PUBLIC WORKS DIGITALISATION

Driving value in the digital era

Development Bureau
The Government of the Hong Kong Special Administrative Region of the People's Republic of China

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Building a better working world

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ABOUT THIS PUBLICATION

Hong Kong's construction industry (the Industry) will have unprecedented growth in the coming 20 to 30 years, and the Capital Works Programme will be no different. In an effort to increase productivity and efficiency to meet the demand of the future growth, the Government of the Hong Kong Special Administrative Region of the People's Republic of China (the Government) has undertaken initiatives to digitalise the delivery of public works from planning and design to construction and operations & maintenance (O&M). This involves capturing and leveraging underutilised or currently unavailable project data into a central location, enabling more evidence-based portfolio level insight and decisions to be made (as detailed in Section 1). This will transition construction and major project environments from being rich in data, to being rich in information.

The transition from 'data rich to information rich' refers to the process of transforming raw data into actionable insight. Data is typically raw unprocessed facts, such as numbers, text, or images, generated by multiple parties, systems and processes. Information, on the other hand, is processed data that has been analysed, interpreted and contextualised to provide insight.

In today's capital works contracts, a large volume of data is created in the existing management processes but it is too often not captured and used in decision-making – data is being treated as a by-product as opposed to an asset in itself. To make effective decisions, it is necessary to transform data into information that is accurate, actionable, standardised and secure. The Government is achieving this through the adoption of five components of digitalisation in the delivery of their capital works projects, which include the use of Common Data Environments (CDEs) at different phases of an asset development life cycle. The data from multiple projects is consolidated in the Integrated Capital Works Platform (iCWP) to provide a near real-time view of the Capital Works Programme performance (as detailed in Section 2).

Through increased use of data and technology in the delivery of the Capital Works Programme, the Government has the opportunity to create a 'circular economic impact' effect of generating and re-investing savings across the asset development life cycle. The savings generated during the planning, design and construction phases can be reinvested in O&M technology, which will further reduce the future budget allocation requirement for the delivery and operation of publicly funded assets. Public funding can then be redirected to meet other societal needs, and therefore generate better outcomes and value for the wider economy, society and environment (as detailed in Section 3).

Economic

For every HK$1 invested in the adoption of data and technology throughout the asset development life cycle from planning to O&M, savings of HK$3.4 could be generated.

Social

Redirecting monetary savings to realise positive outcomes for the society, such as constructing more publicly funded assets and upskilling the Industry in technology adoption.

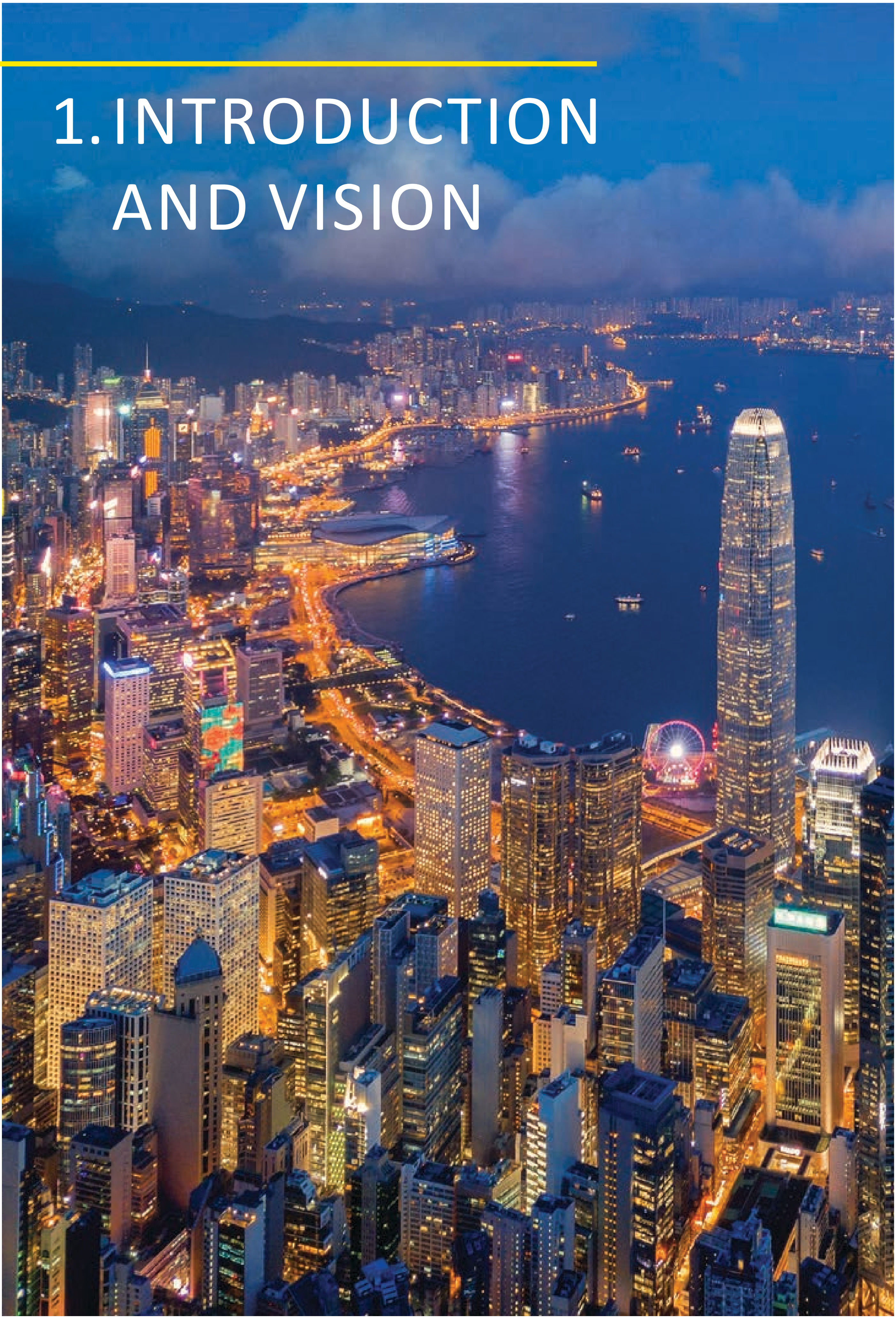
Environmental

Capturing data to generate more evidence-based insights not only around time, cost, quality but also carbon performance, leading to better designed assets that are fit-for-purpose and future ready.

Digitalising the delivery of public works projects is not unique to Hong Kong. Authorities in Mainland China, the United Kingdom (UK), Singapore and Australia have also been actively adopting CDEs to better capture and exploit the data generated in the delivery of publicly funded assets. Through collaborative partnerships with global authorities, DEVB will continue to engage in knowledge exchange and the leveraging of best practice, whilst also sharing Hong Kong's experience globally with the aim of uplifting the construction industry worldwide (as detailed in Section 4).

The iCWP is only the beginning of the Government's digitalisation journey and as the volume of data being captured, governed, controlled and exploited increases, the iCWP has the potential to be the foundation on which to develop a portfolio-wide digital twin (as detailed in Section 5).

1. INTRODUCTION AND VISION



IMPROVING PUBLIC WORKS PERFORMANCE – THE GOVERNMENT'S STRATEGIC DIRECTION

Construction 2.0 was launched by the Government in September 2018 to address key challenges faced by the Industry, such as an ageing workforce, high construction cost, safety performance and declining productivity, etc. At the same time, the Industry is facing unprecedented growth, with the capital works expenditure expected to exceed HK$100 billion per annum. The total construction volume (public and private sectors) will reach HK$300 billion per annum in the coming years[1]. *Construction 2.0* set out the strategy to put in place the pillars of change required to meet these challenges:

PROFESSIONALISATION

The improvement of project leadership, project management, procurement capabilities and professional skills and practices in the Government and the Industry.

INNOVATION

The development of Industry culture, processes, tools and systems to increase productivity and efficiency, leading to more effective management of project delivery.

REVITALISATION

The intention to reinvigorate the appeal of the Industry to attract young and energetic talent to join the workforce, by promoting a collaborative and supportive environment that stimulates continued knowledge transfer.

With *Construction 2.0*, the Government aspired to make positive and lasting change in one of the most complex and impactful sectors from many perspectives, including, but not limited to, economic contribution, health and safety, climate and employment. The Government intends to develop standards and regulation to effect change urgently required by the Industry and to encourage collaboration across the supply chain. Under the Innovation pillar, the Industry requires continued guidance, investment and creativity in adjusting to the increasing need to harness technology and to exploit the significant volume of data created in asset development and O&M, which is commonly inaccessible due to outdated, manual and siloed processes.

The Government has been driving digitalisation of public works since the launch of *Construction 2.0*. The introduction of the Digital Works Supervision System (DWSS) and development of the iCWP in the past few years lays the foundations for optimising the values in the delivery and management of the Capital Works Programme. The Government takes its responsibility to deliver high quality and sustainable built assets seriously and continuously strives to improve value to the public through innovation, global learning and Industry collaboration

In response to *Construction 2.0,* the Construction Industry Council (CIC) published the *Construction Digitalisation Roadmap for Hong Kong – A Pathway Towards Smart Construction*[2] in November 2021, which set out key strategies and milestones to lead the Industry to a more digital future through smart construction and data sharing.

[1] Total construction industry output includes both public and private sectors. Sourced from Construction Industry Council (2022), Construction Expenditure Forecast for Public and Private Sectors (2021/22 to 2030/31).
[2] Construction Industry Council (2021), Construction Digitalisation Roadmap for Hong Kong – A Pathway Towards Smart Construction.

OBJECTIVES OF THIS PUBLICATION

This publication details the key steps the Government will take to achieve the ambition of increased data and technology use in the delivery of public works. The publication also describes how benefits will be realised by transitioning from a 'data rich', to an 'information rich' environment. To address a number of the core Industry challenges, the Government seeks to develop better ways to capture and exploit data at the right time in a common environment that can be accessed by relevant parties. The Government is taking a structured approach in driving improved project delivery and O&M through 'better information' for 'better efficiency' and 'better outcomes', with process and data transformation at the centre of that approach (see Figure 1).

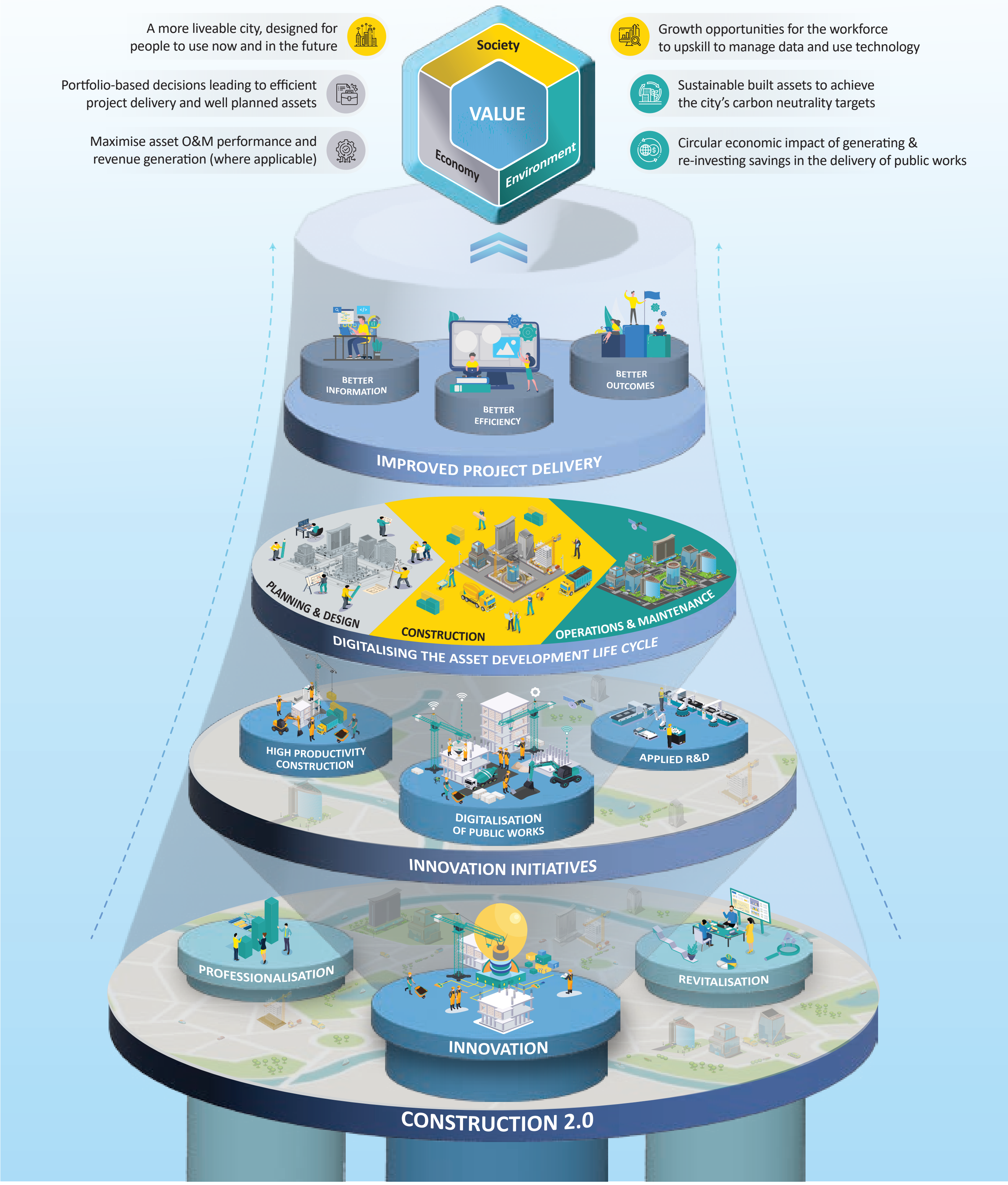


Figure 1 – Structured approach to the digitalisation of Public Works delivery

Better information

Planning, design, construction and O&M processes create a significant volume of data that, in many cases, remains an underutilised resource. Improving how this data is captured will give the Industry an opportunity to use it in more effective ways to improve project decision-making and asset performance. Removing the inefficiencies that block data capture and then creating the processes that effectively govern, control and exploit that data is at the centre of the Government's digitalisation ambition. By improving workflows and processes through the adoption of technology, data will be created as a primary product, enabling improved, evidence-based and timely decision-making from project to portfolio level.

CASE STUDY : DEVB

DWSS was introduced to digitalise construction workflow management, collect construction works data related to site inspections and labour deployment as well as manage and monitor site activities and contract management in capital works contracts. Data can be submitted, accessed and monitored by all project stakeholders in a centralised platform, replacing the manual, paper-based and siloed processes on-site. Project managers can access all site records, manage inspections and stay informed of site works progress through DWSS, enabling faster decision-making to maintain progress or respond to issues, which enhances the quality, safety and efficiency of site supervision and ultimately the overall works.

Better efficiency

Leveraging the data captured that is currently underutilised or unavailable is central to the success of digitalisation. Improving the accessibility of data that can be transformed into accurate, standardised, actionable and secure information will enable better efficiency in process performance. This can be achieved by using CDEs in all phases of an asset development life cycle, which will lead to more evidence-based insight and the potential to use advanced technologies for further efficiency gains.

CASE STUDY : DRAINAGE SERVICES DEPARTMENT (DSD)

DSD's Hydrometric Information System uses Internet of Things (IoT) sensors to capture data on rainfall and water levels of major rivers and channels in real-time. This data is analysed to provide DSD with evidence-based insight into potential flood risks and to facilitate the design and implementation of preventive or emergency response actions. Environmental impact trend analysis can then be used to inform future planning of the location, design and construction of defence mechanisms.

Better outcomes

A structured approach to creating 'better information' driving 'better efficiency' lays the foundation for consistency, commonality and transparency in all processes across the supply chain. This will lead to better designed assets that are fit-for-purpose, future ready and with the potential to offer enhanced user experience. This will positively impact the way public funding is used to deliver and operate assets that meet the needs of the people of Hong Kong and will generate better outcomes and **value for the wider economy, society and environment.**

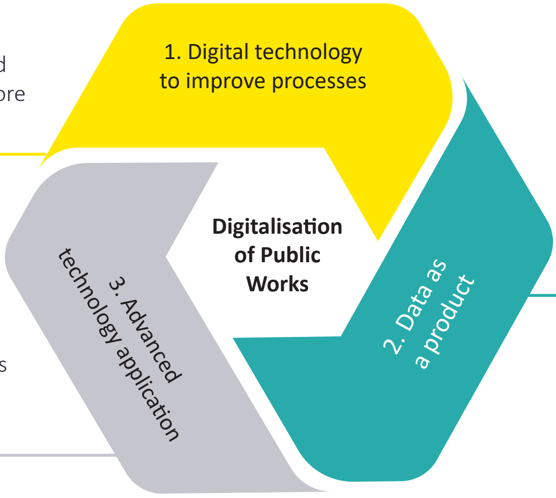
CASE STUDY : HIGHWAYS DEPARTMENT (HyD)

HyD's Smart Lighting Management System uses IoT sensors to continuously monitor the operating condition of all public lighting system points. Data analysis streamlines O&M by enabling accurate maintenance planning, ultimately reducing costs and asset downtime. In addition, automated remote illumination adjustment according to actual road conditions has enabled energy savings of 2% to date.

DIGITALISATION OF PUBLIC WORKS IN HONG KONG

There are three key steps to the digitalisation of public works (as illustrated in Figure 2), that underpin how data is captured, governed, controlled and exploited during public works delivery to realise the benefits from the application of digital technologies throughout the life cycle of publicly funded built assets.

Use of technology to manage and improve processes (e.g. replace manual, paper-based and siloed processes on-site) and enable more efficient delivery.



As a product of technology, data is captured, managed and exploited to drive insight, and better planning, construction, and O&M of assets - transitioning from 'data rich to information rich'.

With data, advanced additional technologies could be used to further enhance asset development processes.

Figure 2 – Three key steps to the digitalisation of public works

CASE STUDY : DEVB

An example of this already in action is DEVB's Project Surveillance System (PSS), a powerful tool that monitors the progress of capital works projects and provides early-warning regarding cost and time performance.

1.Technology to improve processes

The PSS was originally established based upon the cashflow data of over 600 projects completed in the past 20 years, and has taken into account all the typical characteristics of the projects under the Capital Works Programme. All Works Departments are required to submit forecasted and actual cashflows for their capital works projects, which are captured and centralised in the PSS. The data is presented in a dashboard format allowing quick identification of trends and whether projects are ahead of schedule or whether there will be any potential programme delay or budgetary challenges. This allows for early intervention to maintain project health.

2.Data as a product

To date, cashflow data for over 800 completed projects has been captured in the PSS to enable learning from past project performance and anticipate future project outcomes before making relevant interventions to avoid repeated delivery issues. An example project cashflow curve is shown in Figure 3.

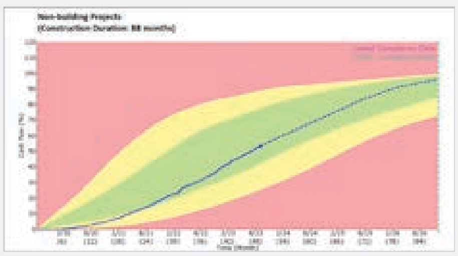


Figure 3 – Project cashflow graph

3. Advanced technology application

Following the successful use of the PSS, DEVB collaborated with Oxford Global Projects to jointly develop an Artificial Intelligence (AI) enabled PSS, applying AI algorithms to better predict the final outturn cost of projects. As AI analyses more complex cashflow datasets, the predictive power of the PSS will be enhanced, leading to more accurate early warning and intervention.

For further information on the PSS, please refer to *AI in Action* co-published by Oxford Global Projects and DEVB.

Based on the three key steps detailed in Figure 2, the Government's ambition is to introduce digital solutions to improve the way that publicly funded assets are planned, designed, constructed, operated and maintained. There are five key components to achieve the Government's ambition, including the capturing of data at project level as components integrated into the iCWP (as illustrated in Figure 4). The five key components are further detailed in Section 2.

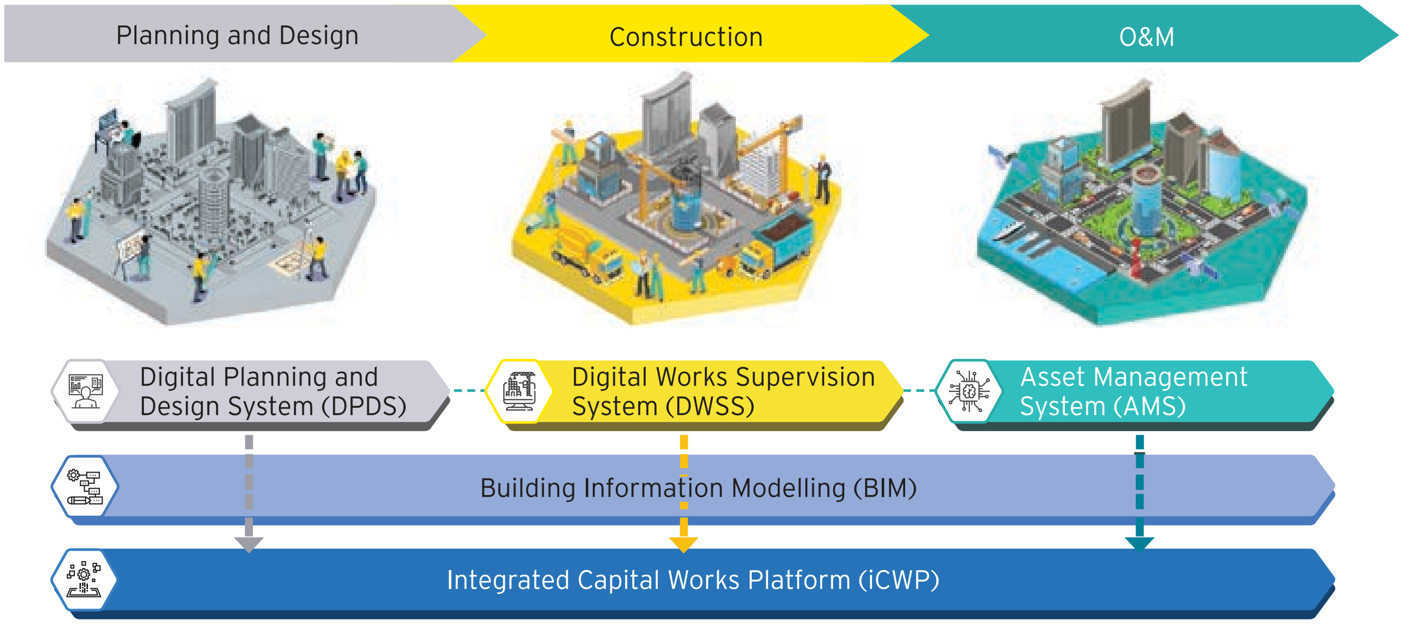


Figure 4 – Five components of digitalising public works across the asset development life cycle

As illustrated in Figure 5, the Government has already been playing a leading role in the digitalisation of public works, for example, DWSS was introduced to capture data related to site activities through structured processes and governance in the construction phase of capital works projects. This, in turn, has enabled accurate information to be stored and made available in the iCWP. To meet the ambitions outlined above, the Government will continue to invest in, and lead the design and implementation of, the iCWP components.

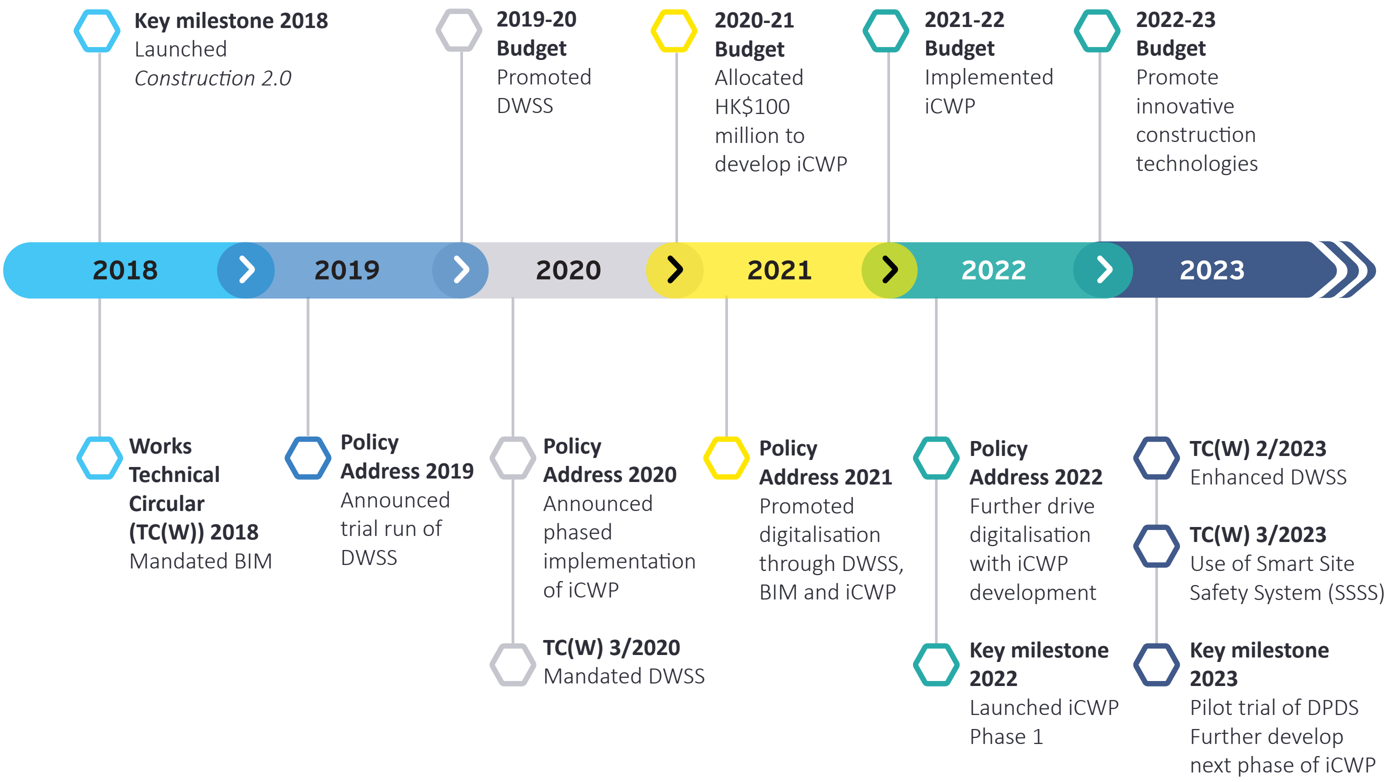


Figure 5 – The journey of digitalisation of public works in Hong Kong

2. FROM PROJECT DATA TO PORTFOLIO INSIGHT

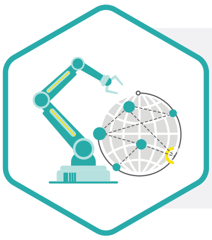
THE OPPORTUNITY

Hong Kong's Capital Works Programme encompasses a diverse range of projects, from Government buildings, sewage and water treatment works to roads, bridges and piers. These crucial built assets serve as the backbone of the city, generating economic, social and environmental value. As each asset progresses through its life cycle, the type of data required to be managed varies significantly and an array of different processes and technologies are needed to manage the diverse datasets. The primary objective of the iCWP is to standardise the information management (IM) processes across the various capital works contracts so that different sources of data can be visualised in a single location. This will provide the Government with efficiency gains at the project level and enable informed decision-making at the portfolio level. The adoption of CDEs is the key to realising these benefits.

COMMON DATA ENVIRONMENTS (CDE)

A CDE, serving as a single source of truth, collects, manages and shares information on a project and can be used throughout the asset development life cycle[3]. It is used to define IM principles and requirements, which improves interoperability, meaning information can be efficiently exchanged and consolidated to provide a wider view and enhanced understanding of a project. A CDE consists of a combination of process workflows and supporting technology solutions.

Process workflows are used to gather, manage and distribute data and information that is structured and unstructured[4]. This is the most important aspect of the CDE.



Technology solutions are used to enable different process workflows. Multiple CDE technologies can be used to facilitate the CDE process, but consideration must be given to how the different technologies interface with one another.

CASE STUDY : ENVIRONMENTAL PROTECTION DEPARTMENT (EPD)

EPD is launching a **Centralised Environmental Database**, a web-based Geographic Information System (GIS) platform as a central repository for storing environmental information (for example, air, noise, water, ecology, fishery and land contamination information) needed for environmental planning and assessment during the planning and design phases. The database will be used by project stakeholders/service providers to plan and conduct Environmental Impact Assessment (EIA) studies, as well as for academics and members of the public for research and learning purposes.

THE FIVE COMPONENTS OF DIGITALISATION

There are a variety of CDEs used to support the delivery of capital works contracts in Hong Kong, each to deal with specific types of data and information at different phases of an asset development life cycle. These CDEs form part of the five components of digitalising public works summarised in Table 1.

[3]Specifically, BS EN ISO 19650 sets out the principles and requirements of CDE with IM using BIM and related information types.
[4]Different information types include structured information and unstructured information. Structured information includes geometrical models, schedules and databases. Unstructured information includes documentation, videos clips and sound recordings. (ISO 19650-1:2018).

Component	Overview of the component
DPDS	The DPDS will be used for transaction management between Works Departments and consultants and will consist of project, financial and document management modules. The aim of DPDS is to facilitate the set up and management of consultancy agreements in the planning and design phase, and support information flow to O&M. DPDS is now being piloted in selected consultancies with feedback being collected for improvements to pave way for wider adoption.
DWSS	The DWSS is used by Works Departments, consultants and contractors for efficient contract management, supervision and monitoring of construction site activities and consists of workflow management modules as well as a smart site application module. DWSS is mandated for capital works contracts exceeding HK$30 million and as of 2023 it has been adopted in over 160 contracts with over 10,000 users. Data captured using DWSS will be transmitted to the iCWP according to the Data Standardisation Report (Works Technical Circular (TC(W)) No.2/2023).
AMS	The Works Departments have been developing their own AMS to facilitate O&M works on Government assets under which successful pilots have been undertaken with further enhancements currently taking place. A guiding framework for how to implement and benefit from the use of technology in the O&M phase is being developed in collaboration between DEVB and the Works Departments.
BIM	Under TC(W) No.2/2021, BIM uses are stipulated as mandatory in respective stages of a capital works contracts with project estimates of more than HK$30 million. Progressively BIM data will be further integrated with Lands Department's (LandsD) Government BIM Data Repository, 3D Digital Map and Common Spatial Data Infrastructure (CSDI) platform facilitated by the implementation of DEVB's *BIM Harmonisation Guidelines for Works Departments* issued under TC(W) No.8/2021.
iCWP	The iCWP is under phased development. It collects and consolidates information from capital works projects adopting the DPDS, DWSS and AMS. The iCWP will enable continuous monitoring and data analysis such that the overall management and performance of capital works projects can be further enhanced.

Table 1 – The five components of digitalising public works in Hong Kong and their objectives

EXPANDING VISIBILITY: ICWP – FROM PROJECT DATA TO PORTFOLIO INSIGHT

Consideration has been given to the data structure within the DPDS, DWSS and AMS components such that the outputs can be collected and consolidated in the iCWP. The aim is to achieve an open exchange of data, allowing data input to be conducted once, but the resultant information to be used multiple times, which will lead to efficiency improvements, greater visibility and more informed decision-making at both project and portfolio level.

At project level, diverse sources of data and information need to be managed from multiple stakeholders, such as drawings from consultants and progress records from contractors. Since this data and information relates to the same project, digitalising the workflows of the asset during the planning, design and construction phases captures asset data from its inception. This can be leveraged in the O&M phase to support better maintenance planning, repairs or replacement and eventually future renovation work.

At portfolio level, data from multiple projects can be consolidated into a central location, providing DEVB and the Works Departments with insight on the performance of the whole Capital Works Programme. This increased visibility provides a comprehensive view of project performance, empowering DEVB and Works Departments to identify patterns and trends that can facilitate better decisions. For example, the Government could more easily assess the availability of resources across their Capital Works Programme, understand their productivity, and look to balance them depending on short, medium and long-term priorities.

To enable the transition from project data to portfolio insight, the iCWP comprises of three main modules, each serving a specific purpose:

- The integrated DPDS (iDPDS) module collects and consolidates data from individual consultancy agreements using DPDS.
- The integrated DWSS (iDWSS) module collects and consolidates data from the individual works contracts using DWSS.
- The integrated Asset Management System (iAMS) module, once established, will collect and consolidate data from individual built assets using AMS.

The consolidation of this data into the three modules of the iCWP is illustrated in Figure 6.

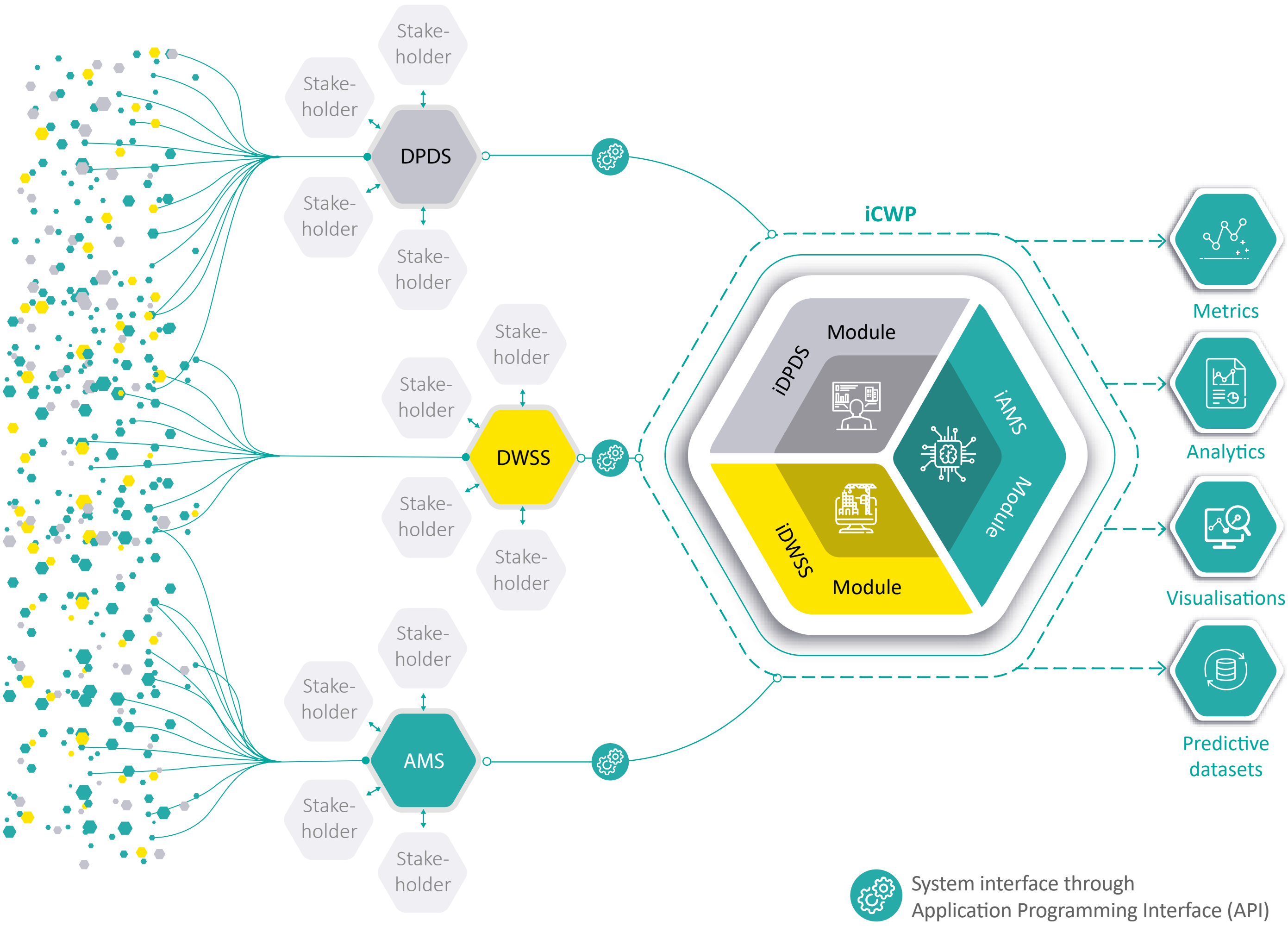


Figure 6 - The iCWP

CASE STUDY : ARCHITECTURAL SERVICES DEPARTMENT (ArchSD)

ArchSD has developed an IoT data hub for the remote monitoring of Government building performance and enhancing facilities management through predictive maintenance. For example, water leakage sensors are installed in Government facilities identified with risk of high-water damage. ArchSD is continuously exploring the use of different sensors, such as tree motion and smart toilet sensors, to expand the IoT data hub.

By consolidating data from multiple sources, DEVB and the Works Departments can gain a holistic view of the Capital Works Programme status and make data enabled decisions that drive project success. Examples of project data to be captured and the portfolio level insight to be gained are illustrated in Figure 7.

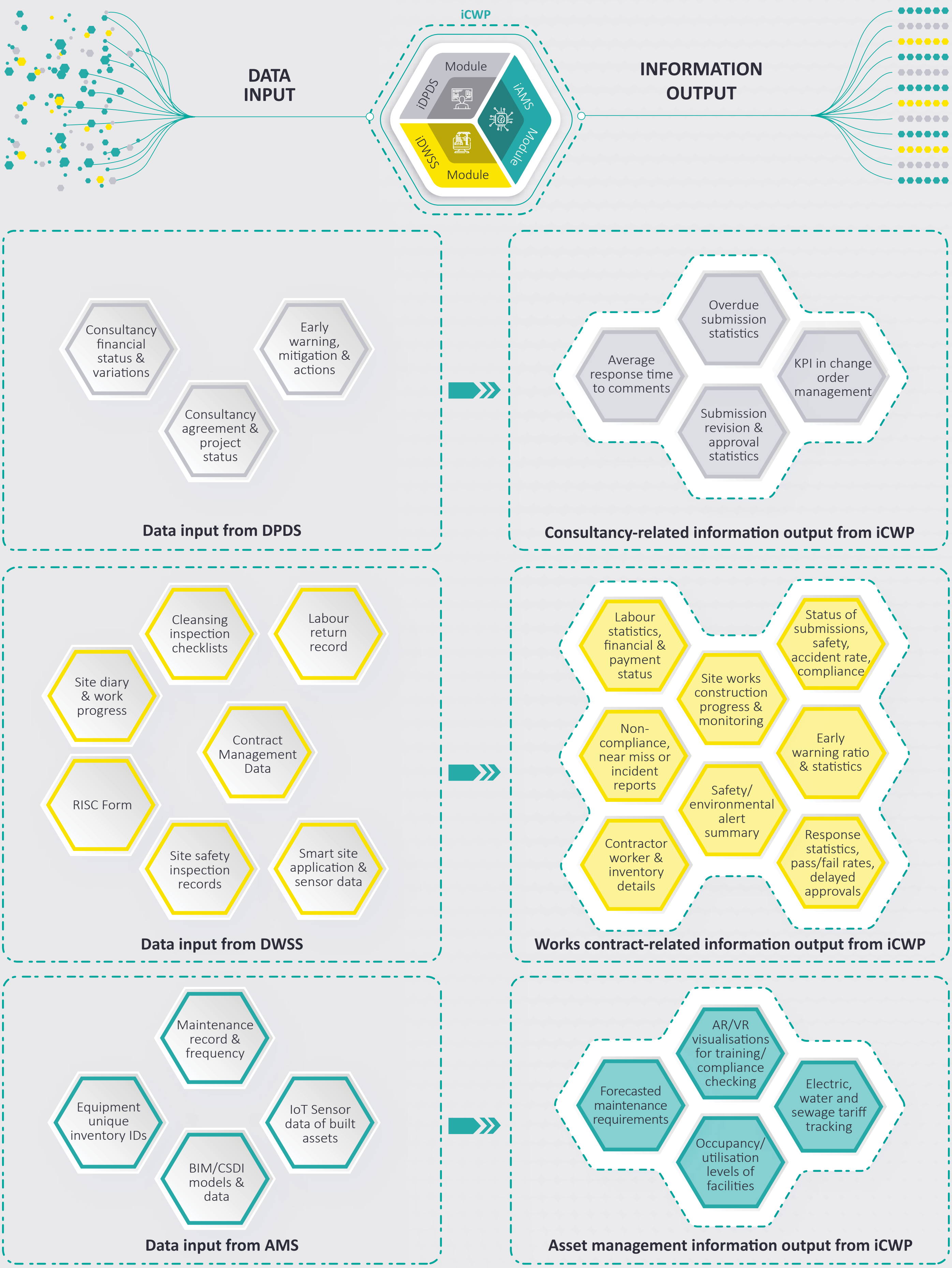


Figure 7 – Data input and information output of the iCWP modules

THE PRINCIPLES OF DATA MANAGEMENT

To facilitate the consolidation of data into accurate and useable portfolio insight, the core principles illustrated in Figure 8 are applied by DEVB and the Works Departments.

ACCURACY

Data should be precise, correct and free from errors or discrepancies.

ACCESSIBILITY

Data should be easily accessible to authorised users whenever needed.

CONFORMITY

Data should adhere to established standards and guidelines.

REUSABILITY

Data should be structured and organised for efficient repurposing.

SECURITY

Data should be protected against unauthorised access, modification, disclosure or destruction.

STANDARDISATION

Data should follow standardised models, formats and processes.

Figure 8 – Core principles of data management

Adherence to these core principles of data management is critical to realising the value of the transition from project data to portfolio insight.

UPLIFTING DELIVERY AND OPERATION PERFORMANCE

By structuring and sharing data in accordance with the core principles of data management, the digitalisation of public works will further enhance project performance across the Capital Works Programme. These benefits can be recognised at all phases of the asset development life cycle.

During planning, design and construction, a near real-time view of portfolio performance will enable the Government to take proactive action to mitigate risks and issues as they occur during capital project delivery. Furthermore, owing to its single source of traceable data, the iCWP will help reduce inefficiencies associated with manual updates, outdated or static information, duplicated data entry and unnecessary cross-checking by multiple project stakeholders.

The data collected during the planning, design and construction phases can then be transferred to the O&M phase, which is where the majority of a built asset total expenditure resides. The ratio of costs for construction to O&M is typically quoted to be 1:5:200, where for every dollar spent on construction, five are spent on O&M and 200 on staffing and business operations[5].

During the O&M phase, data can support asset managers in efficiently maintaining built assets by accessing necessary documentation and enabling proactive or predictive scheduling of maintenance activities. Furthermore, historical data analysis can also facilitate condition modelling and help inform future design decisions, resulting in improved asset performance, extended lifespan and reduced downtime. These outcomes minimise the disruption to the public and enhance the overall effectiveness of O&M practices.

Overall, by adopting the iCWP across the asset development life cycle, data can be transformed into actionable insight, leading to improved design, enhanced construction efficiency and better end-user experiences.

[5] Pearce, D. (2003), The social and economic value of construction: the construction's guide to sustainable development. The Construction Industry Research and Innovation Panel.

CASE STUDY : WATER SUPPLIES DEPARTMENT (WSD)

WSD is trialling a digital twin to monitor water treatment plants. For example, the North Works Digital Twin Pilot together with AI is used for data collection, control and visualisation to monitor the water quality and chemical levels, as well as to detect outliers. Treatment processes, such as filtration, ozonation and residual management, can be simulated using the digital twin and machine learning for better water treatment management. The digital twin also provides suggestions on the amount and type of chemicals, such as aluminium, lime and fluoride, to use to manage the water quality.

CASE STUDY : CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT (CEDD)

CEDD, alongside their construction delivery partners on the Trunk Road T2 and Cha Kwo Ling Tunnel project, have developed a ‘3S Tunnel Defect Inspector’ system based on drone scanning fitted with AI processing technology for real-time tunnel surface defects detection. This allows engineers and inspectorate supervisors to perform inspections with improved safety and efficiency, significantly reducing the inspection time per tunnel lining segment from ten to two minutes. The system also automatically generates digital defect reports, which streamline the inspection process and supports future O&M activities.

Implementing the core principles for data management in public works contracts will encourage wider adoption throughout the supply chain. As an increasing volume of data is collected and consolidated within the iCWP, a higher level of insight can be attained. This, in turn, unlocks opportunities for predictive and prescriptive analytics using advanced AI-enabled technologies.

DEVB and the Works Departments can use this data to better manage their Capital Works Programme, including the optimisation of labour resources, materials, plant and equipment, expenditure and health and safety performance, which will contribute to enhancing the overall productivity, cost effectiveness and efficiency of capital works delivery.

3. VALUE OF DATA AND TECHNOLOGY

Section 3 of this publication was produced in collaboration with HKU Business School.

ASSESSMENT OF THE VALUE OF DATA AND TECHNOLOGY

The implementation of new technologies must be justified by the value they add to the Industry or society. Determining the impact data and technology can have on the way publicly funded assets are planned, designed, constructed, operated and maintained is fundamental to understanding this value. This is complicated due to comparative analysis not being possible and that, to date, a Government benefit/value management and tracking process is still in development. Therefore, a comprehensive review of existing literature on the benefits of digitalising public works delivery and operation has been undertaken. More specifically, 89 prospective evidence-based local and global case studies relating to the use of data and technology in planning and design, construction and O&M phases of an asset development life cycle have been reviewed. A value impact assessment[6], in the form of a cost-benefit analysis, was undertaken, whereby the selected relevant benefits from the case studies were applied to the Capital Works Programme of approximately HK$100 billion per annum (average for the next 10 years) to give an indicative value that can be derived from the implementation of the iCWP.

The results of the assessment demonstrate how digitalisation will unlock savings in the way public funding is used throughout the asset development life cycle. This could allow a reduction in the resource budget allocation requirement for infrastructure, in turn allowing redirection of the funds to (a) develop more infrastructure, (b) address other societal needs or (c) invest in O&M technology.

VALUE IMPACT ASSESSMENT FRAMEWORK

The value impact assessment of digitalising the delivery of publicly funded assets is based on the principle of circular value, as outlined below and illustrated in Figure 9:

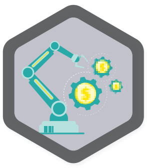
Capital Works Programme: The Government has earmarked HK$100 million in the 2020-21 Budget for the development of the iCWP to facilitate the digitalisation of the planning and design, construction and O&M of the Capital Works Programme of approximately HK$100 billion per annum.

Planning, design and construction: The investment in digitalisation begins in the planning, design and construction phases of an asset development life cycle, for example, with the adoption of:

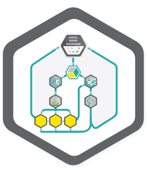
- CDEs for better management of information.
- Technology, such as IoT, to drive more efficient site activities.
- Tools to verify and monitor compliance and accuracy of contracted spend.

Capital expenditure (CAPEX) value impact assessment: The investment made during the planning, design and construction phases of an asset life cycle can generate direct monetary savings that can be redirected to three key uses:

- Developing more publicly funded assets.
- Addressing other societal needs (e.g. upskilling).
- Investing in O&M technology to improve asset operational performance.



Life cycle value impact assessment: By redirecting savings generated during the planning, design and construction phase to invest in O&M technology, asset performance improvement becomes possible without additional resource budget allocation as the technology investment can be funded/part-funded from the original capital budget. For example, AI enables identification of defects and leaks in sewer and stormwater pipes, reducing repair and maintenance costs as well as water loss, therefore creating further monetary savings that can be used to construct more publicly funded assets or redirected for wider societal benefit.



Circular impact: This creates a circular effect of generating and investing savings across the asset development life cycle. As this becomes standardised, it will enable the Government to reduce the resource budget allocation/spend for the delivery and O&M of future publicly funded assets and be able to redirect public funding or expand the investment in additional publicly funded built assets.

[6] Government and EY Hong Kong economists and major projects professionals worked with Professor Haipeng Shen of Hong Kong University Business School to conduct this value impact assessment.

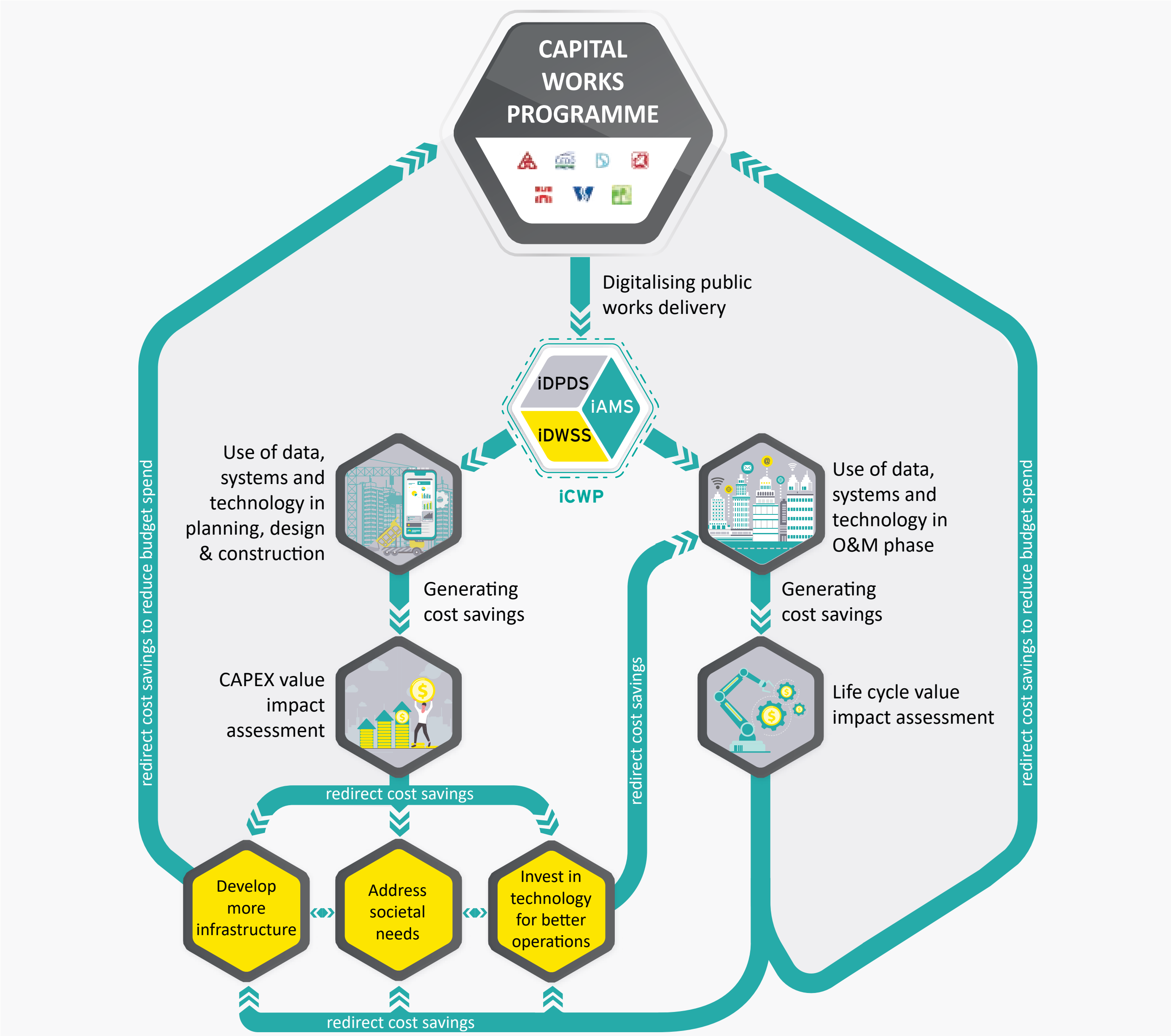
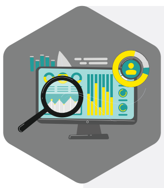


Figure 9 – The circular value of digitalisation

Two cost-benefit analyses were conducted to quantify the value of data and technology use in the asset development life cycle of publicly funded assets. A CAPEX value impact assessment was conducted to consider the costs and benefits over a 10-year construction period only, and a life cycle value impact assessment was conducted, which included the construction period and the operating period to derive the benefits throughout the asset development life cycle.

The analyses indicated the adoption of data and technology to enable better management of information leading to enhanced performance of the asset from planning and design to O&M, which could deliver an estimated benefit-cost ratio (BCR) of 3.4:1 over a 40-year period, or that for **every HK$1 invested, approximately HK$3.4 in cost savings could be generated.** When considering only the planning, design and construction period, the BCR is estimated to be 2.4:1 over a 10-year period.

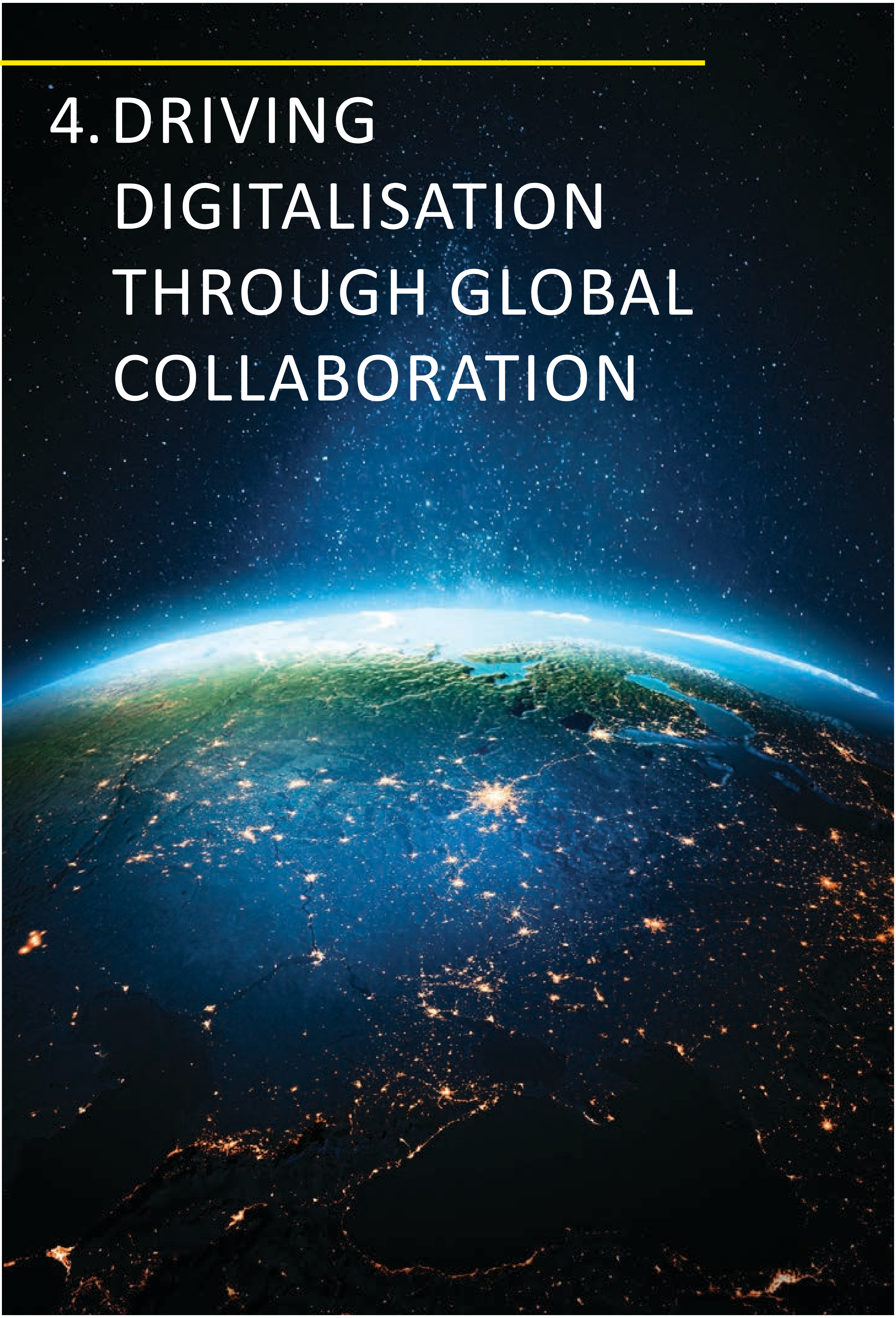
The assessment approach, analysis, findings and a summary of the case studies used are further detailed in Appendix A.



CASE STUDY : ELECTRICAL AND MECHANICAL SERVICES DEPARTMENT (EMSD)

EMSD has deployed a Building Information Modelling for Asset Management **(BIM-AM) System with Asset Digitalisation** to streamline the O&M workflow. This includes the use of IoT sensors for remote monitoring and on-site fault diagnosis, as well as the use of Radio Frequency Identification (RFID) scanning for fast asset locating. The implementation of BIM-AM has generated >15% time saving on processing and responding to typical Heating, Ventilation and Air Conditioning (HVAC) faults. Since 2021, EMSD has been progressively expanding the use of BIM-AM to manage and maintain more than 8,000 Government venues and facilities.

4. DRIVING DIGITALISATION THROUGH GLOBAL COLLABORATION



The challenges facing the delivery of public works projects are not unique to Hong Kong. Authorities in Mainland China, UK, Singapore and Australia have developed digitalisation plans outlining interventions to capture, govern, control and exploit data produced in the delivery of publicly funded assets. This is attempted through various forms of IM frameworks, which in some cases directly refer to the adoption of CDEs. Table 2 summarises different national digitalisation plans.

	Description
Mainland China	**The Ministry of Housing and Urban-Rural Development published** a *'14th Five-Year Plan' Construction Industry Development Plan*[7] in January 2022. The plan outlines the development of various 'internet platforms' to facilitate data led, evidence-based decision-making in the delivery and management of construction works. Other initiatives outlined in the plan include harnessing data and insight gathered from smart construction technology, such as IoT, big data, cloud computing and AI.
Singapore	**The Building and Construction Authority (BCA)** updated their *Built Environment Industry Transformation Map (ITM)*[8] in September 2022, which includes initiatives on integrated data platforms, CDE data standards, multiple BIM guides for use by the supply chain and the first construction digital platform funded by a government grant. BCA's *CDE Data Standard*[9] was published in January 2021 and was developed to guide better integration of work processes and to connect project stakeholders throughout the asset development life cycle. A taskforce has also been established to accelerate the digitalisation of Singapore's built environment with a focus on securing the commitment of 300 construction supply chain participants to adopt interoperable digital platforms based on the *CDE Data Standard*.
UK	**In September 2021, the Infrastructure Projects Authority (IPA)** published *Transforming Infrastructure Performance (TIP) – Roadmap to 2030*[10] in September 2021. This document sets out an 'Action Plan' with timelines and interventions needed to drive a step change in infrastructure performance through the use of data, technology and improved delivery models. This includes an IM mandate and the use of digital twins to enable information to be shared across traditional sector silos.
Australia	**The New South Wales (NSW) government** published the *NSW Roadmap*[11] in November 2022 for digitalising planning, design, construction and O&M of infrastructure. The NSW government identified four workstreams to achieve widespread adoption and application of digital in infrastructure. Under the data workstream, data standards and interoperability, CDE and data security were outlined as key focus areas. **The Office of Projects Victoria (OPV)** released the *Victorian Digital Asset Strategy (VDAS)*[12] in March 2020, to provide detailed guidance on planning, implementing, managing and maintaining an effective digital asset strategy throughout the life cycle of an organisation's asset base.

Table 2 – Summary of digitalisation plans introduced in Mainland China, UK, Singapore and Australia

With the unique structure of DEVB and the Works Departments, the Government is strategically positioned to deliver value in public works through digitalisation, resulting in better designed, higher quality and more sustainable built assets for the people of Hong Kong. DEVB has established collaborative partnerships and signed Memorandums of Understanding (MOUs) with both the UK IPA and the Ministry of Finance (MOF) of Singapore. DEVB also maintains a close relationship with the relevant authorities of Mainland China and ongoing communication with Australian counterparts. Through these relationships, Hong Kong actively engages in knowledge exchange, leveraging best practice and lessons learned, to enhance the delivery and performance of public works. This commitment to learning, as well as sharing Hong Kong's experience in the use of data and technology, extends beyond national borders/boundaries and aims to uplift the construction industry worldwide.

[7]Ministry of Housing and Urban-Rural Development (2022), "14th Five-Year Plan" Construction Industry Development Plan.
[8]Building and Construction Authority (2022), Built Environment Industry Transformation Map (ITM).
[9]Building and Construction Authority (2021), Common Data Environment (CDE) Data Standard.
[10]Infrastructure Projects Authority (2021), Transforming Infrastructure Performance – Roadmap to 2030.
[11]NSW Government (2022) Infrastructure Digitalisation Roadmap.
[12]Office of Projects Victoria (2022), Victorian Digital Asset Strategy.

5. THE WAY FORWARD

UNLOCKING THE POTENTIAL OF A PORTFOLIO-WIDE DIGITAL TWIN

The data collected by the components, introduced in Section 2, is useful at the project level and has contributed to wider Industry improvements, with some of the digital systems also being used in private sector projects. The Government will continue to develop and embed the subsequently enabled digital ways of working on their capital works projects, with the potential benefits extending beyond their own projects and positively impacting the wider Industry.

The next stage of the journey is to realise value from this data at the portfolio level. This is achieved through the iCWP, which collects data from the DPDS, DWSS and AMS components used on individual projects and consolidates it to provide the Government with a portfolio level view of their Capital Works Programme. The Government will continue to develop the interfaces between the iCWP and DPDS, DWSS and AMS to further enhance the overall management and performance of Capital Works Programme.

Beyond iCWP, it is the Government's long-term objective to build a digital twin for each Government asset. A digital twin is a realistic digital representation of physical assets by real-time data collected through IoT and remote sensors. The data is translated into useful information and is represented in the digital models with support by BIM and GIS, etc. With information generated in a digital model, which can be further enhanced by advanced technologies such as AI and Big Data Analytics, Works Departments will be able to make informed decisions and provide feedback and control to the physical assets, which in turn could be automated. The digital twins would achieve better information, better efficiency and better outcomes for asset management. The concept of digital twins for Government assets is illustrated in Figure 10.

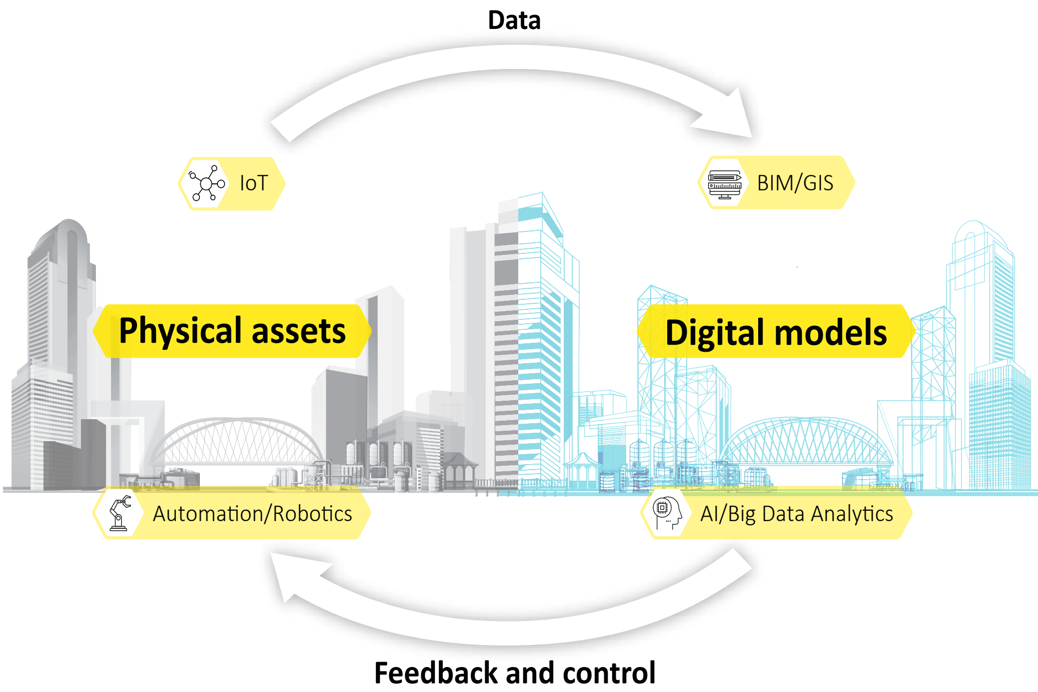


Figure 10 – Digital twin concept for Government assets

The case studies within this publication demonstrate how different levels of digital twin sophistication have already been adopted on capital works projects.

Beyond iCWP, the Government's ambition is to continually build on their structured approach to data management, which will be used to unlock the potential of a portfolio-wide digital twin.

A portfolio-wide digital twin is the connection of multiple digital twins. Rather than existing in isolation, the strength of a portfolio-wide digital twin lies in the ability to understand and share insight across a system. Just as the physical world relies on the seamless connections of different parts to function optimally, the digital world should also be interconnected and integrated for efficient collaboration, data exchange and holistic management of the built environment. This could result in widespread time, cost and carbon savings across the Capital Works Programme.

The connection between iCWP, the asset development life cycle and the portfolio-wide digital twin is illustrated in Figure 11, which demonstrates the relationship between the physical world on the left and the digital world on the right, with data serving as the vital link between them. This data flows upwards to feed into the portfolio-wide digital twin, providing the Government with a realistic digital representation of the Capital Works Programme.

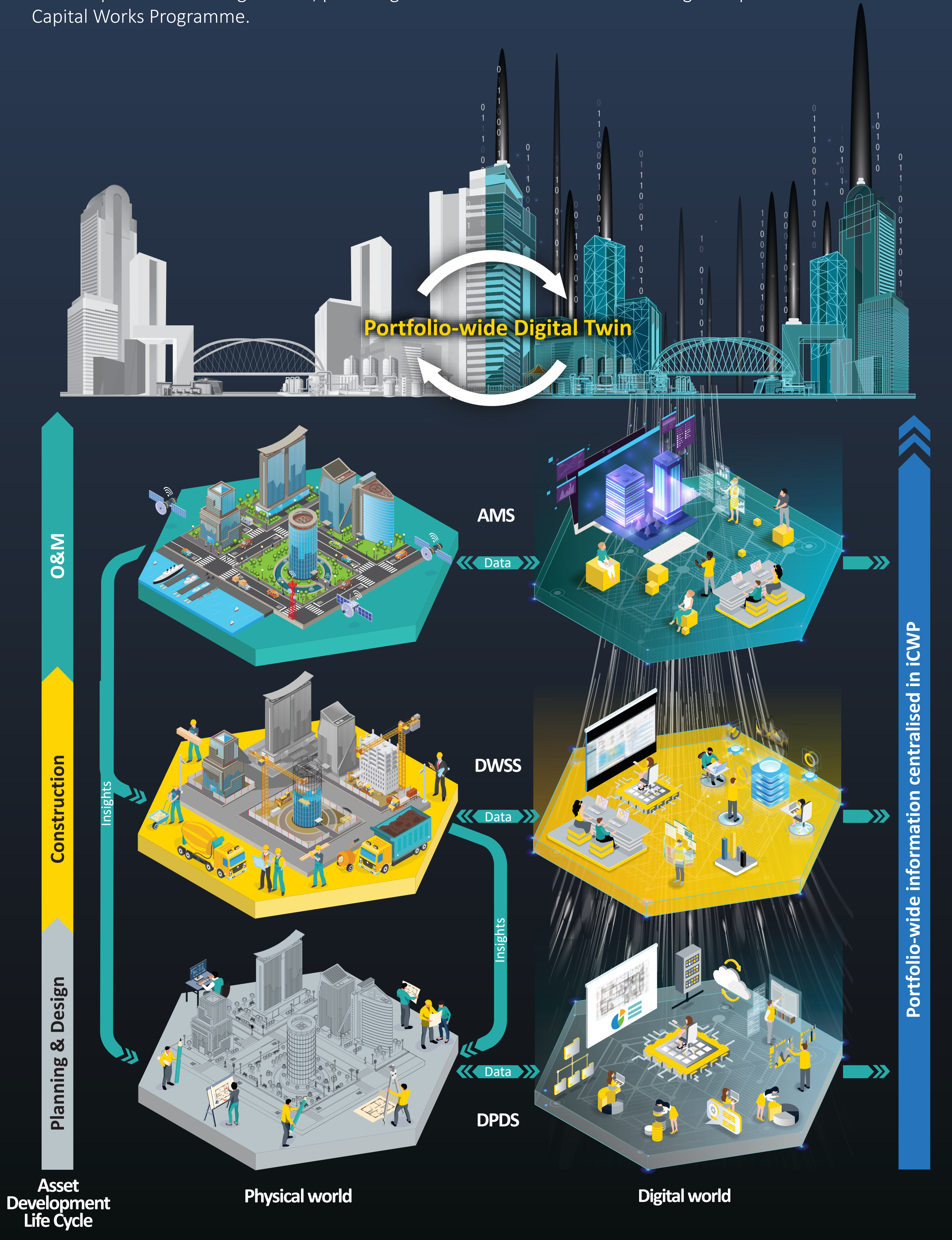


Figure 11 – Digital representation of the Capital Works Programme

CRITICAL SUCCESS FACTORS

This publication details how the effective management of data is critical to developing more efficient ways of delivering publicly funded assets. As different Works Departments are using data and technology at varying maturity levels throughout the asset development life cycle, a coordinated and integrated approach is needed to pull together the existing developments and provide a baseline from which the Government progresses consistently and then measures performance and improvement. This can be achieved through the eight Critical Success Factors (CSF) detailed below, which represent the areas that need to be investigated and developed to support the successful and consistent digitalisation of the public works.

The CSFs are categorised into the following three groups:

- People centric (CSF 1-3)- the implementation of change management to foster the right mindset in the workforce and equip people with the right skills and to attract and nurture the right talent to the Industry.
- Technical (CSF 4-7)- supporting the technical implementation of data and technology.
- Value capture (CSF 8)- the tracking and management of progress so that benefits can be identified and scaled.

1

Mindset and culture
Establishing a digital first mentality in the workforce with a clear understanding of the benefit case and an open attitude towards the use of technology advancements in place of more traditional approaches.

2

Skillset
Developing targeted training programmes to equip the workforce with the capabilities to operate digitally. This is a necessity to creating long-lasting change and is key to successful digital transformation.

3

Needs arising and management process
Continuous feedback processes to identify emerging and evolving end-user needs and Government-led functionalities. This will lead to the further refinement of solutions and facilitate open and collaborative dialogue.

4

Government AMS technology guidance framework
Guidance on the development of O&M technology and associated data architecture to enable the Works Departments and supply chain to promote a consistent, collaborative and streamlined approach for the implementation of advanced technology.

5

Funding
Allocating appropriate and adequate funding to support various stages of digitalisation, spanning from initial trials to the comprehensive implementation of solutions and the continuous improvement requirements such as benefit management (see CSF 8).

6

Data governance
Developing and using a suite of principles and standards to maintain the consistency and quality of data in all five components of the iCWP, enabling compatibility between different systems and technologies.

7

Data security
Developing a set of principles to protect and secure iCWP data in alignment with Office of the Government Chief Information Officer (OGCIO) guidelines to avoid unauthorised access, modification and publication of information.

8

Benefits management framework
Quantifying the impact of data and technology by tracking and measuring the benefits generated to inform the right investment decisions and to manage the scaling of solutions.

By following these CSFs, the Government can achieve the desired outcomes of digitalisation and establish a strong foundation for future developments, such as a portfolio-wide digital twin.

Ultimately, digitalisation is intended to enable the Government to generate better outcomes and value for the wider economy, society and environment. By improving the processes in which public works are delivered under the five components of digitalisation, while being guided by the implementation of the CSFs, the efficiency of the asset performance at project and portfolio level will be uplifted.

This is just the beginning of the Government's digitalisation journey. Engagement and feedback will be continuously sought from the Works Departments and the broader supply chain to enhance and extend the digitalisation of public works delivery. The Government will continue to monitor and refine processes and incorporate advanced technologies that can help generate greater benefits that positively impact the Capital Works Programme.

Throughout the development of the five components (see Section 2), Industry stakeholders have been consulted on an ongoing basis to introduce the Government's digitalisation plan as well as gather feedback to enhance the underpinning architecture, workflows, governance and implementation planning. Going forward, regular engagement will continue to seek input and keep the Industry informed of the direction of digitalisation and allow them to prepare for any operational impact ahead of time.

APPENDICES

A. FURTHER DETAIL ON THE VALUE IMPACT ASSESSMENT

VALUE IMPACT ASSESSMENT APPROACH AND FINDINGS

A three-step process has been undertaken, as detailed below:

- **Step 1** – Global scan for relevant case studies with demonstrable planning, design and construction cost savings followed by selection and subsequent analysis.
- **Step 2** – Global scan for relevant case studies with demonstrable O&M cost savings followed by selection and subsequent analysis.
- **Step 3** – Application of relevant benefits from the shortlisted case studies to the Government's Capital Works Programme of approximately HK$100 billion per annum for the next 10 years to estimate a CAPEX and life cycle value impact assessment.

STEP 1 – CASE STUDY SELECTION AND ANALYSIS – PLANNING, DESIGN AND CONSTRUCTION PHASE

Following a global scan (due to limited evidence available in Hong Kong regarding the benefits of using such technology), a total of 39 prospective evidence-based case studies were selected and analysed for the planning, design and construction phase. The case studies reported measurable cost savings from the use of, for example, integrated data platforms, BIM and CDEs as methods for better data capture and exploitation. The analysis undertaken also considered studies of technologies used to verify and monitor compliance and accuracy of contracted spend. The evidence captured for this assessment was based on desktop study findings of publicly available information and the results from the use of the EY Compliance IQ tool[13].

The initial list of 39 prospective case studies was shortlisted to 15 relevant cases, based on the selection criteria below:

Outliers and reduced bias – Case studies without verifiable support of the stated benefit were excluded to avoid potential bias toward the use of projects that were anecdotally supportive yet lacking evidence.

Technology type – Only projects that involved the use of technologies relevant to the iCWP and the Government’s digitalisation plan were selected.

Asset type – Case studies representative of the asset types developed by the Works Departments within the Capital Works Programme were selected, including Government buildings, E&M facilities, road and public transport infrastructure, sewage collection and treatment assets, stormwater drainage systems, water treatment and supply systems, piers and port facilities.

Portfolio of projects – By digitialising the way publicly funded assets are delivered, better decisions can be made across a portfolio of projects. Therefore, case studies that included portfolios rather than a single built asset, were preferred.

Realised benefits – Only projects that demonstrated actual, evidence-based impact from the use of data and technology were considered relevant (instead of expected benefits).

[13]The EY Compliance IQ tool is a custom-built intelligent automation tool to support contract management process. The tool efficiently reviews large data sets for the real-time identification of third party commercial and billing mistakes, which is used to prevent overpayment and reduce value leakage. Compliance IQ was developed by Ernst & Young LLP in Canada (“EY Canada”), which is an Ontario limited liability partnership.

The 15 shortlisted case studies included a CAPEX saving range of 0.03% to 6.92%. Due to the limited number of relevant case studies, it was not possible to apply specific cost savings to each asset type within the Capital Works Programme, therefore an overall median cost saving of 2.4% was used in Step 3.

STEP 2 – CASE STUDY SELECTION AND ANALYSIS – O&M PHASE

Following a global scan, a total of 50 prospective evidence-based case studies were selected and analysed for the O&M phase. The case studies reported measurable cost savings from the use of, for example, IoT sensors for automated monitoring of tilting, vibration, water levels in sewage treatment facilities, AI-enabled road defect detection systems and IoT data hub for remote monitoring of water leakage, toilet/room occupancy and utilisation in buildings. In addition to international examples with local evidence, information provided by the Works Departments and outputs from workshops with major infrastructure owner/operators in Hong Kong (namely, AAHK, MTR Corporation, KTSP and West Kowloon Cultural District Authority (WKCDA)) have been considered in the assessment.

The initial list of 50 prospective case studies was shortlisted to 29 relevant cases based on the selection criteria below:

Outliers and reduced bias – Cases considered unreliable or biased due to lack of a robust methodology in how benefits were estimated or demonstrated were filtered out.

Technology type – Only projects that involved the use of digital technologies to drive asset operational improvements relevant to the iCWP and the Government's digitalisation plan were selected.

Asset type – Case studies representative of the asset types developed by the Works Departments within the Capital Works Programme were selected, including Government buildings, E&M facilities, road and public transport infrastructure, sewage collection and treatment assets, stormwater drainage systems, water treatment and supply systems, piers and port facilities.

Realised benefits – Only projects that demonstrated actual, evidence-based impact from the use of data and technology were considered relevant (instead of expected benefits).

The 29 shortlisted case studies included an operating expenditure (OPEX) saving range of 0.03% to 14.0% generated from the use of digital technology to drive O&M improvements. As most of these case studies reported savings to specific operating costs instead of overall operating costs, it was necessary to convert the specific savings to overall operating cost savings. This conversion was undertaken by estimating the typical breakdown of operating costs by component and cost types (namely materials and equipment, labour and utilities) for each asset type (information provided by the Works Departments). For example, a 20% saving for water treatment plant O&M labour, would be converted to a 4% saving in WSD's total operational costs, as water treatment plant labour is 20% of WSD's total O&M budget. This conversion allowed all the case study estimates to be directly comparable as a saving in total O&M costs. Due to the limited number of representative case studies for each asset type within the Capital Works Programme, an overall estimated median cost saving of 4.0% derived from the conversion was selected for use in Step 3.

STEP 3 – CAPEX AND LIFE CYCLE VALUE IMPACT ASSESSMENT

CAPEX VALUE IMPACT ASSESSMENT

The CAPEX value impact assessment relied on CAPEX estimates from the Government (an approximate spend of HK$100 billion per annum), which was applied across the next 10 years as a medium-term outlook of the Capital Works Programme spend. This reflects the expenditure for publicly funded assets only (excluding those delivered by major public clients). The median cost saving of 2.4% was applied to the capital works expenditure to quantify the cost savings per annum.

Technology development investment was considered to reflect the net benefit case. The total cost includes the development of Phase 1 of the iCWP and its O&M. The development costs for DPDS and DWSS were also considered, which is estimated to be 1% of project cost per annum[14] (equivalent to HK$1 billion per annum when applied to the Capital Works Programme of HK$100 billion per annum).

[14] 1% is assumed based on statistics of the cost to develop, maintain and enhance DWSS and DPDS from over 100 public works contracts.

The cost-benefit analysis of the planning, design and construction phase indicates the adoption of technology for better IM and to monitor compliance and accuracy of contracted spend could potentially enable a **BCR of 2.4:1** over a 10-year period – suggesting **that for every HK$1 invested in the technology and tools, this could generate approximately HK$2.4 in cost savings.**

LIFE CYCLE VALUE IMPACT ASSESSMENT

To determine the life cycle value impact assessment, the redirection of a portion of the savings generated during the planning, design and construction phase to the investment in O&M technology was considered. This was considered to avoid increase in the resource budget allocation requirement as part of the circular value approach illustrated in Figure 9. Assuming that most of O&M technology is related to E&M components, this reinvestment was determined by assuming that an additional 1% of the E&M budget would be invested in the O&M technology (such as sensors and building management systems). Given E&M components represent approximately 15%[15] of CAPEX, the additional investment required would be 0.15% of the CAPEX (HK$100 billion per annum), which equates to HK$150 million per annum.

Generally, an evaluation period for a cost-benefit analysis is determined based on asset life expectancy. For the purposes of this evaluation, a 40-year evaluation period was selected by considering a range of asset life expectancy for the different asset types within the Capital Works Programme.

To quantify the applicable O&M annual cost for the assessment, 8 case studies, were used to understand the costs of operating different asset types. This assessment gave a range of 1% to 1.5% per annum of the capital cost of the assets. The annual OPEX to maintain the assets developed over the 10-year CAPEX period assumes the O&M technology is built into the assets as they are constructed. For the purposes of this assessment, the cumulative OPEX of the portfolio of assets progressively increases year-on-year throughout this 10-year period as assets move from construction to O&M, commencing at year 2. At completion of the 10-year CAPEX investment period, the 1% to 1.5% OPEX range becomes constant over the remaining O&M period (30 years used for this assessment). The median cost saving of 4.0% (determined by the case study review detailed in Step 2) was applied to the estimated OPEX (1% to 1.5% of CAPEX) to calculate potential annual OPEX savings.

In addition to the technology development investment used in the CAPEX value impact assessment in Step 3, the life cycle value impact assessment includes the development cost of Phase 2 and long-term development of the iCWP as well as its O&M cost.

The cost-benefit analysis results of the life cycle value impact assessment indicate that investing in O&M technology during the construction period for enhanced asset performance in O&M could potentially further increase the BCR from **2.4:1** to a **BCR of 3.4:1** over a 40-year period – indicating that **for every HK$1 invested, approximately HK$3.4 in cost savings could be generated if some benefits are re-invested in O&M technology.**

The results of the CAPEX and life cycle value impact assessment[16] are based on the combined 44 shortlisted case studies, which while based on the best available information, may not be representative of the potential benefits to Hong Kong. This highlights the need for a better benefits management framework to measure the benefit and value generated as well as developing the ability to trace how any re-investment is being used (See Section 5 of the publication).

All costs used in the CAPEX and life cycle value impact assessment applied a discounted rate of 3% per annum[17] to convert into money-of-the-day (MOD) prices, considering the Government's opportunity cost to the CAPEX.

With this framework, benefits can be better captured and investments in the right technology can be made and the Government will be able to progress the ambition of generating circular value in how publicly funded assets are planned, constructed, operated and maintained.

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[15]Reference was made to various industry construction cost handbooks and indices (2021/22) in Hong Kong.

[16]The value impact assessment and its findings carried out for this publication are for indicative purposes only and should not be construed as any form of advice. The approach undertaken for the value impact assessment and shortlisting of case studies is judgement-based. DEVB, HKU Business School, EYTL and any other EY Firm do not accept any responsibility for, or provide any representation or warranty, express or implied, as to the truth, accuracy, completeness or reasonableness of the data or information used in the value impact assessment and publication, whether on behalf of themselves or any of their directors, employees, agents, representatives or other advisers. None of DEVB, HKU Business School, EYTL or any other EY Firm, or any of their directors, employees, agents, advisers or representatives shall have any liability to any party in respect of such data or information, or be obliged to update any such data or information, or to notify any party or to correct any inaccuracies in any such data or information (even if such inaccuracies are discovered subsequent to the publication of such data or information). An "EY Firm" means a member of the EY network and any entity operating under a common branding arrangement with a member of the EY network.

[17]A discount rate of 3% per annum was used based on the real economic growth rate used in the 2022-23 Budget Medium Range Forecast

SHORTLISTED CASE STUDIES USED IN THE VALUE IMPACT ASSESSMENT

The shortlisted case studies used in the value impact assessment are detailed in the following tables. The shortlisted case studies were accessed between 1 August 2022 and 7 November 2022 for the value impact assessment.

SHORTLISTED CASE STUDIES USED IN CAPEX VALUE IMPACT ASSESSMENT

Case no.	IM/BIM/CDE application	Organisation name	Asset type
1	BIM application for a portfolio of construction projects in US[18]	Holder Construction Company Atlanta	Buildings
2	CDE implementation in regional connector transit corridor project[19]	Los Angeles County Metropolitan Transportation Authority	Railway infrastructure
3	CDE implementation in airport expansion, Abu Dhabi International Airport[20]	The Abu Dhabi Airports Company	Airport terminal
4	Implementation of IM in EDAROTH housing projects, UK[21]	EDAROTH	Buildings
5	BIM Study by National Institute of Building Sciences Research, US[22]	National Institute of Building Sciences Research	Buildings
6	Implementation of IM in Government Property Agency (GPA) B2IM Approach, UK	GPA UK	Buildings
7	Implementation of IM of Transport for Greater Manchester (TfGM) Trafford Park Line Metrolink Extension, UK[23]	TfGM	Railway infrastructure
8	The 39 Victoria Street Office Building Refurbishment, London[24]	Department of Health, UK Government	Buildings
9	The Foss Barrier Upgrade Project[25]	Environment Agency, UK Government	Pumping station
10	BIM application on a hospital project[26]	University of California San Francisco Medical Center	Buildings
11	BIM implementation in Hong Kong Public Housing Projects[27]	Hong Kong Housing Authority	Buildings
12	Application of the EY Compliance IQ tool for a large Canadian integrated energy company[28]	Large Canadian integrated energy company	Energy

[18]Azhar, S. (2011), BIM: Trends, Benefits, Risks, and Challenges for the AEC Industry.
[19]GW Prime (2021), BIM and Common Data Environment on the LA Regional Connector Transit Corridor Project.
[20]The BIM Limited (2016), Expanding Abu Dhabi International Airport with BIM.
[21]Atom Publishing (2021), Information management can produce six-fold savings, says CDBB report.
[22]The BIM Industry Working Group (2011), A report for the Government Construction Client Group: BIM Working Party Strategy Paper.
[23]REBIM (2018), REBIM® & TfGM Case Study : BIM to Operations & Maintenance Environment.
[24]Jowett, G. (2022), The value of BIM in the construction sector.
[25]Chevin, D. (2018), BIM benefits quantified for the first time.
[26]Mahajan, S. (2015), A case study example of BIM implementation on a hospital project.
[27]Lu, W., Fung, A., Peng, Y., Liang, C., Rowlinson, S. (2014), Cost-benefit analysis of Building Information Modeling implementation in building projects through demystification of time-effort distribution curves.
[28]Sourced from EY Canada's project experience of the EY Compliance IQ service.

Case no.	IM/BIM/CDE application	Organisation name	Asset type
13	Application of the EY Compliance IQ tool for a large Canadian multinational pipeline company[28]	Large Canadian multinational pipeline company	Energy
14	Application of the EY Compliance IQ tool for a large Canadian developer and operator of oil pipeline system[28]	Large Canadian developer and operator of oil pipeline system	Energy
15	Application of the EY Compliance IQ tool for a large North American energy company[28]	Large North American energy company	Energy

SHORTLISTED CASE STUDIES USED IN LIFE CYCLE VALUE IMPACT ASSESSMENT

Case no.	IM/BIM/CDE application	Organisation name	Asset type
1	IoT Water Management Solutions[29]	IBM	Sewage treatment works
2	Smart Water Meters in South Korea[30]	Gochang Waterworks	Sewage treatment works
3	IoT sensors to detect water leakage in UK[30]	Ofwat, UK	Sewage treatment works
4	Pipe Sleuth – an automated sewer pipe inspection tool[31]	DC Water, in collaboration with Wipro	Stormwater drainage systems
5-7	Application of Dynamic Torque Waveform Technology for Scottish Water[32]	Jacobs	Pumping stations
8	Pumping station automation at Sindelfingen wastewater treatment plant[33]	Festo	Pumping stations
9	Smart tunnel lighting solution in Huguenot Tunnel[34]	South African National Roads Agency Limited	Tunnels
10	Application of Bridge Health Monitoring System[35]	National Chip Implementation Center, Hsinchu, Taiwan	Bridges
11	Inspection Cloud – AI-enabled defect detection and visual inspection of infrastructure[36]	EasyInspect	Bridges
12	Sensor enabled Road Health Analytics solution[37]	Cyient	Roads
13	Intelligent Street Lighting System[38]	Thadomal Shahani Engineering College, India	Roads
14	AI solution for pothole maintenance[39]	Blackpool Council, UK	Roads
15	EyeVi Infrastructure Digitalisation Solution[40]	EyeVi	Roads

[29] Bellias, M. (2017), IoT for water utilities.
[30] Smart Energy International (2020), Role of the IoT and AI in the digital transformation of water utilities.
[31] Intel (2022), DC Water: Streamlined Sewer Pipe Inspection Analysis.
[32] Jacobs (2019), 2019 Industry Report.
[33] Festo (2022), Pumping station automation.
[34] Schréder (2022), Huguenot Tunnel.
[35] Lin, C.H., Chen, S.Y., Yang, C.C., Wu, C.M., Hua, C.M. (2014), Structural health monitoring of bridges using cost-effective 1-axis accelerometers.
[36] EasyInspect (2019), Inspection Cloud.
[37] Cyient (2019), Reduce road maintenance costs and improve drivability and safety.
[38] Rajput, K.Y., Khatav, G., Pujari, M., Yadav, P. (2013), International Journal of Engineering Science Invention, Intelligent Street Lighting System Using Gsm.
[39] Trendall, S. (2020), Blackpool claims £1m savings after using AI to fix potholes.
[40] EyeVi (2022), AI-powered platform for geospatial data production.

Case no.	IM/BIM/CDE application	Organisation name	Asset type
16	EyeVi Technologies[41]	EyeVi	Roads
17	Automated road data capture technology for O&M[42]	Washington Department of Transportation	Roads
18	Machine learning tool for highway drainage maintenance[43]	Intellegens and Skanska	Roads
19	IoT sensors for facilities management[44]	Gartner	Buildings
20	Digital AM Software for buildings[45]	The Edge	Buildings
21	Smart building management system (SBMS)[45]	The Edge	Buildings
22-24	Technology advancements for smart building management and operations[46]	EY	Buildings
25	The Hague City Hall Digital Twin[47]	Province of Zuid-Holland	Buildings
26	Smart illumination systems in a port project[48]	The ports of Valencia and Hamburg	Port and marine facilities
27	Smart port solution at the Port of Valencia[49]	Port of Valencia, Spain	Port and marine facilities
28	BIM-AM Platform[50]	EMSD	Buildings
29	Proactive energy management programme for buildings[51]	Candi	Buildings

SHORTLISTED CASE STUDIES TO QUANTIFY O&M COSTS

Project No.	Project	Ratio of annual O&M cost to capital costs of an asset used in value impact assessment
1	Singapore public housing projects[52]	1.50%
2	National highway project of India[53]	1.00%
3	Water Sector Investment Programme[54]	1.00%
4	Wastewater Treatment Project[55]	1.00%
5	Wastewater Treatment Case in southern Europe[56]	1.00%
6	Large hydropower project[57]	1.00%
7	Small hydropower project[57]	1.00%
8	Energy project (fixed O&M cost)[58]	1.00%

[41]Bodio, M. (2018), Why we invested in EyeVi.
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B. GLOSSARY OF TERMS AND ABBREVIATIONS

Abbreviation/Term	Definition
AAHK	Airport Authority Hong Kong
Action Plan	Action Plan refers to the measures and actions related to Transforming Infrastructure Performance set out by UK's Infrastructure and Projects Authority
AI	Artificial Intelligence
AM	Asset Management
AMS	Asset Management System
API	Application Programming Interface
ArchSD	Architectural Services Department
BCA	Building and Construction Authority (Singapore)
BCR	Benefit-Cost Ratio
BIM	Building Information Modelling
BIM-AM	Building Information Modelling for Asset Management
CAPEX	Capital Expenditure
CDE	Common Data Environment
CEDD	Civil Engineering and Development Department
CIC	Construction Industry Council
CSDI	Common Spatial Data Infrastructure
CSF	Critical Success Factor
DEVB	Development Bureau
DPDS	Digital Planning and Design System
DSD	Drainage Services Department
DWSS	Digital Works Supervision System
E&M	Electrical and Mechanical
EMSD	Electrical and Mechanical Services Department
EPD	Environmental Protection Department
EY Canada	Ernst & Young LLP
EY Hong Kong	Ernst & Young Transactions Limited
GDP	Gross Domestic Product
GIS	Geographical Information System
Government	The Government of the Hong Kong Special Administrative Region of the People's Republic of China
GPA	Government Property Agency (UK)

Abbreviation/Term	Definition
GWIN	Government-Wide IoT Network
HKIA	Hong Kong International Airport
HKU	The University of Hong Kong
HVAC	Heating, Ventilation and Air Conditioning
HyD	Highways Department
iAMS	Integrated AMS
iCWP	Integrated Capital Works Platform
IDD	Integrated Digital Delivery
iDPDS	Integrated DPDS
iDWSS	Integrated DWSS
IM	Information Management
IoT	Internet of Things
Industry	Hong Kong Construction Industry
IPA	Infrastructure and Projects Authority (UK)
IPD	Integrated Planning and Design
ISO 19650	International Organisation for Standardisation 19650 Standards for BIM
ITM	Industry Transformation Map
KPI	Key Performance Indicator
KTSP	Kai Tak Sports Park
LandsD	Lands Department
MOD	Money-of-the-Day
MOU	Memorandum of Understanding
NSW	New South Wales
O&M	Operations & Maintenance
OGCIO	Office of the Government Chief Information Officer
OPEX	Operating Expenditure
OPV	Office of Projects Victoria (Australia)
PSS	Project Surveillance System
Public Works	Public Works refer to the assets constructed, operated and maintained within the Capital Works Programme
PWP	Public Works Programme
RFID	Radio Frequency Identification
RISC Form	Request for Inspection/Survey Check Form
SCADA	Supervisory Control and Data Acquisition
TC(W)	Technical Circular (Works)
TfGM	Transport for Greater Manchester (UK)
TIP	Transforming Infrastructure Performance
UK	United Kingdom
VDAS	Victorian Digital Asset Strategy
WKCDA	West Kowloon Cultural District Authority
WSD	Water Supplies Department

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