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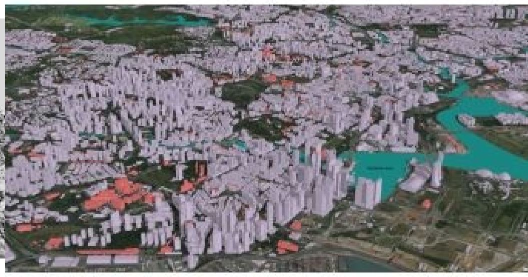
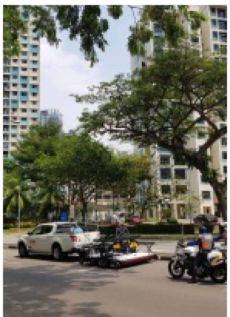
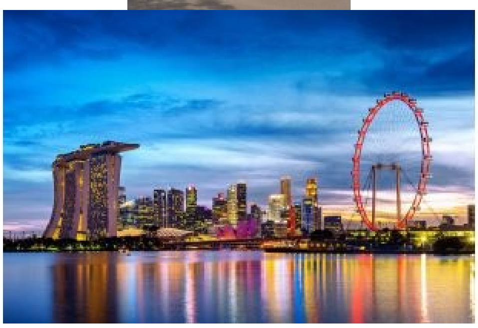
Singaporeâ€™s journey towards a nationwide digital twin







When it comes to utilizing the true potential of digital twin technology, Singapore is miles ahead of most other governments. Even those that have already embraced the concept of the digital twin have often not yet fully realized their plans, while many other cities and countries are still only taking their first steps. This article takes a closer look at how things currently stand in Singapore and at the nation state’s transformation journey so far. The building blocks for success include developing a sustainable system, taking a long-term view from the start, and ensuring the availability of sufficient geospatial professionals.

Singapore assumed ‘pole position’ in 3D urban planning back when it first started planning and conceptualizing its national 3D mapping project in 2012. The project was subsequently rolled out in two key phases: Phase 1 (aerial mapping) in 2014 and Phase 2 (street mobile mapping) in 2015. The aim was to map the entire nation with rapid data capturing technologies to create an accurate, reliable and consistent national 3D map that supports government agencies in their policy formulation, planning, operation and risk management. This national 3D map serves as the foundation of Singapore’s digital twin.

The start of Singapore’s 3D mapping journey

The design stage of the Singapore National 3D Mapping project between 2012 and 2014 revolved around consideration of the geomatics framework of data capture, model, manage and deliver. For data capture, the Singapore Land Authority (SLA) looked for digital sensors and platforms able to deliver rapid digital mapping data with reliable and accurate results to support planning and operational usage. For the data model, the authority explored digital workflows and data formats that would support interoperability between applications, systems and – in a fine example of forward-thinking – even digital twins.

The SLA was keen to ensure digital data management and interaction between the huge amount of data at each refresh campaign, not just in a locational context but also in time/space. Another important condition was that the digital data delivery should be user-friendly in order to allow non-technical users to adopt and adapt with minimal technical learning curves.

Data and people were identified as the two essential aspects. When it comes to the geospatial data, the philosophy is ‘capture once, use by many’. This ‘whole-of-government’ approach is aimed at minimizing duplicative efforts, and translates into economies of scale and the common use of authoritative datasets by government agencies and consultants when working on projects. Thanks to the boundary conditions of the most accurate, reliable and high-resolution data, applications utilizing the data yield reliable results as the basis for informed decisions and predictions. In addition, open data and open source have been advocated since the very start of Singapore’s 3D mapping journey. The open data enables users to use appropriate tools to meet their organization’s needs, regardless of their applications and systems.

The National 3D Mapping of Singapore project created core geodata such as DSM, DTM, orthophoto, 3D building models, imagery and point clouds.

Aerial and street-level mapping of Singapore

The same two key mapping methods were adopted in both phases, namely laser scanners and cameras, although they were mounted on different platforms in each phase. For aerial mapping, data capture was conducted from fixed-wing aircraft, whereas street mobile mapping was conducted from a moving vehicle on the ground.

The first versions of Singapore’s National 3D Mapping project were concluded in 2015 and 2017, creating core geodata such as a digital terrain model (DTM), digital surface model (DSM), orthophoto, 3D building models at various levels of detail, imagery and point clouds. The street mobile mapping captured all public roads in Singapore, which resulted in no less than 600 billion point clouds and three million panoramic images and amounted to approximately 25TB of data. That mountain of data will continue to grow because the journey towards becoming – and remaining – a smart, resilient and sustainable nation requires constant data updates to keep the information current.

This massive amount of geospatial data in various forms and formats turned out to be challenging to handle and integrate. The managing and sharing of nationwide-scale datasets is also a challenge for mapping agencies due to the need for high-performance IT infrastructure, which requires capital investment and maintenance. The SLA adopted a commercially available software-as-a-service (SaaS) solution from Bentley Orbit to manage the large volume of mobile mapping point clouds and panoramic imagery. This has also facilitated the sharing of data with other users with scalable cloud resources to support the long-term sustainable mapping programme and the city-level digital twin.

A 3D reality mesh of Gardens by the Bay.

Underground and indoor mapping

Besides above the ground, the SLA is also working on a national subsurface digital twin of Singapore. Almost all of the nation state’s utility assets are buried underground in order to free up valuable above-ground space for other purposes. However, Singapore’s ongoing expansion – both above and below the surface – means that the subterranean space available for utility services is becoming increasingly scarce. Information about existing subterranean services and structures is not always available, accurate or up to date. As a result, the infrastructure agencies and utility licensees face significant challenges in terms of planning new infrastructure and managing project timelines/costs. Needless to say, there is also a heightened risk of damaging utility assets during excavation work.

According to the SLA, reliable information about underground utilities offers three major benefits: 1) Better land administration and planning outcomes, as well as land use optimization, 2) Fewer uncertainties and risks during the planning and design of infrastructure development, and 3) Minimal disruption to the environment and subterranean services, combined with improved safety of construction and engineering works.

In 2017, the SLA entered into a partnership with the City of Zürich and the Singapore ETH Centre (SEC) to initiate the Digital Underground project, aimed at developing a reliable map of Singapore’s underground utilities for planning and land administration purposes. The first phase mainly involved the formulation of the roadmap and project strategy. The second phase focused on building the foundations of a sustainable utility mapping ecosystem that will continuously provide reliable 3D utility information to both the public and private sectors. A framework for the governance of data quality was developed and the Utility Survey Standards were reviewed, before subsequently being introduced in 2017. Now, in the third phase, workflows are being developed for the capture of reliable digital subsurface utility data.

There have also been some small-scale trials using terrestrial scanning to capture 3D indoor spaces, but these are still in an early stage. The SLA is constantly on the lookout for suitable capturing technology such as backpacks or handheld laser scanners. Depending on the use of the mapping data, the main challenges so far are scan-to-model/scan-to-BIM and the industry’s slow adoption of 3D data. While some of these challenges may be overcome with machine learning and artificial intelligence (AI), a lot of effort is still needed to validate the reliability of the results from these outcomes and to encourage the geomatics profession to embrace such technology.

LoD2 3D city models.

Ensuring up-to-date geospatial data

In order for the digital twin to remain relevant in the long term and to achieve its full potential, it is vital that the geospatial data is kept up to date. Singapore has pursued two strategies to safeguard this: 1) A mapping programme was established, ensuring ongoing funding for continuous data acquisition to keep the 3D city models updated, and 2) Exploration and investment in rapid mapping technologies such as Lidar solutions for data acquisition and AI-based 3D modelling.

The aim is to map the whole nation once every five years using aerial mapping, and to refresh the street mobile mapping data every two years. Technologies such as remote sensing and terrestrial surveying are deployed in non-flight years so that changes on the ground can be detected and updated if necessary. In the meantime, Singapore is keeping abreast of developments elsewhere by monitoring how other cities and mapping agencies are conducting their campaigns.

Exploring the use of ground penetration radar in mapping subsurface utilities.

The gap between 2D and 3D geospatial data

The SLA has a clear view on the current state of geospatial data related to 3D city modelling. Victor Khoo, deputy director of the Land Survey Division at the SLA, emphasizes that 3D city models or a digital twin will not replace the 2D or 2.5D geospatial data. Instead, in most cases, the geospatial data is the building block for the 3D city model. From an application perspective, 2D/2.5D geospatial data will still remain critical and useful for many applications for which 3D is not suitable or efficient.

From the perspective of geospatial data infrastructure, Khoo admits that there is still a maturity gap between 2D and 3D in terms of standards, governance, data model, format and visualization. Many efforts are ongoing to close that gap and he considers it critical for geospatial professionals to be involved in those efforts.

Internally in the geospatial industry, thanks to technological advancements for both data capture and 3D modelling, it is now more attainable to develop useful and accurate 3D city models. Externally, the digital revolution in sectors such as the built environment, climate resilience and future mobility has generated a strong demand for digital twins. Therefore, Khoo's message for the industry is that, in order to drive the adoption of digital twins, geospatial professionals should work closely with users to understand the use cases and provide high-quality and reliable 3D data.

On-site data capture in Singapore.

Considerations when embracing the digital twin concept

Digital twins exist for different purposes and requirements in multiple forms, resolutions and formats: at building level, precinct level, town level or city level. The key building blocks for a successful digital twin include repeatable and rapid reality capture, expandable and open data modelling, and accurate, reliable data coupled with technology.

In Singapore, an open data format is being favoured as this enables the transition to new and emerging technology whenever it becomes available. Above all, reliable data is the key as it creates the basis for deriving accurate insights and supports informed decision-making. One fundamental prerequisite is the availability of enough proficient geomatics engineers to perform 3D mapping in order to ensure the accurate capture of real-world data as input for the digital twin.

3D geoinformation underpins a variety of governmental urban planning applications. For example, it allows planners to simulate how new development will affect the surroundings, supporting flood risk management to prioritize mitigation measures in areas prone to flooding and helping to protect coastlines. The high-fidelity building models of Singapore have enabled a nationwide scan of potential roofs and walls capable of harnessing natural solar power as a source of sustainable and green energy. On the aviation front, the digital models of airport buildings and the terrain facilitate the identification of obstacles to improve flight safety and planning.

As Khoo points out, Lidar and high-resolution imagery coupled with precise positioning also support the research and development work for autonomous platforms. From an asset management perspective, his colleagues specialized in trees and parks at SLA have re-engineered their tree inspection process and management by using the point cloud to measure tree height, girth and spread as the basis for scheduling the tree pruning activities to mitigate risks to road users.

What's next?

Singapore's transformation journey has been shaped by the firm belief that future cities will be powered by the digital twin concept. The SLA is convinced that 3D mapping and 3D city modelling will be the foundation for city-scale digital twins. Khoo urges other national mapping agencies (NMAs) and national geospatial agencies (NGAs) to step up to ensure that authoritative 3D city models are developed and continuously maintained. He envisions that – as AI, the Internet of Things (IoT) and immersive visualization such as virtual reality (VR) and augmented reality (AR) increasingly converge – the 3D city models and digital twins maintained by NMAs and NGAs will be used as key elements for applications in the emerging metaverses.

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Singapore cityscape skyline at Marina Bay at twilight.