complete' a logic of design principles aspires to be, the more likely its full set contains two or more principles contradicting each other. On the other side, individual operator reactions are likely to give the operator too specific or too partial a picture, losing sight of the veldt for the burning grass in front of them. Micro-operations, in other words, can instil a kind of trained incapacity that undermines reliability because operators are not aware of the wider context(s) of their activities (here is where you find the reactively coping herder). In short, if there are such things as 'the right policy' and 'the right person in the field', they are only the starting points for understanding system reliability.

What to do, then, when high reliability in critical service provision is at stake? Moving across the cognitive space from one corner to its opposite is unlikely to be successful. Research finds that attempts to impose system-wide formal designs directly onto an individual event or case—to anticipate, fully deduce and determine behaviour in each instance from macro-principles alone— are inadequate. On the other hand, an individual's reactive operations scarcely constitute a tested template for scaling up and out to the system as a whole.

Instead of corner-to-corner movements, Figure 3.2 indicates that reliability is enhanced when multiple shifts in scope are accompanied by multiple shifts in the knowledge base. Becoming more reliable means becoming more knowledgeable in different ways about different things at different scales. Professionals approach and reach reliability through different skills than those for macro-design and micro-operations when it comes to managing reliability. Their approach is not direct, but indirect. Managers tack to reliability in much the same way that a sailboat would not get from A to B on a windy day via that proverbial straight line.

We know from research that designers enhance reliability when they apply their designs less globally and relax their commitment to identifying principles meant to fully determine system operations. Both happen when designers contextualise design principles by embracing a wider range of contingencies in their analyses. They formulate more localised scenarios for system behaviour and performance ('scenario formulation and localised contingency scenarios hub' in Figure 3.2). Food policy, an obvious example, works better when differentiating management protocols by crop, region, farming practices and such.

We also know that reliability is enhanced when operations shift away from real-time reactions and shift to recognising patterns and anticipating their consequences across a run of cases of behaviour and experience ('pattern recognition and anticipations hub'). Here 'recognition' means looking for and into patterns, and 'anticipation' means not only having expectations based on the patterns perceived, but also being prepared for their implications. Some patterns, in particular, may be visible only at a different scale.

By recognising and anticipating patterns across cases, operators and managers learn to adapt, with better practices emerging across that run of cases. These anticipations and evolving better practices and strategies, based on empirical generalisations, trends or other (quantitative or qualitative) patterns, are likely to be less formal than protocols developed through contingency analysis and scenario formulation. Note the term is better practices, not 'best practice.' A number of touted 'best practices' confuse a scenario that works well in one case for the better practices, if any, that emerge across a run of cases and that even then must be customised, site-by-site, for effective results.

The key conclusion to be drawn when better practices emerge out of a run of different cases is that they import into management the scale(s) of governance at which they work across that run of cases. We can hope that better practices emerge across scales and levels of management, but in reality a practice that turns out to be better across the same levels of government or scales of collective action cannot be presumed to work at different levels or scales.

It is in Figure 3.2's middle ground, bridging the formulation of design-based contingency scenarios to be realised more locally and the recognition of patterns and associated anticipations system-wide that we find the reliability-managing professional networked with like professionals. No one single professional works on his or her own but rather in groups, teams or networks. In the middle is where patterns and the anticipations based on them are probed, and where design-mediated scenarios are modified in light of the patterns at hand, and where both are translated into reliable real-time services. It is in the middle where the skills in pattern recognition and locally specific scenario formulation reinforce each other: repeated pattern recognition helps build skills in being sensitive to context-rich differences, and vice versa.

<u>3.4.2 Pastoralism implications</u>

It is in this middle where pastoralists are to be found as reliability professionals with their special skills and unique knowledge base (no one else has the system knowledge they have). You need reliability professionals, whose job it is to add knowledge at different scales and in key ways. To reduce this knowledge to 'traditional ecological knowledge', 'indigenous knowledge' or 'local knowledge' does not, in my view, describe the full set of practices by reliability professionals nor their special role in the pastoralist system. 'Traditional', 'indigenous' and even 'local' do not capture that unique ability of this cadre of professionals in their system niche to operationally redesign limited macro-policy and limited micro-operations so as to produce real-time reliability at the system level when it matters most—in other words, right now.

If these pastoralists as reliability professionals exist—and nowhere in this paper do I prove so via an exhaustive review of the literature and evidence—then their existence requires major rethinking of pastoralist findings in the literature with which I am familiar.

Much of this pastoralist literature has found that government policies and initiatives fail at the local level. Of course, they would fail if you believe each herder's micro-behaviour can be macro-designed. Much of this literature has found a disappointing gap between good national policy and its enactment at the regional or sub-regional levels; but, of course, you are disappointed to the extent you have failed to understand that national policies have to be adapted to regional circumstance and context, if reliability is a key policy objective.

Much of this literature finds that, when existing better practices on the ground are scaled up to become the basis for national policy, what works in specific cases does not work at the national level for all important cases. Of course, there is a gap between the pattern recognition and macro-design hubs in Figure 3.2, because different knowledge bases are deployed at each hub.

Far too many people are disillusioned by pastoralists who, when promoted to top leadership positions, fall short of expectations. But what do you expect when those promoted are no longer active reliability professionals in active networks of like professionals (if they were ever such professionals in the first place)? As with so much else in complex organisations, where you stand is where you sit.

3.5. Core typology: reliability professionals manage unpredictabilities

Turn to another major way to describe and identify who are reliability professionals, if they are to be found at all in today's pastoralism. Table 3.3 parses Andy Stirling's typology of different kinds of incertitudes through the perspective of our research findings.

Table 3.3. Four types of real-time unpredictabilities for reliability professionals

		Knowledge About Outcomes (Cf)	
		Specified or well-defined	*Unspecified or poorly defined*
Knowledge about Likelihoods (Pf)	*More empirical basis*	RISK	UNCERTAINTY$_{Cf}$
	Less or no empirical basis	UNCERTAINTY$_{Pf}$	UNKNOWN-UNKNOWNS (Ignorance; Unstudied Conditions)

Uncertainty here is consonant with how infrastructure operators see the two types of uncertainty (and as such is more expansive than 'uncertainty' in the Stirling framework). Note also that the operator terms, 'unknown-unknowns' and 'unstudied conditions', do not capture the subjective and intersubjective features that 'ignorance' conveys (personal communication, Andy Stirling).

Professionals in the studied control centres of large infrastructures providing what society considers a critical service, such as water or energy safely and continuously in real time and over time, practice vigilance to stay out of the red area below the diagonal line and stay within the area above it—a stylised version of what the professionals we interviewed call their 'comfort zone'. In a world where risks to be managed follow from the standard and system definition being managed to, unknown-unknowns are full of possible precursors to failure, if not actual failure waiting to happen.

How do infrastructure control rooms we studied stay out of 'unstudied conditions'? The answer is that their control room professionals and support staff *manage risk along with some uncertainties to stay out of unstudied conditions.* Even though this is their comfort zone, one control room supervisor hastened to add, 'I'm always uncomfortable.' They are uncomfortable because these operational professionals cannot manage for reliability solely as managers of known or estimated risks.

The upshot is this: to maintain their comfort zone, reliability professionals—think now of pastoralists—tolerate some uncertainty about outcomes (the consequences of system failure) matched by having high confidence in some likelihoods with regard to that failure (the probability of failure). They also tolerate some uncertainty about probabilities by having higher confidence that consequences are limited. Management within these uncertainties is, in either case, supported by shared situational awareness across the networked professionals. In brief, *the professionals we study manage ignorance—that is, unstudied conditions—by proxy*.

They know they cannot manage the critical service in question reliably when they are ignorant with respect to what matters to real-time performance. To manage you must manage some uncertainty, along with known risk. The professionals we have observed are adept at managing non-measured uncertainty, but not all of it. I cannot sufficiently underscore the significance of reliability professionals already managing uncertainties. They do not have to be formally taught; in fact, the challenge is the reverse: formal risk methodologies have not yet learned from these forms of professional risk and uncertainty appraisal.

Examples of uncertainty management in pastoralist systems also mean rethinking what has been described negatively by others. For I am suggesting that pastoralist households with the strategy of sending members off-site (particularly for forwarding remittances or other support back to resident pastoralists) is uncertainty management. Resident pastoralists may know some of the uncertainties (with respect to consequences or likelihoods) of sending their household members to the cities or elsewhere better than they know what will happen if the entire herd and associated other critical services are lost indefinitely. Yes, some members have no choice but to leave their resident pastoralist households, so dire are conditions there; in that case it is all push and no pull. But that does not go far enough to cover households with the uncertainty management strategies of push and pull just described.

Note something so obvious it might be missed in Table 3.3: what exogenous interventions would push reliability professionals outside their comfort zone? Answer: increase the uncertainties of their tasks and objectives with respect to probabilities and consequences of system failure and/or require the professionals to operate in conditions unstudied by themselves or their networks. That, though, is what many so-called innovations—technical as well as government, regulatory and legal—have done.

More formally, these so-called innovations (1) fail the reliability test for increasing options, reducing volatility and enhancing cross-performance mode manoeuvrability (Table 3.2); (2) require implementation and management outside the skills of pattern recognition and scenario formulation that the reliability professionals already have (Figure 3.2); or (3) even if passing the test and within the competencies of professionals, the innovation pushes them into prolonged just-for-now performance (Table 3.2). It is a simple matter to document cases where premature innovations (including regulatory interventions) have done just that to pastoralists. In contrast, some innovations do enhance pastoralist reliability and safety by increasing real-time herder options and/or reducing their real-time system volatility (think again of the mobile phone and other ICTs in terms of the two dimensions of Table 3.2).[6]

3.6. Core typology: control, manage or cope with risk, uncertainties and unknown-unknowns

The last typologies aim to bring together key features from our first typology (Figure 3.1 on the logic of input, process and output variance) and the preceding Table 3.3's adaptation of the Stirling framework in order to identify a wider operational context than that of management.

Reliability professionals, and the infrastructures in which they operate, do not only manage; from time to time, they seek to control and on occasions they must cope. This distinction between controlling, managing and coping with the types of Table 3.3's unpredictabilities is also central to better understanding pastoralists as reliability professionals and pastoralism as infrastructure. These distinctions are pertinent, as much continues to be made about pastoralists having to cope in the face of what they cannot control. The definitions and understandings distinctive to reliability professionals are summarised in Table 3.4.

[6] One of the few ways to increase their real-time options variety in terms of Table 3.2 for those in just-for-now performance—the least stable performance mode in normal operations—is to adopt and modify better practices, if present, undertaken by other like herders in like situations at like times. The question is: where are there inter-pastoralist or herding associations to share and update better practices?

Table 3.4. Definitions of key terms used by infrastructure reliability professionals

Type of unpredictability	Definition	Type of operational approach	Outcome
Risk	Probability and consequence of failure are known and estimated	*Control*	Low and stable output variance through keeping low input variance and low process variance
Uncertainty	Either probability or consequences of failure is not known or estimated	*Manage*	High input variance matched by high process variance to ensure low and stable output variance
Unknown-Unknowns	Neither probability or consequence of failure is known for estimating	*Cope*	High and unstable output variance and/or inadequate process variance to match input variance

There are of course many other ways to define risk, uncertainty and unknown-unknowns (Scoones 2019), just as there are other ways to define control, managing and coping. In fact, ordinary language takes ‘control’, ‘managing’ and ‘coping’ to overlap on occasion. Reliability professionals do not agree, because the differences between such terms are real and highly consequential for real-time operations. To the extent that some pastoralists act as reliability professionals, do they distinguish between operational approaches for the types of unpredictabilities described in the preceding section?

To see how the answer might be ‘yes,’ consider Table 3.5 that crosses the different unpredictabilities against the different operational approaches.

Table 3.5. Primary operational approaches with respect to primary types of unpredictabilities faced by reliability professionals

		Objective of Operational Approach		
		Risks	*Uncertainties*	*Unknown-Unknowns*
Primary Operational Approach	*Control*			
	Manage			
	Cope			

Start with control of risks and return to our infrastructure findings. Senior staff in some infrastructures make a point of the necessity for risk controls. Here again think of the nuclear reactor power plant. It is an empirical question whether pastoralist systems today exhibit functionally equivalent controls, or, if so, to what extent. Certainly, a control paradigm dominated understandings of pastoralism in the past (Nori 2019a). Some of today’s resettlement schemes, fenced ranches and practices to restrict common property access might arguably qualify, just as pastoralists using weapons could be claimed as to be asserting control as defined.

Reliability professionals I have interviewed know that no existing control measure, however, can be expected to be 100 per cent effective. To reflect this, the cell 'Control Risks' is lightly shaded in Table 3.5 and must be complemented by 'Manage Risks', the darker shaded cell, for risks that cannot be controlled in real-time or must not be assumed to be controllable right now when it matters. For example, it is because tomorrow's heat wave is *uncontrollable* that electric and natural gas grids have to manage the added load requirements and associated risks on assets and personnel. This framework argues that pastoralists as reliability professionals have their own 'heat waves' to which they respond in functionally equivalent ways.

It is not only risks that have to be managed because it is dangerous to assume they can be thoroughly controlled. Key non-measurable uncertainties must also be managed, and as we argued above there are pastoralists who excel at this. The cell 'Manage Uncertainties' has been shaded darker in Table 3.5 to reflect this primary approach. To reiterate, system failure—that is, the complete failure of system-wide provision of the service, whether the system be a large electricity grid or the pastoralist system-as-a-system—is an ever-present reality that has to be managed against.

Should it need saying for a world where some events are uncontrollable or unmanageable (i.e. process options and strategies cannot be increased to reflect increased input variance), there are instances where neither the probability of system failure nor its consequences can be known or studied under the demands of real-time urgency. Here is where the coping behaviour of infrastructure operators in the face of the unknown-unknown is notable—*but coping with a difference*.

When real-time infrastructure operations suffer a shock that pushes those operations into unstudied conditions, the professionals are not only expected to be resilient by absorbing the shock; they are at the same time expected to be planning the next step or operation ahead. They do not want to bounce back to the same position that left them vulnerable; they want to bounce forward to better real-time operating conditions. This coping is *coping-ahead* in the face of real-time unknown-unknowns (shaded darker in Table 3.5), since it involves planning above and beyond the reactions of real time. Do some pastoralists exhibit this type of coping-ahead behaviour from time to time? The framework says they do. Some might want to call this 'resilience'.

To summarise this last set of typologies, the principal point is that pastoralists as reliability professionals manage their operations *because* they do not have entire control of the system at any one time, where however any coping passively to system-wide shocks outside of direct control is not an option either. Instead, they must actively manage risks they cannot control as well as actively manage key uncertainties so as to stay out of unstudied conditions. More, if and when they find themselves in unstudied conditions, they cope by planning the next step ahead.

When so, it is wise to remind ourselves that these different operational approaches combined with different types of unpredictabilities argue against any blanket description of pastoralist systems 'under high uncertainty', full stop. I too have committed this mistake of undifferentiation. It is better to assume from the get-go that reliability-seeking pastoralists are more or less certain about matters, case by case, where the framework provides ways to differentiate that 'more or less certain'.

6 Conclusion

It is fairly easy to raid the paper's framework and assemble a negative narrative about pastoralism today. Just assert the following: herders as reliability professionals are disappearing all over the place; more pastoralists than ever before are having to cope reactively; more and more of these coping situations are altogether unfamiliar or unknown to herders left behind; and so on. Some such changes, modified of course, are emerging in the critical infrastructures I study, and I see no reason why pastoralist reliability professionals would not be experiencing parallel impingements.

But drawing this decline-and-fall (decline-and-stall?) narrative is very misleading, because it ignores the overall thrust of the paper's framework. That thrust is, by and large, positive and not negative.

Pastoralists are—by force of circumstance under wider processes of commodification, globalisation, climate change and the rest—being pushed and pulled to actively manage input variabilities to achieve sustained livelihoods in new ways. Further, a good number of these responses seem to build on special skills and practices, along with unique track records of earlier pastoralists in matching high process variability to always-high input variability. This is management where control is not possible; this is coping-ahead when coping reactively is no option. This is what modern societies, rooted in illusions of command-and-control, can and must learn to do better.

I leave you, then, with a counternarrative to pastoralism today and earlier: pastoralist systems are, in respects that matter, infrastructural; and since pastoralists and their systems are found worldwide, so too is pastoralism a global infrastructure, and importantly so.[7] Pastoralist systems tender the world a key critical service (and have been doing so for a very long time): they, like other globalised/globalising infrastructures, seek to increase process variance in the face of high input variance to achieve low and stable output variance. More, they do so by managing non-measurable uncertainties well beyond the capabilities of formal risk methodologies and in the face of increasing and diversified input variabilities while still facing demands for sustained livelihoods. In this counternarrative, that key service is best understood as foundational to the world economy in times of great uncertainty and complexity.

Have I proven any of my assertions? No. Am I saying a thorough review of the literature would nevertheless support this counternarrative? No. Am I implying that really existing pastoralist systems have their own cognate notions of 'infrastructure', 'unpredictability', 'variance', 'volatility' and other key framework terms? No. But I am provoking you to think of pastoralism as a global infrastructure with profoundly different policy and management implications, even though pastoralists do not conceive it this way nor for that matter would we expect them to.

I have been writing primarily as a researcher to this point, and I would be the first to agree that case-specific research and analysis is needed to gauge the robustness of the framework and counternarrative for the purposes of policymaking and management. That said, allow me to end, not as a researcher, but with how I see all this as a practising policy analyst.

I believe those who take the forces of modernity to be crushing pastoralism as we know it are the wrong 'we' drawing the wrong conclusion. The framework presented here reinforces what some researchers of pastoralism have long known anyway (more recently, Catley *et al*. 2013; Krätli 2015; 2019): pastoralism keeps going on by other means, regardless of how many times pastoralism has been memorialised 'as a lost—worse yet, a losing—way of life'.

Policy types (and I include government officials I remember working with in Botswana, Kenya and Zimbabwe) do not get to conclude that 'herders are the left-behind people of the countryside' as if putting a corpse to rest. These bodies of people are very much alive and demonstrating infrastructural

[7] As a policy analyst, I am at a loss when I read statements to this effect—e.g. rangelands represent 30 per cent to 40 per cent of the planet's land surface and contribute to the livelihoods of somewhere between 1–2 billion people—but then rush on to conclude that the ecological, economic and political marginality of rangelands expose them to encroachment, degradation and immiseration. Even if such statements are true as far as they go, they do not go far enough to capture the sense in which pastoralism is a key infrastructure globally—and will remain key if those numbers are anywhere accurate.

skills, processes and practices that are anything but ‘marginal’ to the modernities that have written them off. To ignore this contribution is lethal to good policy and management worldwide, whatever international elites, let alone those in-country, may think otherwise.

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A New Policy Narrative for Pastoralism? Pastoralists as Reliability Professionals and Pastoralist Systems as Infrastructure

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This paper proposes that pastoralist systems are better treated, in aggregate, as a global critical infrastructure. The policy and management implications that follow are significant and differ importantly from current pastoralist policies and recommendations.

A multi-typology framework is presented, identifying the conditions under which pastoralists can be considered real-time reliability professionals in systems with mandates preventing or otherwise avoiding key events from happening. The framework leads to a different policy-relevant counternarrative to pastoralism as understood today. Some features of the counternarrative are already known or have been researched. The paper's aim is to provoke further work (including case research and interactions with decisionmakers) on how robust the counternarrative is as a policy narrative for recasting today's pastoralist policy and management interventions.