

# WATER INFRASTRUCTURE ASSET MANAGEMENT (WIAM) AND APPLICATION USING DIGITAL TWIN: SYSTEMATIC REVIEW

Mr. G Laolang<sup>1\*</sup>, Prof I. Musonda<sup>1</sup>, Dr. A. Onososen<sup>1</sup>

\* [gift.laolang@gmail.com](mailto:gift.laolang@gmail.com)

<sup>1</sup> Centre of Applied Research and Innovation in the Built Environment  
Department of Construction Management and Quantity Surveying, University of Johannesburg, South Africa

CITC-14 | SEPTEMBER 2-5, 2024  
HOSTED BY FEDERAL UNIVERSITY OF RIO DE JANEIRO  
RIO DE JANEIRO, BRAZIL

**CITC GLOBAL**  
Construction in the 21st Century

# INTRODUCTION

- ❑ Water infrastructure is critical in ensuring the sustainable provision of safe and reliable water resources to communities worldwide (**Mishra et al., 2021**).
- ❑ However, water infrastructure systems in Sub-Saharan Africa (SSA) are commonly described as inadequate, unreliable, and requiring substantial improvement (**Williams et al., 2024**).
- ❑ This is due to climate change, water loss, corruption in water project development, and deficiencies in skills and technology for water utility management are posing significant challenges to the effective operation of the existing water system (**Bulti et al., 2023**).
- ❑ Thus, the study introduces water infrastructure asset management (WIAM) and application using digital twin (DT) technology to attain sustainable development goals, specifically sustainable development goals (SDGs) 6 (clean water and sanitation) & 9 (industry, innovation and infrastructure) as highlighted by the United Nations (UN).

# RESEARCH AIM, OBJECTIVE & SCOPE

- ❑ Water industry is transitioning from conventional water solutions to a new era of smart water systems driven by digital advancements **(Alabi et al., 2019)**.
  - ❑ Adopting digital technologies (DT) in the water sector presents an opportunity to address 21<sup>st</sup> century water risks by improving water supply, demand, and related data by informing public policy and guiding new investments **(Walter, 2024)**.
  - ❑ The fourth industrial revolution has significantly shifted towards digital water utility infrastructure and management **(Suprun et al., 2020)**.
- This shift aims to gain fresh insights that enhance water management, quality, and operational efficiencies **(Pesantez et al., 2020)**.

## • Aim

- Therefore, the study aims to explore the intersection of water infrastructure asset management (WIAM) and Digital Twin (DT) applications in the context of water infrastructure, examining their potential benefits for sustainable water resource management.
- to review existing research and provide insights into the integration of WIAM and Digital Twin (DT) technologies and their benefits for advancing water infrastructure management practices.



9 INDUSTRY, INNOVATION AND INFRASTRUCTURE



SUSTAINABLE DEVELOPMENT GOALS

# METHODOLOGY: SYSTEMATIC ANALYSIS

- ❑ The study utilised a Systematic Literature Review (SLR) to explore the current state-of-the-art in water infrastructure asset management and the application of digital twin technologies within water infrastructure management.
- A systematic literature review (SLR) was performed with adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Fig 1).

**Table 1:** Search databases and strings

Database	Website	Search String
Emerald Insight	<a href="https://www.emerald.com/insight/">https://www.emerald.com/insight/</a>	Water infrastructure asset management and application using digital twin
Engineering Village	<a href="https://www.engineeringvillage.com">https://www.engineeringvillage.com</a>	Water infrastructure asset management and application using digital twin
Sage Journals	<a href="https://journals.sagepub.com">https://journals.sagepub.com</a>	Water infrastructure asset management and application using digital twin
Science Direct-Elsevier	<a href="https://www.sciencedirect.com">https://www.sciencedirect.com</a>	Water infrastructure asset management and application using digital twin
Scopus	<a href="https://www.scopus.com">https://www.scopus.com</a>	TITLE-ABS-KEY (Water AND infrastructure AND management AND digital AND twin)

- ❑ Quantitative approach:
  - Microsoft Excel (M.S. Excel) was utilised for data analysis and presentation of total publications by year, country of origin, publication type, and research methods.
  - A bibliometric and semantic analysis, presenting key issues related to the research theme through content analysis.
  - VOSviewer was utilised for semantic analysis.

**Table 2:** Inclusion and Exclusion Criteria

Criteria	Assessment Criteria
<b>Inclusion</b>	Research articles relating to water infrastructure asset management (WIAM) and applications using digital twin
	The publications made between the year 2014 and 2023
	Publications that are written in English
	Peer-reviewed publications
	Publications which are conference papers or journal articles
	subject areas of Engineering, Environmental Sciences and Social Sciences
<b>Exclusion</b>	Open Access publications
	Papers that are not entirely written in English
	Papers from newspapers, blogs and technical reports
	Publications where the full paper cannot be located
	Papers not within a selected discipline
	Papers not within the 10-year range

# RESULTS AND DISCUSSION

## Documents & Publications

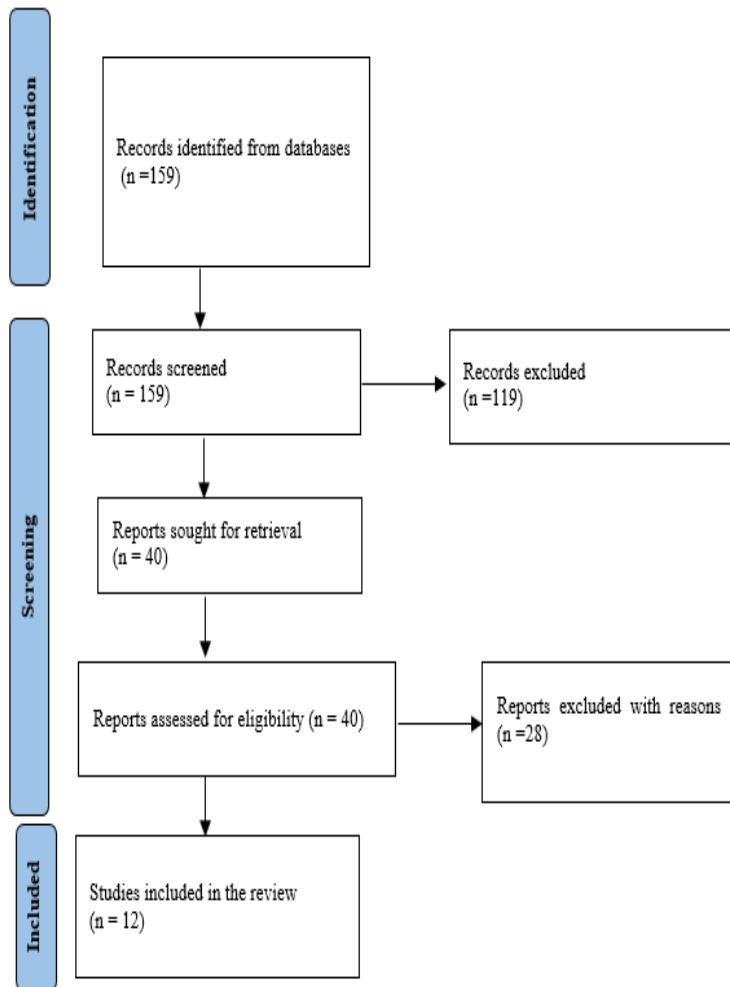


FIG.1: PRISMA Model

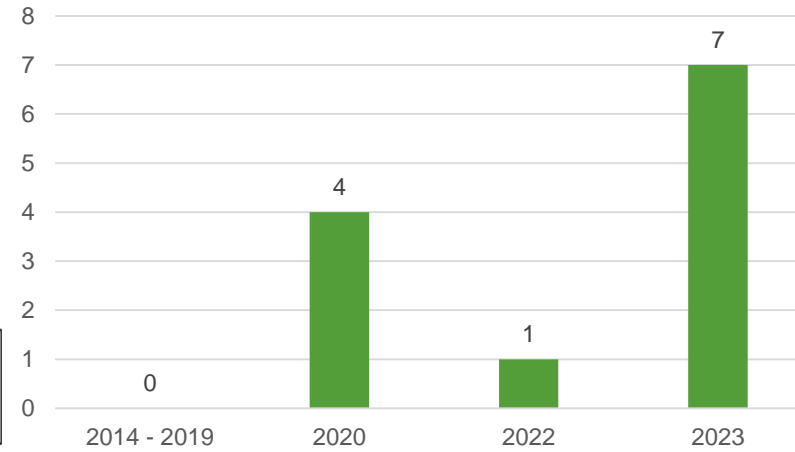


FIG.2: Number of publications per year

□ A total of 12 publications were identified and analysed using descriptive and semantic analysis methods, revealing a clear trend in the research on water infrastructure asset management (WIAM) and Digital Twin applications.

□ From the year 2014 to 2019, no publications were recorded, indicating an initial lack of focus on this topic.

□ Significant interest emerged in 2020 with four publications, in 2022 with 1 publication and this interest grew steadily, reaching a peak in 2023 with seven publications.

# RESULTS AND DISCUSSION

## Geographical, Publication & Method

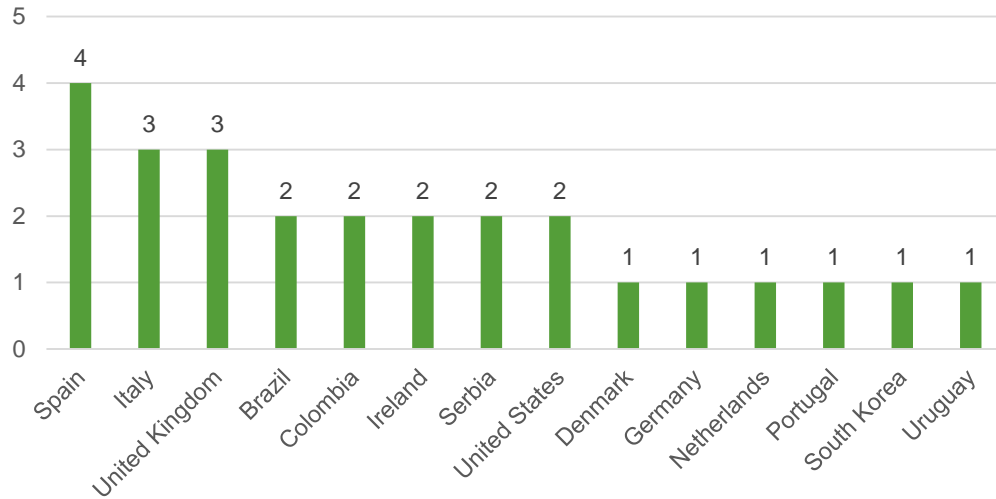
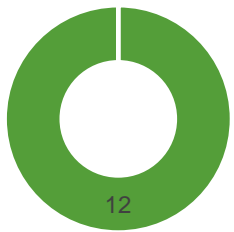
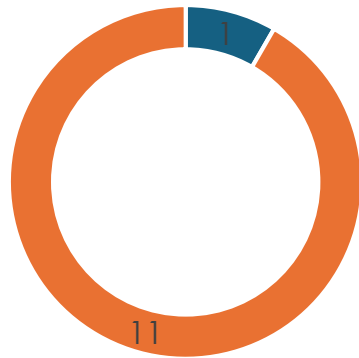


FIG.3: Publications made per country



Articles



Quantitative Qualitative

FIG.4: Publication Type

FIG.5: Research Method

Spain leads with four publications, followed by Italy and the United Kingdom with three each. Brazil, Colombia, Ireland, Serbia, and the United States each contributed two publications, while Denmark, Germany, the Netherlands, Portugal, South Korea, and Uruguay each had one.

None of the African countries met this criteria.

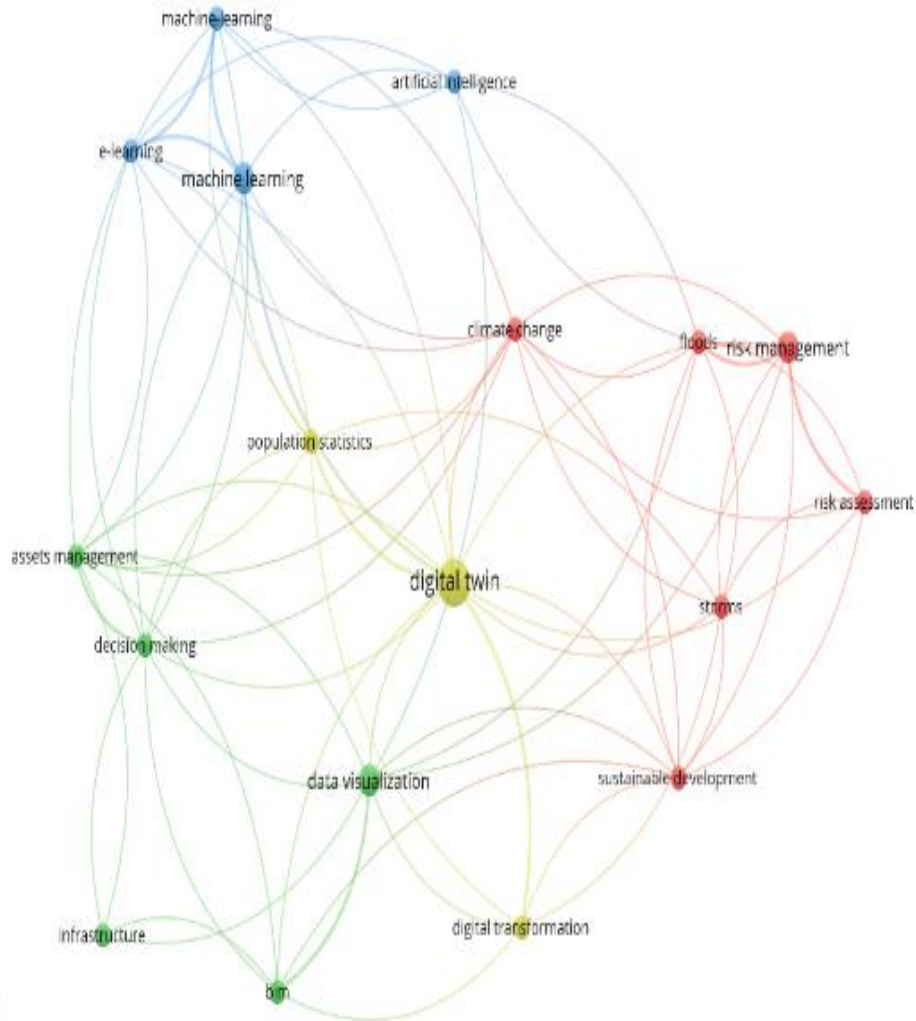
-Dogo et al. (2019) and Alabi et al. (2019) concurred that the readiness for adaptation of water digitalisation in developing economies, including the water industry in Africa, is still at the foundational level and remains in its developmental stage.

The predominant use of Qualitative research methods, with 11 out of 12 publications, suggesting that the field is still exploratory, focusing on conceptual development and understanding frameworks.

Only one study employed Quantitative method.

# RESULTS AND DISCUSSION

## Semantic Analysis (Key Themes and Trends)



VOSviewer

FIG.6: Network visualisation of cluster co-occurrence keywords

## Blue Cluster (One)

Focuses on advanced computational methods and their applications in learning and environmental modeling. This includes Machine Learning (ML), Artificial Intelligence etc.

## Red Cluster (Two)

Centered around environmental challenges and risk management, emphasising the need for preparedness and sustainability. This includes climate change, floods, storms etc.

## Green Cluster (Three)

Highlights the importance of decision making processes in resource management and strategic planning. This includes data visualisation, digital transformation etc.

## Yellow Cluster (Four)

A central node (**Digital Twin**), linking environmental challenges, technical and managerial aspects, advanced technologies, and broader digital transformation efforts.

## CONCLUSION & RECOMMENDATIONS

- ❑ European countries, especially Spain, Italy, and the UK, are leading in adapting and applying Digital Twin (DT) technology in their water infrastructure management.
- The research trends were identified through bibliometric analysis:
  - **Machine Learning (ML) -Artificial Intelligence(AI) – Data Visualisation**
  - **E-Learning - Building Information Modelling (BIM)**
- ❑ Digital Twin as central node offers potential opportunities such as:

**Real-time monitoring, Predictive maintenance, Informed decision-making, Efficient resource allocation, Planning & monitoring, Risk management, Technological integration, Skills development and Sustainable practices.**

- ❑ African countries lag in this research area, and this gap needs to be addressed.
- Future research to focus on bridging the methodological gap by incorporating more quantitative studies and expanding research efforts to underrepresented regions, such as African countries.
- Develop supportive policies and regulatory frameworks to foster research and development.