The Economics of Digital Twins

By: Nir Kshetri

Kshetri, Nir (2021). "The Economics of Digital Twins" IEEE *Computer, 54*(4): 86-90.
http://www.doi.org/10.1109/MC.2021.3055683

Abstract:

Digital twins provide a number of economic, health, social, and environmental benefits. Their value can be amplified by combining them with other technologies and tools.

Keywords: economics | digital twins

Article:

A physical entity's digital twin (DT), which virtually represents and accurately describes a product at micro and macro levels,[1] can offer a number of benefits. In the agriculture industry, for instance, in which DT adoption is rapidly increasing, DTs can facilitate the remote monitoring of crops, soil health, and livestock and farm management, where they can eliminate place and time constraints encountered by humans.[11] DTs of assets such as bridges, cell towers, and cranes enable condition-based, rather than time-based, monitoring, which makes it possible to analyze current and historical data to identify maintenance issues. Such an approach can significantly reduce downtime and repair costs.[2] In the health-care industry, the use of virtual patients and DTs of internal organs can lead to faster regulatory approvals of medical products for ailments such as heart disease, which means that patients can get quicker and safer access to new treatments.[12]

The falling costs of storing and transmitting data; advances in computing and technological innovations and tools, such as artificial intelligence (AI), machine learning (ML), big data analytics, and the Internet of Things (IoT); and ubiquitous connectivity have made it feasible to develop and implement DTs in many settings. The global DT market was estimated at US$3.1 billion in 2020, and it is predicted to reach US$48.2 billion by 2026.[13]

DTs in Various Settings

Table 1 describes DTs in different settings. For example, Shell Nigeria Exploration and Production deployed a structural DT for the Bonga oilfield's floating production, storage, and offloading (FPSO) facility, a vessel for producing and processing hydrocarbons and storing oil.[3] It is arguably the largest asset in the world to be protected by a structural DT. The Bonga

FPSO has a capacity of 225,000 barrels per day and weighs more than 300,000 tons. The DT was designed by the Swiss company Akselos. The DT helps Shell achieve a number of operational objectives. It can identify critical areas and develop prioritized inspection, maintenance, and repair plans. It reduces the number of personnel on the FPSO, and it could minimize physical inspections in areas such as cargo tanks that are hard to reach. Finally, it provides support for planning in times of crisis, including extreme weather events, and in situations that demand asset modifications.[14]

Table 1. Examples of DTs in various settings.

Setting	**Example**	**Explanation**	**Remarks**
Company assets	Shell Nigeria Exploration and Production's DT for the Bonga oilfield's floating production, storage, and offloading facility	Helped achieve operational objectives related to inspection, maintenance and repair, and planning in times of crisis	The world's largest asset to be protected by a structural DT
Geographical area, community, or political unit, such as a city or country	Virtual Singapore platform	3D semantic model displaying land attributes, different forms of transport, buildings, and infrastructures	NRF spent US$73 million over five years to develop [15]
Planet	Destination Earth	Aims to monitor and simulate natural and human activities	Core digital modeling platform expected to be operational in 2023 Full DT developed in 2027
Internal organs of the human body	Living Heart Project	Living Heart Model used to design and test new devices and drugs	Less animal testing and fewer patients required for trials

Government organizations are also developing DTs. In Singapore, the National Research Foundation created a virtual version of the city as a 3D semantic model, in which data can be related to the real world.[15] Such a representation can display land attributes, different forms of transport, and components of buildings and infrastructures.[16] A number of other geographical areas and communities are at various stages of developing DTs. In India, the capital of Andhra Pradesh, Amaravati, is developing DTs. The cities Glasgow, in the United Kingdom, and Boston, in the United States, are also developing DTs. In 2018, the Center for Digital Built Britain, Cambridge University, launched the National Digital Twin project to support a network of DTs in the United Kingdom.[4] To help residents participate in the delivery of a new energy network, Scotland's Orkney Islands developed a 5G-powered DT.[17] Orkney was connected to 5G networks before most major cities in the United Kingdom, under the country's 5G Rural First initiative to link isolated populations.[18]

The European Union's (EU's) Destination Earth (DestinE), which is a virtual representation of Earth, is among the most high-profile examples of a DT. DestinE is expected to be implemented by 2027. It aims to monitor and simulate natural phenomenon, such as those associated with the atmosphere, oceans, ice, and land, as well as human activities. Its goals are to develop and test scenarios to enable sustainable development and to support the EU's environmental policies.[19] It is expected to provide forecasts of extreme events, including floods, droughts, and fires, many days, and even years, in advance. Policy makers can analyze the impacts of climate change and assess the effectiveness of various measures to combat it.[5] DestinE also changes the model of collaboration by providing new opportunities to integrate various disciplines. For instance, the current practice is to extract data from models built by climate scientists and pass that information to experts in areas such as agriculture, economics, and sociology. The latter groups use the information to understand the relationship between the climate and human behavior. DestinE will integrate these fields. This means that models of floods, droughts, and heat waves as well as those of migration, economics, and pollution will be on the same platform.[6]

Finally, DTs of internal organs, such as the heart, can help to complete the design, and gain regulatory approval of, medicinal products and interventions in a fast and cost-effective manner. One example is the Living Heart Project, begun in 2014, which is powered by the French software corporation Dassault Systems' 3DExperience platform. The project's Living Heart Model is used to design and test new devices and drugs. DTs make it possible to arrange and execute an in silico clinical trial through individualized computer simulations to evaluate a drug, medicinal device, or intervention. Such an approach will reduce the need for animal testing and the number of patients required to participate.[12]

Cost–Benefit, Technical, and Other Considerations

DTs offer a number of benefits. By improving process efficiency and automation, they can reduce costs. In a modular construction, for example, the Canadian technology company CadMakers uses DTs. While building an 18-story tower–Brock Commons Tallwood House at the University of British Columbia, Vancouver, a DT was used to plan the prefabrication, which involves assembling components of a structure at a separate location and transporting complete assemblies or subassemblies to the construction site. The project included a simulation of the on-site module assembly and was completed in fewer than 17 months, ahead of schedule.[20]

DTs can aid in identifying and managing various risks. For instance, they can help cities to prepare for environmental hazards, such as flooding. They can also help pedestrians avoid areas that are highly polluted.[2] In the oil industry, the demands of operating with social distancing measures due to COVID-19 increased DTs' value proposition. The North Sea oil industry reported multiple COVID-19 cases. Workers at Mexico's state-owned oil producer, Pemex, were found to be 10 times more likely than the average citizen to die from the virus.[27]

The key to realizing such benefits is to have high-fidelity DTs. Ideally, a DT replicates every detail of the original object.[20] However, there is often a gap between what is ideal and what is realizable. High costs and a lack of technical feasibility and access to relevant data may constrain the ability to benefit from DTs. A central consideration is whether DTs can capture necessary multiphysics and multiscale interactions associated with their physical twins. Note that multiphysics systems involve closely coupled interactions among separate so-called continuum physics: phenomena in which "balance" laws such as mechanics, thermomechanics, and electrodynamics govern motion and equilibrium.[21] For example, a cell phone is single device but involves a multiphysics system. The cell phone's antenna receives electromagnetic waves. The touch screen and buttons have mechanical and electrical components that interact with one another. The battery involves chemical reactions and the movement of ions and electrical current.[22]

It is important to consider the level of detail in which different aspects of the physical system are modeled to meet desired outcomes.[7] The degree of DT fidelity describes the power and accuracy of the multiphysics model. It is a function of the number of parameters transferred between the physical and virtual entities, their levels of accuracy, and abstraction.[1] The entire system is represented at the highest level of abstraction, and the lowest level could involve many components. High-fidelity modeling may result in an extremely complex DT, which could be costly to implement. High-fidelity multiphysics and multiscale models may also require huge amounts of computing power and take a long time to process. A low-fidelity and simplified solution, on the other hand, cannot capture necessary multiphysics and multiscale interactions.

There is the need to improve standardization and interoperability to increase the benefits of DTs.[8] DT standardization initiatives are quickly emerging in some industries. For instance, physical assets in the oil and gas industry undergo rigorous assurance processes throughout their lifespans to ensure the highest performance. There is currently no requirement to subject DTs to such procedures. Companies and trade associations are working to develop DT-related standards and best practices. The quality assurance and risk management company DNV GL and oil and gas company TechnipFMC teamed up to publish the oil and gas industry's first recommended practice (RP) to build and quality-assure DTs. The goal is to guide professionals through 1) assessing whether a DT can meet stakeholders' expectations, 2) establishing confidence in the data and computational models that a DT runs on, and 3) evaluating an organization's readiness to work with and evolve alongside a DT. The RP is expected to increase DTs' trustworthiness and return on investment.[23]

Combination with Other Technologies and Tools

A DT's value can be amplified by combining it with other technologies and tools. Data mining techniques, AI, and ML can analyze the model of operations represented by a DT. In a supply chain, for instance, these tools can process and evaluate multiples sources of data to learn about many facets, dimensions, and contexts to accurately forecast operation and performance.[9] DTs play a key role in augmented reality, which involves the real-time integration of digital information with users' environments. A DT follows a product's location and movement. Images that are overlaid onto the real world through real-time sensor data and analytics can be used to perform product maintenance and services.[24]

In a blockchain-based supply chain, a DT can function as a reference point to check information in a ledger, which can enhance traceability and the transparency of operations. The blockchain platform for the lifestyle company Lukso utilizes DTs of physical goods, such as jackets and shoes, which are stored on a blockchain. Tokenized assets are transferred along with their physical twins to prove ownership. In this way, top fashion designers and luxury merchants can display their collections and enhance their reputations in the digital world. During Helsinki Fashion Week 2020, viewers could purchase digital garments and have their images "dressed" in them. Helsinki Fashion Week worked with Lukso to transfer ownership.[10]

Limitations and Barriers

There are several limitations and barriers to utilizing DTs. Generating a robust DT of a product or process may not be an easy task. In some cases, the inaccessibility and unavailability of relevant data can hinder the development and implementation of a DT. For example, a comprehensive DT of a supply chain requires historical and real-time information. Data need to be streamed from various sources, such as IoT sensors, inventory management, warehouse management, fleet management, track-and-trace and cold-chain monitoring, and enterprise resource planning, which consists of software and systems to map and manage supply chains, manufacturing, services, finances, and other processes. A DT also needs data related to product lifecycle management, which entails manufacturing and marketing products as they move through successive stages, such as development, introduction, growth, maturity, and decline, as well as those related to enterprise asset management systems, which provide a comprehensive view of an organization's physical assets and infrastructure during their lifecycle (for example, design, procurement, operation, maintenance, disposal, and replacement). Relevant data are also required from a company's suppliers as well as suppliers' suppliers. The challenges to accessing data related to products and processes outside an organization are especially prominent.[9]

While many cities are implementing them, DTs may not be much help in addressing urban challenges, such as social inequality and housing crises. A DT is unlikely to address underlying sociopolitical issues.[25] Finally, due to a low degree of digitization, developing economies are unable to benefit from DTs. The computing power needed to create high-fidelity multiphysics and multiscale models is enormous and beyond the reach of countries that lack computing power and bandwidth.[26] For instance, mobile networks cover only 30% of the population of Burundi, which stands in stark contrast to areas such as Singapore and Orkney.

DTs provide many economic, health, social, and environmental benefits. They help organizations improve efficiency, reduce costs, and manage risks in a more systematic and effective manner. DTs of internal organs, such as the heart, make it possible to test new drugs and devices quickly and safely. A DT of Earth, such as DestinE, can provide accurate and timely forecasting of extreme events, including floods, droughts, and fires. In many developing countries, the development and implementation of DTs are hampered by technical and infrastructural challenges. To maximize the benefits of DTs, it is important for developed countries to help digitize developing countries and offer them resources, such as computing power and technical tools.

Acknowledgment

I thank *Computer*'s editor in chief, Jeffrey Voas, for suggestions about a previous version of this article.

References

1. D. Jones, C. Snider, A. Nassehi, J. Yon, and B. Hicks, "Characterising the Digital Twin: A systematic literature review," *CIRP J. Manuf. Sci. Technol.*, vol. 29, no. Part A, pp. 36–52, May2020. doi: 10.1016/j.cirpj.2020.02.002.
2. D. Castro, "*Digital Twin technology can make smart cities even smarter*," GovTech, 2019. [Online]. Available: https://www.govtech.com/smart-cities/Digital-Twin-Technology-Can-Make-Smart-Cities-Even-Smarter.html

3. "*Shell gets advanced Digital Twin for its storage facility*," The Oil Bloc, Sept., 2020. [Online]. Available: https://theoilbloc.com/shell-gets-advanced-digital-twin-for-its-storage-facility/

4. C. Minsky, "*Digital Twins give urban planners virtual edge*," Financial Times, 2020. [Online]. Available: https://www.ft.com/content/15851b06-1b6f-11ea-81f0-0c253907d3e0

5. P. Voosen, "*Europe is building a 'digital twin' of Earth to revolutionize climate forecasts*," Science Magazine, 2020. [Online]. Available: https://www.sciencemag.org/news/2020/10/europe-building-digital-twin-earth-revolutionize-climate-forecasts

6. J. Dykes, "*The EU announces plans to build Destination Earth, a digital twin of our planet*," Jan., 2021. [Online]. Available: https://geographical.co.uk/nature/climate/item/3940-the-eu-announces-plans-to-build-destintation-earth-a-digital-twin-of-our-planet

7. M. Tremblay, "*The Digital Twin: The benefits of taking an incremental journey*," The Maritime Executive, 2020. [Online]. Available: https://www.maritime-executive.com/editorials/the-digital-twin-the-benefits-of-taking-an-incremental-journey

8. V. Piroumian, "Digital Twins: Universal Interoperability for the Digital Age," *Computer*, vol. 54, no. 1, pp. 61–69, 2021. doi: 10.1109/MC.2020.3032148.

9. G. Lawton, "*Early days for digital twins in the supply chain*," TechTarget, 2020. [Online]. Available: https://searcherp.techtarget.com/feature/Early-days-for-digital-twins-in-the-supply-chain

10. N. Kshetri, *Blockchain and Supply Chain Management*. Cambridge, MA: Elsevier; 2021.

11. Research and Markets. "*Digital twin market by technology, type (product, process, and system), application (predictive maintenance, and others), industry (aerospace and defense, automotive and transportation, healthcare, and others), and geography—Global forecast to 2026*." Research and Markets. https://www.researchandmarkets.com/reports/5146336/digital-twin-market-by-technology-type-product?utm_source=BW&utm_medium=PressRelease&utm_code=lnlmx5&utm_campaign=1466158+-+%2448.2+Billion+Digital+Twin+Markets%3a+Aerospace+%26+Defense%2c+Automotive+%26+Transportation%2c+Healthcare+-+Global+Forecast+to+2026&utm_exec=chdo54prd (accessed Feb.2, 2021).

12. 3D Experience Lab. "*Living Heart: A translational research initiative to revolutionize cardiovascular science through realistic simulation*." Dassault Systems. https://3dexperiencelab.3ds.com/en/projects/life/living-heart/#_ga=2.227862681.564567602.1610598960-fefdfda0-5621-11eb-8724-81a441ec6904 (accessed Feb.2, 2021).

13. Research and Markets. "*$48.2 billion digital twin markets: aerospace & defense, automotive & transportation, healthcare—Global forecast to 2026*." Yahoo Finance. https://finance.yahoo.com/news/48-2-billion-digital-twin-133900362.html (accessed Feb.2, 2021).

14. Data Science and Digital Engineering in Upstream Oil and Gas. "*Akselos Deploys Digital Twin of Shell's Bonga FPSO*." Society of Petroleum Engineers. https://pubs.spe.org/en/dsde/dsde-article-detail-page/?art=7579 (accessed Feb.2, 2021).

15. National Research Foundation. "*Virtual Singapore*." Singapore Government. https://www.nrf.gov.sg/programmes/virtual-singapore (accessed Feb.2, 2021).

16. P. Liceras. "*Singapore experiments with its digital twin to improve city life*." Tomorrow Mag. https://www.smartcitylab.com/blog/digital-transformation/singapore-experiments-with-its-digital-twin-to-improve-city-life/ (accessed Feb.2, 2021).

17. J. Blackman. "*Scottish island builds 5G-powered digital twin of smart energy system*." Enterprise IoT Insights. https://enterpriseiotinsights.com/20200429/channels/news/orkney-builds-5g-powered-digital-twin-of-smart-energy-system (accessed Feb.2, 2021).

18. H. Williams. "*5G: Why Orkney got the latest tech before London*." BBC News. https://www.bbc.com/news/uk-scotland-north-east-orkney-shetland-48453474#:~:text=People%20living%20in%20six%20major,and%20some%20cows%20in%20Somerset (accessed Feb.2, 2021).

19. European Commission. "*Destination Earth (DestinE)*." European Commission. https://ec.europa.eu/digital-single-market/en/destination-earth-destine (accessed Feb.2, 2021).

20. D. Patterson and B. Ruh. "*Digital twins: Taking modular construction to the next level*." Global Infrastructure Initiative. https://www.globalinfrastructureinitiative.com/article/digital-twins-taking-modular-construction-next-level (accessed Feb.2, 2021).

21. C. M. Dafermos, "Introduction to continuum physics," in *Hyperbolic Conservation Laws in Continuum Physics*. Berlin, Germany: Springer-Verlag, 2005, ch. 2, pp. 25–49.

22. Multiphysics Cyclopedia. "*What is multiphysics*?" Comsol. https://www.comsol.com/multiphysics (accessed Feb.2, 2021).

23. World Oil. "*DNV GL debuts quality assurance guidance for digital twins in oil and gas*." Gulf Publishing. https://www.worldoil.com/news/2020/11/16/dnv-gl-debuts-quality-assurance-guidance-for-digital-twins-in-oil-and-gas (accessed Feb.2, 2021).

24. Essentra Components. "*The digital twin—What is it and how does it work*?" Essentra. https://www.essentracomponents.com/en-gb/news/product-resources/the-digital-twin-what-is-it-and-how-does-it-work (accessed Feb.2, 2021).

25. L. Wan, T. Nochta, J. M. Schooling, M. J. DeJong, and G. M. B. Viggiani, "Developing a city-level digital twin—Propositions and a case study," in *Proc. 2019 Int. Conf. Smart Infrastructure and Construction*. doi: 10.1680/icsic.64669.187.

26. O. Alais. "*Enabling governments to be ready for big data and artificial intelligence*." Alais.org. https://alais.org/enabling-governments-ready-big-data-artificial-intelligence/ (accessed Feb.2, 2021).

27. A. Stillman, "*How AMLO's crown jewel became the world's deadliest Covid company*," Bloomberg Businessweek. Sept., 2020. [Online]. Available: https://www.bloomberg.com/news/features/2020-09-10/oil-producer-pemex-has-the-most-covid-19-deaths-of-any-company-in-the-world

Nir Kshetri is a professor at the Bryan School of Business and Economics, University of North Carolina at Greensboro, Greensboro, North Carolina, 27412, USA, and the "Computing's Economics" column editor for *Computer*. Contact him at nbkshetr@uncg.edu.