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DOI:
10.1680/jinam.21.00022

Cite this article
Bouch CJ, Shrimpton EA, Makana L, Bowman B and Rogers CDF
Robotic autonomous asset management: benefit/value-based business model creation.
Infrastructure Asset Management, https://doi.org/10.1680/jinam.21.00022

Research Article
Paper 2100022
Received 17/09/2021; Accepted 26/04/2022

Robotic autonomous asset management: benefit/value-based business model creation

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Abstract
Research has shown that value generation is an important factor when it comes to driving technological change. It

follows that business models as narratives of value generation and capture have an important part to play as the end goals in the change process. Research also suggests, however, that the understanding of when, why and how value accrues to stakeholders, and what value to create, appears to be lacking. This paper describes an objective and repeatable methodology for the identification of benefit- and value-generating opportunities that can be used to aid business model creation. The methodology is demonstrated for the generic business of infrastructure asset management and discussed in detail in the context of 'Pipebots', a current scientific research project into the introduction of robotic and autonomous systems to the asset management of buried water and sewage pipe networks in the UK. In conclusion, the paper proposes that the methodology opens the door to a future where radical change in a given infrastructure system can lead to value capture across the wider system of systems.

Keywords: business/infrastructure planning/management/UN SDG 6: Clean water and sanitation/UN SDG 9: Industry, innovation and infrastructure/UN SDG 11: Sustainable cities and communities

Introduction
This paper describes research aimed at the creation of business models involving the adoption of robotic and autonomous asset management systems in the UK's buried water, sewage and drainage pipe networks. The research is being carried out as part of the Pipebots project funded by the Engineering and Physical Sciences Research Council (EPSRC, 2019), whose vision is the development

of pervasive robotic autonomous systems (RASs) to assess pipe condition and identify points of incipient failure. This is in contrast to current arrangements where tethered robots (e.g. RX95 crawler) require continuous operator supervision, or untethered robots (e.g. SmartBall) are carried through pipes by the fluid flow, sensing as they go (AIT, 2022; Pure Technologies, 2022). This in turn facilitates creation of an intelligent, robust and resilient buried pipe network, leading to major reductions in infrastructure and service failures and the disruption that they cause. The project mission is essentially twofold: to create a new, pervasive, autonomous robotic platform that will radically improve the ability of the water industry to generate a real-time condition and performance map of buried pipe networks and, of most pertinence to the research described here, to use this new knowledge to transform the way that utilities manage and maintain buried pipe networks in the future.

The research is based on the assertion that water industry stakeholders will not adopt new RAS technologies unless they can create strong business models that demonstrate that the benefits and value created will accrue directly to them. This is supported by the current regulatory regime in the UK water industry, which requires customer-sourced investment to support strictly defined benefits agreed as part of the Water Services Regulation Authority's (the regulator) 4-yearly price review process, while shareholder-sourced investment is incentivised to provide a return on investment within the same period. Furthermore, the research is cognisant of the fact that the transition from existing asset-management processes to a reconfigured system is complex, requiring a complete reworking of links with the actors currently involved (e.g. the workforce), the institutional rules and norms in force, the pertinent cultural values and the economic resources used. The business case to support that transition makes sense only in the context of a strong business model describing the end goal of value generation and capture

Development of business models is a highly creative and iterative process (FHWA, 2020). Business cases are the arguments for investment involving costs, benefits and value that businesses make in the context of moving from an existing business model to a new one. Business models, on the other hand, are the narratives that businesses create to describe how, through their activities, they will generate and capture benefits and value. It follows that the first step in business model development is to identify the business of interest. Furthermore, business models must be developed in the context of the operational concepts that describe implementation of the new RAS technologies, along with knowledge of the stakeholders involved and the benefits and value that the RAS might help to realise. In developing the business model, asset management of the pipe network cannot be considered in isolation, and research must extend, therefore, beyond RAS technology to include related, potential opportunities for generation and capture of benefits and value in the wider water industry, and with all other systems (e.g. health, transport) that interface with it. Value in this instance is not limited to monetary gain but should include a broad range of value types. It is that wide perspective on value that requires initial study of infrastructure asset management as the business of interest, because it provides the basis for identifying as wide a range of benefit- and value-generating opportunities as possible.

Adoption of RAS technology has the potential to lead to radical transitions in the way that water industry assets are managed. How such transitions are brought about will influence business model development. Much of the literature on infrastructure transitions concerns the need to move from current operating paradigms to ones that are more sustainable. It does not, however, address this from a business model/business case point of view and has little specific to say about how opportunities for benefit and value generation influence the transition process. Instead, it suggests that such are the complexities surround transition, rather than attempt to 'design' a route to a more sustainable future, a process of small-scale experimentation (not in the formal scientific sense of the term, but in the sense of an attempt to innovate, learn or gain experience) is currently used to 'feel' the way forward. A more effective approach might be to view transition from a business perspective and use benefits and value as the drivers by which to steer progress.

This paper reports on research that Pipebots has carried out to identify the broadest set of benefit- and value-generating opportunities for the business of infrastructure asset management, with a view to using this as the basis for business model creation in subsequent research, looking at more specific businesses such as that of a pipework maintenance contractor. The paper begins with a section providing further background on complexity in infrastructure systems and the water industry, in particular hard and soft systems and business models and business cases. This is followed by a literature review on infrastructure transitions and value, which highlights shortcomings in the way that the issue of value is dealt with. The methodology for identifying potential opportunities to generate benefits and value, developed on the earlier EPSRC-funded Infrastructure Business Models, Valuation and Innovation for Local Delivery (iBUILD) project (EPSRC, 2013), is presented along with the results of applying the methodology to the business of infrastructure asset management. Finally, the results of the research are discussed, and conclusions are drawn.

Background

The UK water industry is a complex system with a web of connections, as shown in Figure 1. This shows the demand and supply sides of the industry and alludes to the collaboration required to deliver drinking water and dispose of sewage. The water industry supply chain provides a highly dynamic environment in which research findings and innovative developments in technology and asset-management processes are mediated to deliver service improvements (Nolf and Oregui, 2021). Although not shown in the diagram, governance plays important part with controls imposed through legislation on issues such as the regulatory process (Defra, 2017) and regulatory requirements for environmental sustainability, improved efficiency, standards of service delivery and innovation (Ofwat, 2017).

Figure 1. Multi-tier supply chain and collaboration processes (adapted from Nolf and Oregui, 2021)

The system complexity can usefully be visualised as having hard and soft components, which need to be considered in different ways, but which ultimately must be brought together if the overall system is to function properly. Hard system aspects, such as the development of technology-focused operational concepts mentioned in the section headed 'Introduction', are complicated and can generally be addressed using systems engineering techniques. Figure 2 shows the so-called V diagram, which sets out the main steps in the systems engineering process. Although the steps are shown sequentially, the whole process is highly iterative. The diagram is read from left to right and starts with an understanding of what the system of interest is (in the case of this paper, the introduction of RAS technologies), the environment in which it will operate (pipe network asset management in the water industry) and the elicitation of the user requirements of the system. This is followed by development of the operational concept of the system, which is a general picture of what the system will look like and what it will do – a highly creative activity involving the whole project team. The next phase is the identification of system requirements: the things that the system will do in order to deliver the user requirements. The outline and detailed design of components and software is carried out, after which, on the right-hand side of the diagram, the components and software are assembled and tested to make sure that the system satisfies the user requirements. It is worth noting at this point that in situations where supporting scientific knowledge is not already in place, development of potential operational concepts will be a powerful indicator of where future research efforts should be concentrated (Stevens et al., 1998). It must also be noted that more often than not, systems engineering has to take place in the context of an existing system in what is termed a 'middle-out' process. This is in contrast to the more familiar processes of 'top-down' and 'bottom-up' (Long and Scott, 2011: p. 13).

On the other hand, soft system aspects, such as governance and the development of policy and strategy, are complex and need to be addressed through an iterative learning process, similar to the one embodied in soft systems methodology (INCISM, 2001). The route to a business model for RAS technology cannot be construed as linear or sequential, with a very clear beginning and end. There is no optimal solution to be found, science and technology do not stand still and neither do the requirements of society, government, infrastructure and market regulators and asset managers. Development of RAS technology requires, therefore, an iterative learning process, and businesses operating in the water sector must continually refresh their perspectives and look for new solutions in response to the changing environment in which they operate. This process is embodied in soft systems engineering and is shown in Figure 3 for asset management of buried pipe networks. The process starts in the top left of the diagram with the identification of the situation, or situations, of concern – in this case the application of RAS technology to the UK water industry.

Figure 2. Systems engineering 'V' diagram (FHWA, 2021)

Figure 3. Soft systems methodology (adapted from Soft Systems Methodology in Action (Checkland and Scholes, 1999))

When considering this, it is important to remember that the current situation has not 'sprung out of thin air'. It is something that has developed over time, and this historical development trajectory will have some influence on how things develop going forward – so understanding the history is important. Having understood the situation of concern, the process moves on to develop possible transformation options in the form of potential business models. These are tested against the existing situation to determine whether they are systemically desirable and culturally feasible. If they are, the solution can be implemented, thus creating a new, real-world situation (Checkland and Scholes, 1999).

Successful combination of hard and soft system components is crucial to the formulation of compelling business models and business cases and requires development of systemically desirable and culturally feasible operational concepts for the RAS technology. An operational concept in this case is a description of the characteristics of a proposed system from the viewpoint of the firm that will use that system (SEBoK Authors, 2021a). Ideally, it will address the range of scenarios within which the technology is likely to operate. To support the creation of strong business models, operational concepts must also consider what value the application of Pipebots technology can deliver. A simple visualisation of a business model is shown in Figure 4. At the centre of the diagram, and core to the development of the business model, is the value proposition: the activity or activities that will generate benefits and value. To the left of the value proposition are the key activities and resources involved. Also to the left are key partners in the supply chain. To the right of the value proposition, there are customer segments (the different types of customers requiring different types of services), the relationships with those customers and the channels through which services are supplied. At the bottom of the diagram, there is the cost of delivering the service, and revenue, which is determined by price and sales.

Figure 4. Business model canvas, from Osterwalder and Pigneur (2010)

To remain competitive, businesses must continually review and change their business models in light of market conditions and technological developments. Business models are narratives explaining how value will be created and captured (Magretta, 2002), whereas business cases are the arguments that companies make internally for the investment required to support the business models (LDOCE, 2021). The business models and business cases of both contractors and clients are, therefore, tightly interlinked, and this linkage extends beyond the business sphere to include various forms of government, and by extension society more widely, as shown in Figure 5. The diagram shows three principal stakeholders of the water industry: contractors, water companies and those responsible for governance, in this case the UK government. Each of them has its own narrative around value generation and capture (business model) and makes its own business cases to support change. Moreover, the diagram suggests that the issues driving the business model review process and the creation of business cases are the 'messaging' that flows between the stakeholders – for example, water companies making it clear to contractors the needs that they have now and can foresee in the future. It follows that this message flow is critical to the effective uptake of RAS technology.

Figure 5. Diagram showing business models and business cases of water industry stakeholders and examples of the 'messaging' between them that drives change

The influence of governance on the development of RAS technology has already been alluded to in the discussion of Figure 1. Developments in asset-management technology offer increasing levels of automation and functionality. The integration of these into existing systems should be considered throughout the development process to ensure that early adoption does not prove to be abortive spend for the client. Multilevel perspective (MLP) studies have been carried out by others investigating how infrastructure systems change over time and what might support or hinder societal acceptance and adoption (Bulkeley and Castán Broto, 2013). Similarly, as RAS technology develops through the technical stages, it will encounter different layers of governance, including standards, ethics and principles at the level of the firm; the regulatory regime of the water industry itself; and the law, justice principles and policies of the UK. The operational concepts and scenarios mentioned earlier will, therefore, have different governance drivers and influences.

The literature search in the next section looks in detail at MLP analysis of complex sociotechnical systems such as the UK water industry. It explores whether MLP is a suitable platform for the creation of business models or whether a more value-centred approach is required.

Literature review: infrastructure transitions and value

Sociotechnical systems, such as the UK water industry, are systems that include a combination of technical and human or natural elements (SEBoK Authors, 2021b). Therefore, they comprise not only physical artefacts and technologies, but also '… the actors involved in providing and using the services, institutional rules, and norms for operating the systems, cultural values and the economic resources to construct and maintain them' (Moss, 2014: p. 1434). Acting together, these create, stabilise and sustain sociotechnical configurations that can be resistant to the sort of radical change that might be prompted by the emergence of new technologies such as RAS.

Research by others has highlighted the ability of sociotechnical systems to evolve over the long term – for example, the evolution over a period of 50 years of the electricity supply industry from a plethora of small, independent generators and local supply networks to larger-scale integrated systems (Hughes, 1983). The UK water industry has gone through a similar evolution.

Things are more complex when the aim is to achieve a desirable system reconfiguration over a much shorter timescale. Research has turned its attention to analysing this situation from an MLP, which

'… conceptualises change as the result of interaction between three levels: technological niches at the micro level, socio-technical regimes at the meso level and landscapes – or exogenous factors, such as governance – at the macro level' (Moss, 2014: p. 1436). Within that context, Hodson et al. (2017: p. 1) state that '… transitions are not about technological or social innovation per se, but about how multiple innovations are experimented with, combined, and reconfigured in existing urban contexts and how such processes are governed'. Similarly, Grabowski et al. (2017) stress the need to overcome siloed decision-making processes around a single infrastructure and to take a wider view that acknowledges the inherently political nature of infrastructure systems. This requires '… embracing the added intellectual challenge of understanding how social perception and values frame the parameters of desirable infrastructure development' and '… highlighting the broad and cross-sectoral role infrastructure decision-making plays in escaping unsustainable development trajectories, as well as its potential to alleviate inequality in income and access to economic opportunity' (Grabowski et al. 2017: p. 02517002-2).

While applying MLP to analyse the transition process is enlightening in itself, it does not provide a sure pathway to a desired new paradigm. Hodson et al. (2017) note that those seeking to engineer infrastructure transitions have adopted 'innovation experiment' as a possible solution, but that still leaves the need for some way of steering those experiments towards the desired goal. There is a suggestion in the literature that the generation and capture of value could fill that gap. Moss (2014) notes the importance of cultural values in sociotechnical systems, and Wolfram (2018: p. 13) states that a strong civil society requires '… articulation of value orientations and social needs that may drive grassroots activity …'.

The generation and capture of benefits and value in the UK water industry is complicated by the fact that it occurs in a multistakeholder environment that includes water companies, equipment manufacturers, maintenance contractors, construction companies and business, retail, and domestic consumers, as well as wider society. Each of these stakeholders is likely to have a different concept of value system, based on their assumptions about value. The social science literature describes value systems as ordering and prioritising the ethical and ideological values that an individual or society holds (Macedo and Camarinho-Matos, 2008). The business literature, on the other hand, talks about value systems as being the links between firms and their suppliers, distribution channels and the end user customers of the firm (Porter, 1985). Either way, it suggests that the identification and characterisation of value systems has an important part to play in the stakeholder collaboration required to deliver conflict free radical change in sociotechnical systems (Halis et al., 2007).

This paper approaches adoption of RAS technology from a business point of view, and it seems fair, therefore, to concentrate here on the generation and capture of value and benefits from a business perspective. Value is often referred to in conjunction with cost and price. Cost is the amount spent on production, while the price is the financial reward that a company receives for its work. Value, on the other hand, is seemingly less tangible, being what the customer believes a product or service is worth to them (nibusinessinfo.co.uk, 2021). While this definition is useful, it is simplistic, because in economic terms, the business value of an investment is the net present value of the after-tax cash flows associated with that investment or, in other words, linking the potential benefits of an investment through to price and the revenue received as a result. This means that while an investment may lead to a wide range of business benefits such as improved agility, responsiveness, customer intimacy, information sharing, flexibility and collaboration, under the strict economic definition, there can be no business value associated with them unless the benefits achieved result in increased after-tax cash flows (Williams and Williams, 2003).

Despite recognition of the importance of value in business decision making, ‘little has been written in the business strategy literature on when, why and how value accrues, and what value to create, and what constitutes a well-defined product concept from a value perspective’ (Brock Smith and Colgate, 2007: p. 7). While opportunity recognition and exploitation have been considered definitive concepts in both new product development and entrepreneurship (Cooper, 2001; Shane and Venkataraman, 2000), researchers have paid relatively little attention to the opportunity recognition process (Ucbasaran et al., 2001), or to tools to assist with that (Gaglio, 1997). It is difficult to assess accurately the value of a product at a particular point in time, but the suggestion is that it is possible to understand ‘the categories or dimensions on which such assessments are made and to create a customer value framework that captures the domain construct’ (Brock Smith and Colgate, 2007: p. 8).

In summary then, value is an important consideration in sociotechnical system change but does not appear to be used to any great extent to ensure that change heads in the desired direction. At the same time, multi-stakeholder enterprises are likely to involve a range of value conceptualisations, thus complicating any change process. A process for identification and characterisation of value systems has, therefore, an important part to play in the creation of business models required to deliver conflict-free radical change in sociotechnical systems. As a first step towards this, the following section describes an objective and repeatable methodology for the identification of potential benefit and value-generating opportunities as applied to the business of infrastructure asset management.

Methodology

The aim was to identify as wide a range of potential benefit- and value-generating opportunities as possible arising from the business of infrastructure asset management. The methodology adopted was developed on the earlier EPSRC-funded iBUILD project (EPSRC, 2013) and based on research by Morris et al. (2005) into the creation of a unified approach to business model formulation. The methodology has been employed previously to assist in the development of business models for smart infrastructure in the context of a business described as an ‘energy centre’ and reported in the paper by Bouch et al. (2018). The methodology was used here, however, to identify opportunities for subsequent use in the development of business models. Bouch et al. (2018) describe application of the methodology, but in summary, the process starts with the 12 principal business model components identified by Morris et al. (2005): economic, market, strategy, technical, governance, social, culture, environmental, competition, reputation, resilience and intellectual curiosity. The web is then searched for publicly available documents (‘state-of-the-art’ reports and consultancy documents offering a ‘real-world’ perspective, rather than academic documents) using the following research terms:

“Infrastructure asset management” “opportunity” “economic” .pdf

“Infrastructure asset management” “opportunity” “market”.pdf

“Infrastructure asset management” “opportunity” “strategy”.pdf

“Infrastructure asset management” “opportunity” “reputation”.pdf

“Infrastructure asset management” “opportunity” “technical”.pdf

“Infrastructure asset management” “opportunity” “governance” .pdf

“Infrastructure asset management” “opportunity” “social” .pdf

“Infrastructure asset management” “opportunity” “culture”.pdf

“Infrastructure asset management” “opportunity” “environmental” .pdf

“Infrastructure asset management” “opportunity” “competition” .pdf

“Infrastructure asset management” “opportunity” “reputation”.pdf

“Infrastructure asset management” “opportunity” “resilience”.pdf

“Infrastructure asset management” “opportunity” “intellectual curiosity” .pdf

The documents arising from each search are reviewed by the researchers involved who, based on their knowledge of innovation and business in the water industry, select those regarded as most relevant; approximately five to ten documents per search term. These documents are then searched for the word ‘value’ to identify potential benefit/value opportunities. The opportunities found are presented in the spider diagram of Figure 6. At the centre is the business of infrastructure asset management. The grey boxes show the principal components of the business model, and the branches are the opportunities. A small circle at the end of a branch indicates further branching and more opportunities, which had to be left off the diagram in order to keep it legible, but which exist in the (large and extensive) master diagram that provides comprehensive coverage. The example arrows linking opportunities are intended to indicate potential links between opportunities that could contribute to business model creation. Every factor appearing in the spider diagram then needs to be analysed quantitatively and/or qualitatively from the perspective of the business being considered (e.g. asset management in the water industry), to determine its benefit or value contribution in the context of the proposed change (e.g. the introduction of RAS technology) to the infrastructure asset-management system.

Figure 6. Spider diagram showing potential benefit- and value-generating opportunities.

Different analyses are then possible at a more specific business level (e.g. a water industry pipework asset-management contractor) based on current asset-management practices and on novel or transformative practices, such as the introduction of RAS technology along with an associated set of operational concepts (EPSRC, 2019). Indeed, different forms of RAS technology and/ or different operational concepts can, and should, be analysed in this way since they will result in different sets of impacts and therefore different forms of multiple value realisation – for example, better data collection and processing in support of proactive maintenance and reductions in reactive street works. Put another way, the introduction of RAS technology into water infrastructure asset-management practices is an intervention in the system of systems represented in Figure 6: engineering iteration of the intervention to bring about the most effective solution to a problem is a standard engineering approach. One complex feature of this process is that there are many different stakeholders and each will identify with a different set of values or benefits – there are multiple benefits or forms of value, but the conundrum of ‘who pays and who benefits?’ arises here.

Discussion

The research in this paper has been based on the assertion that water industry stakeholders will not adopt new RAS technologies unless compelling business models are made that show that the benefits and value created will accrue directly to them. The literature indicates that driving through radical change in sociotechnical systems is so difficult that system stakeholders resort to experimenting in ways that may be regarded as unscientific to see what works. However, experimentation of this sort is not possible in the safety-critical, highly regulated and politically sensitive water sector. The literature also indicates that benefits and value are important considerations in deciding what works, but that little research has been done to explore how benefits and value in the context of business cases and business models can help to facilitate and steer radical change.

This research has further developed and refined a methodology to identify a wide range of benefit- and value-generating opportunities that could form the basis for business model formulation. Opportunities have been identified in the context of infrastructure asset management as the business of interest. The aim of adopting such a high-level business was to identify as wide a range of benefit- and value-generating opportunities as possible. In the UK, however, there is no single business encompassing management of all of the nation's infrastructure assets, so business models will be developed at a lower level involving the water companies or other stakeholders in the supply chain. The business models will be formulated in the context of those companies and operational concepts yet to be determined, and it is likely that only some of the full set of benefit/value opportunities identified in the research will apply. The ability to apply these benefits and values may also be influenced by the governance structure that is in place. The ultimate aim, however, is to build business models that seek to maximise benefit and value capture. This will involve opportunities that might normally be considered to lie outside the interests of a specific firm. The issue will be how to capture benefits and value in those circumstances and, in particular, how to convert benefits into value. It may be that this can be done in the context of the outcome delivery incentives of the water industry or the supply chain acting together, or it may be that stakeholders have to join together in quasi-companies, or companies are compelled to deliver a wider set of benefits by being subjected to the formal levers of governance such as legislation or regulation.

It is possible here, however, without selecting a specific generic company and operating concept, to demonstrate the analysis of benefit- and value-generating opportunities in the context of infrastructure asset management, looking at opportunities identified under the heading of environment (environmental components of the Pipebots business model) as shown in Figure 7, which shows the full set of benefit and value opportunities identified. Looking at each of the opportunities in turn, the following points can be made.

Figure 7. Benefit/value-generating opportunity map for infrastructure asset management – environment

■ Resource recovery and cyclic economies. This is judged likely to be a significant feature in the alternative business models building on revised asset-management practices involving RAS technology. However, it will require considerable further research and deeper analysis.

■ Low carbon dioxide (CO_2) and reduction of carbon dioxide emissions (decarbonisation). This is judged likely to be a highly important element in the business models for RAS technology. The UK has set ambitious targets to decarbonise and move to net zero, while the water industry specifically has set a more pressing date for reaching net zero with pressure applied to the supply chain to help achieve this target. The legislation that supports this refers to a far future date, but it is widely appreciated that action needs to take place immediately if these targets are to be achieved in the long term. It is anticipated that this will involve regulations being altered to mandate companies to adopt plans to make the move towards net zero. In such a scenario, asset-management procedures would come under scrutiny and the use of trenching for repair, maintenance and upgrading of buried infrastructure would likely be either prohibited or become 'prohibitively expensive' (perhaps in terms of using up the carbon dioxide budget of a water company). RAS technologies would, therefore, provide an attractive alternative. Regardless of a change in regulation, companies are

Infrastructure Asset Management Robotic autonomous asset management: actively considering their options for decarbonisation, and RAS would, therefore, be one means of helping to deliver on this aspiration. Deeper scrutiny of legislation and regulation is required.

■ Effluent mining. This is a possible opportunity for RAS, but the better solution is to reduce effluent production as much as possible.

■ ESG and rebranding. ESG refers to environmental, social and corporate governance, the three central factors in measuring the sustainability and social impact of an investment in a company or business. A RAS approach that results in more sustainable infrastructure asset-management techniques can be presented as a positive contribution to the brand, ethics and ESG credentials of a company and an opening for new marketing initiatives.

■ Linked outcomes. RAS can help in delivering across a number of the UK government's desired outcomes where there are obvious links – for example, support for trenchless technologies contributing positively to desired outcomes of reduced traffic congestion, reduced greenhouse gas emissions and cleaner air in cities.

■ Centralised control. RAS offers the opportunity to gather a comprehensive set of data on pipe network condition that can be used in a centralised infrastructure asset-management control function or contribute to the development of a digital twin of the system, to improve efficiency.

■ Ecosystem services and their management. This requires further research and consideration, but this will undoubtedly feature in the business models for Pipebots since the repair, maintenance and upgrading processes will interrupt, at best, and perhaps permanently affect the provision of ecosystem services to people and society.

■ Total economic value. This is the linking of all these opportunities to maximise benefit and value generation and capture and will require further collaborative discussion among the various stakeholders.

Conclusions

The research has shown value to be an important and complex consideration when seeking to drive change in sociotechnical systems such as the water industry. Based on the assertion that radical change in sociotechnical systems is unlikely to take place unless stakeholders can see value accruing to them, the research has demonstrated use of a novel methodology to identify benefit- and value-generating opportunities that could be used to help steer radical change through business model development. It should be noted that the translation of benefits to value is not trivial and that further research is required on this. The set of opportunities has been created for the generic business of infrastructure asset management based on the following key business case components: economic, market, strategy, technical, governance, social, culture, environmental, competition, reputation, resilience and intellectual curiosity. The opportunities for the 'environmental' component of the business case have been explored in detail to illustrate how they might contribute to a business model. This foundational methodology can now be applied to specific systems interventions such as RAS and its operational concepts, to reveal the opportunities for benefit/value realisation as part of an exploration of business model formulation. Rather than a comprehensive articulation of the potential benefits, business models can be formulated for specific businesses, such as a pipework maintenance contractor. The aim, however, is for business models to capture value outside what might be regarded as the immediate confines of that business. Therefore, further research is required to explore how stakeholders in the water industry supply chain, businesses that interface with it, those who govern it (regulators, the government) and consumers (the users of the services that the pipe networks facilitate) can work together to create a shared business concept and the business case to support change. One crucial point to note in this is that the consumer is the same individual who is disrupted by (unnecessary) street works to repair failed pipes, who has to pay for the costs of earlier maintenance to roads and other buried infrastructure because they have been damaged by trenching, whose planet has been further harmed because of unnecessary carbon dioxide emissions, whose air quality has been further compromised by idling traffic queueing to get past street works and indeed suffers the other myriad indirect economic, social and environmental costs of trenching work that could be avoided by the introduction of new RAS technologies. An important factor in that endeavour, of course, will be for the stakeholders to agree on operational concepts for the application of RAS technology – the alternative to traditional, and surely outdated, practices.

Acknowledgements
This work on business cases for RAS technology in the UK water industry's buried pipe network has been carried out under the Pipebots programme, which is funded by the UK Engineering and Physical Sciences Research Council (Grant Reference EP/S016813) and has been underpinned by findings from the iBuild programme (Grant Reference EP/K012398). The methods for formulation of business models and business cases are being advanced by the UK Collaboration for Research on Infrastructure and Cities through its Coordination Node (Grant Reference EP/R017727). The authors are grateful to Vitech Corporation, Blacksburg, VA, USA, for providing an academic licence for Core, their system-modelling tool, together with technical support. The authors are equally grateful for the help received from Dŵr Cymru Welsh Water.

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Figures

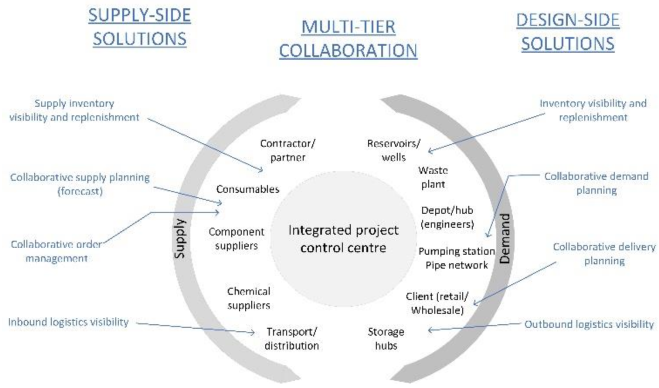

Figure 1. Multi-tier supply chain and collaboration processes (adapted from Nolf and Oregui, 2021)

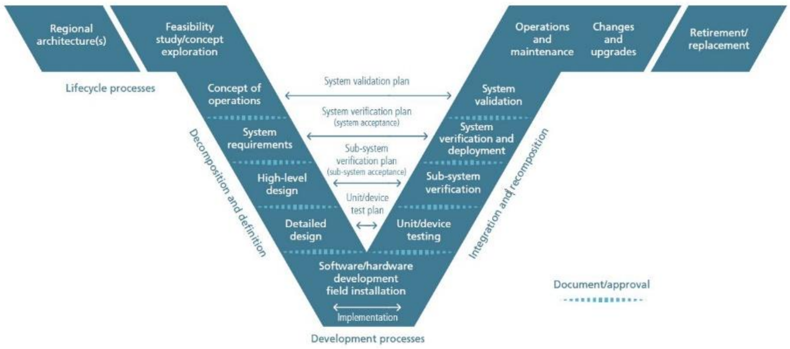

Figure 2. Systems engineering 'V' diagram (FHWA, 2021)

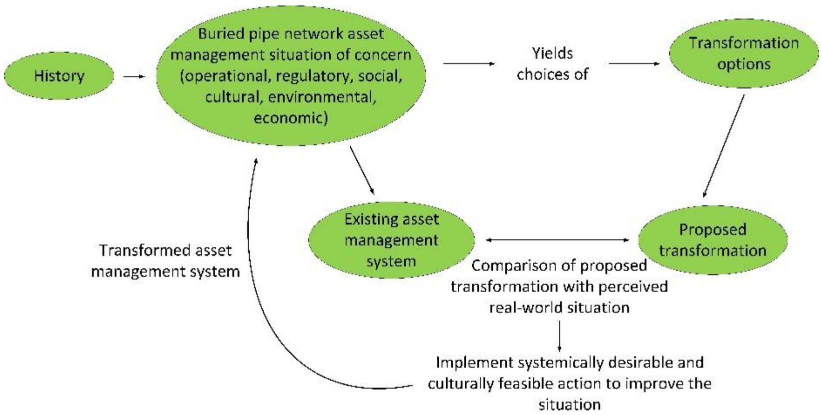

Figure 3. Soft systems methodology (adapted from Soft Systems Methodology in Action (Checkland and Scholes, 1999))

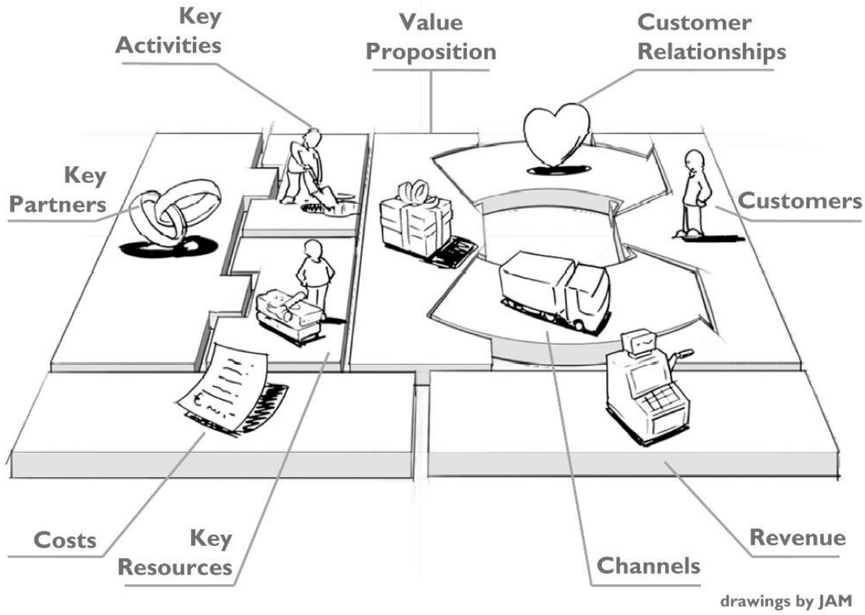

Figure 4. Business model canvas, from Osterwalder and Pigneur (2010)

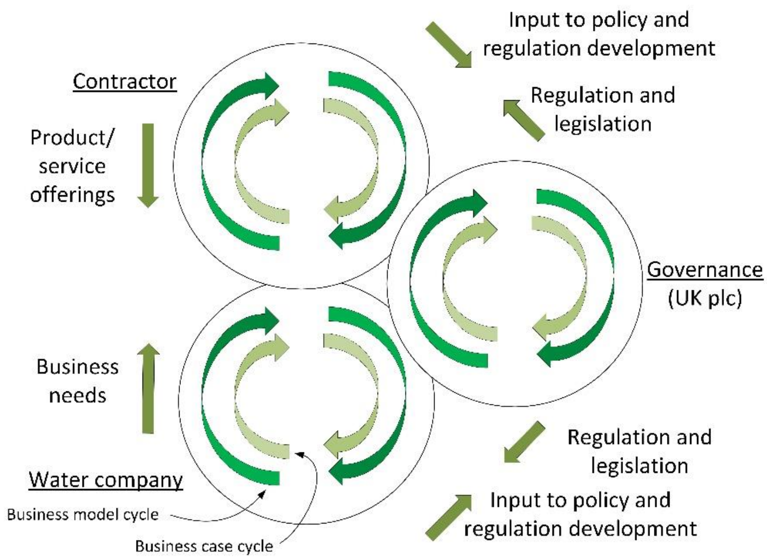

Figure 5. Diagram showing business models and business cases of water industry stakeholders and examples of the ‘messaging’ between them that drives change

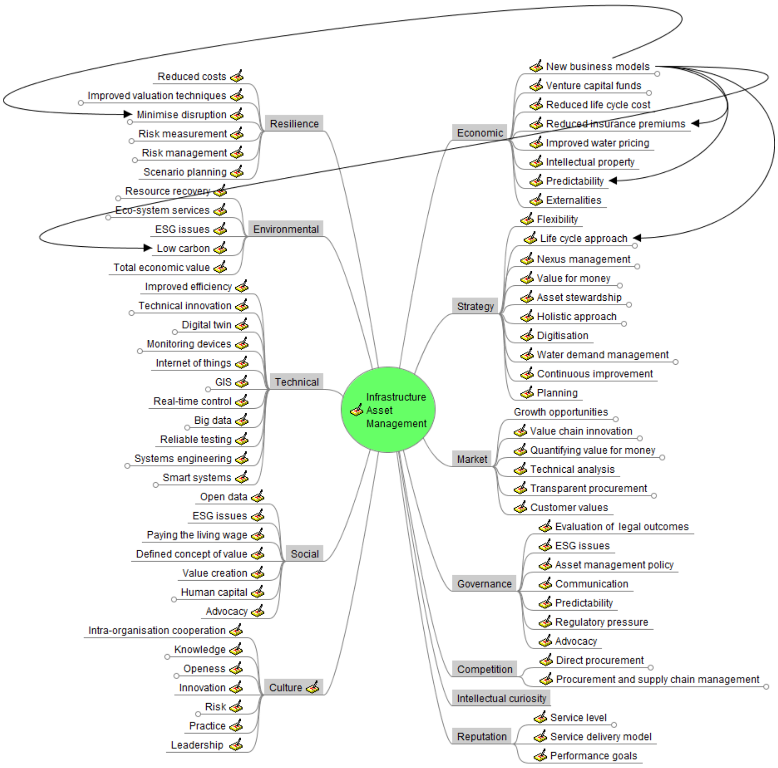

Figure 6. Spider diagram showing potential benefit- and value-generating opportunities

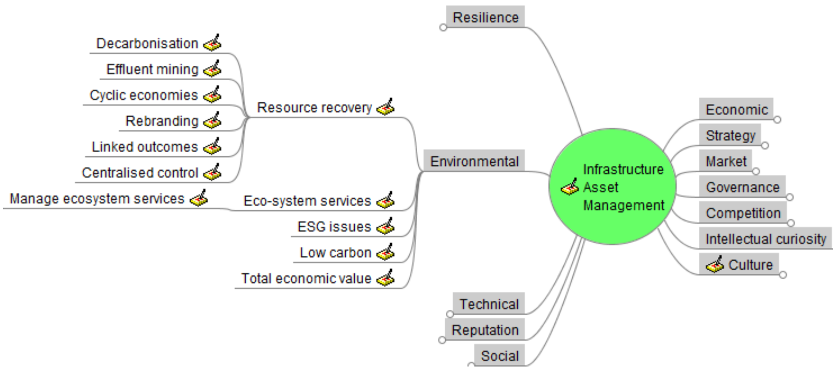

Figure 7. Benefit/value-generating opportunity map for infrastructure asset management – environment