# 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. Digital Twins 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 UKs infrastructure sector and how DTs can help contribute towards strengthening the industry. The conclusion of this review suggests uptake in 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

**Track:** Innovation

**Word count:** 1911

## 1. Introduction

The United Kingdom (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 (Pregnolato et al., 2022 and Boge 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 (Pregnolato et al., 2022). According to Lu et al (2019) a DT 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, Pregnolato et al (2022) states that when all systems are connected in the built environment an DT can then be achieved. In contrast to other digital representations of infrastructure assets, such as Building Information Models (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 (Pregnolato 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.

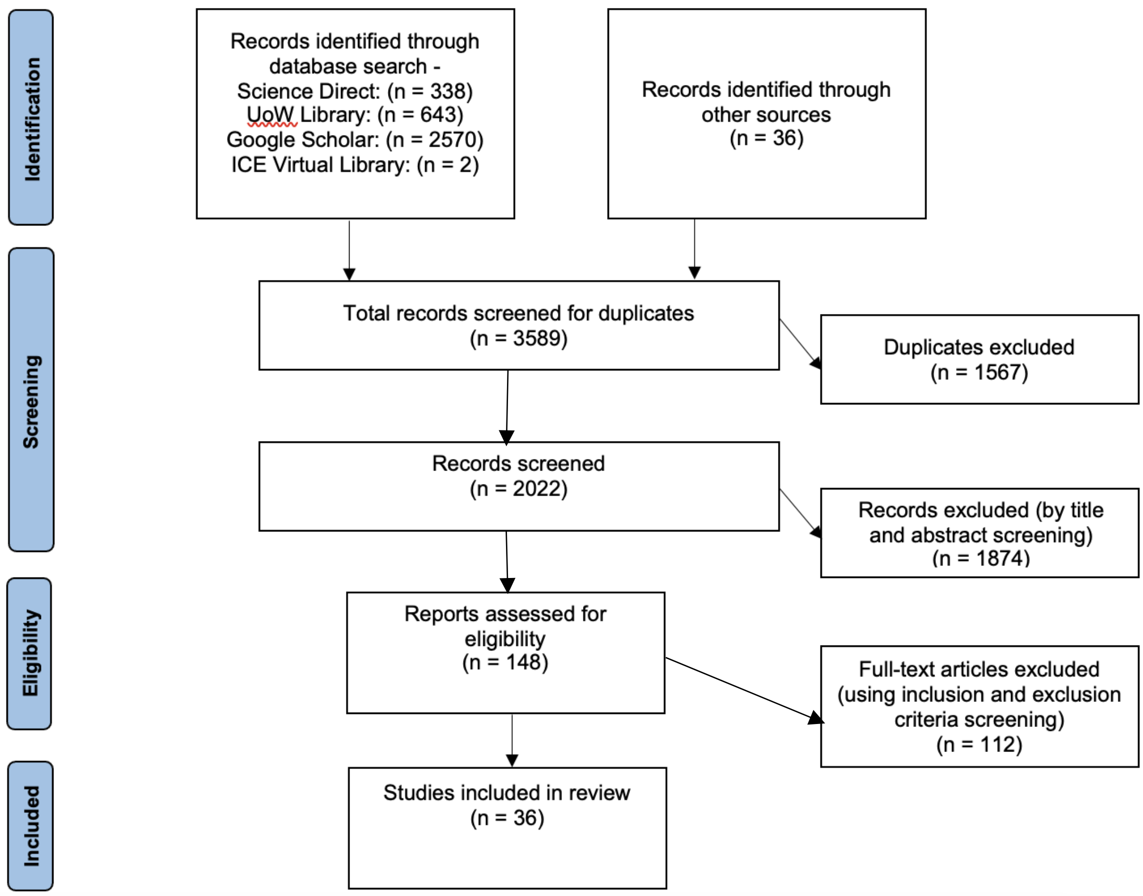


**Figure 1** – PRISMA article screening tool flow diagram

## 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). Ferré-Bigorra et al., (2022) argues that the initial step to enable the vision is to create DTs of individual assets which works 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 water supply and transportation. 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 DTs, 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 (Ferré-Bigorra et al., 2022).

In order to justify the scope and development of a DTs, the value of information and business models may help to explain how the DTs generates value (Pregnolato 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 DTs 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.

Asset owners and managers can use DTs to improve the operational efficiency of the asset lifecycle and its condition (Pregnolato 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 (Pregnolato et al., 2022). As of present, there is very limited guidance for recognising and capitalising on the wider business prospects associated with this technology in addition to with the associated saving in cost and operational proficiencies (Pregnolato et al., 2022). Similarly, Ferré-Bigorra et al., (2022) recognises that an evaluation of costs the associated advantages is critical for understanding and appreciating the practical applications of a DT. Evidence with the support of business models may contribute to understanding how DTs generate significance (Pregnolato 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 initiate DTs within infrastructure projects. This is what enables a National DTs (CDBB, 2020), but clear structure in terms of how this is achieved it not evident by existing literature and Government policies.

It is clear from the research papers discussed that a DTs could provide more insight to 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 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.

## 5. References

Arup (2019). Digital twin: towards a meaningful framework, November. London: Arup.

Boje, C., Guerriero, A., Kubicki, S. and Rezgui, Y. (2020). Towards a semantic Construction Digital Twin: Directions for future research, Automation in Construction, 114, pp. 103179. doi: 10.1016/j.autcon.2020.103179.

Bolton, A., Butler, L., Dabson, I., Enzer, M., Evans, M., Fenemore, T., Harradence, F., et al. (2018). Gemini Principles. (CDBB_REP_006) https://doi.org/10.17863/CAM.32260.

Broo, D.G. and Schooling, J. (2021). Digital twins in infrastructure: definitions, current practices, challenges and strategies, International Journal of Construction Management, pp. 1-10. doi: 10.1080/15623599.2021.1966980.

Centre for Digital Built Britain. (2020). The Approach to Delivering a National Digital Twin for the United Kingdom. Available at: https://www.cdbb.cam .ac.uk/files/approach_summaryreport_final.pdf.

Ferré-Bigorra, J., Casals, M. and Gangolells, M. (2022). The adoption of urban digital twins, Cities, 131, pp. 103905. doi: 10.1016/j.cities.2022.103905.

Fuller, A., Fan, Z., Day, C. and Barlow, C. (2020). Digital Twin: Enabling Technologies, Challenges and Open Research.

Grieves, M. and Vickers, J. (2017). Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. In Transdisciplinary perspectives on complex systems (pp. 85-113). Springer, Cham.

Gürdür Broo, D., Bravo-Haro, M. and Schooling, J. (2022). Design and implementation of a smart infrastructure digital twin, Automation in Construction, 136, pp. 104171. doi: 10.1016/j.autcon.2022.104171.

Hall, W. and Pesenti, J. (2017). Growing the artificial intelligence industry in the UK', Department for Digital, Culture, Media & Sport and Department for Business, Energy & Industrial Strategy.Part of the Industrial Strategy UK and the Commonwealth.

Howell, S., Rezgui, Y., Hippolyte, J., Jayan, B. and Li, H. (2017). Towards the next generation of smart grids: Semantic and holonic multi-agent management of distributed energy resources, Renewable and Sustainable Energy Reviews, 77, pp. 193-214. doi: 10.1016/j.rser.2017.03.107.

Huang, M.Q., Ninić, J. and Zhang, Q.B. (2021). BIM, machine learning and computer vision techniques in underground construction: Current status and future perspectives, Tunnelling and Underground Space Technology, 108, pp. 103677. doi: 10.1016/j.tust.2020.103677.

Infrastructure & Projects Authority. (2021). Transforming Infrastructure Performance: Roadmap to 2030. Available at: https://www.gov.uk/government/publications/transforming-infrastructure-performance-roadmap-to-2030/transforming-infrastructure-performance-roadmap-to-2030#focus-area-5-optimising-the-performance-of-our-existing-built-environment.

Jiang, F., Ma, L., Broyd, T., Chen, W. and Luo, H. (2022). Building digital twins of existing highways using map data based on engineering expertise, Automation in Construction, 134, pp. 104081. doi: 10.1016/j.autcon.2021.104081.

Jiang, F., Ma, L., Broyd, T. and Chen, K. (2021). Digital twin and its implementations in the civil engineering sector, Automation in Construction, 130, pp. 103838. doi: 10.1016/j.autcon.2021.103838.

Jones, D., Snider, C., Nassehi, A., Yon, J. and Hicks, B. (2020). Characterising the Digital Twin: A systematic literature review, CIRP Journal of Manufacturing Science and Technology, 29, pp. 36-52. doi: 10.1016/j.cirpj.2020.02.002.

Lamb, K. (2019). Principle-based Digital Twins: A scoping review. Available at: https://www.cdbb.cam.ac.uk/files/scopingreview_dec20.pdf.

Lu, Q., Xie, X., Heaton, J., Parlikad, A.K. and Schooling, J. (2019). From BIM towards digital twin: strategy and future development for smart asset management. In International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing (pp. 392-404). Springer, Cham.

Lu, Q., Xie, X., Parlikad, A.K. and Schooling, J.M. (2020). Digital twin-enabled anomaly detection for built asset monitoring in operation and maintenance, Automation in Construction, 118, pp. 103277. doi: 10.1016/j.autcon.2020.103277.

Lu, Q., Xie, X., Parlikad, A.K., Schooling, J.M. and Konstantinou, E. (2021). Moving from building information models to digital twins for operation and maintenance, Proceedings of the Institution of Civil Engineers - Smart Infrastructure and Construction, 174(2), pp. 46-56. doi: 10.1680/jsmic.19.00011.

Lu, Q., Parlikad, A.K., Woodall, P., Ranasinghe, G.D. and Heaton, J. (2019). Developing a Dynamic Digital Twin at a Building Level: Using Cambridge Campus as Case Study. In Proceedings of the International Conference on Smart Infrastructure and Construction 2019 (ICSIC), Cambridge, UK, 8–10 July 2019; Thomas Telford Ltd.: London, UK, 2019; pp. 67–75.

Lu, Q., Parlikad, A.K., Woodall, P., Ranasinghe, G.D., Xie, X., Liang, Z., Konstantinou, E., Heaton, J. and Schooling, J. (2020). Developing a Digital Twin at Building and City Levels: A Case Study of West Cambridge Campus.

McMillan, L. and Varga, L. (2022). A review of the use of artificial intelligence methods in infrastructure systems, Engineering Applications of Artificial Intelligence, 116, pp. 105472. doi: 10.1016/j.engappai.2022.105472.

National BIM Report. (2020). NBS' 10th national bim report, NBS. www.theNBS.com. Available at: https://www.thenbs.com/knowledge/national-bim-report-2020.

National Infrastructure Commission (2017). Data for the Public Good. https://www.nic.org.uk/wp- content/uploads/Data-for-the-Public-Good-NIC-Report.pdf.

Nochta, T., Wan, L., Schooling, J. M., & Parlikad, A. K. (2021). A socio-technical perspective on urban analytics: The case of City-scale digital twins. Journal of Urban Technology, 28(1–2), 263–287. doi: 10.1080/10630732.2020.1798177.

Pregnolato, M., Gunner, S., Voyagaki, E., De Risi, R., Carhart, N., Gavriel, G., Tully, P., Tryfonas, T., Macdonald, J. and Taylor, C. (2022). Towards Civil Engineering 4.0: Concept, workflow and application of Digital Twins for existing infrastructure, Automation in Construction, 141, pp. 104421. doi: 10.1016/j.autcon.2022.104421.

Ramos, H.M., Morani, M.C., Carravetta, A., Fecarrotta, O., Adeyeye, K., López-Jiménez, P.A. and Pérez-Sánchez, M. (2022). New Challenges towards Smart Systems, Efficiency by Digital Twin in Water Distribution Networks. Water, 14(8). doi: 10.3390/w14081304.

Savić, D. (2022). Digital Water Developments and Lessons Learned from Automation in the Car and Aircraft Industries, Engineering, 9, pp. 35-41. doi: 10.1016/j.eng.2021.05.013.

Seabright, L., Renukappa, S., Suresh, S., Hiremath, R. and Stride, M. (2022). Digital innovations for infrastructure asset management: A case of the railway sector. British Academy of Management.

Sharma, A., Kosasih, E., Zhang, J., Brintrup, A. and Calinescu, A. (2022). Digital Twins: State of the art theory and practice, challenges, and open research questions, Journal of Industrial Information Integration, 30, pp. 100383. doi: 10.1016/j.jii.2022.100383.

Srewil, Y., Scherer, R.J. (2013). Effective Construction Process Monitoring and Control through a Collaborative Cyber-Physical Approach. In: Camarinha-Matos, L.M., Scherer, R.J. (eds) Collaborative Systems for Reindustrialization. PRO-VE 2013. IFIP Advances in Information and Communication Technology, vol 408. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-40543-3_19.

Valerio, P. (2021). UK Network Rail uses IOT, AI, and deep learning to improve the world's oldest railway system, IoT Times. Available at: https://iot.eetimes.com/uk-network-rail-uses-iot-ai-and-deep-learning-to-improve-the-worlds-oldest-railway-system/.

Vrabič, R., Erkoyuncu, J.A., Butala, P. and Roy, R. (2018). Digital twins: Understanding the added value of integrated models for through-life engineering services, Procedia Manufacturing, 16, pp. 139-146. doi: 10.1016/j.promfg.2018.10.167.

Wan, L., Nochta, T. and Schooling, J.M. (2019). Developing a City-Level Digital Twin Propositions and a Case Study, International Conference on Smart Infrastructure and Construction 2019 (ICSIC) ICE Publishing, pp. 187-194.

Zambrano, V., Mueller-Roemer, J., Sandberg, M., Talasila, P., Zanin, D., Larsen, P.G., Loeschner, E., Thronicke, W., Pietraroia, D., Landolfi, G., Fontana, A., Laspalas, M., Antony, J., Poser, V., Kiss, T., Bergweiler, S., Pena Serna, S., Izquierdo, S., Viejo, I., Juan, A., Serrano, F. and Stork, A. (2022). Industrial digitalization in the industry 4.0 era: Classification, reuse and authoring of digital models on Digital Twin platforms, Array, 14, pp. 100176. doi: 10.1016/j.array.2022.100176.