# A systematic review of studies examining the relationship between resilience and physical asset management for water system

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**Abstract.** The resilience in the water system can produce great benefits; one of the ideal ways to achieve resilience is through asset management. The purpose of this study is to systematically review the literature that presents the relationship between asset management and resilience. We searched multiple databases such as Emerald Insight, Sage Publication, Science Direct, Scopus, Taylor and Francis, and Wiley Online Library ranging from the year 2000 until the year 2020. The papers are written in English. A total of 7845 articles have been successfully identified and only 6 papers met the inclusion criteria of the study. The study has concluded that most of the previous research that discusses asset management and resilience are in groups dating 5 years back (2015-2019). Several features of physical asset management require further investigation that can enhance the resilience of the water system. The topic is relatively new and hopes to open a huge gap for research.

## 1. Introduction

The ability of a system to bounce back to its normal state is called 'resilience'. The term 'resilience' may be interpreted differently from other subjects of study. However, the concept, in this context, shows how quickly the system can gain its normal condition is the baseline. The resilience system is greatly desired by the management; however, the asset management needs to figure out the factors on enhancing the resilience of the system [1]. The goal of the operators or asset management is to quickly remove the obstacles in the flow of supplication of water towards the consumers. The process of asset management is established in the moment of the architecture design planning to end of the disposal of assets. Asset management plays a vital role in the water infrastructure system by strengthening the system through resilience and sustainability. Additionally, the process of asset management is to plan the operation, maintenance, repair strategy, procurement planning, as well as to search sources of funding because the water infrastructure system uses a lot of money to run its operation. Not only, asset managers have to educate their staff on how to monitor the system as best as they can, but also to educate the community on the importance of taking care of the infrastructure in avoidance of issues such as vandalism (e.g. damage to the water pump, pipeline, or pollute the source of water). This shows that the process of asset management has a strong significance towards the resilience of the water system by organizing and planning the right program to ensure the demand of the population is continuously fulfilled [2]. The purpose of this study is to systematically review the literature that presents the relationship between asset management and resilience. The study of systematic review is focused on

attaining unbiased knowledge in the scope of the study. The study solely focuses on papers that discuss "resilience" and "asset management" in the water infrastructure sector. However, the term may be slightly different and will be explained in-depth in the methodology context.

## 2. Methods

The study follows Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [3] to synthesis the paper in the relationship of asset management and resilience in the water infrastructure system. The details are specifically written below:

### *2.1. Inclusion Criteria*

The collection of papers is limited only in the range from the year 2000 to the year 2020, and open access or full-text access is provided by the university. The selected papers contain keywords such as “resilience”, “asset management” and “water infrastructure system”. The inclusion criteria are listed in table 1. The Boolean phrase is as follows:

(Resilience OR System Resilience OR Durability OR Adaptability) AND (Asset Management OR physical Asset Management OR Infrastructure Asset Management OR Management OR Water Management) AND (water infrastructure system OR water supply system OR water distribution system OR wastewater system OR rainwater system)

OR

(Resilience OR System Resilience OR Adaptability) AND (Asset Management OR Physical Asset Management OR Infrastructure Asset Management) AND (water infrastructure system OR water supply system).

**Table1.** Search terms

| Resilience | Asset Management | Water System |
|---|---|---|
| Resilience | Asset Management | Water Infrastructure System |
| System resilience | Infrastructure Asset Management | Water Distribution System |
| Adaptability | Physical Asset Management | Water Supply System |
| Durability | Management | Wastewater system |

### *2.2. Strategy*

The papers were searched on databases such as Emerald Insight, Sage Publication, Science Direct, Scopus, Taylor and Francis, and Wiley Online Library. The search has identified a total of 7845 articles. The selected papers are written in English. The strategy began by inserting the criteria that have been identified as above. In the first round, we searched papers that meet the criteria following the title. The title must have at least, “Water”, “Resilience” and “Asset Management”. From this, 61 papers were shown to have relevance to the said title. Then, we studied the abstracts to make sure that papers were related to the keywords: “water system”, “resilience”, and “asset management”. In the end, 6 papers were found that discusses resilience and asset management in regards to water infrastructure systems.

## 3. Results

The result shown in figure 1 were generated from the data based on the approximately 7845 papers. In conclusion, only six publications have met the inclusion criteria for the research paper. The idea of exclusion of the papers throughout the flow is to ensure the papers must contain terms such as: “resilience”, “asset management”, and “water infrastructure system”. From this, we can analyse the relationship between asset management and resilience. Table 2 shows the summary of the final paper.

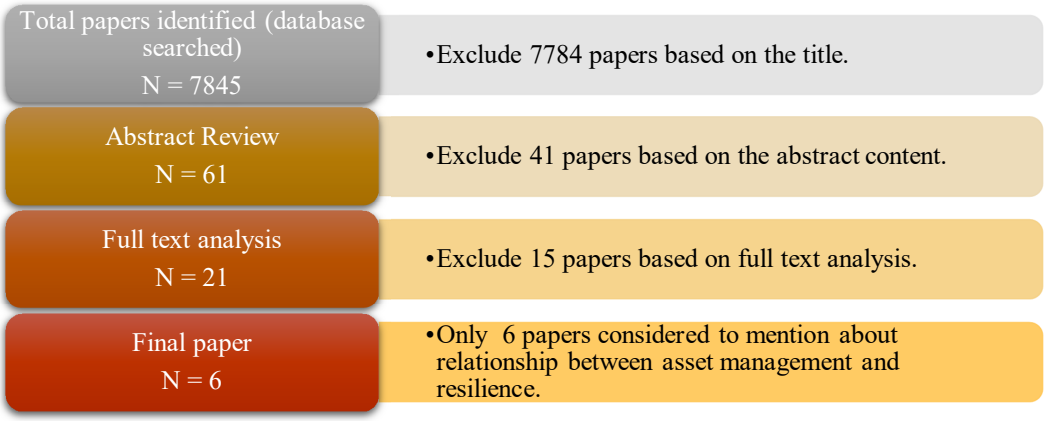


**Figure 1:** Flow chart of paper selection.

*3.1. Description of studies*

The selected papers that were used in this study are categorized into two parts which are: - research article and review article. These are the only studies that discuss resilience and asset management, particularly in water systems. Each paper has a different purpose for discussing resilience and asset management in water systems.

*3.1.1. Purpose of study*

The purpose of this study from each paper is different. [4] specifically develops an integrated resilience framework for multisector infrastructure asset management. Importantly, the example from the case study used in this paper is a water system in a case of an earthquake and how the system should follow the protocols of the framework to enhance its resilience. [5] investigates the relationship between awareness of energy recovery within the Municipal water distribution system and the lack of knowledge of the extent and location of such potential to enhance sustainability and resilience of the cities. [5] also develops an information elicitation and analytical framework of resilience infrastructure asset management. The difference between the studies in [4] and [6] is the investigation of the best infrastructure asset management practice in different countries and the development of a framework based on the qualitative approach. [5] discusses the utilization of asset management data to enhance resilience.

As for the review article category, [7] discusses various compilations of literature review of resilience and the current methods used in civil infrastructure systems for resilience performance. [8] argues regarding the asset management regulatory in a water system. They focus on the resilience asset management, but not on the resilience water system. The key to enhancing resilience asset management according to [7] would be in their policies and regulation, while [9] reviews the existing literature and current practices related to the assessment, retrofit, and repair of a water system. The difference between [7] and [9] where the studies were reviewed by [9] are specifically focusing on the buried pipeline water system.

*3.1.2. Methodology*

From the perspective of the 6 papers, all of the studies deploy several techniques of methodology to investigate resilience. Three of them [6], [7], and [9] rely on past research or literature to achieve their objectives of the research. These papers suggest the relationship between asset management and resilience is available in the water system. Another three studies focus on investigating frameworks to enhance the understanding between asset management and resilience in the water sector [5-6, 8] leverages asset management data to enhance resilience in the water system. The studies made by [6] and [7] uses interview analysis to achieve their research objectives.

*3.1.3. Summary of the studies*

The conclusion of each study shows that the resilience of the water system can be derived from many aspects as suggested by [7]. Every aspect such as engineering, economy, social, and ecology can contribute to enhancing resilience in the water system by asset management solutions. [6] and [7] provide an integrated framework of asset management for civil infrastructure systems. Studies in 2018 provide asset management practices in different parts of the world such as America, Australia, the United Kingdom, and Canada. The gap of information about asset management should be filled to enhance the resilience and sustainability of the civil infrastructure. The study from 2019 focuses on the development of a framework and how the framework can be used by other asset management agencies. The focus of these two studies is on how to create an integrated asset management framework that can be used by different civil agencies such as water, electricity, and road and rail system.

A study investigated by [5] derived asset management data to enhance the resilience of the South African cities. The data that have been leveraged are focusing on energy recovery in Municipal Water Distribution systems. Identification of the amount of energy leakage can be made using asset management data. The recovery of energy leakage can contribute to a more sustainable and resilient water system. [8] countable to citizens. Lean regulatory framework and enforcement mechanism must deliver a better service to the end – customers and maximum optimization to the public. [7] for their literature review analysis suggests that infrastructure resilience also has evolved from a theoretical concept to more specific frameworks, models, metrics, and tools to improve (water) system management in practice. [9] suggests that every organization must place their asset management decision under a socio-economy perspective to help achieve optimal decision system-wide rather than subsystem.

## 4. Discussion

This section has discussed two different parts of the category: based on the literature review and framework. The discussion is based on these two categories to make the information comprehendible on the important topic that we want to investigate which is the relationship between asset management and resilience in the water system.

*4.1. Review on Literature*

This section discusses the literature on resilience concepts and operational definitions that have been accepted by a majority of the resilience researchers, approaches, techniques, concepts, key fields related to resilience in the infrastructure system. According to [7], the operational definition is widely accepted of resilience in infrastructure systems is "the ability to bounce back". Infrastructure resilience is the integration of management that puts practical consideration to the resilience concept in its infrastructure system. [7] emphasizes infrastructure asset management is not a well-established resilience model with the integration of risk assessment and management approaches. Knowledge on this gap area is worth investigating especially in the water system. The water system is derived from the population demand because water is one of the essentials for daily uses. Their investigation shows that the water system has four key fields that are significant to its system. The components are engineering, ecology, society, and economics. The design, management, operation, and performance of the system mostly belong to the engineering fields. Natural resources are related to ecology. The environmental care, resources security, the anti-pollution program can be categorized as ecology. This is the foundation of the system. Without the proper care of its resources (or proper resource management), the water system cannot function well and is unsustainable to the population. Society is the consumers of the water supply or demand side of the chain. An increase in the demand is the challenge of the water system to cope up.

There are about five resilience approaches in the asset management framework of water systems: graph theory network, engineering, ecology, social and economic approaches. Most of the authors such as [9] and [10] thought that the resilience of water systems is through an engineering approach.

**Table 2**. Summary of the final paper

| Author | Objective | Result | Relationship of Asset Management and Resilience |
|---|---|---|---|
| Yang et al [4] | An integrated framework for multi-sector infrastructure asset management. | IAM framework is established from a holistic perspective such as information integration, process integration, collective decision, and harmonization between interdependent systems. | Integrated Asset management framework to enhance resilience. |
| Bonthuys et al [5] | To bridge the gap between the awareness of the potential for energy recovery within Municipal Water Distribution Systems and the lack of knowledge of the extent and location of such potential to increase sustainability and resilience of South African cities. | Identify the amount of energy leakage using asset management data. | Using asset management data to enhance resilience. |
| Hukka and Katko [8] | Argues regarding asset management and regulatory regime regarding water system. | The principles of related legislation and be more open, transparent accountable to citizens. Lean regulatory framework and enforcement mechanism are in place. | Asset management regulatory governance. |
| Gay and Sinha [7] | Compilations of literature reviews on the resilience of the current status of resilience in civil infrastructure systems. | Infrastructure resilience also has evolved from a theoretical concept to specific frameworks, models, metrics, and tools to improve system management in practice. | Literature review addressing civil infrastructure resilience as an important component of improved formal infrastructure management frameworks is lacking. |
| Mazumder et al [9] | Examines existing literature and state of practice related to the assessment, retrofit, and repair of the water distribution system. | Placing asset management decisions under their socio-economy context helps to achieve optimal decision system-wide rather than subsystem. | Asset management strategy is one the key that is lack of practices by water utility companies. |
| Yang et al [6] | Develops an information elicitation and analytical framework for resilient inter-networked infrastructure asset management (RIAM). The framework comprises two components: Asset information elicitation and resilience analytical workflow. | The framework has valuable potential for aligning the understanding and practice of different sectors in implementing RIAM. | Resilience management is important to be implemented in the current asset management system. |

There are about five resilience approaches in the asset management framework of the water system; graph theory network, engineering, ecology, social and economic approaches. Most of the authors such as [9] and [10] thought that the resilience of water systems is through an engineering approach. Better models, better analysis of network systems can detect the cause of disruption and disturbance on the water system. Not only relying on the engineering approach, [6] states that the adoption of new technology, reconfiguration, and reengineering topological structures can improve the resilience of the system. The reconfiguration of the water system and adoption of new technology not only involves authority but also cost huge financial program. However, with sustainable initiatives, there are a lot of countries issuing Green Bond and Green Sukuk to tackle such problems that pose a threat to sustainable initiatives. According to [11], there is a party that involves in a water industry that keens on upgrading their water system to a much more sustainable and resilient aspect. However, that vision is ceased to exist due to certain reasons. For one, this is because major water systems in the world are developed during the Industrial Era. The water systems are not updated during that era as the objective was solely supplying water to the industrial sector to boom the economy. The system design was mainly focused on the system's physical resistance but it is not shifting to resilience, according to [12]. Now throughout the time, the system is deteriorating while urbanization causes stress to the water system that supplies water for the population. Due to the lack of awareness, irresponsible people also discard the chemical waste to the river (water sources) which results in water pollution and disruption in the water system. The ecological approach ensures the quality of water is at the best quality. Therefore, legalisation must be set as a high priority for the policymaker to punish those irresponsible people accordingly. Community response also can help to increase the resilience of the water system. Reporting to the authority will ease the authority so that they can take action immediately. The role of the organisation to prioritise resilience management in their asset management policy will enhance the value of the business itself. This shows that the organisation cares about the continuous water supply quickly to the consumers after a certain disruption.

### *4.2. Framework analysis*

This section elaborates on the framework that has been developed by [4] and [6]. This section will investigate any similarities or differences between these three frameworks and the relationship with asset management. These two studies have different purposes but the similarity is 'resilience'. The framework developed by [6] suggests some consideration on long-term and continuous resilience improvement. It is said that a long-term resilience strategy could solve the occurrence of disruption that frequently happens from climate change, surging water demand, an adaption from installing new technology in the system, reconfiguration, reengineering of topological structures, and operation mechanism. The technique of long-term and continuous resilience improvement should be ever-changing to the related parameters in the simulation model. Investigation on topological factors should be highlighted for a long-term resilience strategy. Modifying operating systems or the addition of new technology is also a key that should be taken into consideration for long-term resilience. [4] suggests an integration of multi-sector infrastructure asset management of electricity, road, and water. The features of asset management in the water sector consist of (policies) strategic planning, target level of service, coordination with and across agencies, (human resources) asset management committee, regular training, (information system) consolidating asset register system, customer service system, (performance assessment) condition monitoring techniques, (risk analysis) risk event identification, (capital investment plan) lifecycle cost planning. Based on these three frameworks, [6] focuses more abroad aspects to enhance the resilience of the water system rather than focus on engineering aspects. The engineering aspect is important, however, with the support from different aspects, the resilience of the water system can be achieved greatly.

## 5. Conclusion

From the investigation of these six articles, it is found that there is a relationship between asset management and resilience in the water system, however, the relationship is not fully addressed and has not been discussed critically except for [4], [6], and [7]. The adoption of asset management as mentioned by [4] where asset management features have been categorized into six themes; policies, human resources, information system, performance assessment, risk analysis, and capital investment plan. The resilience in the water system is mostly discussed from engineering perspectives as mentioned by [7].

Resilience in the water system where the ability to bounce back to normal performance is driven by its engineering mechanism but also follow by policies such as human resources, etc. as mentioned by [4]. It is an eye-opener on the factors of the physical asset management practices which have a high impact on the resilience of the water system. This research paper encourages other researchers to investigate this new gap of research as it could help to organize better resilience management and achieve greater resilience performance in the future.

## 6. References

[1] Adger W N, Brown K, Nelson D R, Berkes F, Eakin H, Folke C, Kathleen G, Lance G, Marisa G, Karen O'Brien, Jack R and Tompkins E L 2011 Resilience implications of policy responses to climate change, *Wiley Interdiscip. Rev.: Clim. Change* **2**(5) 757-766

[2] United States Environmental Protection Agency 2017 *Asset Management for Water and Wastewater Utilities* Retrieved on October 01, 2021 https://19january2017snapshot.epa.gov/sustainable-water-infrastructure/asset-management-water-and-wastewater-utilities_.html

[3] Moher D, Liberati A, Tetzlaff J and Altman D G 2009 Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement, *PLoS Medicine* **6**(7)

[4] Yang Y, Ng S T, Xu F J, and Skitmore M 2018 Towards sustainable and resilient high density cities through better integration of infrastructure networks, *Sustain. Cities and Soc*. **42** 407-422

[5] Bonthuys G J, Van Dijk M, and Cavazzini G. 2019 Leveraging water infrastructure asset management for energy recovery and leakage reduction, *Sustain. Cities and Soc.* **46** 101434

[6] Yang Y, Ng S T, Xu F J, Skitmore M, and Zhou S 2019 Towards resilient civil infrastructure asset management: An information elicitation and analytical framework, *Sustainability* **11**(16) 4439

[7] Gay L F and Sinha S K 2013 Resilience of civil infrastructure systems: literature review for improved asset management, *Int. J. of Crit. Infrastruct.* **9**(4) 330-350

[8] Hukka J J and Katko T S 2015 Resilient Asset Management and Governance Fordeteriorating Water Services Infrastructure, *Procedia Econom. and Finance* **21** 112-119

[9] Mazumder R K, Salman A M, Li Y and Yu X 2018 Performance evaluation of water distribution systems and asset management, *J. of Infrastruc. Sys.* **24(3),** 03118001.

[10] Punmia D B C, Jain A K, and Jain A K 1995 *Water Supply Engineering* (Firewall Media)

[11] World Bank 2020 *Pioneering the Green Sukuk: Three Years On* (World Bank, Washington, DC).

[12] Cimellaro G P, Tinebra A, Renschler C and Fragiadakis M 2016 New resilience index for urban water distribution networks, *J. of Struct. Eng.* **142**(8) C4015014