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A Governance Framework for Implementation of Scientific and Engineering Innovation in Buried Infrastructure Systems

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This article draws on experience within a pervasive sensing research project, the Pipebots project. The aim of the project is to design miniature robots to gather physical condition and environmental data on buried pipe networks, using potable water distribution and wastewater pipe systems as the initial target applications. One of the challenges of the project is to anticipate and address the potential governance issues triggered by the project. Due to the lack of a suitable tool with sufficient breadth to guide thinking, the existing literature has been drawn upon to form the basis of a governance framework for use in infrastructure projects. Whilst the original intention was to be alert to and interrogate the forms of governance that may impact on new infrastructure interventions, what is emerging is a tool that would support the strategy for implementation, improve the design (a no-regrets design policy) and help build the business case for the transformational change the project envisages.

Keywords: infrastructure, justice, business case, governance, water and waste water, transformation, pervasive sensing, framework

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INTRODUCTION

The Pipebots project is a cross-university, multi-disciplinary research programme consisting of around 48 researchers seeking to create new science on pervasive sensing in buried pipe networks. The Pipebots vision is to create a swarm of autonomous, miniaturised robots to gather and transmit data, initially focussing on water and wastewater infrastructure systems (Pipebots, 2020). The robots will move autonomously within the pipework, mapping and gathering data on the integrity of the system, and communicating with one another and with outside systems. The aim of the project is to advance the science deployed to improve incipient leakage, blockage and early failure detection in underground pipes. This should enable a more responsive and effective asset management regime and reduce the disruption of repair work by avoiding the need for trench excavations in roads and pedestrian areas. The Pipebots will amass a wealth of environmental data on the use and health of the network and support the drive towards a digital twin of our infrastructure systems.

The programme seeks to make a transformational change in how buried pipe networks are managed, i.e., designed, operated, maintained, refurbished and upgraded as the need arises. The scientific and engineering feat needed to deliver the robots will be considerable and the project draws on the talents of an array of technical experts in their field. With challenges of navigation, sensing, communication, miniaturisation and movement in varied and hostile environments there a temptation to focus acutely on the exciting, technical engineering challenges. However, the water and wastewater service sector operates within a complex and extensive governance system (Osbeck et al., 2013; Walker, 2014). As seen in water re-use schemes, it is not necessarily the lack of technology that holds back change, but whether there is a supportive governance system around it (Frijns et al., 2016; Goodwin et al., 2019). The project is therefore challenged with not only advancing science and engineering but ensuring that those advances are supported and acceptable within the governance system it will have to operate within.

A team within the Pipebots project (Theme 7)[1] has been tasked with addressing governance concerns, in tandem with technical and non-academic teams to understand one another's issues and priorities for a practical, workable outcome. In doing so it challenges those involved to communicate outside disciplinary silos and consider matters beyond their immediate area of expertise. A key tenet is the promotion of interdisciplinary and transdisciplinary[2] working. As systems come under increasing stress, the need for inter- and trans-disciplinarity to address complex issues of resilience and sustainability has been recognised in conjunction with systems-thinking (Lang et al., 2012; Markolf et al., 2018) and an associated call to expand thinking beyond disciplinary silos has emerged (Markolf et al., 2018; Rogers, 2018; Ahlborg et al., 2019; Jensen, 2020; Leach and Rogers, 2020). The aim is for the Governance Framework to be a tool that encourages more expansive thinking and transdisciplinary engagement, and ultimately to achieve adoption of more resilient solutions.

No existing tool for systematically drawing in, communicating and integrating governance impacts for use in the project was identified in the literature review. In the absence of a tool or framework to guide such projects, a Governance Framework is being created. The new framework is not a set of prescriptive rules but asks questions for project teams to consider and reflect upon, to be alert to the topics where opportunities or issues may arise, flag areas where additional expertise may be needed, be open about trade-offs and prompt further enquiry. The intention is to help the project team members navigate governance issues, which may not be within their technical area of expertise and yet which may still impact on the design and acceptability of their work—and vice versa for Theme 7 to understand how the governance regime could adapt to the new science.

Another way of looking at the challenge is that it seeks to move the sector from one business model to another, and the framework has a place in supporting that move. For Pipebots, the business case for change mediates the move from the current business model (with current detection models to find the points of failure and trench excavations to facilitate repair) to a new model [with pervasive sensing that identifies defects prior to failure, which enables maintenance free from trench excavations (see Rogers, 2018)]. In other words, in addressing how the formal and informal rules of a given governance system may resist (or support) new technology it becomes a necessary part of that process (see Read et al., 2016; Loorbach et al., 2017).

Whilst a directly applicable (pre-existing) tool was not identified, there was a wealth of literature around governance that was used to support the new Governance Framework's design. It was established that governance has been tackled from a number of different viewpoints and disciplines, often behind the framing of the problem in focus and the primacy ascribed to technology, society or environment in a given context. The opportunity was taken to consider the literature from multiple disciplinary perspectives, in keeping with the project's transdisciplinary principles.

The sections below present the literature review. This is followed by a discussion on any existing frameworks that address similar issues. The framework is then introduced followed by a discussion on its intended use. Further research areas and limitations of the framework are then addressed.

LITERATURE REVIEW

In this section what is meant by governance for the purposes of the project is addressed followed by a review of the bodies of literature relevant to governance and the Pipebots project. Due to the different issues facing infrastructure projects in the developing and developed worlds, the focus here is on infrastructure systems in developed economies.

Governance

The governance literature has been reviewed for themes that can be drawn upon to guide the Governance Framework, starting with understanding the term "governance" itself.

A common criticism of academic literature around governance is a failure to define what is meant by "governance" in the context under discussion (Özerol et al., 2018; Lyall and Tait, 2019). It is a term used differently across disciplines, levels and contexts; for example, the financial controls and structures of a business within "corporate governance" or the State actors, democratic processes and accountability in "good" governance (see Rhodes, 2017a). The lack of coherent use of the term makes drawing from the literature and applying themes to other contexts problematic. For any discussion on governance to be translatable to another context, it is necessary to understand how that term is being defined (Rhodes, 2017b) both generally and within the confinement of this study. This is an issue of being clear on the terms being used and the framework being adopted—not least because is intended to be used as a communication tool across disciplines that may not have considered the governance implications of their work before. Being clear on what governance is, and what it is not, becomes a necessary part of that process.

Government to Governance

When using the term governance, for many, it represents the move from "Government to governance", a reference to the

[1] A description of the various Pipebots "Themes" can be found at https://pipebots.ac.uk/themes/ (accessed 19th May 2021).

[2] The distinction used by Jensen (2020) is adopted; interdisciplinarity is used to denote the integration of work between academic disciplines; transdisciplinary here denotes effective collaboration across disciplines (and hence across disciplinary boundaries) between academic and non-academic stakeholders.

changes in Government structures from traditional top-down, command-and-control to the networks of State and non-State actors involved in running public services (Watson et al., 2009; Osbeck et al., 2013; Walker, 2014; Schulz et al., 2017). The network of actors may be affected by diverse forms of governance from framework statutes with delegation powers to webs of statutory instruments, standards or voluntary codes, as well as complex social relationships, informal practises, behaviours and values (e.g., see Frijns et al., 2016). Additionally actors, as well as the forms of governance used, may change with the type of governance regime chosen.

Water governance in England was considered controversial in its privatisation, and arguably embodies the essence of what is meant by "Government to governance" (Walker, 2014). The network of bodies involved in the governance system for this sector is considerable, including Government bodies, quasi-Government bodies, regulators, independent advisers, implementers, citizen groups and users, utility providers, NGOs and lobbyists (Osbeck et al., 2013). The current governance regime and the nature of the State's involvement in the sector changed significantly post 1989. It is now a privatised, market-based system, albeit tempered with heavy regulation from the State to address the negative externalities of an unchecked market allowing for international and national policy to remain an influence.

The goals set by Government originally focussed on meeting demand and financial regulation. This has developed and expanded over time with duties extended around consumer objectives, competition, sustainable development and most recently to expressly include resilience (Centre for Competition Policy, 2021). It is anticipated those goals will be extended further in the next price review, with stricter environmental targets (Ofwat, 2020) reflecting the current climate and biodiversity crises and associated policies and international agreements—all whilst keeping bills to consumers down. The resulting politics and complexity of the regime is well-documented, adding to the challenge in integrating with other equally complex infrastructure systems such as energy or transport (Hall et al., 2016). This is exactly the regime, with its complexity, networks and forms of governance that a project team, such as Pipebots, needs to be aware of if it is to successfully integrate proposed solutions into a real-world setting.

The above discussion on "governance" addresses actors and compliance with the forms of governance chosen, but does not address all functions of governance, for example, such as embedding justice. In only a handful of cases do governance definitions expressly refer to justice or similar allied terms such as equity (for examples, see Barbazza and Tello, 2014). That considerations of justice should be made clear is recognised by its express insertion into the "just" transition agendas, leaving no-one behind (e.g., UNFCCC, 2015); we are not only seeking to move to more sustainable practises, but those practises must be just. It has been suggested that sustainability has become so paramount a goal it has been seen as the essence of good (Shrimpton et al., 2021). However, justice thinking can further improve upon the concept of sustainability in meeting a much broader set of societal and environmental needs (Neal et al., 2016), not least as our understanding of systems and ecosystems continues to mature (Shrimpton et al., 2021); with transformational change in a system there will be "winners" and "losers", but decisions on competing interests should be openly and equitably addressed. The need to expressly integrate justice thinking as we use science to make transformational change is already recognised in other sectors. For example, it has been recognised in climate engineering that a better understanding of justice can help understand public perception to climate engineering, an issue that has been under-addressed in the past (McLaren et al., 2016). In addition, justice thinking is already evident in work on energy infrastructure provision (e.g., Jenkins et al., 2018) and is prevalent in energy justice discussions particularly around the move to net zero. However, in stark contrast it is much less prevalent in the water and wastewater sector in the UK (Shrimpton et al., 2021), hence providing further reasoning for why it would be useful to explore in this current study.

Justice in Governance

The view that justice thinking is needed to underpin governance when transforming a system is all-the-more powerful when dealing with the allocation of a life-essential resource such as water. Water is a resource under stress, even in temperate climates such as the UK (Environment Agency, 2021), addressing changes in priorities and distribution requires a fair and just approach (Neal et al., 2014). Justice is a term that as a species we may share an innate sense of Brosnan (2018), but at the same time arguments can reign fervently over whether it has been achieved in any given circumstance. This raises the question of how justice can be interrogated and what it means for the purposes of a Governance Framework.

In seeking to articulate justice for the purposes of this study, reference is made to the conceptual framework around empirical notions of justice developed by Sikor et al. (2014), which draws on the highly regarded works on environmental justice by such as Schlosberg (2004) and Walker (2012). It draws on three dimensions of justice, namely distribution, participation (or procedural justice) and recognition (and respect). Distributive justice considers the equitable distribution of benefits and burdens, and the principles used to determine that distribution (Schlosberg, 2007). Procedural justice addresses decision-making processes, the due process used to allocate and distribute resources; it is not only about what decisions are made, but how they are made. Recognition (or respect), as part of procedural justice, addresses the factors behind maldistribution such as social status and embedded institutional structures (Schlosberg, 2012). That hidden issues of maldistribution may arise is highlighted most clearly by studies raising concerns of socio-economic and racial inequalities in access to safe drinking water in the US (Marcillo et al., 2021). This emerges despite the US being a high income country with a safe drinking water governance regime in place.

This current study seeks to explore the potential for justice questions at a project level for promoting adoption of better infrastructure interventions. The three dimensions of justice of distribution, process and recognition appear key to infrastructure decisions, especially in view of the post-pandemic levelling-up agendas (e.g., HM Treasury Ministry of Housing Communities Local Government Dept of Transport, 2021). One of the key principles for policy post-pandemic is distributive to "expand the systems for universal provision of quality public services" (UK Parliament, 2021), leading to questions of what is distributed, and how it is distributed, for example, through what processes and consultations? The asking of justice questions has already been promoted in the energy justice sector (Sidortsov and Sovacool, 2015) and a similar approach could be adopted here. Justice questions could be explored to encourage better dialogue and understanding, and to highlight potential imbalances in fairness and equity whilst "illuminating causes of conflict" (Sikor et al., 2014, p. 529).

In summary, and from a project team's point of view, asking questions around who benefits, who carries the burden and who is consulted (communicated with) could help identify areas of conflict, aid understanding and communication, and make trade-offs explicit. In asking questions openly and systematically, it may also help shed light on unwitting prejudices or biases.

Governance Defined

Drawing this together, the water and wastewater sector in the UK can be viewed as operating within a sphere of "governance", rather than under a linear, top-down "Government". Moreover, there are networks, relationships, power plays and social norms to be considered. This is, or should be, set against justice principles. It is from this grounding that the Governance Framework will be drawn.

Governance for this study can be summarised as the sphere created by rules (formal and informal), networks, processes and relationships, underscored by justice principles, that drive the water and wastewater sector forward and into which the project will need to integrate or influence to be successful.

The forms of governance for a given context are shown in **Figure 1**.

It follows from the use of the term governance in different contexts and in different epistemological backgrounds that there is more than one body of literature that may be relevant to the project. Drawing on different strands of literature also accords with the inter- and trans-disciplinary requirements for the resolution of "wicked" problems. The literature review uses a governance lens to address the following areas, looking for themes to take forward to support the project with a focus on aspects likely to be of relevance to a project team working in the sector, these are:

1) Governance around the interface of society and technology (See Sections entitled 'Governance of Socio-Technical Systems (STS)', 'Transitions Research and the Multi-Level Perspective' and 'Responsible Innovation');
2) Governance of natural resources, in this case water and wastewater management, centred around Socio-Ecological Systems (See Sections entitled 'Governance of Natural Resources', 'Socio-Ecological Systems and Adaptive Management', 'Resource and Place' and 'Rules-in-use')
3) How the disparate strands of SES and STS have been drawn together when considering infrastructure; and
4) Themes drawn from the above.

Governance of Socio-Technical Systems

The Pipebots project seeks to bring about a transformational change to the existing water and wastewater infrastructure system. In doing so it accepts that bringing about change is not just about the technological "artefact" but its relationship to the existing system, the system including human and non-human components (Rip and Kemp, 1998; Smith and Stirling, 2010). Social and political factors are embodied in "technology" (Hughes, 1986). A technology can fail to be adopted for multiple "non-technical" reasons, including a failure to address culture, scale, social or governance issues (e.g., van Vliet et al., 2011). The STS literature accepts that technology and society are co-formed and influenced and can provide a lens within which to view the current project. In particular, the transitions research literature, evolved from STS, seeks to understand long-term change in an STS and how we can move from one state to a more sustainable one (Foxon et al., 2009; Loorbach et al., 2017).

Transitions Research and the Multi-Level Perspective

Studies within transition research address the best nurturing conditions for innovations to thrive and bring about the desired change or transition. The MLP is one model that helps visualise a new technologies' journey from its creation in the "lab" *(niche)*—where it is protected from the outside system or rules—to its introduction outside the lab (*regime*)—where it competes with the incumbent system—and ultimately becomes embedded into everyday life (*landscape*) (Rip and Kemp, 1998; Geels, 2002, 2011). The MLP literature explores the niche-regime-landscapes range of perspectives, processes and how they align for a transition to happen. The importance of network engagement beyond the "niche" can be an aid in the transition from niche to beyond, for example (Ward and Butler, 2016). It is a simple model reflecting a complex system and as such has its flaws; for example, the boundaries between niche, regime and landscape and around the importance of agency (for a discussion see Geels, 2011, 2019), but its continued use and reference attests to its relevance (Arranz, 2017; Loorbach et al., 2017; El Bilali, 2019). Linking back to justice principles, the MLP could be explored within the Sikor framework when considering "scales" of justice, accepting perceptions of justice may differ when considered at local, intermediate or global levels (the drive for carbon reduction or improved biodiversity at a global level, for example, may be viewed differently by those individuals or communities whose livelihoods have come to depend upon the status quo). Indeed, the MLP is already seen in some justice studies in the energy arena (Jenkins et al., 2018).

Applying the MLP to the current context (**Figure 2**), it is possible to envisage the design of a Pipebot in the niche phase, its tests and small-scale deployment into an enclosed system (regime) and potentially its embedding in the national infrastructure landscape affecting water services processes, behaviours and transformation of the system. The MLP is not

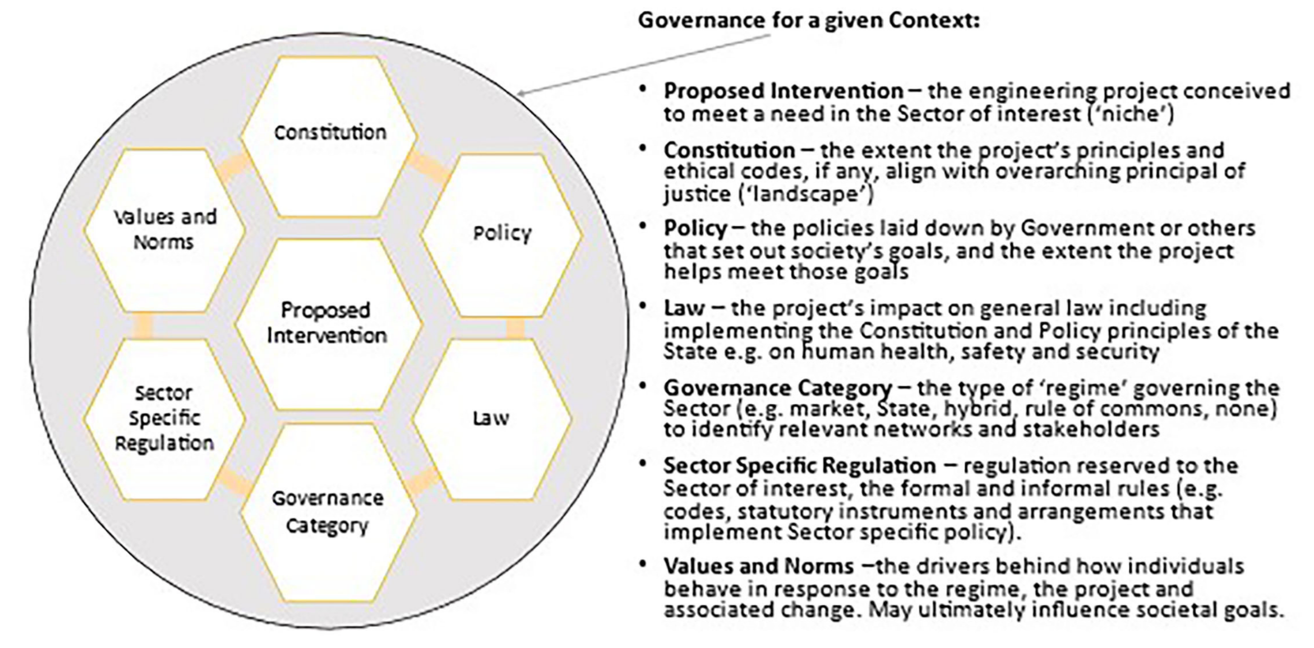

FIGURE 1 | Forms of governance.

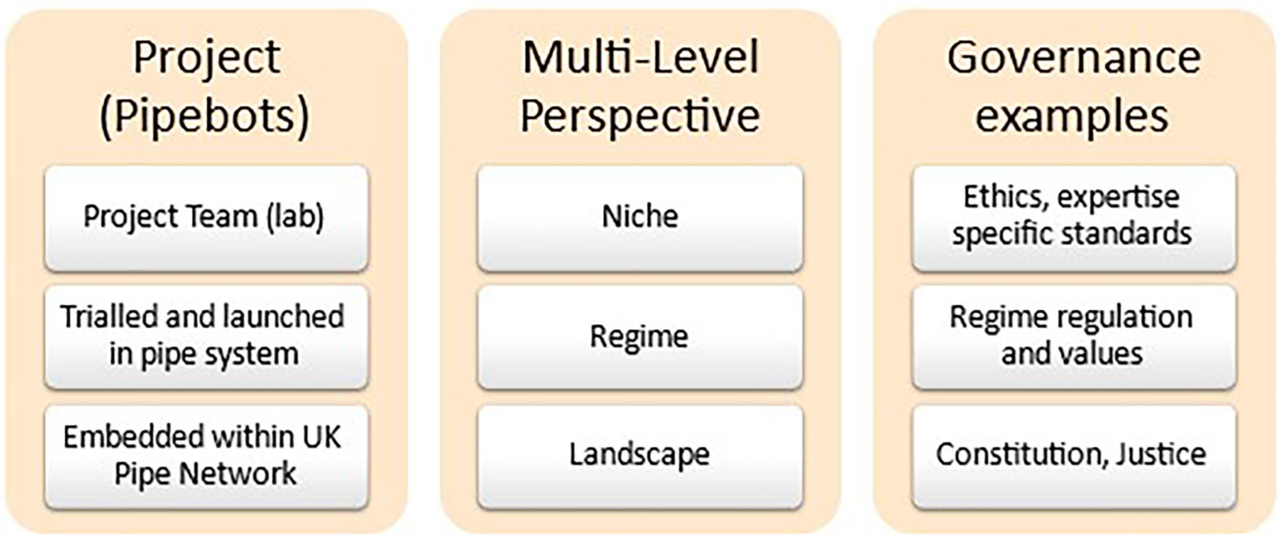

FIGURE 2 | The multi-level perspective interpreted for pipebots.

just about technology (Loorbach et al., 2017); from a governance point of view, it is possible to see the standards and principles within the project itself in the "niche", the industry specific regulatory sphere and networks of the water sector as the "regime", and the policies, constitution and laws of the land as part of the governance "landscape". Impacts and benefits may be felt at different levels by different subjects, as may the participation opportunities and recognition accorded to them.

Looking at governance in this way, it is possible to see how a new technology may not only be influenced by governance (e.g., in allowable design parameters), but may also bring about the creation of new governance (e.g., prompting new policies or regulatory requirements). It also suggests that the forms of governance of primary influence over an intervention may change over time as the project moves from niche to regime to landscape engagement.

Responsible Innovation

The Pipebots project needs to understand, and may even need to challenge, the governance landscape and regulatory regime. However, it has the most immediate opportunity to address its reason for being, influence outcomes and improve likely acceptability through its early engagement with ethics and principles in its own niche stage. This leads to engagement with a sub-section of STS literature: that of project level governance and Responsible Innovation (RI). In RI it is argued that project level governance becomes central to technology, not divorced from it or something left for others to consider later (Groves, 2015). It places responsibility on science itself to develop interventions responsibly, socially, and politically (Stilgoe et al., 2013). Stahl (2018), acknowledging the work of Stilgoe et al. (2013) and the AREA framework of Anticipate, Reflect, Engage and Act, sets out what this means in practise:

> *"A piece of research or innovation activity, in order to count as having been undertaken responsibly, would need to incorporate anticipation about possible consequences, integrate mechanisms of reflection about the work, its aims and purposes, engage with relevant stakeholders and guide action of researchers accordingly" [p183]*

It is noted the AREA approach has been adopted by the UK's EPSRC (Stilgoe et al., 2013; EPSRC, 2021). In a similar way to the framework in this study, it has also been used to devise a list of questions (rather than prescriptive rules) on RI to pose to a project team (Stilgoe et al., 2013). Projects can draw upon RI themes and questions as they consider their project's design.

Illustrating this through Pipebots, the project is intended to bring about transformational change in how pipes are inspected, and assets maintained. Their deployment is intended to impact on other infrastructure services such as highways and other buried infrastructure systems (through fewer trench excavations). Through an AREA lens, impacts can be anticipated. For example, the use of Pipebots in the regime will have an impact on what people are employed to do and the skills they require. Although this does not form part of the current grant, it is not far-fetched to anticipate the sensors could be adapted to gather data on the content of wastewater, identify energy sources in the network and gather a wide range of data on the use of water and disposal of wastewater. Indeed, a range of projects already exist exploring the use of sensors in wastewater, from detecting heat (Elías-Maxil et al., 2017) through to detecting fragments of virus such as COVID-19 (Kumar et al., 2021). What data is collected, and how, may become an issue, as could issues of security both of data and of software connected to infrastructure services (CPNI, 2021). These may be issues of potential concern to stakeholders that would benefit from being addressed in advance of implementation, or at least the project team should be made aware of them so that it can discuss their potential relevance. Connected is the issue of trust, particularly as Pipebots will come into contact with potable water (they clearly must be inert and, for public confidence, be shown to be inert) and how the Pipebots will be viewed and accepted by wider society as robots "living" in the water supply. A code that prompts these types of enquiry and encourages action appears responsible, as well as sensible, and will be incorporated into the Governance Framework.

This study embraces the RI philosophies, often generated from the social sciences. There are alternative views. The lead author has encountered a range of responses when raising RI principles within the science and engineering communities, from full-scale embracing to outright rejection, and such an array of views may exist within any project team. Of course, the RI principles may not be applicable to all projects; it is argued they are more firmly applicable to technologies that are disruptive rather than those that bring about incremental change (Tait et al., 2017). Within boundaries, there must be scope for science for science's sake without social or commercial outcomes being at the fore in all cases. There are also understandable concerns that the *ingenuity* at the heart of engineering could be inhibited, or already challenging scientific aims could be made more complex, if additional governance factors need to be accommodated within their work; an overarching fear being the snuffing out of innovation when it is barely born. A factor that may help to address some of these concerns is the timing of engagement with RI and governance, so allowing for exploration and experimentation, particularly at the early stages of the project. In this respect, it is suggested the application of RI codes be connected to the TRL (Technology Readiness Level) stages of development (Tait et al., 2017).

From anecdotal comments, the author's experience and conflicts in an interdisciplinary setting is not an isolated one (e.g., Tait et al., 2017). Open, formal examples of conflict in the literature are understandably rare, but exist; for example, in Leydens et al. (2012), when addressing engineering and social justice, there were elements of, what appears to have been, open hostility between some disciplinary-based factions. The Leydens study highlights the potential issues in engaging in an interdisciplinary environment. This, at least in part, acknowledges that differences may be representative of different world views, a move in the right direction being a requirement for each "side" to be cognisant of each other and their concerns, to apply these concepts at the appropriate time, and to accept a transdisciplinary way of working. It is argued this is essential if a project's aims are for just and sustainable outcomes (Lang et al., 2012) rather than simply technically competent ones.

Governance of Natural Resources

The study of governance of socio-economic systems (SES) is considered as Pipebots directly impact on the management of key natural resources. The reasoning behind why issues such as water leakage need to be addressed is because a precious, natural resource needs to better managed and governed (Walker, 2014) for current and future generations. A business-as-usual approach is no longer an option; anthropocentric-induced climate change threatens the socio-ecological systems and provides a harsh reminder that human prosperity is inextricably linked to the healthy functioning of ecosystems (Dasgupta, 2021).

Socio Ecological Systems and Adaptive Management

In exploring differences between STS with SES studies, it has been argued that with STS studies there is a lack of interest, knowledge and consideration of the many complexities of an SES (Ahlborg et al., 2019), noting SES and STS studies have developed from different academic disciplines with different problem framing (Foxon et al., 2009). There may be themes within SES studies that can add to those elicited from STS studies, and work has started to address this (Foxon et al., 2009; Ahlborg et al., 2019). Foxon et al. (2009) note connections between *adaptive management* (from SES), and *transitions management* (from STS). Adaptive management seeks to maintain the function of a system in the face of change or shock (such as climate change) and is rooted in concepts of resilience from Holling (1978) and beyond. Although with transitions research in STS there is not the maintenance of existing structures, but the breaking down and re-forming of new, more sustainable structures, both adopt a (complex adaptive) systems thinking approach allowing for unpredictable and emergent features (Smith and Stirling, 2010). An SES is not something that can be "controlled", but is unpredictable and requires multiple inputs to aid learning, responsiveness and flexibility.

Resource and Place

A key aspect of the governance of an SES, through adaptive management, is the identification of the natural resource itself, its boundaries and its context. In contrast, STS is said not to be as "place bound" (Smith and Stirling, 2010). Boundaries and place would appear useful considerations as, at the very least, they may influence the legal and administrative jurisdiction and so governance for the project. Ostrom's Institutional Analysis and Development (IAD) framework, based in SES for example, seeks to understand the various factors of a governance regime that support the sustainable use of a common-pool resource (1990; 2011) and what mitigates against Hardin's (1968) "tragedy of the commons". A key feature is the "action situation" where the components of the system interact, affected by such factors as the attributes of the community, the rules-in-use and the biophysical conditions (Ostrom, 2010).

SES suggests that how the resource is viewed and treated can be influenced by the governance regime. Governance being used in this way can be seen, for example, in metering policy which uses technology to seek a change in behaviour towards the resource (Loftus et al., 2016). Water services provision in England is a privatised regime. There are global discussions around the impacts of privatisation as a governance regime and whether water (services) are, or should be, a public good or a commodity that can be traded (for a discussion and nuances in the debate see Bakker, 2003, 2007). For many the distribution and provision of water and sanitation is part of their citizenship, a human right and a public good, and it being subject to markets, trading and profit, particularly benefiting large corporations, is an anathema (Right2Water, 2021). Conversely there are questions on the societal value (or lack thereof) given to a resource that is provided free of charge and effort, and how that may incite wasteful behaviour.

Whatever stance is taken, the literature suggests the governance regime may shape behaviours towards the resource itself. Understanding the regime, and being conscious of the context and the boundaries of the system (where possible), could provide useful lines of questioning for a project team, such as Pipebots.

Rules-in-Use

What also becomes apparent from SES studies and a consideration of "governance" is that rules may not only emanate from the State, but from a variety of situations and groups with varying degrees of formality (Ostrom, 1990). Furthermore, it is not necessarily the rules-in-writing that are of most significance, more likely the rules-in-use (which may be different) and of understanding the regime within which these come into being and how they are maintained (Ostrom, 2011). Reflecting on this in the current context (the highly regulated water sector), knowledge may be required of the rules and laws, and more importantly which are prioritised and applied most readily in practise. An illustrative example is presented by Larcom and van Gevelt (2017) in their study of the water-energy-food nexus in England, which identified up to 2,700 potential regulations. In applying their framework to a hydro-electric plant on Dartmoor they note, amongst other matters, that mapping the entire regulatory framework is a "formidable" task, where many rules are "unwritten" suggesting what may be on the books can differ significantly from what is enforced (Larcom and van Gevelt, 2017, p. 56).

This presents a formidable challenge for a project team, not least Pipebots. A route forward may be to draw in those with practical experience of the regime to support the project and help cut through to what is key, another potential link to, and justification for, the importance of networks. An aim would be to draw in insights from stakeholders on the actual rules-in-use. To an extent this is indicated by the conclusions of Larcom and van Gevelt (2017), who suggested that procedural justice aspects of governance can be adopted by drawing in a wide range of stakeholders allowing for the exchange of information and values for decision-making.

Infrastructure Governance

There are common themes within STS and SES, in addition to subtle differences. For example, the lack of engagement with the resource itself in STS studies has been noted (Ahlborg et al., 2019) and with SES studies there are question marks over where the influence of technology should sit in the overall picture (Markolf et al., 2018; Ahlborg et al., 2019). The potential problems of considering STS and SES systems separately are acute when infrastructure is the centre of attention (Markolf et al., 2018); climate change, population growth and changing demographics, or "landscape" changes, highlight the uncertainties hard infrastructure faces and the interdependence of social, environmental and technological challenges.

To illustrate the point, it is well recognised that technology, the environment and societal services are intimately combined, at both a fundamental and practical level, and decision-making therein requires an appreciation of their interconnectivity within a system. With Pipebots in mind for example:

- Technology, includes (or should include) life cycle considerations–the extraction of natural resources, its production, manufacture, recyclability and, where all other options have been exhausted, end of use disposal. All of these can be justice issues, with impacts both environmentally and socially. This is well illustrated in the discussions around electric cars and battery disposal (Bonsu, 2020), this is pertinent given that any Pipebot will likely be electrically powered.
- Whilst acknowledging the many benefits, critical infrastructure is sensitive to threats from technology and digitisation failure or abuse (including cybersecurity issues), in turn making STS and ecosystems more vulnerable (Cassotta and Sidortsov, 2019).
- Vice versa, existing infrastructure can be overwhelmed by a complex mix of factors including social (poor governance, data management and planning) and environmental (climate change impacts), attested to in studies of disasters such as Hurricane Katrina (Daniels et al., 2006), often with the most vulnerable in society the most acutely affected (Pelling, 2003).
- There is potential for technological solutions to work alongside nature-based solutions (NBS), with calls to consider eco-engineering and smart NBS (Snep et al., 2020).
- There are also less obvious influences. The Pipebots project for example draws upon research into bio-robotics to learn from how the natural world has overcome physical hurdles.
- Most directly, Pipebots is a technological tool that can, through pervasive sensing, gather data (or viewed another way, feedback) from the environment. It can provide that feedback to inform about the state of the environment or resource, and for human learning, decision-making and adaptation to take place in response. The impacts of this are likely to increase as we move towards digital twinning of our infrastructure systems and AI, with opportunities to better understand and manage natural resources through infrastructure.

The latter point may have particular resonance as we begin to fully appreciate human-induced threats to our environment. In his recent study for the UK Government, Dasgupta (2021:273) refers to Nature being "silent and invisible" and describes how this gives rise to negative externalities in its use or abuse. One can see how sensing may have an increasingly important role in supplying data and feedback to make the environment potentially more "visible" and support more resilient and sustainable (and environmentally just) outcomes, but this will only happen if supportive governance arrangements are in place. Particularly in cities, infrastructure systems are how we try to control (or at least manage) our natural resources; they are the mechanisms through which society functions and how we reduce (or produce) vulnerability (Tellman et al., 2018). In these ways the environment is not separate from the technology any more than it is removed from societal influence. If not considered together, the ways of thinking prompted by marrying the two could be lost.

Work here is not complete and there are calls for more to be done to explore the merging of these concepts (Markolf et al., 2018; Ahlborg et al., 2019). There are attempts to expand thinking. The Coupled Infrastructure Systems (CIS) framework for example, and its adaptations, considers the interaction between hard infrastructure, soft infrastructure (which includes legal systems), natural infrastructure, human infrastructure (knowledge) and social infrastructure (relationships; see Janssen et al., 2019). As an SES-based study it aims to gain insights into the interactions within a system and their effect on the robustness of the regime. This can help re-frame a problem more widely or be applied to a problem scenario to raise questions around interactions in the system and resulting institutional performance or robustness. It is not a project-focussed tool, more of a useful overview of a wider system, and does not seek to guide a project team on specific governance concerns around an infrastructure project.

Similarly, a relatively new concept, still in its infancy, is SETS (Social, Ecological and Technical Systems) which suggests the need to better integrate technology into SES thinking (e.g., Markolf et al., 2018). The stimulus for the SETS approach are the "wicked" problems around climate and population changes, and the increased uncertainty this brings to future infrastructure needs (an already difficult assessment). It considers that an interdisciplinary approach is needed to address these problems (Markolf et al., 2018, p. 1653). It places infrastructure as a mediator between ecosystems and society, and draws on examples of infrastructure failures and disasters, such as Hurricane Katrina, using SETS to better understand issues such as infrastructure lock-in and vulnerability. As a new top-level concept, it is recognised by the authors that SETS requires testing and development (Markolf et al., 2018) and may act as a launch pad for expanded thinking and research.

SETS here is not a governance framework, but a discussion piece and call to accept that resilient solutions require an understanding of ecological and social factors, not just technological factors. Governance is not absent but falls within the social system and is not discussed in detail (although there are calls in the paper for strong and just governance and improved transdisciplinarity; Markolf et al., 2018). Neither is there an express articulation of justice. That is not to say that justice-type issues are missing from the narrative. For example, through discussions on concepts such as vulnerability it connects with the disaster risk reduction literature and issues of social equity; it is well documented in vulnerability studies that those in more deprived (often urban) areas are at heightened risk of infrastructure failures as well as having reduced access to ecosystem services, and the health and economic prosperity those systems can bring (see discussion in Dasgupta, 2021). Conversely, well designed, sustainable city infrastructure, including NBS, offer potential solutions (Dasgupta, 2021). With infrastructure considered as a mediator between environment and society, how that infrastructure distributes assets and burdens (environmental and social) to address vulnerabilities becomes a live justice issue.

In short, there are clear openings for SETS to be expanded upon to address governance and justice more explicitly.

To illustrate the issue, by considering networks within STS, SES and justice together, what becomes more evident is that the range of stakeholders may change depending on the disciplinary focus. For example, the stakeholders that may support the progress of new technology may differ from the stakeholders interested in the natural resource one may be seeking to influence or the societal inequalities one is seeking to re-balance. Conversely, it highlights how asking limited questions from a single viewpoint can inadvertently miss stakeholders and their relevant views. Research recognising this, engaging with participants and asking questions from the multiple perspectives of justice, SES and STS, may be of benefit. It may also be the case that engaging and improving the project team's network, systematically and with these principles in mind, can help in articulating and understanding why there is engagement with particular groups, who may be missing, and what it hopes to achieve.

Governance Themes

Drawing this together, through engaging with the literature, nascent questions that combine with the forms of governance start to materialise showing how governance and its rules, formal and informal, may shape and influence a project:

1. The Overarching Governance Regime: What type of governance regime (e.g., market, regulatory, common, hybrid) is in operation? Who are the actors involved in governing? This sets the regime from which forms of governance and actors come into being.
2. The Forms of Governance: What tools do the actors use to govern the system? What is the law of the land relevant to the project and what regulatory framework, if any, is in place? How does the regime influence the informal and formal forms of governance that are implemented?
3. Social Networks: Who is in the project's network? Are there gaps in the stakeholder groups represented? Can the network be drawn upon as a resource; e.g., can the network advise on rules-in practise (not just rules-in-writing)?
4. The Resource: How is the resource itself viewed, how are the boundaries of the system defined and how may that affect the policy, rules, social norms and behaviours to be considered?
5. Technology and Rules: Applying new technology to that system, what rules and policies are in play and how do they impact on the project and its business case? How may AREA (anticipate reflect, engage and act) be used to inform a project's strategy when considering the impact of the new technology and where responsibilities may arise?
6. Justice: How (and when, or at what TRL stage) does the project address justice issues (including Responsible Innovation and AREA), if at all?

And once those questions have been explored:

7. Iterative Processes: How should the governance regime be adjusted (refined and enhanced, interpreted, better articulated)?

In terms of point 7, should the governance regime not form part of the same iterative engineering (design, operation and progressive improvement) process as the infrastructure and its operational systems? This has been argued in terms of "engineering all the forms of governance to enable the business models (associated with an infrastructure intervention) to deliver their full suite of intended benefits" by Rogers (2018)–at its most basic level, engineering of the governance regime has the potential to enhance the outcomes from infrastructure systems, i.e., deliver their full potential, rather than (potentially unnecessarily or unintentionally) constraining the systems by imperfectly designed, targeted or out-dated rules. The Governance Framework will therefore include questions around challenging the governance status quo and where it could learn and adapt.

These can be taken forward as themes from which questions for a project team may be raised.

WHAT DO THE CURRENT FRAMEWORKS SHOW US?

Review

The Governance Framework is intended to support a project team (such as Pipebots). In addressing this aim, several frameworks[3] were found be relevant to water and wastewater infrastructure, including Safe SuRe (as applied in Hall et al., 2014; Ward and Butler, 2016), NISMOD (Cardoso Castro et al., 2020) the governance issues map (Frijns et al., 2016), however the shortfall of these is in the fact they were not designed to meet the specific requirements of this current study. For example, the scope, rationale and/or target audience did not match the focus of attention herein with most frameworks aiming at policymakers. Furthermore, it was also noted that there were a number of frameworks where governance was one factor amongst many others for consideration. Therefore, governance was not sufficiently a focus, or not defined with sufficient detail, for integration (within Pipebots) to take place.

In reviewing the frameworks, the PAS (Publicly Available Specification) framework (BSI, 2020) stood out as one that acknowledged the need for more project level support and was most in line with the studies aims. This will be discussed in Section PAS440:2020.

[3]As well as immersion in governance literature as part of the project, a formal literature review using the Web of Science database was used to check for any less well-known sources. A search was undertaken using "governance" and "infrastructure" as search terms alongside "frameworks" or "tools". This elicited 1134 responses. A category filter was used to exclude categories such as meteorology and imaging science and focus on civil engineering, environmental sciences and studies, urban studies and law. Those not readily accessible and not open source were also excluded as these may not be accessible to a project team. This resulted in 142 responses. As anticipated the range of subject matters and focusses of attention was considerable. An initial filter through titles not relevant to the project goals left 75 documents where abstracts were considered. The abstract review identified 2 responses of interest, one of which had already been identified by the author.

PAS440:2020

PAS:440:2020 (BSI, 2020) is a recent addition to the work on Responsible Innovation codes. It is derived from wider work looking at governance of innovation. It is also recent, seeks to draw on previous work on codes (including AREA) and experiences, and has a goal to embody good practise in Responsible Innovation. The target audience is innovators, although background material and literature on the research leading up to its creation suggests its roots are in STS and a desire for more adaptive and proportionate regulation to support the needs of innovative technologies; in short, the overall aim of the project that prompted the PAS focussed on regulators and policymakers (Tait et al., 2017).

Responsible Innovation (RI)is seen as a foundation for more flexible governance, noting that key to allowing flexible governance is the extent to which the actors behave responsibly (ibid). In this way, responsible behaviour and standards, rather than prescriptive laws, form the basis of regulation at an early TRL stage. Governance then moves into different forms of flexible and adaptive governance depending on the nature of the innovation. It is prompted by concerns around governance of innovation and the need for safety to be balanced with scope, for an innovation to be explored and not constrained by pre-emptive, overly constraining governance systems. The rationale for the work has further resonance with the Pipebots project, where current regulatory regimes were never intended to cover robots in the water supply (infrastructure). How such innovations are managed to allow for new potential solutions, whilst keeping a precautionary approach, is the balance that is sought (not least for a project such as Pipebots). A first step suggested is for responsible behaviour and trust to be built by innovators, guided by RI codes.

There are two frameworks. The first addresses Corporate Social Responsibility (CSR) the second addresses Responsible Innovation (RI). The former addresses CSR alongside issues of corporate governance which are outside the scope for this current study. The latter aligns with this current study in its recognition that there is very little to support a project team. The RI framework is project-specific and aimed at innovations in the corporate sector. Therein it asks eight questions aimed at addressing the impacts of an innovation: what are the societal benefits (1); and risks (2); environmental benefits (3); and risks (4); health-related benefits (5); and risks (6); value chain elements (RI behaviour by other significant actors) (7); and what are the regulatory elements (8)? There is also guidance on how to complete the table. The guidance acknowledges the need to draw on "outsiders", as with a network. The framework draws on AREA in responding, engaging and acting on those questions. The associated literature also stresses the importance of the timing of engagement, particularly with the wider public, and how that engagement should take place.

It uses a risk assessment approach, albeit to encourage broader thinking about the impacts of a project beyond its immediate design and construction. The questions are broadly drafted (albeit with separate guidance). This has the benefit of keeping the framework itself simple and accessible, but, for the purposes of this study, does not make plain thinking elicited from the governance literature. The only direct question on governance is "what are the regulatory elements"? This is a very general question. It may be the project team has specific and detailed knowledge of the sector, but maybe not the wider legal landscape, while the experience of members of the project team around legal and other regulatory issues may be limited. It does not promote a deeper understanding of the governance context required for the current project (accepting, of course, that this was not why it was drafted).

Whilst it was not designed to address the aims of this study, there is scope to use and adapt the PAS framework. The risk categories used in the framework (health, environment and society) align with the issues legal systems often seek to protect, and as such could be adapted further for use in a governance framework. The focus is also not just on risks, but on articulating benefits—social, environmental and economic—which can be useful as a communication tool, to make plain trade-offs and to support a future business case. It touches upon networks, society and ethics, and regulation to a degree. It does not directly address the regime, the natural resource, rules-in-practise (as opposed to formal regulation in writing) and the forms of governance in any detail. Justice is not referred to expressly, but its foundations are based on ethical considerations.

It has helpful thinking to take forward, capturing some of the themes elicited. It also provides endorsement for this study in its acknowledgement of the need for more practical tools and support, not just for policymakers but for projects and innovators. It provides a basis to expand upon.

THE PROPOSED GOVERNANCE FRAMEWORK

Framework Structure and Underlying Philosophy

The themes garnered from the literature were collated. A series of questions were then devised to address the issues raised by the themes. Those questions form the basis of the Governance Framework to be piloted (**Figure 3**). This Governance Framework was then applied to the Pipebots project as part of the activity undertaken in Theme 7 of the project team. The aim was to consider the potential of the Governance Framework to help the project systematically address potential governance issues, aid communication and expand thinking beyond the technical challenges of the project.

A summary of the key findings is as follows:

1. The Governance Framework provided a prompt for potential landscape governance issues to be considered at an early stage by considering risks and the potential impacts on human safety, security (including data), land and the environment. This led to several varied conversations, for example around the transfer of data from below to above ground and the legal position of the robot "escaping" from the pipe.

Matters for Consideration by the Project Team

The Intervention

1 Briefly describe the proposed infrastructure intervention (the project) Context and Narrative

2 Who is in the project team? As well as engineering expertise can local, resource, operational and governance knowledge be drawn upon ? Network

The Resource

3 Describe the water/wastewater system (system) affected including any natural, geographic and administrative boundaries. Context and Narrative

4 Are you clear on the system boundaries and its interconnectivity with other relevant systems? Context and Narrative

5 Are there opportunities to re -frame any 'burdens' into assets e.g. flood water, removed nutrients, 'waste'? Context and Narrative

The Regime

6 Who is responsible for the system in the boundary areas affected by the project? If responsibility is split how will multiple stakeholders be managed? Network

7 Who are the key regulators of interest for your project? Do you know how to access them, if required? Network

8 Is the project novel? Are you aware of regulatory mechanisms in place to support novelty/ innovation? Strategy

9 What cycles or timescales does the regime operate under - e.g. price reviews, regulatory reviews? How may that affect the people in your network? How will you account for these cycles in your project plan? Strategy

Policy

10 What are the intended benefits of the project? Other than technical goals are there wider social and/or environmental benefits? Business case

11 Can you link the above benefits to a public policy or international goals such as SDGs? Are there benefits that policy does not recognise? If so what are they? Business case.

Law (Legal Landscape Impacts)

12 Could the project risk human or ecosystem, health, safety and security (positively or negatively)?How will this be understood, managed and communicated Design requirements

13 Could the project impact directly or indirectly (e.g. nuisance) on another's use of land or property? How will this be addressed? Who needs to be involved? Network

14 Is data collected and communicated? Is this safe and secure? Have protocols for the handling of data been identified and put in place? Design requirements

15 Does the project's impact on the security and resilience of critical infrastructure need to be considered? If relevant, how will this be addressed? Design requirements

Regulation (Regime Impacts)

16 Does the project support a regulatory requirement? If not, what supports the business case for change? Business case

17 Do the current regulations impact on the design of the project? For potable water projects are you alert to Reg 31*? Design requirements

18 If the rules are complex can your network advise you of the 'rules -in-use'? Network

19 Are you alert to any issues regarding contract/ procurement and existing suppliers that need to be addressed? Strategy

20 If regulatory hurdles exist should other jurisdictions be considered? Strategy

Justice (Niche)

21 Have you identified/embedded a responsible innovation (RI)* code including an AREA* assessment Strategy

22 If a code is still being considered do you need buy-in from the project team? Strategy

Justice (Application)

23 Who or what will benefit from the project? Why has this group been chosen to benefit? Business case

24 Who or what may suffer a detriment? Why is this group affected ? Does the RI code address communication and mitigation strategies? Strategy

25 Where there are detriments, does your strategy include preparing for a delayed or late response from the public /NGOs? Strategy

26 In answering Q23/24 have future generations and the environment been considered? Business case

27 If there is no RI code, how will benefits, detriments and trade -offs be anticipated, balanced and discussed? Business case

28 How will the data generated by your project be used? Can it enhance our knowledge of the environment? Business case

Network

29 Who is in your stakeholder or contact list (plus see answers to Q2,6,7,13,23 and 24). Does this include operations, R&D and engineering contacts? Network

30 Are all potential stakeholder groups represented / do gaps need to be filled? Strategy

31 How do you plan to engage and respect your network/ stakeholders to understand values that may impact on the project? Does your RI code address this? Network

32 If any of these framework questions cannot be answered can you draw on the expertise of your network? If not how can you expand your network? Network/Strategy

Challenge

33 Standing back, do you feel this project delivers the best feasible result for people and planet? Business case

34 If not, what legal, regulatory or policy drivers could be put in place to support you, can you lobby for change, escalate these issues or draw on your network to improve future projects? Strategy

Review

35 How / to whom, will you communicate the answers to this framework? Network

36 How can this framework be improved?

37 When do you plan to revisit and review the answers? Strategy

FIGURE 3 | Governance framework.

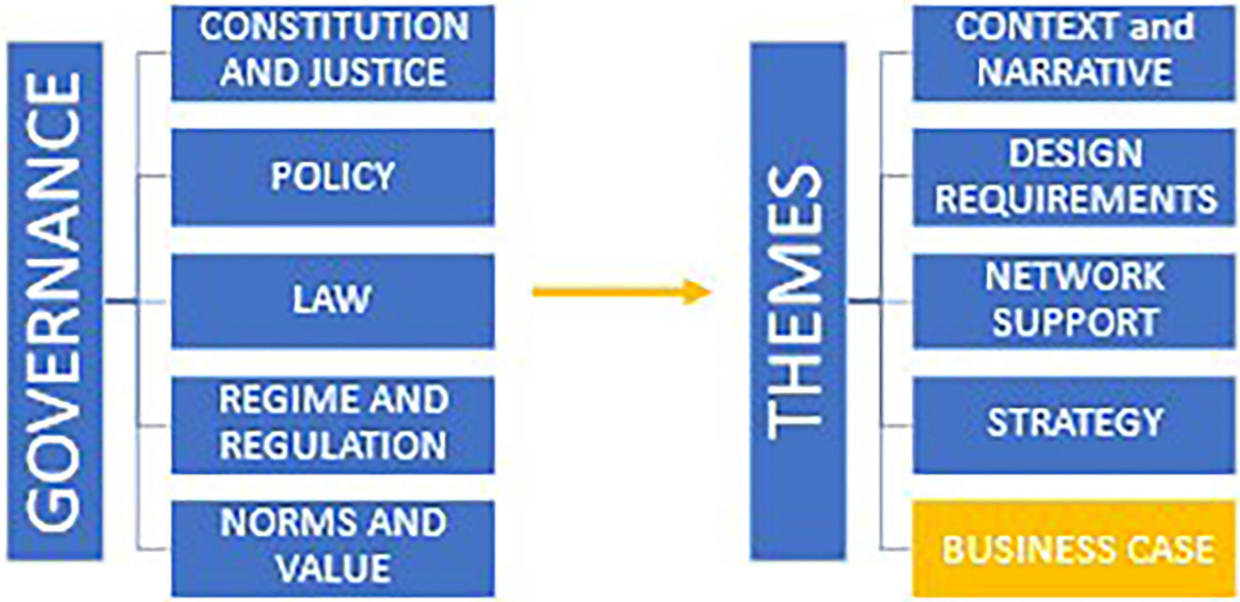

FIGURE 4 | Governance to themes (via framework).

2. Early transdisciplinary work with governance questions in mind highlighted practical issues over regulation and procurement contracts, which were not otherwise observable.
3. The most significant findings were the type of answers that the Governance Framework prompted and how they could be used (see **Figure 4**). They could be categorised in five groups as follows:

   a. Context and Narrative: For example these revolved around the resource of interest and its spatial distribution, as well as the type of regime governing them. These questions provide a clear context for the application of the intervention beyond the technology itself. In the current project there were clear governance differences between "water" and "wastewater" applications.
   b. Networks: Connection to regulators proved to be a notable absence. The current regulations governing potable water were not drafted with the use of miniaturised robots in mind, prompting the need for consideration of how this new application may be viewed by the Drinking Water Inspectorate (DWI).
   c. Design Requirements: As an example within the regulations governing drinking water quality in England (see UK Parliament, 2016), associated advice sheets provide the opportunity for certain test requirements to be abridged subject to calculations on the surface area of the final robot. This was information provided to the design team at an early stage and enabled questions to be raised on its application to the DWI (once the network had been expanded).
   d. Strategy: There were several examples, such as the extent to which there were network gaps prompted thinking as to how and when those gaps should be filled; to what extent an RI code should be adopted and how could this be used to address justice and societal concerns around robotics; a review of policy was one factor that led to further training within the project team on the issues around digital twinning and how Pipebots may better integrate with a national infrastructure digital twin initiative.
   e. Business Case: How the current governance regime and landscape supports (or hinders) the case for change. As the project moves forward, future governance scenarios will also be considered.

4. The Governance Framework provided an impetus for dialogue across an interdisciplinary team, sensitivity to providing governance information without stifling creativity being an important premise for the project team.
5. The Governance Framework did not provide answers but flagged areas of enquiry or gaps in knowledge. Mechanisms to address and follow the findings would be needed as part of project management. For example, gaps in networks could be addressed with social or stakeholder network tools.
6. Following on from the above, the Governance Framework would be at its most useful when integrated into the project's strategy planning so gaps and unanswered questions could be resolved or carried forward.
7. The Pipebots project is in the early TRL stage (1–3). Whilst thinking about future TRL stages is helpful, the need for the Governance Framework to be re-applied at different TRL stages was apparent.

The Governance Framework was therefore able to form the basis of constructive dialogue. The categorisation of the answers—the context and narrative for the project, design requirements, network development, strategy and the business case for change—helped channel the responses into wide-ranging proposals for integrating governance into the project. It provided another lens to view a technical project, with tangible proposals that could integrate with the technical and design aspects of the project rather than being distinct from them; in this respect it supported multi-disciplinary working.

LIMITATIONS AND FURTHER RESEARCH

The study has sought to ensure its foundations are rooted in academic theory, taking advantage of the works of the pivotal thinkers around the governance of social, environmental and/or technical systems. The literature is showing a move towards more integrated thinking, particularly around infrastructure, although more work, including around the integration of justice, is warranted as the development of thinking on governance that marries these concepts, and treats them as a whole, remains in its infancy. In view of the nascent nature of the merging of disciplines at a conceptual level, it is not surprising there is a lack of usable tools embracing these perspectives. This study has taken steps to address this gap as well as ensuring that justice thinking is also expressly embedded.

It follows that the Governance Framework created is both novel and original, and in its first manifestation. The framework was prompted by the absence of an adequate existing tool that could be used—the ambition in marrying these strands and designing a practical tool was born out of necessity. It therefore requires further application and development to cover the wide range of potential uses. It is hoped this publication will prompt insightful thoughts and comments on its adaptation from the academic and practitioner communities.

In terms of furthering its application, it could be used as a framework of themes from which to pin research on future governance scenarios (through the analysis of the regime, the forms of governance chosen, the issue-specific regulation and policy, the network, rules-in-practise, justice and ethics, and the view taken of the natural resource or asset affected). It may also support work on how governance can be created to be both supportive of necessary change whilst protecting that which requires protection. Work within the current project will consider what these themes look like in various future scenarios, and in turn how this may affect the business case for change.

There is also potential to extend the study beyond the overarching governance regime to thinking around project and corporate governance. The project governance literature draws on corporate governance and economic theory such as transaction cost economics (TCE) (see Ahola et al., 2014). Project governance, developed from the more mature area of project management, is concerned with the corporate accountability structures, personnel roles particular to a project and the implications of those structures on the project. Drawing on theories such as TCE, it may help explain and address behavioural issues such as opportunism bias and why a business may choose to outsource a project or take it in-house. The current study concerns itself not with the variable corporate structures around a particular project and their implications for how a project is formed, more so the development of the project within those structures, the latter being issues about which the project team may have more direct influence and control. It is however a further interesting avenue that could be pursued.

CONCLUSION

The Pipebots project, a pervasive sensing tool affecting water and wastewater systems, recognised the importance of engaging with governance at an early stage for the success of the project. The first step was to be clear on what governance looks like in this context, both for terms of reference and for communication. Governance, in its whole essence, is a trans-disciplinary subject and the means of analysing it can be a tool to bring together science, justice, society and natural resources. However, whilst governance is an issue that has been grappled with from multiple perspectives and disciplines, those thoughts have not yet been fully integrated. It has grown from different needs and focusses. The subsequent challenge was to draw in knowledge on governance issues from different disciplinary backgrounds, synthesise that thinking where possible, and then take steps to operationalise those concepts in a useful and practical way to an interdisciplinary team. The Governance Framework is proposed as a novel and essential step to meet that formidable challenge.

Whilst issues abound on governance of the environment, technology and society, it is project teams that grapple with the practical consequences. Governance regimes impact on networks, forms of governance and shape infrastructure interventions. At one level the resulting Governance Framework gives a way forward for a project team seeking to engage with the governance sphere that will surround the intervention they are seeking to make. What it also does is reflect on how governance affects projects, not only what they choose to deliver but whether the results will be embraced or rejected. Early results from the Governance Framework show the potential of using governance as a prompt for thinking. It asks questions around the wider implications of an intervention, informs design and flags areas where governance itself may need to be challenged. It highlights how projects may need to adapt their strategies, business plan and design, and seeks to embed questions of whether they are responsible and just.

What has also become apparent is how governance itself could adapt and transform. Most significantly perhaps, rather than erecting barriers to creativity it can support a business case for the transformational change needed to thrive. Accepting that governance regimes, like the design and operation of infrastructure systems, should be subjected to engineering processes (i.e., undergo iterative analysis and progressive refinement, leading to better outcomes) might be a helpful starting point for such a transformation.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

ES conceived and designed the framework as part of her doctoral studies, under the supervision of CR and DH, and wrote the first draft of the manuscript. CR added substantive material to, and DH provided detailed comments on, the first draft. All authors contributed to the manuscript revision, read and approved the submitted version.

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