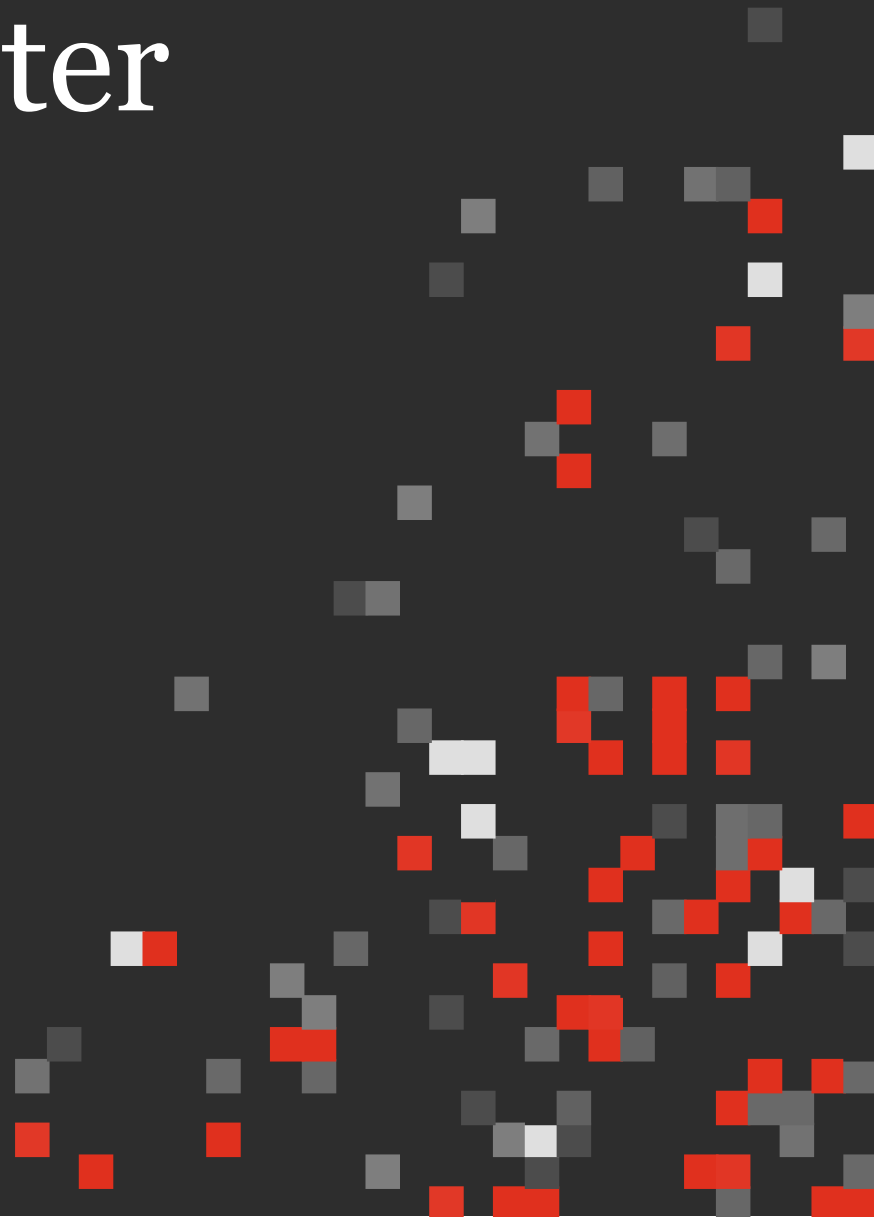
How digital twins can make smart cities better

Real-time simulations can create a bridge between physical and virtual worlds



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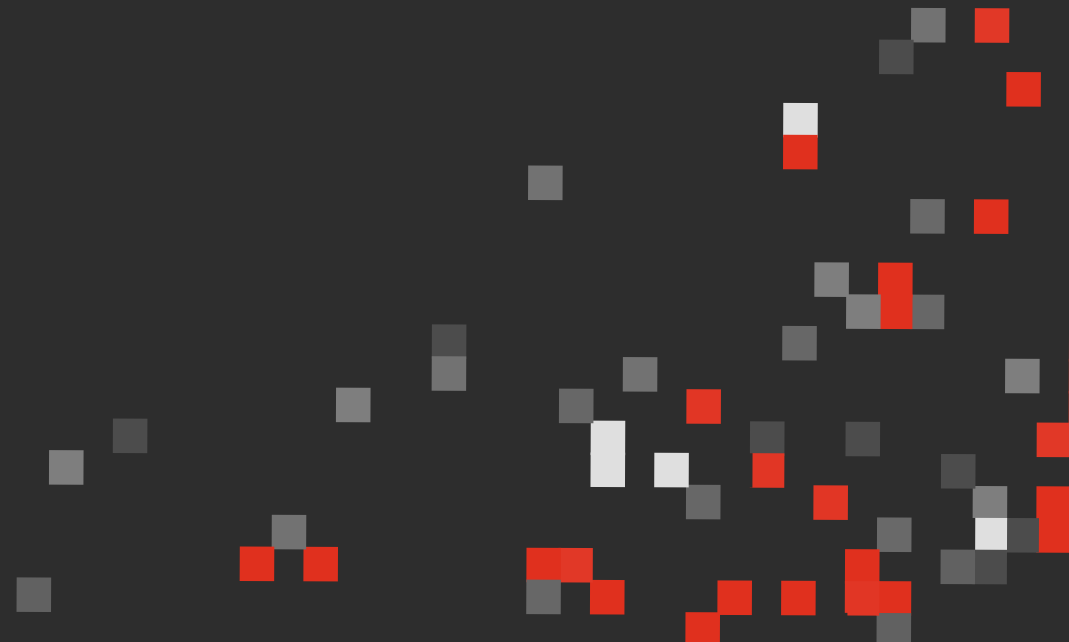
Digital twins are part of Gartner's top 12 strategic technology trends for 2022[1] and have been recognised by public organisations as an effective tool for city planning and management. This paper presents our views on the benefits of digital twins for this purpose, focusing on the opportunities in the Middle East, a model for developing a fit-for-purpose digital twin, and common requirements for implementing the technology.



[1] https://www.gartner.com/en/information-technology/insights/top-technology-trends

What is a digital twin?

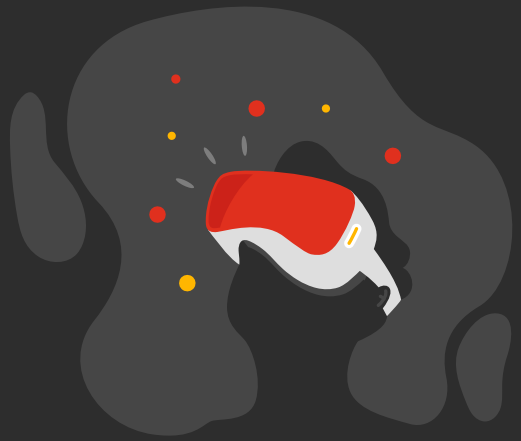
A digital twin, in its simplest sense, is a linked virtual model of a physical object. By connecting the real-time data of the physical object or process into its digital representation – programmed with mathematical models, AI and pattern recognition to faithfully recreate its sibling – the digital twin comes to life.

The living replica, constantly updated with data from its physical twin, enables a user to analyse data, monitor systems and run simulations exactly as if they were working with the physical asset. The approach has roots in manufacturing, providing the ability to test a new asset such as a jet engine virtually, without the risk involved in failure during a test of the physical asset. Today it has a wide range of applications. These include testing new designs for equipment or spaces; conducting diagnostics on organisational health; issuing digital twin IDs to citizens and residents for public access; and enabling more effective city management.

In the context of a smart city, a digital twin continuously collects information from the built environment via technologies such as sensors, drones and mobile devices to present an up-to-the-second picture. An urban digital twin will be receiving data from sources including vehicles, buildings, infrastructure and individuals. This is further enhanced with data captured by smart city devices and the Internet of Things (IoT) and additionally augmented by the use of artificial intelligence (AI) and advanced analytics.

These technologies enable static, historical and real-time data to be processed and synthesised almost immediately to provide valuable insights about the performance of the city. In this way, a digital twin can be considered to be a “strategy accelerator” that enables public sector organisations to identify insights and connections more effectively, and drives better solutions with more confidence. Cities including Singapore, Sydney and Amaravati, a greenfield city in India, are already using digital twins to enable smart development.

At PwC, we’ve been looking at ways that digital twins can be used to help investors, planners and other key smart city stakeholders make data-informed decisions.



Harnessing the power of data and real-time simulation to build insight-driven public sector organisations

As cities around the world experience extraordinary growth and increasingly complex urban challenges, municipal authorities are encountering greater pressure for more efficient resource allocation and effective city management. This is particularly true in our region, where cities are expanding, redeveloping and witnessing new mega projects.

There is growing recognition amongst public sector organisations in cities around the world of the value of leveraging real-time digital data for monitoring the performance of existing services, improving city planning and optimising decision-making. By feeding different sources of dynamic data to a digital twin, there is potential to test ideas or simulate what-if scenarios for facilities, processes and city landscapes before any real-world implementation - even before cities are built or developed.

We believe that digital twin technology will have a vital role to play in managing this next phase of urban development in a safe, efficient, environmentally conscious and cost-effective way.

Real benefits

Digital twins can optimise planning, operations, finance and emissions-reduction decision-making in large, complex building projects and assets in new and unique ways. Users can benefit from substantial cost savings, productivity gains and carbon emission reductions city-wide.

From a city management perspective, a digital twin of a building, a neighbourhood or even an entire city can greatly assist in urban planning as well as the operation and maintenance of physical assets.

For instance, simulating the risks created by high temperatures or dust storms in a city can ensure that designs for the built environment are more resilient and sustainable. In addition, identifying and preventively maintaining physical assets or city networks can minimise downtime as a result of any operational issues.

In the Middle East, whole cities are in development and new neighbourhoods are being constructed. Dubai's 2040 Urban Master Plan will see five new urban areas developed in the city over the next two decades, with space for hotels and tourism increasing by 134% and health and education space growing by 25%. In total, the city expects to add 2.5 million people by 2040. Saudi Arabia's Vision 2030 programme will see the Kingdom build and develop major cities: Neom aims to be the world's most technologically advanced city, and one of the most sustainable; Al Ula, one of the

world's oldest cities, is being re-thought as a cultural and outdoor hub; Amaala will be a tourist destination, and Prince Mohammed Bin Salman Nonprofit City will include homes as well as business premises and spaces for socialising.

Planning ahead

Planning for this kind of rapid growth across our region is complicated. Unlike historical patterns of urban growth where streets are gradually added and cities evolve over time, new cities need to get it right straight away. Facilities for residents, such as public transport stops and wireless network antennas, need to work perfectly. Retailers want assurance that their outlets will be in the best places to attract passing customers and receive stock deliveries with ease.

This is where digital twin technology can help. It can give investors better information to assess the risks and opportunities of such large-scale projects. It can also serve as an effective engagement tool to facilitate discussion among different sectors of society including the general public, private sector, civil society and policymakers.

The ability to simulate scenarios and translate data into meaningful insights through a virtual representation of the real world brings issues to life for those who have a stake in the city. In this way, a digital twin can not only enable better policymaking and service improvements, but also present an opportunity for public sector organisations to demonstrate more responsive and agile governance that can ultimately maximise impact and value to communities.

These ideas were discussed during the Business Breakfast session on digital twins and their large-scale use in city planning, and where they fit within the realm of the metaverse.

Listen here: How digital twins can be used in city planning

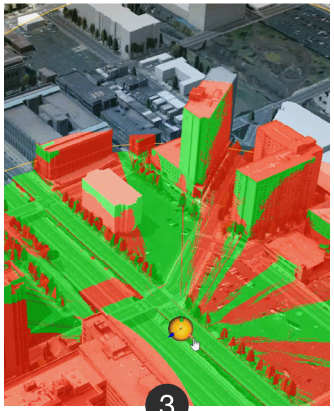
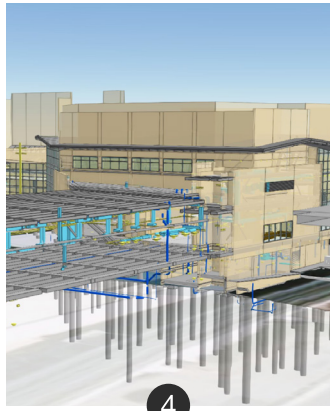
Using the digital twin model to construct a fit-for-purpose replica

The UAE and KSA aren't the only countries tackling the challenges of massive expansion of cities. By 2050, around 2.5 billion more people could be living in urban areas worldwide[2] and these cities need to work. That means planning the necessary construction, as well as the services, infrastructure and transport, and allowing for any socio-economic impacts.

The following chart shows how digital twin solutions can play their part with various levels of maturity and adoption: from descriptive analysis through predictive modelling, followed by scenario planning and simulations, all the way to operational excellence.

[2] https://www.un.org/development/desa/en/news/population/2018-world-urbanization-prospects.html

Digital twin solutions go through various levels of maturity & adoption

	Descriptive Analysis	Predictive Modelling	Scenario Planning & Simulations	Operational Excellence
	 1	 2	 3	 4
Description	Visualize the city in 3D and its changes over time such as new assets, roads & bridges, movement of people, demographic & economic changes	Model, predict and forecast underlying activities in sectors, such as real estate, transport, sustainability & socio-economic sectors	Run multiple what-if scenarios and simulations by pulling levers of change and its effects on the city	Improve operations by making the organization proactive through live command centres and AI powered recommendations backed by real-time data integration
Indicative Use Cases	• 3D model of all assets • Street view and building facade • Socio-economic information • Demographic details	• Understand the relation between changes in demographics, immigration, etc • Real estate, transport sector and public assets demand predictive analysis	• Model infrastructures to accommodate for changes in the city • Simulate economic activity & demographic changes	• Live command centre and dashboard powered by AI • Real-time social listening & impact on real estate and asset management

Visualisation technologies… and the metaverse

Development of digital twins needs to consider the dynamic and static aspects of the data they rely on, and the need for 2D and 3D representations of situations and environments. In particular, the 2D/3D dimensional data representation could be further differentiated between “on the ground” vs “below ground” applications and “indoor” vs “outdoor” applications. For instance, the on the ground application would involve data captured on building façades for buildings’ management purposes and can be utilised by investors and external users. The below ground application meanwhile, allows the tracking and maintenance of facilities such as pipe networks by urban planners, engineers and others.

This model can be further overlaid with visualisation technologies such as augmented reality (AR), virtual reality (VR) and mixed reality (MR), to introduce additional information about the landscape or building, or show potential future scenarios. This continuum of immersive technologies is housed under the umbrella term, extended reality (XR).

Collaborative VR environments enable people to come together and interact, even when they are remote.

VR also enables multiple users to experience the same content but as a customised experience depending upon each user's choices.

MR merges real and virtual worlds to produce new environments and visualisations, where physical and digital objects co-exist and interact in real-time.

While VR allows people to visualise 3D virtual environments, **AR** takes computer-generated images and overlays them on a real world view.

XR technology can benefit all industries by creating more efficient processes, enhancing training and offering ways for people to collaborate in a virtual environment. It enables design teams to explore, test and evaluate different concepts without investing in physical prototypes. This can help organisations bring higher-quality products to market faster.

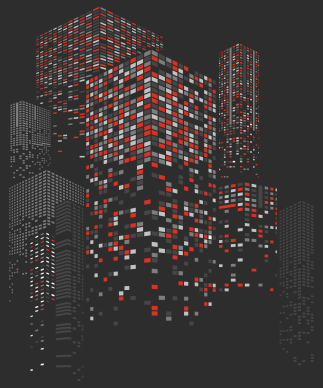
Welcome to the metaverse

The metaverse may profoundly change how businesses and consumers interact with products, services and each other. It promises a stunningly realistic 3D digital world where you can, for example, buy and sell goods and services, sign and enforce contracts, and interact with customers and communities. As some technology visionaries imagine it, this metaverse won't primarily run on platforms whose owners control data, governance and transactions. Instead, customers and businesses will be able to take their identities, currencies, experiences and assets anywhere they wish. Also, unlike today's web experiences, much of this digital world will persist even when no one is in it.

Such technology has the potential to take digital twin modelling to another level of immersion, experience and capabilities.

Digital twin and Metaverse:

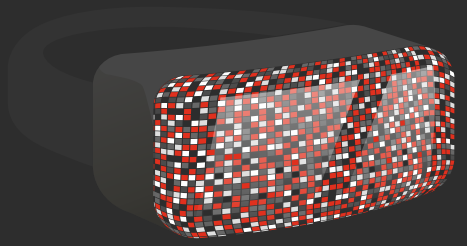
Digital Twin



- Immersive 3D visualization in a web browser
- Analytics & Actionable Insights
- Simulation & Cognitive capabilities

A virtual representation of the real-world assets

Metaverse



- VR/AR immersive interactions & interface
- Experiential transactions and community
- Powered by crypto, 5G, AI, and edge computing

User activity & data

3D model

Building models

GIS Data

Digital twins underpin smart city development - but need to be used wisely

While the application of digital twins is promising, it comes with a whole set of requirements that both public and private organisations need to address when developing and executing any strategy. Some common challenges to consider are:

Vision

- **Establishing** a clear vision and KPIs: the implementation of digital twins can be a resource-intensive exercise involving a wide range of stakeholders. It's vital to have a common understanding of the vision of such an implementation and an agreed set of performance indicators.
- **Coordinating implementation**: having a clear vision is just the start; delivery is even harder. Such complex projects involve an overload of decisions and multiple stakeholders. Cities need an effective mechanism to prioritise use cases by impact, and then to coordinate and govern the approach to digital twin implementation.
- **Building trust**: key public and private stakeholders must work together to create trust in the ecosystem of technology, data and processes, talent and security that provide the building blocks for digital twins.

Data

- **Data quality and sufficiency**: historical data may be duplicative or lack the detail and accuracy needed for use with the desired digital twin model and technological solutions such as AI.
- **Willingness to share data**: stakeholders may be reluctant to share data with other parties, especially sensitive or personal data. A robust accountability framework (discussed below) is required to encourage data sharing, while offering sufficient protection to those parties doing so.
- **Data standards**: a lack of consistent data standards and rules for collecting data can make it hard for different units to share data. It's important to create synergies through collaboration and maximise the value of data.
- **Updated information**: for accurate decision-making, it is necessary to have a systematic updating mechanism to constantly update static objects and scan new objects to ensure the accuracy of digital twins in real-world representations.

The above challenges also depend upon the specific use case. For a new build development, challenges are more centred around simulation.

Talent

- **War for talent**: while technologies such as AI can do more with less manpower, more specialised professionals such as data scientists or engineers and architects will be needed to make sense of the abundant information. These key skills will be in increasingly high demand.

Accountability, Security and Privacy

- **Information security and privacy**: the entire data lifecycle from capture to enrichment, maintenance, usage, archiving and purging, must be secured against malicious actors and violations of privacy rights.
- **Accountability**: the design and execution of digital twin applications relies on an accountability framework around open data licensing, evolving regulations about privacy and cybersecurity, conditions of use and liability of parties, as well as IP rights.

Technology

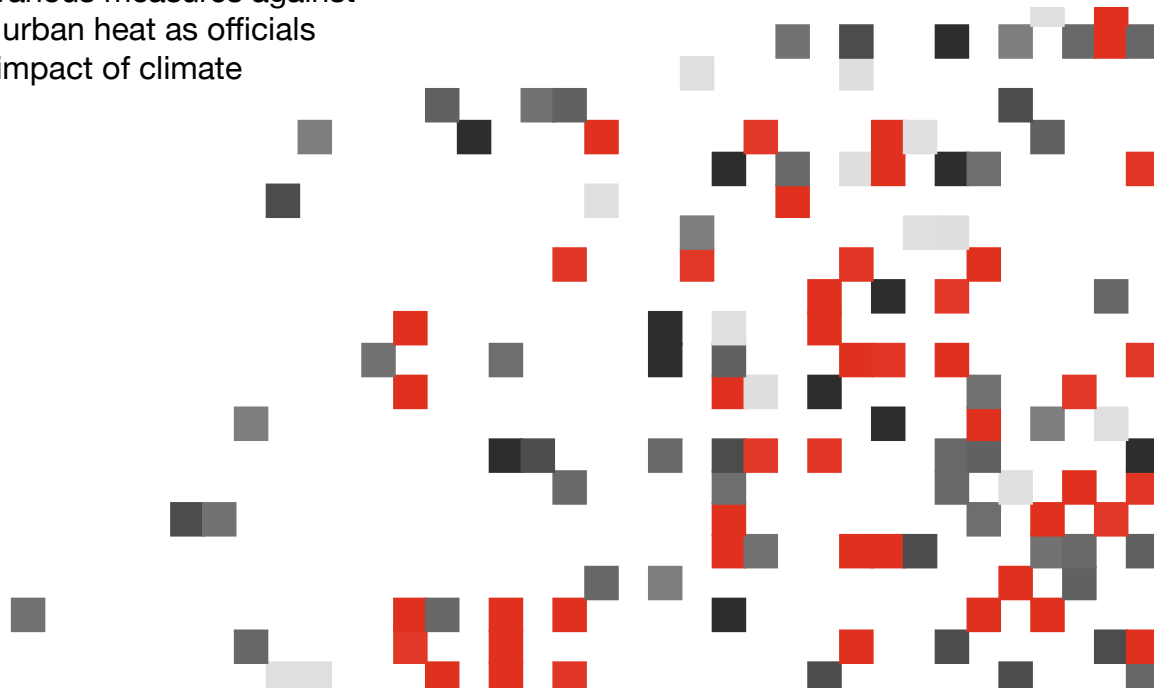
- **Technology platforms**: different units may have diverse legacy systems or software with limited functionality for exchanging and/or sharing data, resulting in challenges in rapidly identifying useful information from the data, integrating different data sets such as geo-information systems, and building information management. To maximise benefits, several technology platforms must coexist, including AI, predictive analytics, sentiment analysis, and others.
- **Sensor deployment**: retrofitting existing infrastructure and networks with sensors – so-called brownfield deployment – might present more challenges than greenfield deployment in ensuring the integration of sensor devices and networks.

It's important to note that digital twin technology doesn't have to be applied to a whole city; it could simulate a planned building, for example, showing how people will move around it. This would help planners determine the ideal locations for elevators, washrooms, and other amenities.

Could digital twin technology help smart cities realise their original environmental goal?

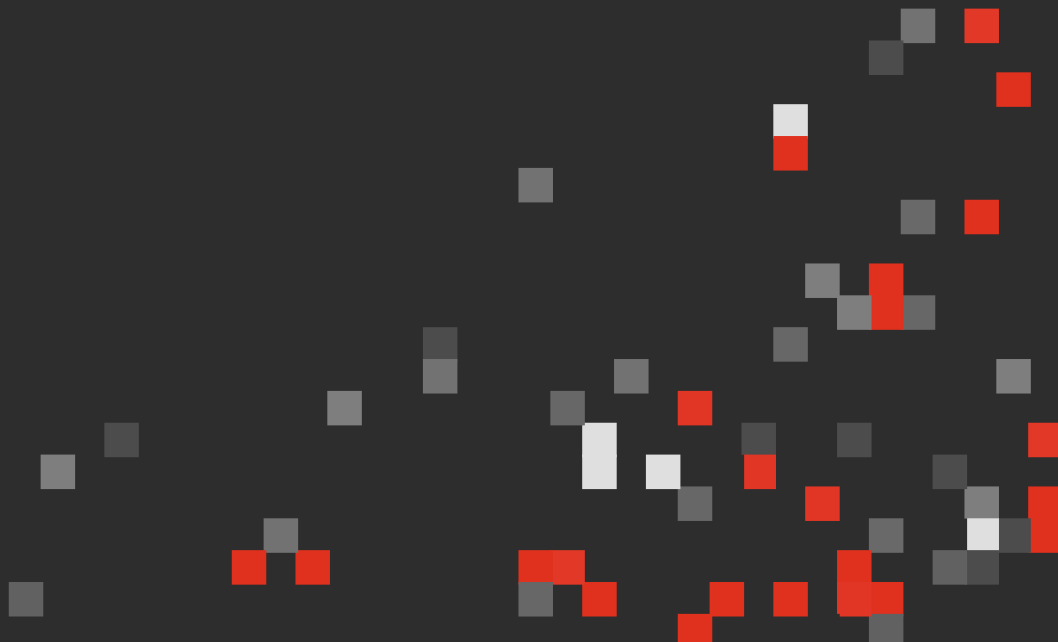
The concept of smart cities was initially developed partly in response to a heightened awareness of environmental issues including global warming. The goal was to achieve citywide energy efficiency by using a mechanism called a smart grid to optimise the management of energy supply and demand. The concept then expanded to include the utilisation of resident data not only for energy but also in the areas of public services, healthcare, mobility and agriculture.

The emergence of various technologies including IoT, AI and big data made it possible to collect, analyse and utilise various forms of data that had previously been overlooked. Now digital twin technology could help officials cut the costs and carbon emissions of new construction and avoid costly modifications after a project is completed. It could also enable cities to test the effectiveness of various measures against rising sea levels and urban heat as officials seek to mitigate the impact of climate change.



The way forward

While digital twin technology promises vast benefits to both the public and private sectors, it also poses implementation challenges that require prudent planning and deliberation before the benefits can be realised. When considering digital twins for smart city implementation, we recommend the following **five key considerations**:



Set a clear vision and KPIs

Stakeholders must establish a common understanding of the expected outcomes associated with the implementation of digital twins (having due regard to resource constraints) and develop an appropriate set of KPIs reflecting the benefits of digital twins. This will help to reduce the risk of projects requiring unexpected large-scale investments.

Stock-take on existing digital twins and data

Being able to synchronise and integrate existing data, which may be presented in different formats and housed in different systems with levels of granularity, is key to building a successful model that accurately reflects historical and current information for future scenario-planning. A stocktaking exercise of data and any digital twins already in use would be beneficial in understanding the current adoption landscape and data available to support future implementation.

Establish data governance and regulation

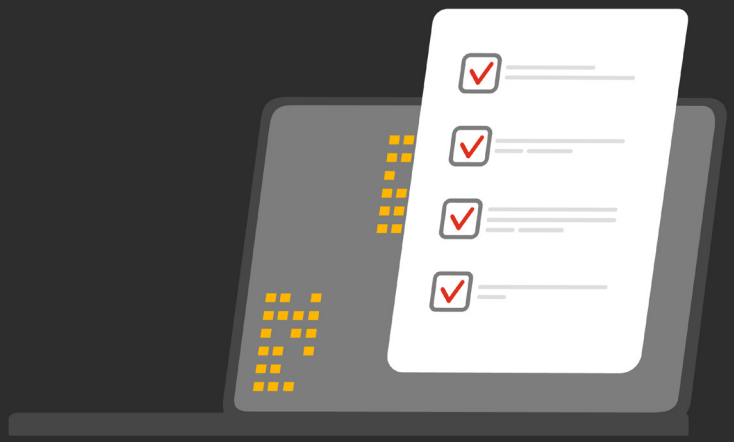
It is vital to set up a data-rich environment with high security and privacy, and policy and standards, with clear guidelines on how data is collected, exchanged, distributed and disseminated and how the information is used. Creating trusted and regulated processes is key to developing a robust data environment, which drives the use of data and digital twins.

Tailored implementation

is no “one-size-fits-all” approach for digital twin development. The local context drives the digital twin models (and mix) and implementation schedule. This highlights the need for each city to cater to local circumstances. For instance, with a wide spectrum of possibilities but limited resources, governments need to prioritise and map out an implementation plan for turning greenfield sites into smart developments with well-integrated infrastructures and seamless device connectivity, or converting existir sites to enable digital twin applications.

Leverage the broader digital technology landscape

The development of smart cities – enabled, powered and integrated by digital technologies including IoT and mixed reality – is set to be one of the crowning achievements of societies worldwide in the 21st century. Today, the world’s cities are in the midst of extraordinary growth and we’re only just beginning to explore the possibilities of using digital twins for projects that have yet to be built.

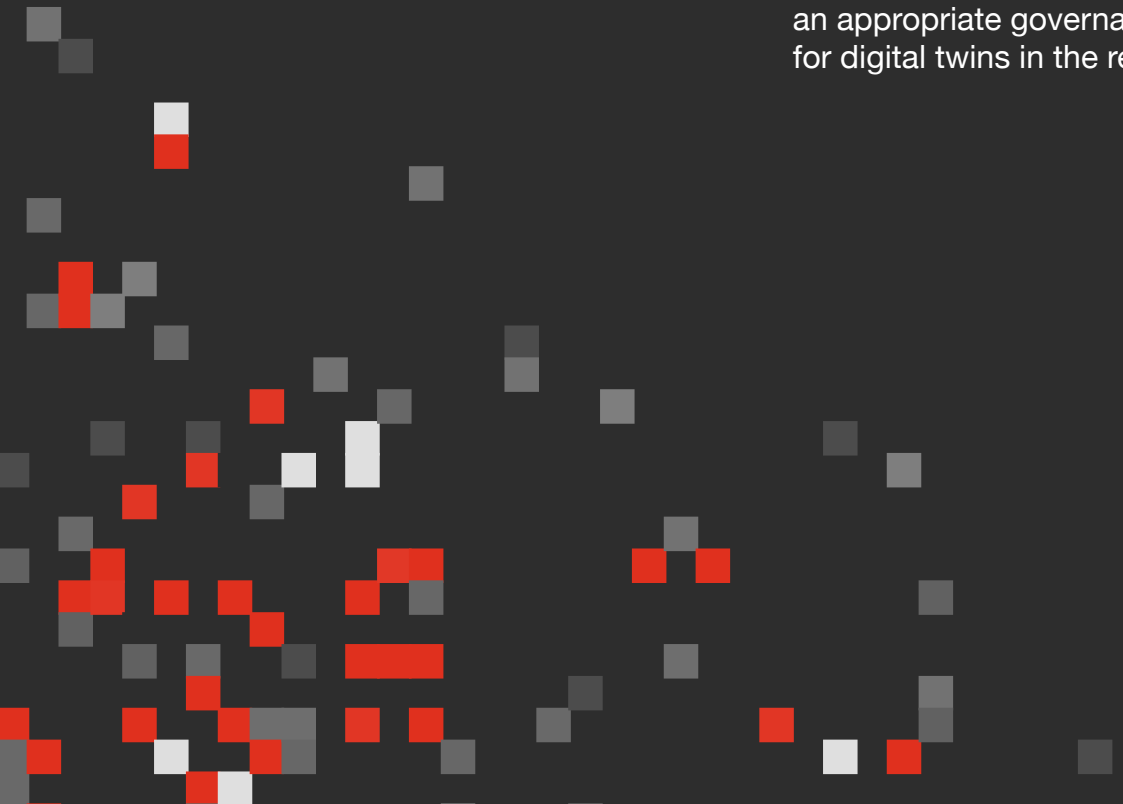


Arise, the smart region

We believe digital twin technology will have a vital role to play in managing the next phase of urban development in a safe, efficient, cost-effective and more sustainable way. Digital twins also have the potential to address urban challenges such as climate change and cross border movement of people and goods.

In the Middle East, digital twins could be important forms of soft infrastructure that help transform the area into a truly smart region. However, achieving this requires large-scale data sharing and the harmonising of different legal, data, privacy and regulatory policies through collaboration. Governments should consider and focus on key priorities such as assessing use cases that digital twins could support; stock-taking data that is of the required quality to support the application of digital twins; determining the digital twin model that should be adopted; and ensuring an appropriate governance structure exists for digital twins in the region.

It's clear that our future could be much better envisaged with digital twins. As our region's cities continue to grow and expand, leveraging digital twin technology will allow planning in ways not previously possible. Simulations will help to make execution precise, efficient and accurate. We will be able to push the boundaries of design and imagination by envisaging projects through their digital twins, and ultimately build them in the most cost-efficient and timely manner.



At PwC we are using VR for digital twin visualisations. We can create and replicate whole cities digitally and experience them in VR. We recently created a rapid prototype of a digital twin of an existing space in KSA to showcase future plans about the area to key stakeholders. Get in touch with us to learn how this capability can benefit your organisation.

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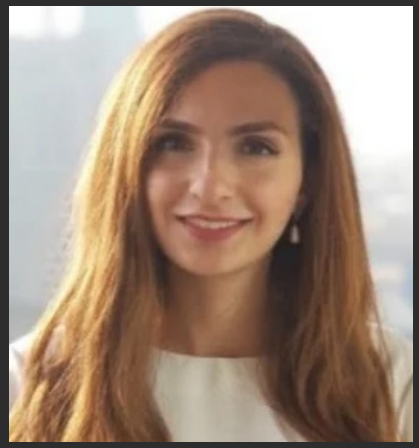

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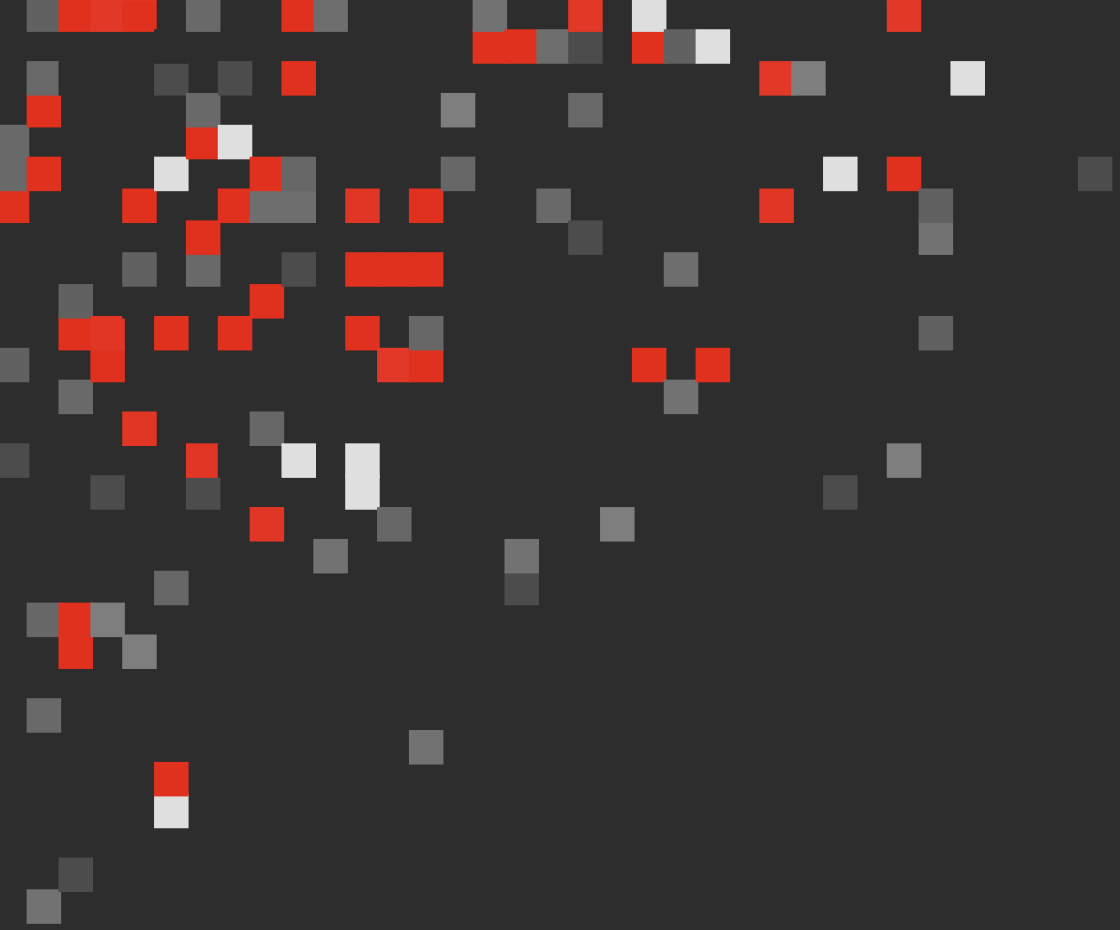

(Adapted from original PwC China thought leadership and contextualised for the Middle East region)

About PwC

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Established in the Middle East for 40 years, PwC has 22 offices across 12 countries in the region with around 7,000 people. (www.pwc.com/me).

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