Digital Twins in Smart City
智慧城市中的数字孪生

A bridge between the physical and virtual world
现实世界与虚拟世界之间的桥梁

pwc 普华永道

Being one of the top 10 strategic technology trends as rated by Gartner, digital twins are recognised by public organisations as an effective tool to city planning and management. This paper presents our views on the benefits of digital twins, a model for assessing the approach for development of a fit-for-purpose digital twin, a development framework outlining key elements of a digital twin ecosystem and examples of how digital twins have been used in other cities. The paper also discussed common challenges encountered when implementing digital twins as well as the way forward and opportunities for digital twin development in the Greater Bay Area (GBA).

Digital twins set the foundation on which smart services could be developed to serve the physical world.

数字孪生是Gartner评选的十大战略技术趋势之一，被公共机构公认为是城市规划和管理的有效工具。本文介绍了普华永道对数字孪生的好处的看法，展示用于构建切合需要的数字孪生的评估模型，概述数字孪生生态系统关键要素的发展框架，以及其他城市如何应用数字孪生的案例。本文还探讨了在实施数字孪生时常见的挑战，以及大湾区进行数字孪生发展的前景和机遇。

数字孪生奠定了发展智能服务为现实世界服务的基础。

What is a digital twin

A digital twin is a digital model or replica of a physical asset, be it a product, an organisation, a public infrastructure or even an entire city. It has a wide range of applications – from conducting diagnostics on organisational health, augmenting service designs to enabling more effective city management. In the context of a smart city, a digital twin of the city continuously collects information from the built environment (via technologies such as sensors, drones, or mobile devices). It is made possible with the use of remote communication technologies such as WiFi and Bluetooth as well as through Internet of Things (IoT) sensors that gather data from the physical world to reconstruct an identical digital copy of the city. Apart from IoT, the use of Big Data, Artificial Intelligence (AI), cloud computing, machine learning and advanced analytics also enhance the accuracy and dynamism of this replica, allowing static, historical and real- time data to be processed and synthesised almost immediately to provide valuable insights about the performance of the city. Therefore, a digital twin can be considered as a “strategy accelerator” that facilitates public sector organisations to identify insights and connections more effectively, and to drive to better solutions with more confidence.

什么是数字孪生

数字孪生是产品，机构，公共基础设施甚至整个城市的数字模型或实物资产的副本。它具有广泛的应用 — 从对机构进行监测，增强服务设计到实现更有效的城市管理。在智慧城市的背景下，城市的数字孪生不断（通过传感器，无人机或移动装置等的技术）从建筑环境中收集信息。通过使用远程通信技术（例如WiFi和蓝牙），物联网（IoT）传感器以及从现实世界收集数据，能实现构建与城市相同的数字副本。除物联网外，运用大数据，人工智能（AI），云计算，机器学习和分析的功能，亦可提高数字副本的准确性和动态性，令数字副本可实时处理和汇总静态，历史和实时数据，提供有关城市表现的见解。因此，数字孪生可被视为“战略加速器”，促进公共部门机构更有效地洞察数据与城市管理的关联，并为公共机构推动更佳的解决方案注入信心。

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

In the face of intensifying global competition and growing complexity in urban challenges, cities are encountering increasing pressure for more efficient resource allocation and proper city management. In fact, there is growing recognition amongst public sector organisations from around the world on the value of leveraging real time digital data for monitoring performance of existing public services, improving city planning and optimising decision making of policy makers.

By feeding different sources of dynamic data to a digital twin, there is potential for this replica to testbed ideas or simulate what-if scenarios for the facilities, processes and city landscape which one wished to change before actually putting actual resources behind real-world implementation. Such an exercise allows for identification of potential issues in any proposed plans or initiatives before they actually happen, thus allowing organisations to further tailor their actions and mitigate the risks early on.

From a city management perspective, a digital twin of a building or even an entire city can greatly assist in urban planning as well as the operation and maintenance (O&M) of physical assets. For instance, by first identifying and preventively maintaining physical assets or city network, this can save time from subsequent corrective maintenance and minimise downtime to any issues. Likewise, by first simulating solar energy exposure or risks created by severe weather conditions in a city, there is potential for enhancing designs of built environment to be more green and resilient.

For public sector organisations, a digital twin can also serve as an effective engagement tool to facilitate discussion amongst different segments of society, including the general public, the private sector, civil society and policy makers amongst others. The ability to simulate scenarios and translate data into meaningful insights through a virtual representation of the real world bring issues to life for those who have a stake in the city. A digital twin will thus not only enable better policymaking and service improvement, but also present an opportunity for public sector organisations to demonstrate more responsive and agile governance that can ultimately maximise impact and value to the communities and the public.

利用数据和实时模拟的力量来构建受洞察力驱动的公共部门机构

面对日益激烈的全球竞争和城市挑战的复杂性，各城市正面临越来越大的压力，并要求更有效的资源分配和适当的城市管理。实际上，全球的公共机构都越来越认识到利用实时数字数据来监察现有公共服务的绩效，改善城市规划和优化决策者制定决策的价值。

通过将不同的动态数据源提供予数字孪生，此数字副本将能测试想法，或在投入实际资源应用时，模拟日后改变设施，流程和城市景观的假设情景。这样的模拟可以提早识别任何拟议的计划或举措中的潜在问题，从而使机构可以进一步调整其行动并尽早减轻风险。

从城市管理的角度来看，建筑物或整个城市的数字孪生可有效地协助城市规划以及实物资产的运营和维护。例如，通过首先识别和预防性维护有形资产或城市网络，可以节省后续纠正性维护的时间，并最大程度地减少因任何问题而造成的服务中断时间。例如，通过首先模拟日晒的情况或城市中恶劣天气条件造成的风险。可令建筑环境的设计更环保和更具弹性。

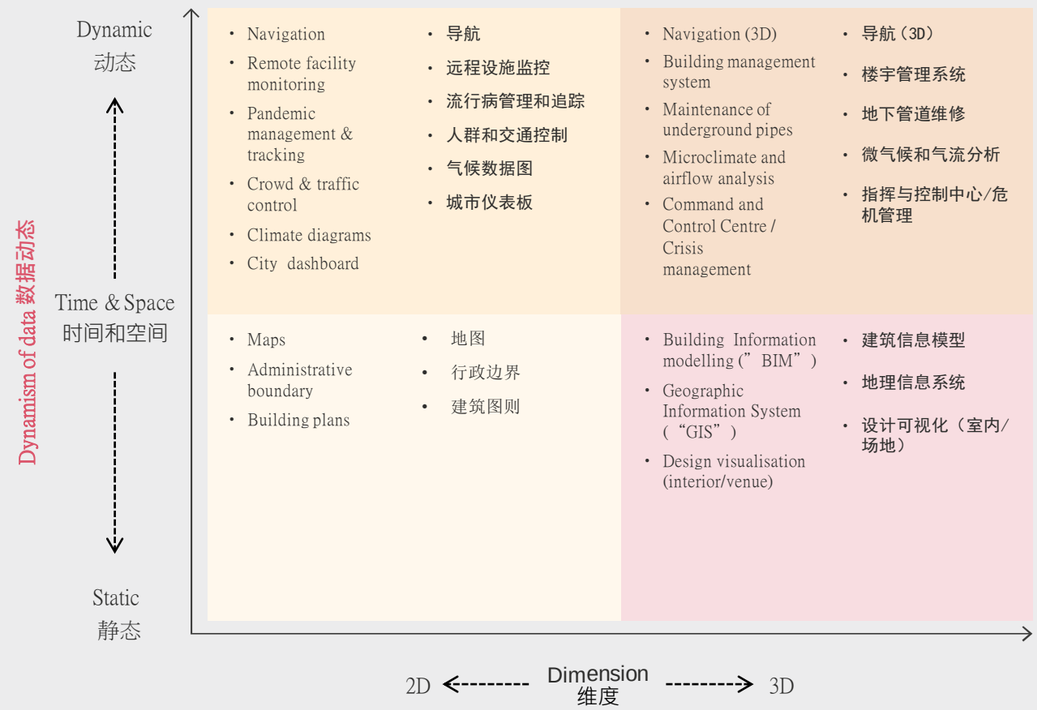
对于公共机构而言，数字孪生可用作有效的参与工具，促进社会各阶层之间的讨论，包括公营，私营部门，民间社会和决策者等。数字孪生赋予模拟场景以表达真实世界的能力并将数据转换为有意义的见解，让那些相关者可以更确切地看到问题的要点。因此，数字孪生不仅可以优化政策制定和服务水平，而且还为公共机构展示更具响应性和弹性治理的机会，最终可以最大程度地提升对社区和公众的影响力和价值。

Using the Digital Twin Model to construct a fit-for-purpose replica

With a specific challenge to be addressed, the right approach needs to be used when constructing a fit-for-purpose digital twin. To facilitate this process, we have developed the Digital Twin Model for assessing the approach for developing digital twins depending on the purpose of use. Both data and technologies will need to be duly considered.

For data, this can generally be classified along two axes – time-space and dimensional components of data as shown in the 2-by-2 matrix below. Some indicative applications in the Digital Twin Model are also shown in the diagram.

Technologies: Visualisation via AR, VR or a mixture of both
虚拟化技术：现实，虚拟现实和混合现实



Representation of data 数据维度表示

使用数字孪生模型构建切合需要的数字副本

为了解决特定的挑战，在构建切合需要的数字孪生系统时需要使用正确的方法。因此，我们构建了数字孪生模型，根据使用目的评估构建数字孪生的方法，其数据和技术都需要适当考虑。

数据通常可以沿两个轴进行分类 — 数据的时空和维度，如以下的2×2矩阵所示。图中还展示了数字孪生模型中的一些参考性应用。

Development of a digital twin will need to consider the dynamic and static aspects of data, as well as the need for 2D and 3D representation of situation and environment. In particular, the 2D/3D dimensional representation of data could be further differentiated between “on the ground” vs “below ground” applications, and indoor vs outdoor applications. For instance, “on the ground” application would involve data captured on building façade for buildings management, while “below ground” application allows the tracking and maintenance of pipe networks for cities.

With regard to virtualisation technologies, this model could be further overlaid with Augmented Reality (AR), Virtual reality (VR) and Mixed Reality (MR) for illustrating the environment and its associated information. While VR allows people to visualise 3D virtual environments, AR takes computer-generated images and overlays them on real view of the world, and MR is the merging of real and virtual worlds to produce new environments and visualisations, where physical and digital objects co-exist and interact in real time.

Different applications can adopt different Digital Twin Model that balances benefits and resource requirements (such as data).

数字孪生的構建将需要考虑动态和静态方面的數據，以及運用2D和3D展示情況和環境的要求。2D/3D維度的數據可進一步分成“地面”和“地下”及“室内”和“室外”的應用。例如，“地面”应用场景用例之一是将采集在建筑物立面上的数据用作建筑物管理，而"地下"用例之一是采集数据以便追踪和维护城市的管道網絡。

关于虚拟化技术，此模型可以进一步与增强现实（AR），虚拟现实（VR）和混合现实（MR）重叠，以说明环境及其相关信息。VR能提供一个3D虚拟环境，AR可以拍摄计算机生成的图像并将其叠加在真实世界上，而MR是现实世界与虚拟世界的融合，以产生新的环境和可视化效果，令實物和數位物件共同存在并实时互动。

不同的应用程序可以采用不同的数字孪生模型，以平衡效益和资源需求（例如数据）。

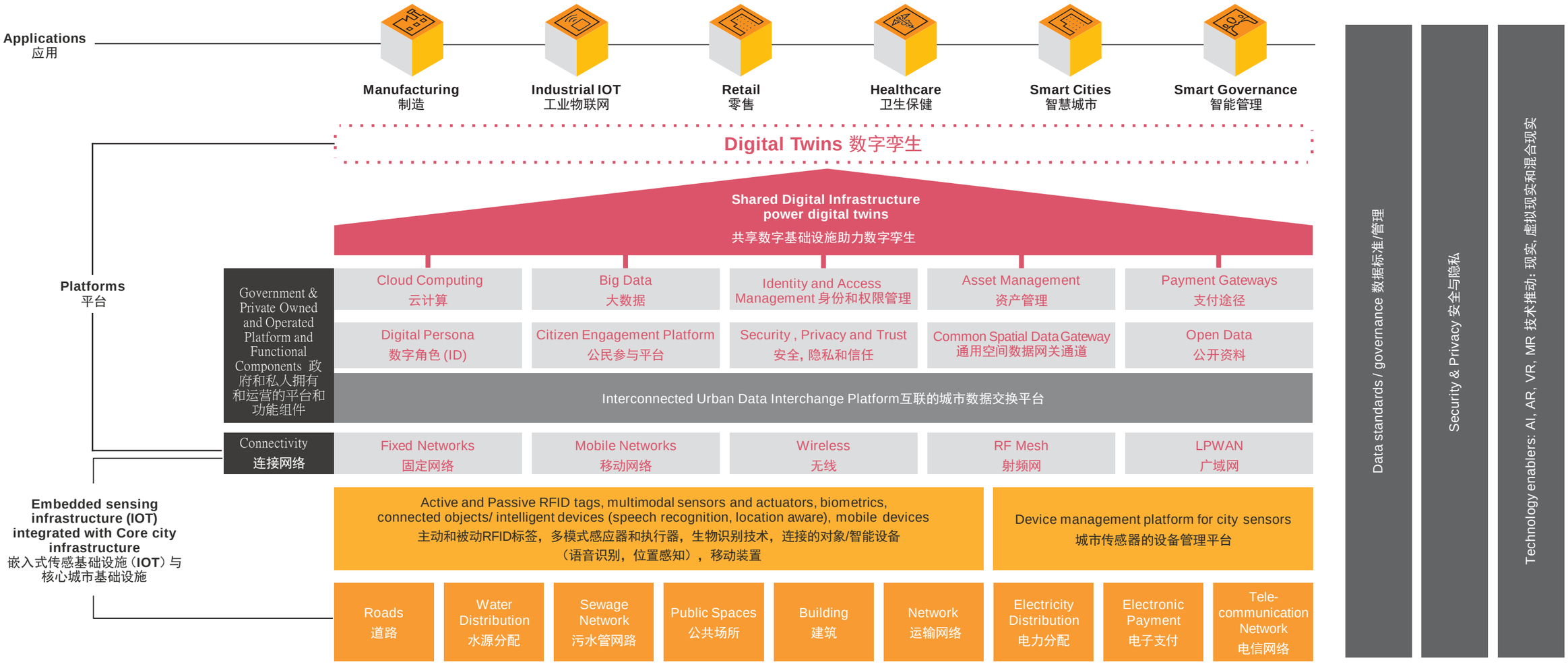
Looking at digital twin development as an ecosystem

Digital twins are more than just virtualisation of information. It functions as a system with the need for collaboration of actors as well as the establishment of appropriate networks, systems and standards. Most critically, it has to be powered by a whole suite of embedded sensing infrastructure and data processes, which will be responsible for gathering data from the physical world. This is supported by a myriad of platforms where machine learning and advanced data analytics generate valuable information feeds for real-life real-time applications. These activities are governed by data standards, security and privacy regulations. The diagram below illustrates a high-level framework of a digital twin ecosystem:

将数字孪生发展视为生态系统

数字孪生不仅仅是信息虚拟化。它透过参与者之间的协作以及建立适当的网络，制度和标准，从而发挥系统的作用。最关键的是，它必须由一整套嵌入式感应基础建设和数据处理程序支撑，并负责从现实世界中收集数据。

数据收集依赖众多平台支持，这些平台透过机器学习和数据分析为实时应用提供具价值的信息。这些活动受数据标准，安全性和私隐的法规约束。下图说明了数字孪生生态系统的高概要框架 。



Infrastructure required to support the development and adoption of digital twins include:

- **Data collection & production** through sensors (managed by a device management platform), use of mobile and smart tracking devices;
- **Data transmission** through connectivity networks;
- **Data storing, processing & exchange** through platforms that allows integration of data from various data points and systems; and
- **Data usage** through applications that are able to translate data inputs into valuable insights and provide real-time diagnostic of situation.

Protecting privacy and security are key to establish trust in a digital world.

支持数字孪生的构建和采用所需的基础建设包括：

- **数据收集和生产**：通过传感器（由设备管理平台管理），移动装置和智能追踪设备，进行数据收集和生产；
- **数据传输**：通过连接网络进行数据传输；
- **数据存储、处理和交换**：通过平台汇整来自各个数据点和系统的数据，进行**数据存储，处理和交换**
- **数据使用**：通过应用程序进行数据使用，这些应用程序可以将数据整合并输入转换为有价值的见解以及提供实时状况诊断。

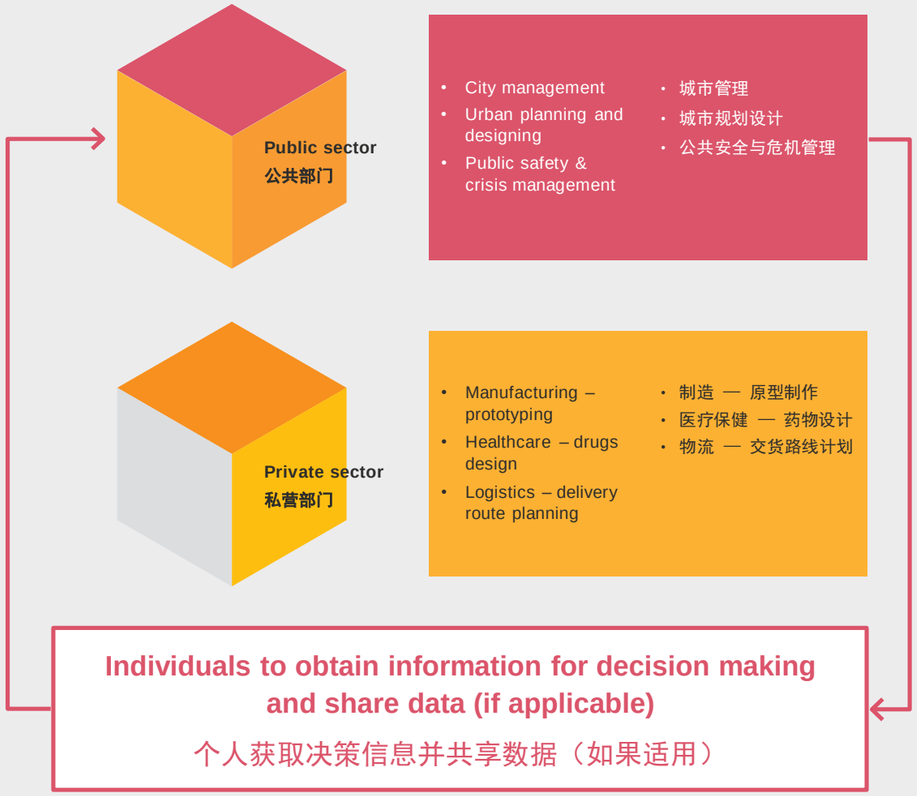
保护隐私和安全是在**数字世界**中建立信任的关键。

Why digital twins – examples from around the world

The concept of digital twins has immense potential to be applied across different industries, sectors and cities in order to optimise productivity and performance. The diagram below shows the potential use cases of digital twins in both public and private sectors, and how individuals interact with it:

As we put more and more sensors into service, a centralised device management platform could help channel data collected from sensors to support smart city implementation.

Potential use cases
数字孪生的潜在使用案例



为什么选择数字孪生 — 来自世界各地的例子

数字孪生的概念具有巨大的潜力，可以在不同的行业，部门和城市中应用，以优化生产力和性能。下图显示了公营和私营部门中数字孪生的潜在使用案例，以及个人与数字孪生的互动：

随着我们将使用越来越多的传感器，集中管理设备的平台可以帮助引导从感应器收集数据，支持智慧城市的实施。

- Virtual Singapore is a digital platform that will enable the public, businesses, government and research agencies to derive insights, develop solutions and run simulations using a large scale city model of Singapore as part of a Smart Nation initiatives.

  With a rich data environment, Virtual Singapore provides a collaborative platform to help make long-term decisions on areas such as infrastructure and resource management, urban planning. Its capabilities include:

  - Virtual experimentation, e.g. examine coverage areas of 3G/4G networks to provide realistic visualisation of poor coverage areas;
  - Virtual test-bedding to validate provision of services, e.g. 3D modelling of the new Sport Hub with semantic information to simulate crowd dispersion to establish evacuation procedures during an emergency;
  - Planning and decision making, Virtual Singapore is a holistic and integrated platform to develop analytical applications, e.g. apps to analyse transport flows and pedestrian movement patterns; and
  - R&D, data to be made available to research community to innovate and develop new technologies or capabilities.

- Virtual Singapore是一个数字平台，作为智慧国家计划的一部分，它让公众，企业，政府和研究机构能够使用大型的新加坡城市模型来获取灵感，建立解决方案并运行模拟测试。

  凭借丰富的数据环境，Virtual Singapore提供了一个协作平台，协助在基础设施和资源管理，城市规划等领域做出长期决策。其功能包括：

  - 虚拟实验，例如检查3G / 4G网络的覆盖区域，以显示网络覆盖较差的区域;
  - 以虚拟测试进行服务验证，例如Sport Hub的3D建模，可模拟人群分散情况，并建立在紧急情况下疏散程序;
  - 规划和决策；Virtual Singapore是分析应用程序的平台，例如分析交通流量和行人运动方式的应用程序；和
  - 研发，将数据提供给研究团体，以革新建立新技术的能力。

- New South Wales Government of Australia has launched a virtual 4D model of Western Sydney area's built and natural environment, with data such as buildings, strata plans, terrain, property boundaries, and utilities (e.g. power, water and sewer pipes). The 4D model is a 3D depiction with the addition of time so that users can create models based on historical or future scenarios. The model has brought great benefits as it enables:
  - Urban planners, developers and policymakers to make more informed decisions and to enable integrated city planning;
  - Data from public agencies and private sector to be brought together, hence enabling the government to better communicate plans for infrastructure development; and
  - Better prediction and management of traffic congestion, monitoring of land cover and structural changes, bushfire prediction.

- 澳大利亚新南威尔士州政府已启动了悉尼西部地区建筑和自然环境的虚拟4D模型，其中包含建筑物，地层平面图，地形，物业边界和公用事业（例如电力，自来水和下水道）等数 据。4D模型是带有时间的3D描绘，因此用户可以根据历史或未来场景创建模型。该模型具有以下重大优点：
  - 城市规划师，地产商和政策制定者做出更明智的决策，并实现整合的城市规划；
  - 将公营机构和私营部门的数据汇整，使政府能够更好地传达基础建设的发展计划；和
  - 更好地预测和管理交通拥堵，监测土地覆盖和结构变化，以及预测山火。

- Amaravati, India is the first greenfield city borne out of digital twin. It enables planners, architects, engineers, and policy makers to work in unison towards achieving collective design, policy, social, and financial goals. Scenarios are developed in advance to optimize outcomes, also adjusted on the fly to keep pace with change. New digital services and functions planned to be included as part of the digital twin include:
  - Real-time construction progress monitoring, environmental and wellness monitoring, et al. via ubiquitous, multi-nodal IoT sensors;
  - Advanced mobility and traffic monitoring and simulations;
  - Advanced microclimate and climate change monitoring and simulations;
  - Digital “drag and drop” building permit submissions;
  - Digital zoning, setback, environmental, traffic, and other statutory compliance-related preliminary analysis; and
  - Digital twin user ID scheme for every Amaravati citizen that will serve as a single citizen portal for all government information, notifications, forms, and applications.

• 印度阿马拉瓦蒂（Amaravati）是第一个由数 字孪生衍生的发展中城市。它使规划人员，建筑师，工程师和政策制定者能够齐心协力实现集体设计，政策，社会和财务目标。预先建立场景以优化结果，并配合变化进行实时的调整。计划纳入数字孪生的新数字化服务和功能包括：

– 实时施工进度监控，环境和健康监控等。通过无处不在的多节点物联网传感器;

– 流动性和交通监控及模拟;

– 先进的微气候和气候变化监测与模拟;

– 数字建筑许可证提交;

– 数字分区规划，障碍，环境，交通和其他合规相关的初步分析；和

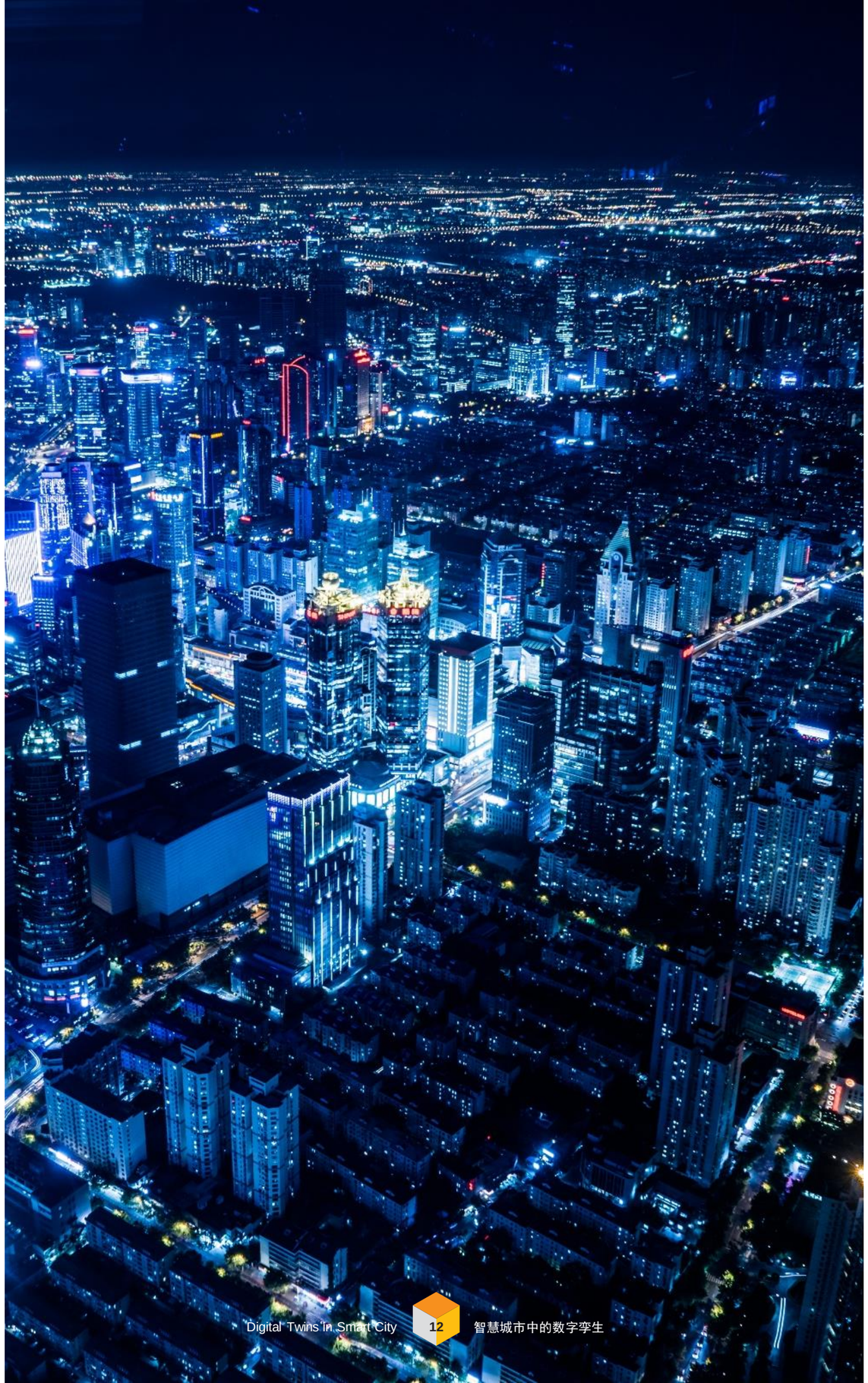
– Amaravati公民的数字孪生用户ID方案，将成为单一便民窗口，用作处理所有政府信息，通知，表格和应用程序。

Digital twins underpin Smart City development, but inevitably come with challenges

While the application of digital twins is promising, it comes with a whole set of challenges that both public and private organisations may encounter when developing and executing the strategy. Some common challenges include:

Vision

- **Establishing a clear vision and KPIs** – Implementation of digital twins can be a resource-intensive exercise involving a wide range of stakeholders. Establishing common understanding of the vision of such implementation and developing a set of performance indicators are key to a successful digital twin implementation.
- **Implementation coordination** – Vision is just the start, delivery is the hard part. At present, Governments are facing challenges like too much choice and too many cooks. Cities need to have an effective mechanism to coordinate and govern the approach to and contents of digital twin implementation.



数字孪生是智慧城市发展的基础，但亦不可避免地面临挑战

尽管数字孪生的应用前景广阔，但是公共和私人机构在制定和执行该策略时亦可能遇到一系列挑战。一些常见的挑战包括：

愿景

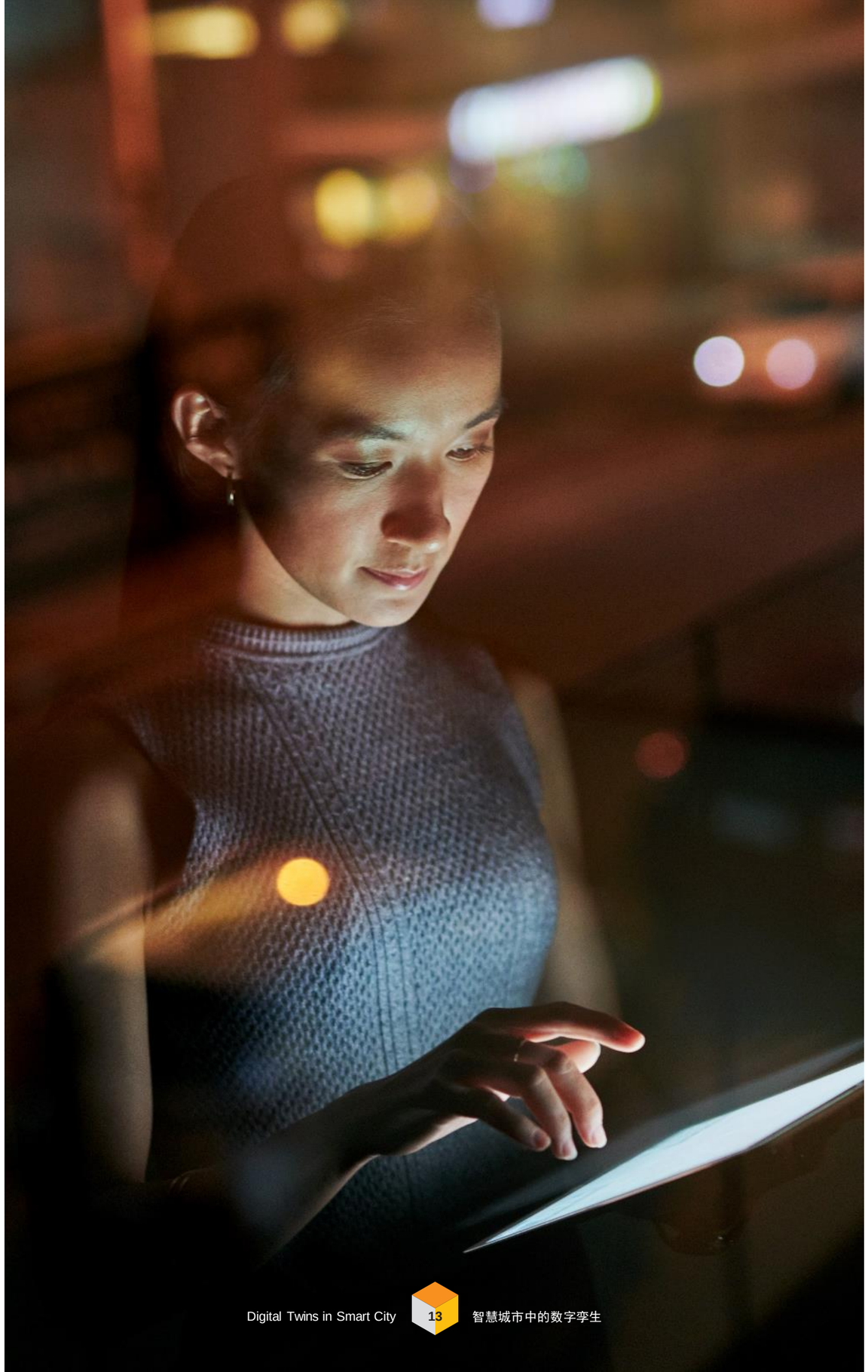
- **建立清晰的愿景和关键绩效指标** — 数字孪生的实施可能会动用大量资源，并牵涉不同领域的持份者。建立对此类实施愿景的共识，并制定一套绩效指标，对于成功实施数字 孪生至关重要。
- **实施协调** — 愿景只是起点，而交付才是困难的部分。目前，各国政府面临的挑战包括过多的选择和过多的声音。因此，城市需要有一个有效的机制来协调和管理数字孪生实施的方法和内容。

Data

- **Quality and sufficiency of data** – Historic data may be duplicative or lack the level of 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) would be required to encourage sharing of data while offering a sufficient degree of protection to those parties sharing data.
- **Data standards** – Lack of consistent data standards and rules for collecting data, creating difficulty for different units to share data, create synergies through collaboration and maximise the value of data.
- **Updated information** – The need for systematic updating mechanism to constantly update static object and scanning of new objects to ensure accuracy of digital twins in real world representations for accurate decision making.

Talent

- **Competition for talent** – While technology such as AI can do more with less manpower, mores specialised professional such as data scientists/ engineers and architects will be needed to make sense of the abundance of information.



数据

- **数据的质量和充分性** — 历史数据可能有所重复，或缺少与数字孪生模型和AI之类的技术解决方案匹配的的细节和准确程度。
- **共享数据的意愿** — 持份者未必愿意与其他各方共享数据，尤其是较为敏感的数据或个人数据。因此，需要有一个强而有力的问责框架（如下所述）来鼓励数据共享，同时为共享数据的各方提供足够程度的保护。
- **数据标准** — 缺乏一致的数据标准和规则来收集数据，导致不同部门难以共享数据，无法通过协作创造协同效益，及最大化数据价值。
- **更新信息** — 需要一套系统更新机制来不断更新静态对象并扫描新出现的对象，以确保与现实世界对应的数字孪生的准确性，从而做出准确的决策。

人才

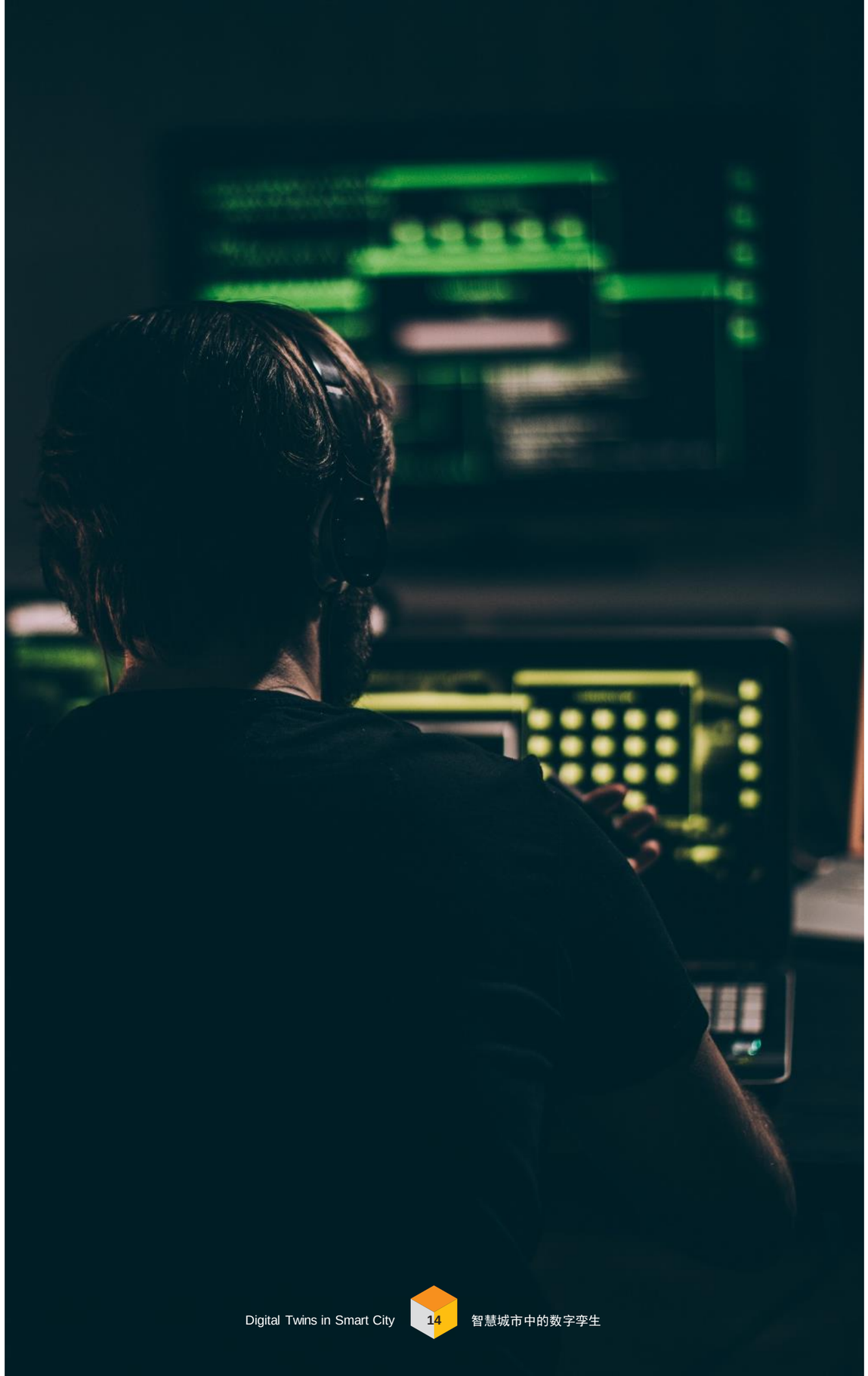
- 人才竞争 — 尽管AI等技术可以用更少的人力资源来做更多的事情，事实上仍需要大量的专业人员（例如数据科学家/工程师和建筑师）来梳理海量的信息。

Accountable, Security and Privacy

- **Information security and privacy** – From capture, enrichment, maintenance, usage, archiving and purging, the entire data lifecycle must be secured against malicious actors and violation of privacy rights.
- **Accountability** – Lack of an accountability framework such as open data licence of data issue, evolving regulations pertaining to privacy and cybersecurity, conditions of use and liability of parties as well as IP rights will have implications on the design and execution of digital twin applications.

Technology

- **Technology platforms** – Different units may adopt a diversity of legacy systems or software with limited functionality for exchanging and/or sharing data, resulting in challenges in rapidly identifying useful information from the data, integration of different data sets such as geo-information system and building information management.
- **Sensor deployment** – Brown field deployment by retrofitting on existing infrastructure and network might present more challenges than green field deployment of sensors, to ensure integration of sensor devices and network.
- **Device Management** – With the number of internet-connected devices reaching 30 billion by 2020 (source: IDC), challenges lie in the provisioning and authentication, configuration and control, constant monitoring and diagnostics, and timely software updates and maintenance.



问责，安全和私隐

- **信息安全和私隐** — 从获取，充实，维护，使用，归档和清除，整个数据生命周期必须确保免受恶意行为者和侵犯私隐权的侵害。
- **问责制** — 缺乏问责制框架，例如数据发布的开放数据许可证；与私隐和网络安全有关而不断更新的法规；各方的使用条件和责任；以及知识产权，将对数字孪生应用程序的设计和执行产生影响。

技术

- **技术平台** — 不同的部门可能会采用功能有限的旧版系统或软件作交换和/或共享数据，导致无法快速识别数据或数据集（例如地理信息系统和建筑信息）内的有用信息。
- **传感器部署** — 通过对现有基础建设和网络进行改造来进行棕地部署，可能比新发展区土地部署传感器面临更多挑战，以确保传感器设备和网 络的整合。
- **设备管理** — 到2020年，与互联网相连的设备数量将达到300亿（来源：IDC），其挑战在于身份验证，配置和控制，持续的监测和诊断以及及时的软件更新和维护。

Way Forward

While digital twins promise vast benefits to both public and private sectors, it also poses implementation challenges which requires prudent planning and considerations before the benefits could be realised. When considering digital twins for smart city implementation, four key implementation considerations are outlined below:

1. **Clear vision and KPIs** – Stakeholders have to establish 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 to be delivered by digital twins.

2. **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 different levels of granularity, is key to building a successful model that accurately reflect historical and current information for future scenario planning. A stock-taking exercise of digital twins and data would be beneficial in understanding the current landscape of adoption and data available to support future implementation.

3. **Data governance & regulation** – In ensuring a data rich environment with high security and privacy, policy and standards need to be established to spell out how data is collected, exchanged, distributed and how information is disseminated and used. Creating trusted and regulated processes is key to develop a robust data environment which drives the use of data and digital twins.

4. **Tailored implementation approach** – There is no "one-size-fits-all" approach for digital twin development. This highlights the need for each city to cater to local circumstances. The local context drives the Digital Twin Models (and mix) and implementation schedule of digital twin initiatives. For instance, with a wide spectrum of possibilities but limited resources, governments need to prioritise and map out an implementation plan on turning green field sites into smart developments with well-integrated infrastructures and seamless device connectivity, or converting existing sites to enable digital twin applications.

展望未来

尽管数字孪生给公共和私营部门带来巨大的好处，但亦带来了实施方面的挑战，因此需要谨慎的计划和考虑以实现数字孪生的好处。在应用数字孪生实现智能城市时，需考虑以下四个主要注意事项：

1. **清晰的愿景和KPI** — 持份者必须对实施数字孪生的预期结果达成共识（并适当考虑资源限制），并制定一套适当的KPI，以反映数字孪生将带来的益处。

2. **现有数字孪生和数据的盘点** — 能够同步和集成现有的数据（可能以不同的格式显示并存储在具有不同细化级别的系统中）是建立成 功数据模型的关键，从而准确反映历史数据和当前信息，并有助于将来的方案规划。对数字孪生和数据进行盘点练习将有助于理解当前的采用情况 和可用于支持未来实施的数据。

3. **数据治理与监管** — 为了确保具有高度安全性和私隐性的丰富的数据环境，需要建立政策和 标准，以阐明如何收集，交换，分发数据以及如何分发和使用信息。创建受信任和受监管的流程是建立强大的数据环境的关键，该环境将推动数据和数字孪生的使用。

4. **量身定制的实施方法** — 数字孪生建立没有"一刀切"的方法。这凸显了每个城市都需要适应当地情况的需要。当地环境驱动着数字 孪生模型（和混合模型）的应用以及数字孪生计划的实施时间表。例如，在各种各样的可能性下，碍于资源有限，政府需要按优先次序制定实施计划，以将新发展区土地发展为具有良好基础建设和无缝设备连接的智能发展区域，或者将数字孪生应用在已经开发的土地。

Looking beyond Smart City to further unleash the potential of digital twins by aiming towards a Smart Region in the Greater Bay Area

The Outline Development Plan for the Guangdong Hong Kong-Macao GBA is a national strategy that aims at promoting closer cooperation and coordination between the 9+2 cities at the GBA and at maximising the economic strength and regional competitiveness of the GBA as a whole. The use of technology and data is clearly a key enabler to strengthen connectivity of the GBA. Cross-border collaboration is essential to enhance capital flow in the region, nurture innovation, facilitate information and capital exchange particularly in a rapidly transforming economy where speed, variety and security of information flow is of the essence.

Addressing urban challenges at a regional scale such as climate change, cross border movement of people and goods, will also require sharing of data for collective solutions. However, getting there requires the different legal, data, privacy and regulatory policies to be harmonised through collaboration.

In addition to physical infrastructure and connectivity, digital twins of the GBA are important soft infrastructures that could help transform the GBA into a truly Smart Region. The governments in the GBA are suggested to consider and focus on key priorities such as assessing use cases that the digital twins should support; stocktaking data that are 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 for the digital twins of the GBA is in place.

The transformation towards a Smart Region where the 9+2 cities are interconnected by digital twins and data would unlikely be an easy undertaking. However, by taking small steps towards building a Smart Region with common standards and aligned regulatory framework, this would help pave the way towards more synergetic management of urban challenges in the region and strengthen the future benefits of “one country, two systems” while minimising risk.

瞄准大湾区的智慧区域，超越智慧城市，进一步释放数字孪生的潜力

《粤港澳大湾区发展纲要》是一项国家战略，旨在促进大湾区9+2城市之间的紧密合作与协调，最大程度地提高大湾区的经济实力和区域竞争力。技术和数据的运用显然是增强大湾区连通性的关键推动力。跨境合作对于增强大湾区的资本流动，促进创新，信息和资本交换尤其重要，其中，信息流动的速度，多样性和安全性在迅速变化的经济中至关重要。

在区域范围内应对城市挑战，例如气候变化，人员和货物的跨境流动，也将需要共享数据以实现集体解决方案。但是，具体实现需要通过协作来协调不同的法律，数据，私隐和监管政策。

除了实体基础建设和连接性之外，大湾区的数字孪生网络也是重要的软基础设施，并可将大湾区打造为真正的智能区域。大湾区政府应考虑并关注优先事项，例如评估数字孪生的应用；盘点质量足以支持数字孪生应用的数据；确定应采用的数字孪生模型；并确保针对大湾区的数字孪生的管治架构准备就绪。

虽然透过数字孪生和数据，将9+2城市紧密连接，迈向智能区域的道路未必一帆风顺，但通过逐步建立通用标准和协调监管框架，将为协同管理大湾区智慧区域奠定基础，强化“一国两制”的优点，并减低风险。

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Contacts 联系我们

Albert Wong 王君弼
Partner 合伙人
+852 2289 1807
albert.wong@hk.pwc.com

Chris Mo 毛英伟
Senior Manager 高级经理
+852 2289 2941
chris.yw.mo@hk.pwc.com

Kate Shieh 谢凯程
Senior Manager 高级经理
+852 2289 2548
kate.kc.shieh@hk.pwc.com

Siew Ee Sim 沈秀忆
Manager 经理
+852 2289 1768
siew.ee.sim@hk.pwc.com

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