

Digital Twin in delivering infrastructure sector projects

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Summary

The United Kingdom (UK) is moving towards advancing digitalisation in delivering infrastructure sector projects with Digital Twins (DTs) being at the forefront of this improvement. The anticipated strong growth of the infrastructure industry over the coming decades will require more modern, digital approaches to create data centric infrastructure that allows infrastructure to be monitored and managed throughout its lifecycle. DTs is currently seen to be in an infancy stage with regards to implementation on infrastructure projects across the UK. However, the UK Government has recognised the potential impact using DTs will have on upcoming infrastructure projects demonstrating the positive influence DTs has to support planning, predicting, and understanding infrastructure assets. However, it is unclear how far this technology is developing in order to maximise its impact in the infrastructure industry. The purpose of this paper is to understand the current uptake of DTs within the UK's infrastructure sector and how DTs can help contribute towards strengthening the industry. The conclusion of this review suggests that the uptake of DTs is low in relation to the infrastructure sector and further research is required to demonstrate the potential for DTs to help improve and increase the awareness and understanding of the topic to aid digital representation holistically on UK infrastructure projects.

Keywords: digital twins; digitalisation; and infrastructure sector

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1. Introduction

The UK infrastructure sector (water, transport, energy, smart cities, telecommunication, and waste management) is moving towards advancing digitalisation to deliver more complex, resilient and sustainable infrastructure projects (Gürdür Broo et al., 2022). It is forecasted in the National Infrastructure and Construction Pipeline (2021) that £649 Billion will be invested into UK infrastructure over the coming decade, demonstrating the industry's expected growth. To maximise the impact of this future investment decisions on how infrastructure is built,

maintained and renewed digital transformation needs to be considered alongside the outcomes needed in society characterised by the United Nations Sustainability Development Goals (IPA, 2021) to unlocking that value.

The National Infrastructure Commission (2017) highlighted the emerging technologies that had the most potential in optimising the performance, management and maintenance of existing and future infrastructure assets to support the nation's economy, with DTs being a primary focus. Since DT in the infrastructure sector is a developing concept there is no generally recognised definition (Broo and Schooling, 2021). The UK's Nation Digital Twin programme (NDTp) refers to a DT as a "realistic digital representation of assets, processes, or systems" representing the real-world behaviours of the physical system through data-connection (CDBB, 2020; NIC 2017). However, several studies (Pregolato et al., 2022; Boje et al., 2020) argue that the transition of this technology into the infrastructure sector is not well defined.

Passive infrastructure assets can be turned into data-centric systems of systems with DTs improving the flow of information and operations (Gürdür Broo et al., 2022). With the integration of sensors, the Internet of Things (IoT), data analytics, Artificial Intelligence (AI), Machine Learning (ML), DTs can create dynamic digital models that can monitor, inform and update the physical asset from various sources (Pregolato et al., 2022). According to Lu et al. (2019), DTs will simulate and predict the performance and future state of its physical equivalent providing data driven infrastructure with smarter management and decision-making capabilities which will in hand further support the sector. Similarly, Pregolato et al. (2022) states that when all systems are connected in the built environment a National DT can then be achieved. In contrast to other digital representations of infrastructure assets, such as Building Information Modelling (BIM), DTs change and evolve alongside its physical counterpart throughout its lifecycle based on the synchronisation between the physical asset, process or system and its DT (Pregolato et al., 2022). With this background, the aim of this study is to explore the uptake of DTs in delivering UK infrastructure projects. Understanding how the UK infrastructure sector perceive and act on DTs, the various components that enable DTs and the wider national context of this.

2. Methodology

A literature review was conducted to review the current research and related work regarding DTs in the UK infrastructure sector. For the purpose of ensuring that reviewed literature was relevant to the topic, a systematic review of available published literature was conducted. As part of the literature review for this report, a comprehensive number of published papers in the form of academic journals, online government reports and websites have been collected primarily through Science Direct, ICE Virtual Library and Google Scholar. The literature review considered work only in the English-language and at the earliest year 2011 as this is when digitisation started to develop within the infrastructure sector. In the online search, the following keywords and titles were used: ("digital twins" OR "digitalisation") AND ("infrastructure sector" OR "civil engineering" OR "building information modelling" OR "railway" OR "smart city" OR "water" OR transport OR "energy" OR "telecommunication" OR "waste management") AND ("united kingdom" OR "britain" OR "england" OR "scotland" OR "wales" OR "northern island").

Published literature based on DTs in the UK infrastructure sector was not well addressed compared to other countries due to it being an evolving topic. Therefore, additional reports, articles, and datasheets were sourced from other sources, including literature based outside of the UK. The literature retrieved was carefully screened and then reviewed to ensure relevance to the topic and to reduce the possibility of biased information being presented.

During the extraction of the possible papers to be used in the study an advanced screening tool, PRISMA, was used to ensure the identified literature was appropriately filtered, associated to the topic and as per the inclusion and exclusion criteria. Based on the screening process, 36 studies were determined to be eligible for analysis and were subsequently included in this systematic review.

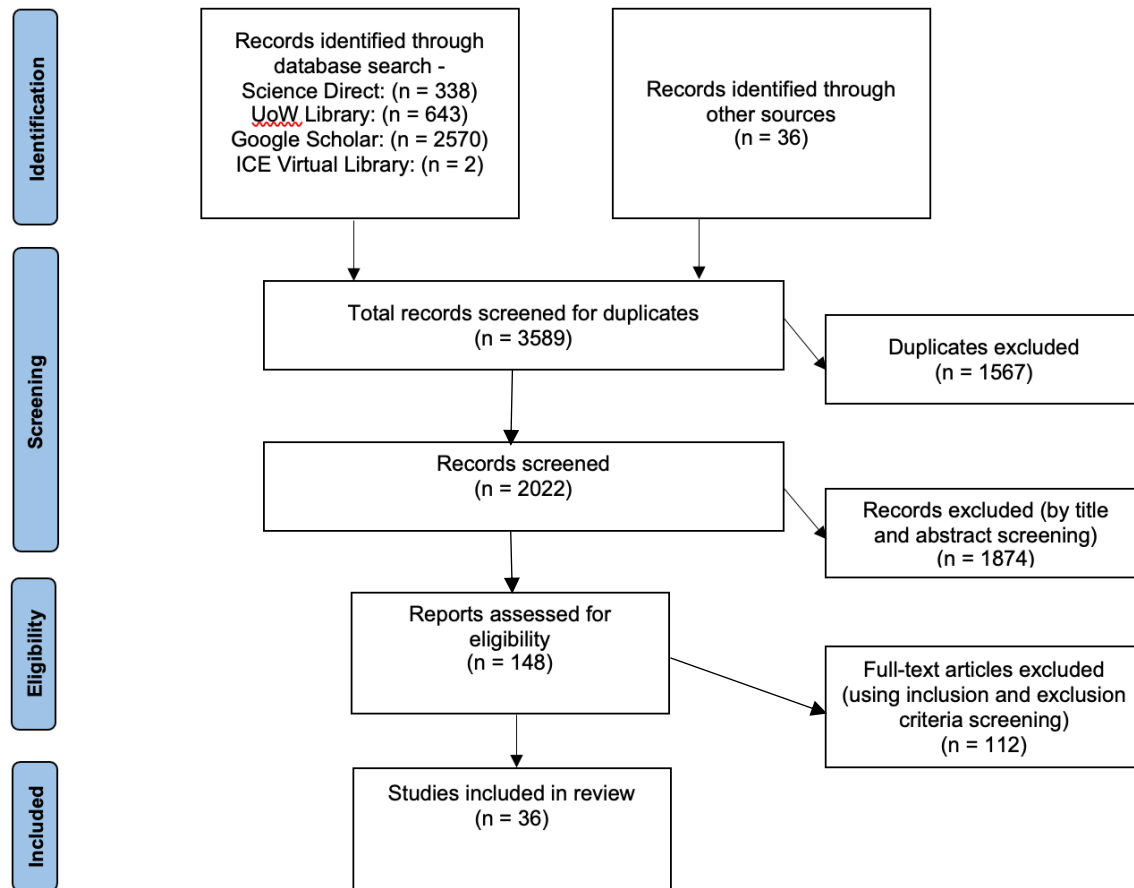


Figure 1 – PRISMA article screening tool flow diagram

3. Results and Discussion

Despite the UK's Governance of the Digital Framework Task Group to create a real policy impact, the implementation of DTs in the infrastructure sector is still unclear. To move forward and validate DTs as a technological advancement an innovative governance framework must be accompanied to provide significant and practical policy visions (Wan et al., 2019). Pregnolato et al. (2022) argues that the initial step to enable the vision is to create DTs of individual assets which work as an optimised system, compared to the CDBB (2020) which looks at a National DT.

After conducting a review of current literature, the publications on DTs technology in the infrastructure sector have been observed to be very low which is also supported by Lamb (2019). DT literature has mostly emerged in the past 10 years with 96% of publications appearing since 2016 (Pregnolato et al., 2022). Even so most being related to manufacturing and production (Jones et al., 2020), with little focus in the built environment (Approx. 5%)

(Lamb, 2019). This could be attributed to the low implementation of DTs and awareness of DTs.

There are many types of infrastructure affected by a set of systems such as energy, water supply and transportation (Ferré-Bigorra et al., 2022). As a result, DT models require a large number of interconnected systems (Ferré-Bigorra et al., 2022) with contrasting dimensions that are determined by the scale and rate of change of the particular type of infrastructure (Wan et al., 2019).

It is recognised that the potential barrier for implementation is the lack of case studies that are used to demonstrate the practical application of a DT, this could also be related to the low level of awareness of DTs. Fundamentality in order to adopt a new technology an assessment of cost and benefits is crucial to drive the industry into enhancing the current technologies used (Pregolato et al., 2022).

In order to justify the scope and development of a DT, the value of information and business models may help to explain how the DT generates value (Pregolato et al., 2022). It is clear from the usages of DTs that various applications must be supported at once to allow efficient operations and maintenance decisions and to enable predictive analysis (Lu et al., 2019). However, since a DT is supported by the data attributed to the model, if the value of data is degraded it can cause the physical model to not operate efficiently (Lu et al., 2019).

Asset owners and managers can use DTs to improve the operational efficiency of the asset lifecycle and its condition (Pregolato et al., 2022). Through their detection of anomalies and prediction of asset behaviour, they can offer an enhanced understanding of potential asset risks. In addition, they can facilitate maintenance optimisation, facilitating planned maintenance opportunities to anticipate and prevent failure of the components (Pregolato et al., 2022). As of present, there is very limited guidance for recognising and capitalising on the wider business prospects associated with this technology (Gürdür Broo et al., 2022), in addition to the associated savings in cost and operational proficiencies (Pregolato et al., 2022). Similarly, Jones et al. (2020) recognises the importance of evaluating costs as well as the benefits accruing from DTs in order to quantify and understand their practical applications. For infrastructure and workflow changes to be justified, a clear understanding of the extent of benefits associated with DTs is necessary for effective implementation (Jones et al., 2020). Evidence, with the support of business models, may contribute to understanding how DTs generate significance (Pregolato et al., 2022), thereby justifying their scope and development based on their costs and returns can further support these suggestions.

5. Conclusion

A DT facilitates the understanding of how various aspects of the infrastructure industry interact. Overall, there is a need to increase awareness regarding the implementation of DTs and their potential impacts on projects, and the cost savings and damage savings they can result in. In practice, the application of DTs is very low and requires further development in order to shed light on their potential for strengthening the infrastructure sector.

With particular focus in the UK there is little research relating to the uptake of DTs despite clear knowledge of the benefits a DTs can offer. Although industry is still progressing with digitalisation of infrastructure, there is still much to be achieved to enable effective implementation that can then lead to sustainable infrastructure, safer projects with cost and time benefits, considering that DTs can optimise an infrastructure asset. Despite the acknowledgement from the government in terms of how DTs can improve the Nation's infrastructure, this does not involve the influence that businesses and stakeholders must have

to initiate DTs within infrastructure projects. This is what enables a National DT (CDBB, 2020), but clear structure in terms of how this is achieved is not evident by existing literature and Government policies.

It is clear from the research papers discussed that DTs could provide more insight into how the system of an infrastructure asset work and provide more effective operations and maintenance. However, despite the clear acknowledgement of the requirement to provide data-centric infrastructure, no research papers were identified that clearly presented how well this topic was developing in the UK infrastructure sector. In order to further research the uptake of DTs in the infrastructure sector, it is key to look at the viable ways to collate new information in regard to the current uptake of the technology and what can practically enable DTs to be implemented within the infrastructure sector, since there is limited understanding of the current development of implementing DTs. By compiling all of this information, a collation of views, challenges, and what may be hindering the adoption of DTs from different sectors across the industry can be provided.

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