Resilient and Sustainable Water Infrastructure: A Systematic Literature Review Protocol

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ABSTRACT

Background: Lifeline critical infrastructures are pivotal for the uninterrupted flow of goods and services that are crucial to the functioning of society (Singh, 2021). This review will be the second in a series of four systematic literature reviews examining the resilience and sustainability of critical lifeline infrastructures in Australia, with a focus on the state of Tasmania. The first SLR examined energy infrastructure. The recent passing of the 2021 Security Legislation Amendment (Critical Infrastructure) Bill in Australia, coupled with the lack of a governing document at the state level in Tasmania, necessitates a review to uncover the governance settings, which will aide in increasing the resilience and sustainability of water infrastructures, contributing to broader critical lifeline infrastructure resilience, in Tasmania.

Methods/Design: Following the 2015 PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols), the review focuses on scholarly sources that address the governance of water infrastructures. In addition to governance settings, secondary evidence is sought regarding interruptions to water infrastructures; policy problems and solutions; and resilience and sustainability definitions.

Discussion: Findings from this review will contribute to a comprehensive understanding of how the resilience and sustainability of water infrastructures may be enhanced via deeper knowledge of their governance settings. This research is directed at Tasmanian policy-makers, practitioners, industry specialists, and researchers to inform and enhance their decision-making on this important topic.

Keywords: Systematic literature review, resilience, sustainability, water, infrastructure

1. Background

The purpose of this article is to register a Systematic Literature Review (SLR). This review will be the second in a series of four SLRs examining the how governance settings can increase the resilience and sustainability of critical lifeline infrastructures (CLIs). The similarities between this protocol, and a previous protocol for energy infrastructures, and two proposed future SLR focussing on the communications and transport sectors, are purposeful. The similarities ensure that a number of important research outcomes occur. They ensure that the information sought, extracted, and analysed is undertaken to support the identification of

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http://dx.doi.org/10.7565/ssp.v5.6966

synergies across each infrastructure. These synergies include the governance settings that increase the resilience and sustainability of CLIs, the interconnectedness between and interdependencies across CLIs, and common problems, and solutions which CLIs have.

As such, this protocol is neither an update, nor an amendment, but a stand-alone review seeking to address the challenge of CLI resilience and sustainability, albeit from a different CLI perspective. The added value will be synthesising the results from each review on their completion.

Informed by the PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist (Moher et al., 2015), we identify water infrastructure as the topic to be examined. As with the previous SLR on energy infrastructures, this review also explores a range of exposure to outcome pathways, always beginning with water infrastructure, followed by identifying governance settings, the policy problem(s) identified, and the solution(s) provided. We initially investigate key themes within three domains: governance settings, resilience and sustainability, and policy problems and solutions.

We expect the inductive emergence of new themes and domains throughout the course of the review that will be documented as they emerge. As with the SLR on energy infrastructure, this review has the overarching goal of providing actionable research for policy-makers, practitioners, industry specialists, and researchers involved in critical infrastructure resilience.

With no universally agreed upon definition of what constitutes a critical infrastructure (CI) (Panda & Ramos, 2020), and with international agreements leaving it largely to national governments to determine their own definition (Panda & Ramos, 2020), the Australian Government lists ten CI: (1) Communications; (2) Financial Services and Markets; (3) Data Storage or Processing; (4) Defence Industry; (5) Higher Education and Research; (6) Energy; Food and Grocer; (7) Health Care and Medical; (8) Space Technology; (9) Transport (including aviation and maritime assets); and (10) Water and Sewerage (Department of Home Affairs, 2021). Within this list, there are four identifiable CLIs: (1) Energy; (2) Water; (3); Transport; and (4) Communication (Singh, 2021). It is clear that international agreements seek to engage their signatories in devising plans that increase the resilience and sustainability of their CIs, chief among these agreements are the 2015 Sendai Framework for Disaster Risk Reduction and the 2015 Sustainable Development Goals (Panda & Ramos, 2020).

Definitional ambiguity aside, the problems associated with increasing the resilience and sustainability of CLIs are further compounded by the multitude of risks involved in their day-to-day operation. With the average person only able to survive three days without water, water infrastructure has been a consistent target since 3000BC (Birkett, 2017). The expansion of the world population in the twentieth and twenty-first centuries, coupled with the increase in water supply chains, has further increased the vulnerability of water infrastructures to attack from both state and non-state actors (Birkett, 2017).

Water systems are now an assimilation of computational and physical capabilities in order to monitor physical processes, or a Cyber-Physical System (Tuptuk et al., 2021). Coupled with the emergence of the Internet of Things and Industrial Control Systems, the traditional isolated water system of the past is now known as the Industrial Internet of Things, or, contemporarily, as Industry 4.0 (Tuptuk et al., 2021). This new system is characterised by autonomous decentralised decision-making that aims to improve real time data and predictive analytics to promote greater reliability, efficiency, and productivity (Tuptuk et al., 2021). Due to the above transformation, water infrastructures are now increasingly more vulnerable to cyber-attack. Hassanzadeh et al. (2020) highlight that in 2015, in the United States, twenty-five Water and Wastewater Sector infrastructures were the target of cyber-attack. In 2015 this made the Water and Wastewater Sector the third most targeted sector in the United States. The interconnectedness across, and interdependencies between, CIs also impact their resilience and sustainability. This is evident when looking at flood, waste, and drinking infrastructures.

As identified in our previous SLR protocol for Energy infrastructures, CIs are akin to the arteries and veins of humans, without which it would be impossible to function (Newlove-Eriksson et al., 2018) As such, CLIs like those identified by the Australian Government are labelled as critical. Water is a CLI for a number of reasons. After air, it is generally agreed that water is the most valuable commodity that humans require to survive (Cohen, 2010). Not only this, but water is a key element in the removal of waste treatment, as well as the separation of both waste and drinking water, without which humans would be subject to waterborne disease (Birkett, 2017). Additionally, water infrastructure also serves to manage flood water. As an essential life sustaining element, the continuous functioning of water infrastructures is essential to the social and economic well-being of Australians. According to the Australian Government, water is the nation's lifeblood, and is essential to the resilience and success of the nation (Australian Government, 2020). It is therefore in Australia's national interest that its water infrastructures are protected from both cyber and physical attacks.

As an assimilation of computational and physical capabilities (Tuptuk et al., 2021), water systems are prone to cyber-attack. According to an audit report by the Queensland Audit Office, a state water supplier owned by the Australian Government suffered a cyber breach between the months of August 2020 and May 2021(Queensland Government, 2021). The report states that the attackers targeted the web server, an older and more vulnerable part of the system, which stores customers' information. It did not result in lost customer or financial information, however, there were suspicious files found that increased visitor traffic to an online video platform (Queensland Government, 2021). According to the audit, this organisation responded to the breach by implementing measures including updating software stronger password protocols and monitoring incoming and outgoing network traffic (Queensland Government, 2021). This was not the first time that the cyber vulnerabilities of Australian water infrastructures were highlighted. As recently as 2017 the Queensland Audit Office noted security concerns of water systems. They pinpointed the age of control systems, coupled with the incorporation of corporate networks, led to an increase in vulnerability that was not identified by entities (Queensland Government, 2017). The audit further pointed out that entities were not prepared to respond adequately to cyber-attacks, summarising that 'they had not planned or tested their response and recovery from a malicious or cyber incident' (Queensland Government, 2017). It recommended that entities need to strengthen their information technology networks, tighten their physical security, and better manage user access to systems (Queensland Government, 2017).

Aligned to our review on energy infrastructures, these challenges warrant a SLR to collect, synthesise, and map exiting scholarly evidence about the effects of different governance settings on the resilience and sustainability of water infrastructures. A SLR will identify synergies for improvement as well as potential gaps where further research can be conducted. For rigour and continuity, and as performed with the previous review on energy, the review will concentrate on three major tasks. Firstly, it will search through databases for scholarly evidence to address the research question. Secondly, it will determine the definitions offered for resilience and sustainability within the context of water infrastructures with the aim of providing a workable definition for this study. Thirdly, the review will provide an evaluation of the quality of the included studies for the review. From this, a governance framework will be developed to enhance the governance of resilient and sustainable water infrastructures in the state of Tasmania and more broadly. A governance framework will aid in addressing the resilience and sustainability of water infrastructures by operationalising scholarly definitions of resilience and sustainability. Furthermore, it will increase governance cadence and contextual understanding within the water sector.

2. Methods/Design

2.1 Protocol design

The methodological approach of this review is known as a SLR. A SLR allows for the identification of the current literature (Piper, 2013). SLRs are a method of understanding and interoperating large knowledge bodies, which seeks to answer questions regarding what works, and what does not, and are helpful in mapping areas of uncertainty and of tracking down areas where little research has been conducted (Petticrew & Roberts, 2008). Policy-relevant systematic reviews aim to clearly deliver findings in order to highlight policy issues and challenges, and/or to develop policy theories (Oliver et al., 2018). Policy decision-making, informed by evidence, requires policy-makers to use reviews, and researchers to publish them. The capacity to achieve this needs to be matched with the relevance and timeliness of evidence to inform policy problems (Oliver et al., 2018).

2.2 Research question

The research question that this review seeks to answer is:

Q1: How can governance approaches enhance the resilience and sustainability of water infrastructures?

2.3 Eligibility criteria

This review will include peer reviewed articles and reviews only. This is in line with the aim of reviewing the scholarly material to answer the research question. The protocol may be updated at a later date to include grey literature if required. All studies with English abstracts will be screened in the Title-Abstract screening stage. The addition of full non-English studies, if they comply with the inclusion criteria, will be determined based on the financial cost of translation. There will be no time restrictions. Studies will have to refer to enhancing the resilience and sustainability of water infrastructures to be included. These infrastructures can be across three domains; flood, drinking, and waste-water infrastructure. Details of the strategy can be located in Table one.

2.4 Information sources

The Web of Science and Scopus databases are used for the search strategy. Daigneault et al. (2014) identifies that PhD candidates may struggle with the enormity of conducting a systematic literature review. It is with this is mind that we have limited the review to searching within two major databases only. While both Scopus and Web of Science are the largest and most comprehensive bibliographic databases (Pranckutė, 2021), we recognise that further databases may have to be added should this review be updated at a later date. Scopus and Web of Science provide the ability to conduct complex searches using their advanced search option. These searches can be performed by exact phrases, truncated words, or by employing wildcards (Pranckutė, 2021).

2.5 Search strategy

The reporting of the search strategy is in line with the update to the PRISMA methodology (Page et al., 2021). This update requires that the full strategies for every database searched within are produced. The full strategy can be seen below in Table one.

Table 1. Full search strategy.

Database	Stage	Area	Search string
Web of science	1.	TI	(resilien* AND sustainab*)
	2.	TI	(centrali* OR decentrali* OR "top down" OR "bott om up" OR "command and control" OR hierarch* OR grassroot* OR polycentric OR monocentric OR govern OR governs OR governed OR governance OR governin g)
	3.	TI	(water* OR hydro* OR wastewater OR stormwater OR flood* OR groundwater OR bore OR boring OR drink* OR rain* OR sewage OR sewer* OR effluent OR septic OR biosolid* OR “treatment plant” OR “pumping plant” OR reservoir* OR bund* OR weir* OR aquifer* OR aqueduct* OR cistern* OR river* OR stream* OR creek* OR pond OR pool OR dyke* OR seawall* OR “sea wall” OR “sea walls” OR breakwater* OR levee* OR groyne* OR bulwark* OR spur* OR delta* OR polder* OR dam* OR spillway OR runoff OR lake* OR delta OR canal* OR waterway* OR estuarine OR watercourse* OR catchment* OR drain* OR basin*)
	4.	AB	(resilien* AND sustainab*)
	5.	AB	(centrali* OR decentrali* OR "top down" OR "bott om up" OR "command and control" OR hierarch* OR grassroot* OR polycentric OR monocentric OR govern OR governs OR governed OR governance OR governin g)
	6.	AB	(water* OR hydro* OR wastewater OR stormwater OR flood* OR groundwater OR bore OR boring OR drink* OR rain* OR sewage OR sewer* OR effluent OR septic OR biosolid* OR “treatment plant” OR “pumping plant” OR reservoir* OR bund* OR weir* OR aquifer* OR aqueduct* OR cistern* OR river* OR stream* OR creek* OR pond OR pool OR dyke* OR seawall* OR “sea wall” OR “sea walls” OR breakwater* OR levee* OR groyne* OR bulwark* OR spur* OR delta* OR polder* OR dam* OR spillway OR runoff OR lake* OR delta OR canal* OR

			waterway* OR estuarine OR watercourse* OR catchment* OR drain* OR basin*)
	7.	Combine #1 AND #2 AND #3 AND #4 AND #5 AND #6	
	8.	Refine by Articles and Reviews Only	
Scopus	1.	TITLE-ABS	(resilien* AND sustainab*)
	2.	TITLE-ABS	(centrali* OR decentrali* OR "top down" OR "bott om up" OR "command and control" OR hierarch* OR grassroot* OR polycentric OR monocentric OR govern OR governs OR governed OR governance OR governin g)
	3.	TITLE-ABS	(water* OR hydro* OR wastewater OR stormwater OR flood* OR groundwater OR bore OR boring OR drink* OR rain* OR sewage OR sewer* OR effluent OR septic OR biosolid* OR “treatment plant” OR “pumping plant” OR reservoir* OR bund* OR weir* OR aquifer* OR aqueduct* OR cistern* OR river* OR stream* OR creek* OR pond OR pool OR dyke* OR seawall* OR “sea wall” OR “sea walls” OR breakwater* OR levee* OR groyne* OR bulwark* OR spur* OR delta* OR polder* OR dam* OR spillway OR runoff OR lake* OR delta OR canal* OR waterway* OR estuarine OR watercourse* OR catchment* OR drain* OR basin*)
	4.	Combine #1 AND #2 AND #3	
	5.	Refine by Articles	

		and Review	

2.6 Data management and selection process

The data will be managed with the reference management software Endnote. Results will then be exported to the software Covidence for screening and data extraction. All data will be managed and stored according to the University of Tasmania's 2019 Management of Research Data Procedure.

One researcher will conduct title and abstract screening in accordance with the eligibility criteria. However, two 5% pilot screening studies will be conducted between three researchers and inter-rater reliability will be determined using Fleiss' Kappa. Upon reaching 80% inter-rater reliability, the single researcher will begin screening. Kappa coefficients are interpreted using the guidelines outlined by Landis and Koch (1977), where strength of the Kappa coefficients is interpreted in the following manner: 0.01-0.20 slight; 0.21-0.40 fair; 0.41-0.60 moderate; 0.61-0.80 substantial; 0.81-1.00 almost perfect. The two other researchers conducting the pilot study will have no less than three years' research experience.

A random article generator has been developed in Microsoft Excel to remove bias from the pilot screening process. Discrepancies in the screening process will be resolved between the three screeners for clarity, and to ensure consistency.

2.7 Data extraction

Data extraction will be conducted in Covidence according to a pre-designed data extraction template. The data template in Covidence can be amended during title/abstract screening, full readings, and any time during data extraction (Covidence, 2021). If new themes are identified, the template can be updated to capture them. Studies that have already been extracted will go through extraction again, but only to search for the newly identified theme. This allows for new themes to emerge. The initial data extraction table can be seen below in Table two.

Table 2. Initial data extraction template.

Data item	**Information sought**	**Options**
1.	Country where study is located?	Australia; China; USA; UK; Germany; Other
2.	Methods used	Qualitative; Quantitative; Mixed
3.	Are study funding sources declared?	Yes; No
4.	Are conflicts of interest declared?	Yes; No
5.	Are infrastructures other than Water discussed?	Yes; No

6.	If so, which ones?	Water; Energy; Transport; Communication, Health, Food and Grocery; Space, Defence, Banking and Finance, Data and the Cloud; Other
7.	How is infrastructure referred?	interconnected; interdependent; coupled, linked, joined, interacting; Not referred to; other
8.	How is infrastructure disrupted?	Fire; Flood; Earthquake; Hurricane; Tsunami; War; Terrorism; Cyber; Drought; Other
9.	Is resilience defined?	Yes; No
10.	If so, how?	Author, year
11.	Is there more than one definition used?	Yes; No
12.	Who By?	Author, year
13.	Is sustainability defined?	Yes; No
14.	Who By?	Author, year
15.	Is there a policy problem identified?	Climate change; infrastructure age; urbanisation; globalisation; extreme events; Capitalism/neoliberalism; terrorism
16.	Other?	Yes; No
17.	What is it?	
18.	More than one?	Yes; No
19.	Which?	
20.	Is there a solution offered?	Yes; No
21.	What is it?	
22.	Is solution specifically tied to an international agreement?	Sendai Framework; Paris Agreement; Sustainable development Goals; Hyogo Framework Kyoto Protocol; Millennium Development Goals; Other
23.	Does solution emphasise collaborative or cooperative approaches?	Yes; No
24.	Are governance settings identified in solution?	Yes; No
25.	Which ones?	Centralised; decentralised; polycentric; monocentric; adaptive; transformative; collaborative; networked; hybrid; other

26.	Does the study refer to policy instruments to support solution?	Yes; No
27.	If yes, which ones?	Financial; legal; regulatory; mixed; other

2.8. Outcomes and priorities

The primary goal is to identify which governance settings best promote the resilience and sustainability of water infrastructures. In addition to this, there are a number of secondary outcomes for which information will be sought. They are:

1. How resilience is defined;
2. How sustainability is defined;
3. The disruption to infrastructure;
4. The "connectedness" of infrastructures;
5. The identification of policy problems and solutions;
6. Whether solutions align with international agreements, and;
7. The rate of collaborative or cooperative approaches offered in solutions.

2.9 Quality Assessment and Risk of Bias

Quality appraisal is a key component of evidence-based practice and decision-making (Rosella et al., 2016). The notion of quality is complex. It can be applied in a narrow-purpose/situation specific judgements or in a genetic manner (Gough, 2007). Therefore, it may be assessed against generic quality criteria, or against tighter purpose-bound criteria (Gough, 2007). This project will not exclude individual studies owing to the quality judgements made on them; they have been included in the review due to them passing the screening stage. However, it will provide a quality assessment summary.

Risk of bias in individual studies will be assessed using the Public Health Ontario Meta-tool for quality appraisal. The appraisal tool comprises four spheres: relevancy, reliability, validity, and applicability (Rosella et al., 2016). The tool is designed with transparency at the forefront. Each sphere provides space for long-form written answers for justification. This allows for contextual factors to be considered when capturing the strengths and weaknesses of items (Rosella et al., 2016).Publication bias has been reduced due to: (1) the broad spectrum search strategy employed; (2) the protocol for utilising dual databases (Scopus and Web of Science); (3) two rounds of pilot screening processes conducted by three experienced researchers; and (4) no set time limit for studies within the search; (5) the inclusion of non-English studies if they are relevant; and (6) by contacting authors if access to studies is impeded. Bias is impossible to avoid, however, we have listed the known biases as we understand them. An update of this research project could attend to the known biases we have listed. This would increase the rigor and value of the results. Additionally, twin screeners could be employed throughout the entire screening process. As with most research projects however, there is an expected timeframe and a finite budget to draw on. We believe we have adequately addressed the known biases evident in this research project.

2.10 Data analysis and presentation

Due to the anticipated heterogeneity of the included studies, a statistical analysis of the data may not be appropriate. However, subgroup analysis will be conducted on sources of homogeneity arising from dichotomous questions in the data extraction template. For qualitative outcomes, a thematic summary will be employed to report on eligible studies. This approach involves the identification followed by extraction of common themes from qualitative narratives. It allows the review to classify studies into appropriate thematic groups for the reader (Snilstveit et al., 2012). The discoveries from each thematic group are then examined and synthesised separately with interpretive narrative syntheses (Snilstveit et al., 2012). This approach will provide a format to better understand not only the governance settings that lead to more sustainable and resilient water infrastructures, but also capture the common and individual stressors and risks they face. The findings will then be summarised and reviewed for their consistency and to ensure they are appropriate regarding the investigation.

2.11 Confidence in cumulative evidence

We will use the Grading of Recommendations Assessment, Development and Evaluation - Confidence in Evidence from Reviews of Qualitative research (GRADE-CERQual) approach. This approach provides guidance on how to assess the level of confidence that should be placed in systematic reviews of qualitative research (Lewin et al., 2018). It has been created in order to aid the use of outcomes from qualitative evidence syntheses in decision-making, together with guidance on policy development and formulation (Lewin et al., 2018).

3. Discussion

This protocol has set out the conditions in which a systematic literature review will be conducted. As identified in the previous review, globally, CIs are facing threats and stressors that their designers did not consider. Governments worldwide are formulating and implementing policies to increase the resilience of their interdependent CI(s). Many of these policies are being formulated in tandem with policies aiming to reduce the effects of climate change. A systematic literature review will contribute to this knowledge by providing an evidence base for the governance systems and policies that increase the resilience and sustainability water infrastructure(s). This will be beneficial to policy-makers, disaster resilience practitioners, and the owners and operators of CLIs.

The limitations of this review include that it will suffer from selection bias as it is only including peer reviewed scholarly studies. Although a twin-pilot screening process will be used for inter-rater reliability and checked against Fleiss's Kappa, the study may be accused of further selection bias through the use of only one screener. In addition, there are other metrics with which to measure inter-rater reliability. Furthermore, and importantly, by limiting the databases used and omitting grey literature, we introduced research bias.

Following this review, we will submit protocols and commence systematic literature reviews on the remaining two CLIs: communication, and transport. The results from each CLI will then be combined so that synergies and common themes can be identified. With the recent passing of the amended Security of Critical Infrastructures (SOCI) act in the Australian Senate, and the State of Tasmania's absence of critical infrastructure protection legislation, this research will further inform the Tasmanian State Government as it develops its CI security agenda.

4. Conclusion

In this article, we have laid out a set of comprehensive conditions for the SLR to be undertaken. Should there be any deviations from this protocol throughout the course of the research project, we will document and report them to ensure that the process remains as rigorous and transparent as possible.

Declarations

Competing/ conflict of interests: The Authors report none.

Funding: This research was made possible through a Research Training Program Stipend provided by the Australian Federal Government and a top-up scholarship provided by Natural Hazards Research Australia. The Australian Federal Government and National Hazards Research Australia had no role in the design of the protocol or the writing of this manuscript.

Ethics approval and consent to participate: This is a systematic literature review protocol; therefore, ethical approval is not applicable.

Consent for publication: All authors have reviewed and consent to this publication.

Availability of data and material: There is currently no data available for this review.

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