Digital Cities

Volume 1 - Second Edition

Future Differentiating Strategies

AECOM

AECOM Asia Digital

In Asia, the world's fastest urbanizing region, we help our clients to envision and achieve differentiated impact for cities and the communities they serve, through the pioneering development and deployment of digital infrastructure. We deliver bespoke solutions to enable transformational growth, integrating business strategy, technology and innovation with our technical expertise and experience in planning, designing and delivering the core infrastructure, buildings and places that define a city. Thinking and acting globally, we bring the best minds together to solve our clients' biggest challenges, from developing digital cities strategies, to the integration of digital tools for project design and delivery, to enabling our clients' digital adoption and transformation for their business.
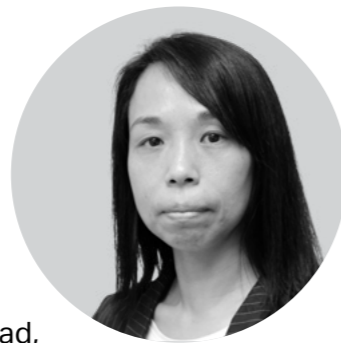
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Future Differentiating Strategies is the first part of our series on Digital Cities.
With mankind facing a growing number of challenges that are unprecedented in nature and scale, digital cities are where we should look for the strategies to pre-empt risks, the remedial solutions to restore equilibrium, and the path for better future outcomes.

Many industries are already deploying digital twins as a means to identify risks, simulate processes and plan ahead. Even so, the potential to apply the concept to cities is still largely untapped. Facing new scenarios where there are no existing playbooks, the ability that technology gives us to collect data and replicate physical objects, can be further flexed to help extrapolate, anticipate and strategize more comprehensively. A digital replica fueled by data can become an extremely powerful analytical tool. A holistic approach to data enables the whole to be far greater than the sum of the parts, providing city leaders with vital information to make better decisions for how the future built and natural environment should sustain communities, and how communities should sustain them in return.

As the data available to be mined continues to expand, and technologies become more diverse, the journey towards digital transformation becomes ever more worthwhile, and simultaneously ever more complex. Data democratization gives more participants an entry ticket to information. However, data collaboration will be the real game-changer that will propel the quantum leap from the current state where data coexists, to the future state where data is consistently and comprehensively connected in a digital ecosystem that offers new perspectives, and supports a holistic approach to innovation and the development of solutions. Counterbalancing the weight of daunting challenges such as accelerating urbanization, climate change and viral pandemics, is the encouragement that the data already exists that can reveal to us the problems we must prepare for, and the solutions to them. What is needed to enable it, is human collaboration on intelligence, best practices and new ideas.

In the same spirit of collaboration, key experts who have played a significant role in the development of four emblematic and diverse digital city strategies in Europe, North America and Asia, share the big idea that underpinned their work. The case studies of Helsinki, UK, Toronto and Singapore each offer a distinct approach to the deployment of People, Process, and Technology, the vital components to catalyze the disruption necessary for transformation, and to be strategically integrated into the Digital Ecosystem — an orchestrated and interconnected realm in which society, environment, economy and technology share data to respond and adapt to fast-evolving scenarios — with the ultimate goal of creating an accessible, sustainable and resilient world for current and future generations.

Many industries are already deploying digital twins as a means to identify risks, simulate processes and plan ahead. Even so, the potential to apply the concept to cities is still largely untapped.

What makes a digital city?

James Kirkpatrick
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Digital is a word that is frequently used but hard to define. Getting a digital watch at the height of their popularity in the early '80s was my first encounter with the term. At that time, digital simply meant a watch that was more fascinating than an analog timepiece. To understand what is meant by digital in its contemporary use, and when used in the context of cities, we need to move beyond just knowing the basic definition of storing information in signals of 0 and 1 to fully grasping its importance to our daily lives.

'Digital' is about using data — those 0s and 1s — to make better and faster decisions. When we apply this concept to the city with the dimensions of physical space and inhabitants, we get a 'digital city,' from which we can leverage data. This allows us to make better individual and collective decisions to improve lives and provide better services for residents.

To get a clearer picture of what a digital city may look like, think of the many intricate data maps that can be found online, the network of lines on a globe showing the connections between Facebook friends, or the lines on a map tracing our morning commute — these provide a visualization of the data from our interactions with the city that illustrates the potential of the digital city. So how do we realize this potential and what benefits can we experience from the digital city?

Why make our city digital?

We are already increasingly relying on data to improve planning decisions, physical infrastructure investment and operations. Digitalizing the city has provided significant benefits to communities around the world and its outcomes are diverse — from the efficient realignment of transit routes based on social media data, to the use of locational services for contact tracing amid the coronavirus pandemic.

Although there are countless examples, in many cases they function in isolation or with limited interaction with one another. With continued adoption and integration of these approaches, fed by new and better data lies the potential of more holistic and greater benefits.

The end game is a cognitive city which continuously improves its outcomes through ongoing interaction between the technology and its data inputs, the people, the suppliers and users of the data, and the processes deployed to manage this complex realm — a community within a built and natural ecosystem. The ultimate goal is to create a more efficient, more sustainable, and more resilient place in which to live; where we can analyze and provide solutions to current challenges such as wellness, economic imbalance, environmental degradation and climate change. As these tools become increasingly adopted and refined, so too will they increase in accessibility — enabling more digital cities around the world. It is then that we can pull our cities collectively into a regenerative dialogue with our planet.

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Why we need to dream of electric unicorns

Sylvester Wong
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The digital city — everyone has a different take, be it academia, industry or "kit sellers." Technologies constantly evolve faster than our ability to capture and analyze the firehose of data created and consumed by cities and their citizens. It is easy to get caught up in the science-fiction promise of flying cars and automated utopias, and end up myopic in the search for the next clever killer app, or lost in the dystopian zeitgeist of a world gone awry — the *Blade Runner* future spawned from the classic *Do Androids Dream of Electric Sheep?*

It is easy to forget — in the chase for digital twins and smart cities — that cities around the world are grappling with gritty, decidedly low-tech, existential threats. We are in the throes of a fundamental shift in the way communities evolve, in and beyond pandemics, realigning around climate change, inclusivity and digital economic revolution. Environmental footprints are driving investment decisions. The need for social equity is upending old shortcomings of technical efficiency. Governance is more critical than ever to prevent abuse of privilege, access and asymmetric advantage. Throughout this, our communities and their citizens yearn for daily needs unchanged throughout time: to be nourished, to be healthy, to be secured, to be fulfilled, to be loved, to be happy.

We are today in a world in search of purpose, which makes the journey of societies toward digital transformation more pointed and poignant. At the intersection of evolving technologies, global challenges and human needs is a realization. Digital tools and digital cities should be but a means to an end: to create value for society and to create opportunity for recovery and prosperity. To achieve that end requires strategy, or chess game thinking: thinking about where we want to be — *who* we want to be — and making the steps to get there happen.

Putting outcomes before strategy

Strategy is a state of mind, a holistic perspective that answers the "why" before the "how," and then the "how" before the more tactical "what" and "when." In the context of digital cities, strategic thinking looks past the technology and data, past the civic systems and processes, towards the ultimate value realized for citizens and their aspirations.

So before designing a platform to improve the way a city functions, before coding algorithms to solve efficiencies in traffic or infrastructure, or before procuring the latest sensors to record every change in a community's habitat, we ask: to what end? Is it to save our city managers a few hours of work? Or is it to gain our citizens a few years, neé decades, of advantage?

If the purpose is the latter, it becomes apparent that designing digital solutions requires answers to questions deeper than those about mere technical performance or functionality. These questions must be strategic questions, and their answers may dash our pre-conceived notions of technologies to deploy.

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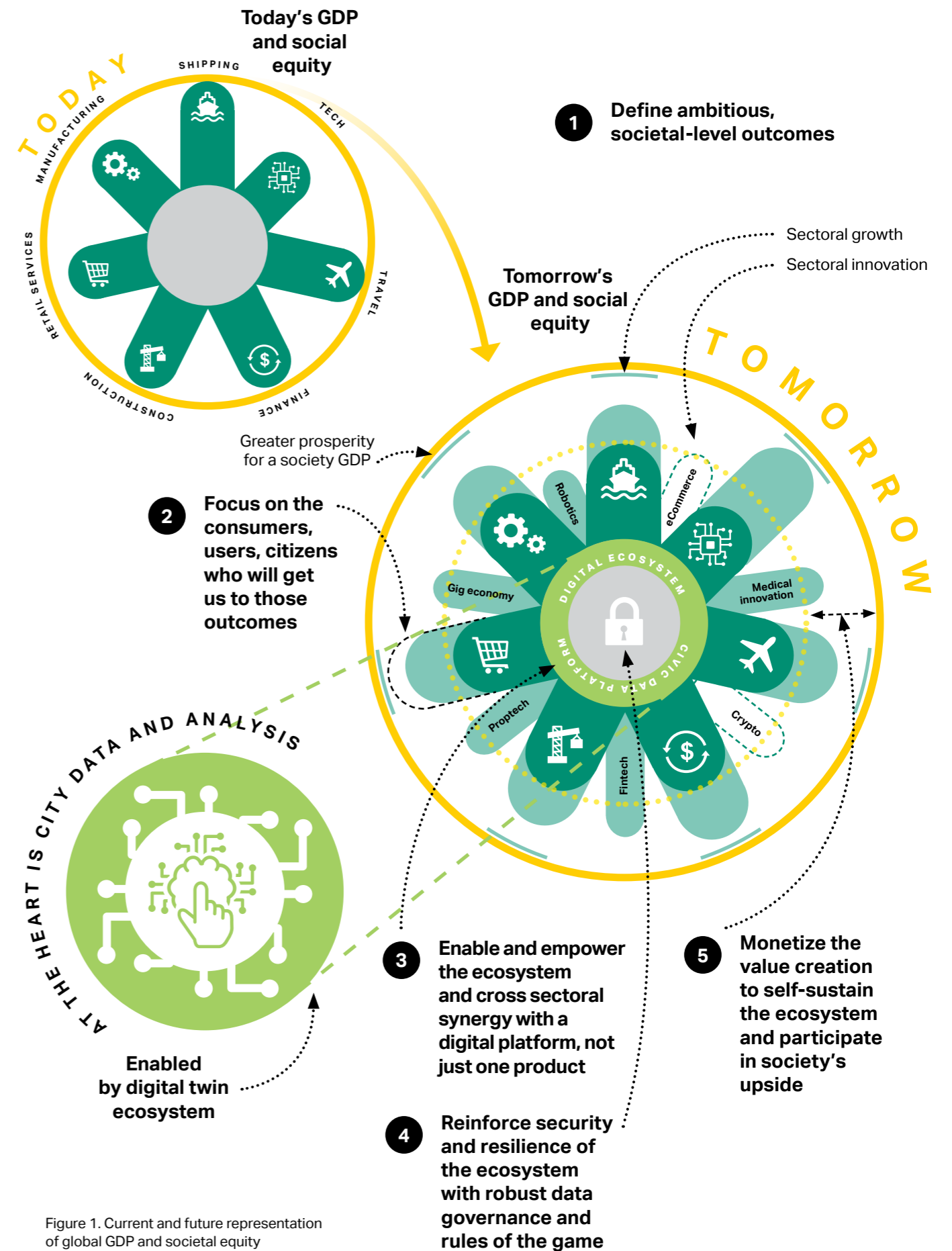

Figure 1. Current and future representation of global GDP and societal equity

Outcome-driven questions

1. What are we trying to achieve? Quality of life? Reduction of congestion? Increased land value? Inclusiveness? Resilience?
2. What value are we creating? What is the value proposition?
3. What is our Big Hairy Audacious Goal (BHAG), or vision-led mission?
4. How shall we measure success? How are results managed?

User-centric questions

1. Who are the ultimate beneficiaries? What are their expectations and demands?
2. What are the pain points to be solved? What are the use cases to learn from?
3. What are the users' profiles and journeys? Who are the early adopters?
4. What's the per-user cost and gain?
5. How does the community benefit inclusively and build equity, justice, resilience and competitiveness?
6. What granularity and frequency of data/integration are needed?

Enabling networks questions

1. How can solutions leverage tech/data/operational gains to enable economic growth in both private and public sectors?
2. Are solutions creating more equitable access to services, opportunities and citizen needs?
3. Is there sufficient openness and modularity to avoid becoming hostage to monolithic legacy systems or methodological black-boxes?
4. How might the combination of data growth and technology obsolescence impact the maintenance, upgrades and agility of the systems?
5. How can we spawn new ideas, innovations and sectors of industry to propel the city forward?

Business cases viability questions

1. How can a developer/city be capital-efficient, and not hampered by bureaucracy?
2. How can solutions self-sustain: Traditional city budget procurement? Operational PPP concessions? Infrastructure-as-a-service? Grants and ESG finance for impact results?
3. How does the solution create and monetize value, and not just remain a cost?

Data governance and resiliency questions

1. Who owns the data, and who is responsible and liable? Who watches the watchers?
2. How are data and critical systems secured against known and unknown risks?
3. What are the safeguards? How are management frameworks developed?
4. How is privacy protected while empowering innovation?

With stakeholder engagement and articulation of answers to the above questions, digital city conversations can focus on the value creation and broader outcomes that should guide the details of implementation. This is the heart of strategy — enabling solutions to respond to the unique context of natural and built environments, and the distinctiveness of a community's cultural and social characteristics.

At the end of the day, digital infrastructure and integrative technology is not just about making a city more efficient, as that's just a chase after diminishing returns. A proper strategic digital city approach measures success by gauging how well an entire region and its population is leveled up and elevated together by unleashing data and connectivity. A great digital city is not one that merely functions well and without waste, it is one that elevates the city in this constant struggle for global competitiveness, and as importantly, in so doing, uplifts a whole nation.

Competitiveness creates opportunities. Opportunities create sustainable futures limited only by the imagination and dreams of those fabled utopias. One doesn't choose to buy a bed based on, say, the tensile strength of the springs, but rather on whether one gets a good night's sleep and mind-awakening dreams. Then instead of counting sheep in an insomnia of stress about how our fragile cities will survive, we shall be counting unicorns and celebrating how well our cities can thrive.

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The tales of four future differentiating city strategies

In this chapter, we present four emblematic digital cities approaches from around the world. The city initiatives of Helsinki, UK, Toronto and Singapore demonstrate how to develop a consensus strategy, inclusiveness framework, and technology-neutral approach tailored to the unique history, culture and nuances of each, and offer usable lessons for other cities.

FI — Helsinki 3D+: Developing a dream over three decades

UK — UK: The Gemini Principles

CA — Toronto: The parallel approach

SG — Singapore: Smart Nation

Helsinki 3D+: Developing a dream over three decades

Jarmo Suomisto
Manager, Helsinki 3D+,
Consultant, AECOM

Helsinki today ranks as one of the world's top smart cities. From its eighth place in 2019, it has jumped up six places in the Smart City Index 2020, and is now ranked in the top three alongside Singapore and Zurich[1]. The road to this milestone started 35 years ago when much of the technology available to today's digital cities did not exist. Jarmo Suomisto, manager of Helsinki 3D+, talks to AECOM about pioneering the digital city, the challenges that came with it and what he sees for smart cities in the years ahead.
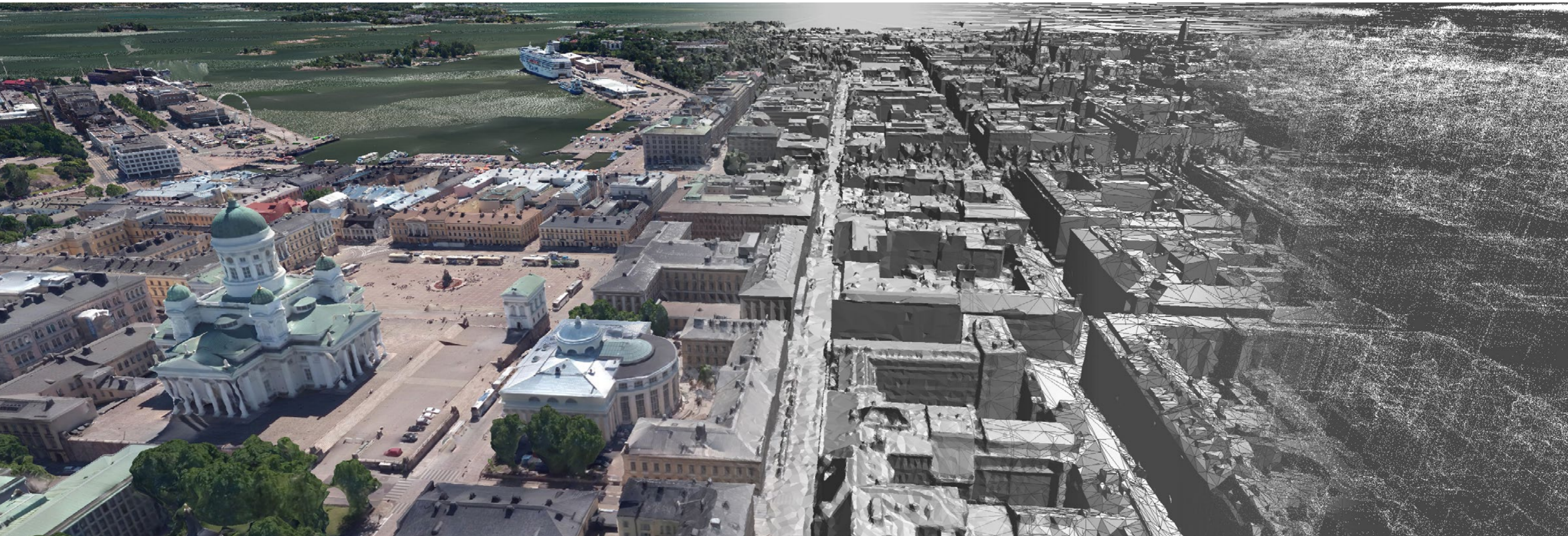

Figure 2. Helsinki historic center – physical and digital overlapping

What motivated Helsinki to be a Digital City pioneer, and how has its strategy evolved?

Helsinki 3D+ started its journey towards being a Smart City back in 1985. At first, 3D city models were constructed to support the judging process of architectural competitions. The goal was to better understand the city as a complex entity and to make it more beautiful and functional. Creating the Helsinki 3D digital model resulted from our visionary dream of implementing technology to intensify processes. We dreamed of a city where technology was at our service, a tool to make our lives better in our magnificent habitat. As city planners, we wanted to focus on what we like the most — the creative aspect of designing and shaping the city. At that time, the available technology was limited, costly, and its benefits were blurry and unclear for the general public. Now we can attest that Helsinki was a pioneer in implementing technology for the city's public realm and its citizens. I must admit that back then, we were excited to adopt an experimental attitude. Everything had to be discovered with a "learning by doing" attitude, improving through mistakes, learning and unlearning, and calibrating our knowledge to master the technology.

Helsinki achieved its first key milestone in 2000 when we developed the initial city model in a computer-aided design (CAD) format that covered the entire city. The model allowed us to create visual simulations and demonstrate new opportunities to the city leaders. Step by step and through practical examples, the city leaders and the general public started to perceive the potential of creating a "digital city" and in 2015, the current Helsinki 3D+ was created. We developed it through a structural approach based on the experience that matured during the previous 30 years. Indeed, Helsinki developed its first strategy back in 1985, with a sharp vision and a clear intention, but with a flexible approach that allowed us to adapt to the ever-evolving technology.

What are the primary challenges and benefits for Helsinki 3D+?

The initial challenge in 2015 was creating the model. "How do we produce the new generation 3D city model?" was the first question we asked ourselves. The first step was to develop a critical analysis of our situation, understanding the available resources and our integral strengths. We started by creating a clear picture, and we linked it to the city vision. We decided what to do, and as equally important, what not to do.

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Figure 3. Helsinki3D+ storyline

Once we created the model, the subsequent challenge was demonstrating its capability and potential to the city leaders to earn their support. We knew that the decision-makers wanted to see solid and practical examples, so we decided to develop 12 agile pilot projects, engaging universities and external companies. While not all the projects were successful, about half of them were fruitful and convincing, so we received enough resources to continue our journey.

On top of that, another challenge was the model maintenance. As the city evolves over time, so should the model as new development awakes the most interest. We planned for the future from the early stage, creating and producing models with as much automated process as possible. Today our city model updating and maintenance system is nearly 70% automated — this means fewer manual work, which also reduces human error.

Throughout 35 years of experience developing the 3D City Model, we learned to manage technologies to optimize the city's benefits. We integrated technologies into our processes without letting technology lead the agenda. We also learned to be realistic with the objectives and not to hype and promise too much in advance.

Working with the 3D City Model for an extended period certainly facilitates the digital city's general public awareness. Citizens, city leaders and decision-makers understand and support the development of Helsinki 3D+, and their engagement and demands motivate our daily work. Over time, we have created and cultivated a culture of participation, and as a result, Helsinki now ranks second in the world Smart City Index.

What does it mean to be a smart city for Helsinki?

To be a smart city for Helsinki means to be a functional city. It means making use of the available technology to deliver value, with the ultimate goal of creating a sustainable environment where people can have a good life, have access to education and more innovative services and enjoy equal rights. One example of this is Helsinki's Carbon Neutral 2035 program. This strategic goal is strongly supported by the Helsinki Energy and Climate Atlas service, built on the semantic 3D City Model. This open web service demonstrates alternative power sources like solar and geothermal energy and more efficient use of energy for lower carbon emissions.

A digital city is also a platform that helps stakeholders make better decisions by building deeper understanding through analyses, simulations, and visualization. It can start as a simple model that implements analytical tools — it is not necessary to develop a fancy eye-catching model from the start. The model can evolve with more accurate and complex features over time, as the city allocates more significant resources, just as Helsinki did with the 12 pilot projects.

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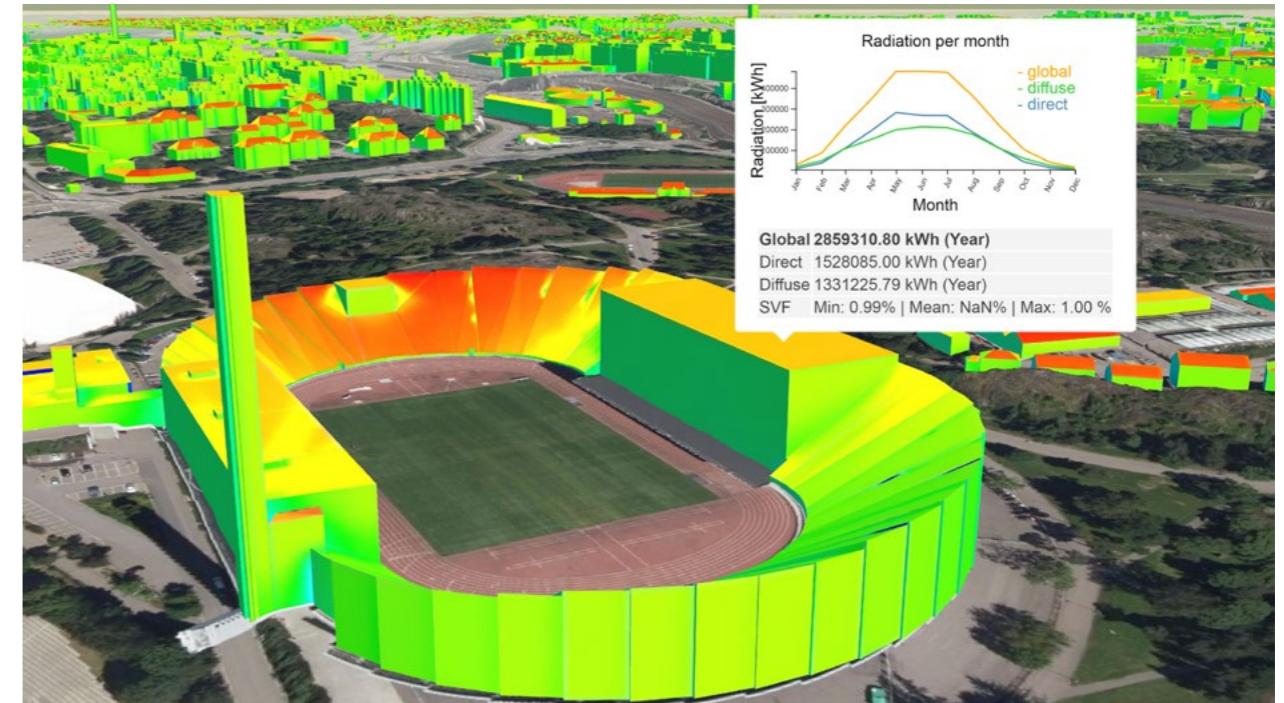

Figure 4. Monthly average of solar radiation – Helsinki Olympic Stadium

How does Helsinki navigate within this fragmented scenario of different formats, sources and possible partners?

The situation today is significantly different from 35 years ago. At that time, we were alone, and we had to discover and develop everything. Today, several market players make up a vast offering, and the challenge is to navigate through this environment. Yet, there is no universal pattern for cities to follow. It all depends on each city's resources, knowledge, needs and intentions. Cultural characteristics also mean a lot, as the "digital leap" requires not only the technology, but also the collective willingness and readiness.

Each city should start with a self-reflection that can then facilitate selecting the appropriate collaborators. Cities worldwide should choose collaborators with a comprehensive and holistic understanding of the city's complexity to develop strategies that make the best use of the latest technologies.

In Helsinki, our approach begins with making choices. The reality is that we cannot do everything, so it's critical to focus and also decide what not to do. These choices must be based on the diagnosis of the city's strategic needs and goals, resources and operating culture rather than simply the promise and hype of the different kinds of technology.

In Helsinki, our approach begins with making choices. The reality is that we cannot do everything, so it's critical to focus and also decide what not to do.

After addressing these points, we act according to our strengths and embark on multi-level cooperation with companies that match our practices. We split our work all over Europe to different companies. It's a very demanding way of working, but it suits us as we have three decades of experience.

Besides working with companies across Europe, we develop creative, practical and realistic approaches through open innovation initiatives with universities and developers. Throughout these approaches, we have found the best benefit in staying level-headed and reflecting on the technology's ultimate purpose. We constantly question ourselves: What is the real benefit of a Smart or Digital City? What value can we create for our citizens? How can we support sustainability?

Ultimately, suppose the proper steps are taken: from the diagnosis to strategy development to selecting appropriate actions to implement. In that case, smart cities and digital cities will not need 35 years to get to the point where Helsinki is today. Other global cities can develop their own Smart or Digital City plan in a little more than a year with the right circumstances.

How is Helsinki planning for the next 35 years, smart city and beyond?

First of all, this new decade — the 2020s— can be a breakthrough for Digital Cities development. There is a changing attitude and interest in digital cities, and an increasing number of people will live in urban settings. But building cities needs infrastructure, iron, concrete and other resources. To develop additional cities with a sustainable approach, we can leverage digital models, utilize data and optimize our processes to carefully plan the resources we need. We should build and analyze our cities digitally first to understand and tackle real challenges before facing them.

For Helsinki, we want to optimize and retain our position as one of the top smart cities globally. We want to follow the technology carefully, and at the same time, not be afraid of making mistakes. We can afford and accept to make mistakes that we can learn from and constantly adjust our target. In the same way we began 35 years ago, we continue to progress by cultivating our "learning by doing" attitude.

In the next 35 years, city models will be real-time. We have satellites, sensors, cars and radars and billions of people producing data every second, which we can use to create accurate and real-time city models. We can then build upon this to see how it will transform the cities of the future. Ultimately, the integration of all these complexities is the first step in building the future.

The Gemini Principles

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Digital technology such as digital twins offers new and valuable information to the infrastructure industry, enabling developers and owners to make significantly better informed plans in building and maintaining real estate assets. In the UK, the use of digital twins is gaining momentum. To fully optimize these tools, the government has laid out a governance framework to guide the deployment of digital twins for the good of society.

Over the past decade, the UK's journey towards sector digitization has matured significantly aided by the government-led program *digital built Britain*. Industries and decision-makers have turned to digital technologies and information management processes, such as Digital Twinning (DT), to enable this transformation.

However, the road to digitization cannot rely on technology alone. The utilization of data for digital twins must be guided by a solid framework and strategy to be used effectively. The UK has taken this approach in its own digitization process. Central to this is the Gemini Principles[2], which define a set of common values that underpin the creation of digital twins and create a foundational consensus framework for the effective use of information from the physical environment.

The Gemini Principles were conceptualized following the release of a National Infrastructure Commissions (NIC) report in 2017[3]. The report, entitled *Data for Public Good*, called for the adoption of smart technology in UK infrastructure, which could collectively work as an optimized system. The move, according to the report, would help relieve the pressure from increasing population, economic growth and climate change to existing infrastructure. The report added that the preservation of valuable data generated at each stage of an asset lifecycle should be preserved and used for public good.

The utilization of data for digital twins must be guided by a solid framework and strategy to be used effectively.

Figure 5. The Gemini Principles. Reproduced with kind permission of Centre for Digital Built Britain (CDBB)

The Gemini Principles

Purpose:
Must have clear purpose

Public good Must be used to deliver genuine public benefit in perpetuity	**Value creation** Must enable value creation and performance improvement	**Insight** Must provide determinable insight into the built environment

Trust:
Must be trustworthy

Security Must enable security and be secure itself	**Openness** Must be as open as possible	**Quality** Must be built on data of an appropriate quality

Function:
Must function effectively

Federation Must be based on a standard connected environment	**Curation** Must have clear ownership, governance and regulation	**Evolution** Must be able to adapt as technology and society evolve

It examined how opportunities such as big data, data analytics and machine learning can deliver greater insights into infrastructure assets and systems, enabling greater efficiency, and creating social and environmental value.

However, the report highlighted that it is not just about collecting all kinds of data. Rather, the importance is on collecting high-quality data that can be used effectively, understanding what information is needed and sharing these to be used more productively.

Following the NIC report recommendations, the Centre for Digital Built Britain (CDBB) at the University of Cambridge was launched to lead the UK Building Information Modelling (BIM) program and deliver key recommendations on the UK's National Digital Twin program (NDTp). The BIM program proved to be successful, helping save the UK £840 million in construction costs in 2013-2014.

The importance is on collecting high-quality data that can be used effectively, understanding what information is needed and sharing these to be used more productively.

The NDTp envisages an ecosystem of connected digital twins, that offer the opportunity for data to flow between the physical and digital environments to enable better insights. This relies on enabling secure, resilient and reliable integration of digital twins from different domains to allow the valuable sharing of information.

To this end, an ever-developing Information Management Framework (IMF) establishes a common language by which DTs can communicate securely and effectively[4]. The IMF provides the means to federate digital twins — and ultimately the national digital twin — and will be pivotal in sharing and connecting data and information between built assets and across sectors. It does this by way of three aspects:

1. A structure for sharing and validating data (Foundation Data Model)

2. A common language for describing digital twins (Reference Data Library)

3. Design and build of the digital systems that manage the connected digital twins (Integration Architecture)

Key takeaways from the UK

☐ **Integration with legacy asset management systems** – Understanding the data sets, data quality and how data can be exchanged between these systems is key to a rich digital ecosystem.

☐ **Interoperability issues** – Embedding the principles of good interoperability into procurement routes and supporting use of open standards will lead to better outcomes and better data re-use.

☐ **Process refreshing** – Digitization often enables a process to be fundamentally reconfigured and should be a key consideration.

☐ **Various organisational standards, information naming and classifications** – Harmonization of information management standards and methods is key for better informational retrieval and querying.

☐ **Curation of the live system** – Think with the end in mind and ensure that the operational asset management systems and asset information models will be properly managed and curated as the asset adapts over time.

☐ **Stakeholders engagement** – Ensure that data produced and managed will support an end user's decision making and experience.

☐ **Proportionality** – The strategy must be able to be applied at an appropriate level of digitization aligned with the complexity and risk profile of a built asset.

☐ **Use agile, design thinking approaches and early proof of concepts** – Solution-oriented approaches with the development of minimal viable proof of concepts create better client understanding and much more rapid development cycles.

Digital estate

Aside from the journey to the National Digital Twin, the UK is also moving towards the concept of a digital estate — as clients, owners and operators seek a holistic understanding of not just their projects but overall portfolios.

A digital estate can be defined as an enterprise-level source of reliable searchable information about an organization's built assets supporting collaborative decision making, dynamic insights and ultimately resulting in more resilient outcomes.

Following the Grenfell Tower fire of 2017 in London and other tragic events, the drive towards the creation of a "golden thread of good quality information" gained momentum. This allows building owners to receive the information they need and maintain a clear link between the design, construction, occupation and maintenance. The crucial purpose of this golden thread is to safeguard the availability, completeness and correct record of a facility's construction and its regulatory compliance.

National Health Service (NHS) Scotland, one of the UK's largest asset owners in the curation of a digital estate, clearly demonstrates this digital transformation maturity. From using BIM aimed at individual new capital projects, they transitioned to the digitization of their retained estate at a portfolio level. AECOM has been assisting NHS Scotland with their digital estate program which is described as "an information management led approach which facilitates the digitization, integration and curation of appropriate digital models — unifying existing data and records — to enable the efficient management of NHS Scotland real-estate portfolios." In such a context, the AECOM team adopted agile and design thinking approaches to ensure a high-quality result. NHS Scotland adopted the Gemini Principles as a means of guiding their various health boards and achieving consensus on definitions, values and effective information management principles.

The existing retained estate comprises a broad range of healthcare assets (from acute hospitals to doctor surgeries), all with different levels of complexity, risks and existing data and information. In many instances, the retained existing estate may have a mixture of models — if information exists at all — from CAD drawings to traditional hand-drawn information, often within distributed legacy asset management systems. While the digital twin is often looking at new technologies from a blank slate, the digital estate usually works within the constraints of distributed technologies such as CAFM systems and asset resisters, where integration is more challenging.

The National Digital Twin program demonstrates the crucial importance of developing a foundational framework, engaging various stakeholders on a personal level, and supported by a clear and impactful communication strategy. With such a complex system, the critical challenge is developing and implementing a harmonizing strategy, creating standards and conventions to promote inter-sector collaboration by leveraging data accessibility.

Ultimately, one of the key seminal aspects is creating a framework, guided by strong principles, to enable effective management of information across the entire built asset lifecycle. The Gemini Principles act as a foundation in the deployment of digital twins and sets a strong example of digital city implementation that other cities may adopt.

The National Digital Twin program demonstrates the crucial importance of developing a foundational framework, engaging various stakeholders on a personal level and supported by a clear and impactful communication strategy.

Digital Cities: Future Differentiating Strategies

The parallel approach

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Canada, AECOM

In its road to smart city delivery, Toronto took two different, parallel approaches — one strategic and top-down, and one more bottom-up focusing on the opportunities that technology presents. A combination of different approaches is now generally regarded as the ideal in building a digital city, but lack of an overarching strategy could undermine a program's potential in delivering successful results.

Back in 2016, Toronto ranked highly on a number of city metrics — it was eighth among 500 of the world's most innovative cities[5], third best tech hub to live and work[6] and fourth overall most liveable city in the world[7]. It was home to the World Council for City Data, founded in 2014, and was among the first to implement smart city-type technology such as computerized traffic operations in 1963. In 2014, it was named a global leader by Intelligent Community of the Year.

However, like other cities, it had serious challenges to address — ones that needed coordinated and innovative solutions. Population growth was putting pressure on affordable housing and social programs. Traffic congestion was estimated to be losing the region C$6 billion annually in productivity[8]. In addition, there was an overarching feeling that much more benefit could be obtained by connecting the broader city ecosystem of world-class educational institutions, associated research and talent pools, innovation incubators, industry players, and more importantly, the citizens themselves.

It was at this point the City of Toronto and the Toronto Region Board of Trade collectively formed the Smart Cities Working Group (SCWG), a collaboration between the government, businesses, non-profit organizations, local academia and cultural sectors, to respond to these challenges, engage local stakeholders and facilitate the development of a **Smarter Toronto vision and strategy**. The development of this vision and strategy was seen as critical in rallying all stakeholders around a common understanding and ensuring that the city's ecosystem would move forward in a coordinated manner.

At the same time, the early planning for what would become Sidewalk Toronto was underway. Waterfront Toronto, the multi-level government body charged with redeveloping the city's waterfront, sought to bring in an **'innovation partner'** to collaboratively create a testbed for digital city solutions and consequently pave the way for smart/digital cities of the future. Sidewalk Labs, a subsidiary of Google parent company Alphabet, would become this partner, making it the first technology company to propose mass city development.

It is quite unusual that a city would undertake two large but separate smart city programs in parallel. **Smarter Toronto was more a top-down approach**, with outcomes and high-level frameworks being the driver, while **Sidewalk Toronto utilized a bottom-up approach**, focusing more on the applications of data and technology and the opportunities they present. A combination of these approaches is now generally regarded as the successful way of deploying a digital city, and as such, this case study briefly looks at these two approaches in the same municipal context and extracts the key positive components and lessons learned.

A Smarter Toronto

The SCWG identified that the city had already undertaken numerous positive digital initiatives from its pioneering **open data** and **open government programs** through to a number of critical service modernization schemes. It also had separate transformative digital programs underway, such as the annual C$500,000 Bloomberg grant to run a Civic Innovation Office[9]. However, it acknowledged that further coordination and action beyond the municipality would align the entire city ecosystem behind a common goal and enable a broader set of inputs towards success. It posited that smarter, more resilient cities are the result of a unified approach and not simply clever technological deployments. The challenge was how to go about such a task and obtain a **unified strategy**.

Three key components had to be considered in order to cover all angles of a successful digital strategy:

- The overall vision and strategy for the city in general — a single smart city strategy that can support the general city priorities
- The pain points for the city — the city's most critical needs and the imminent addressable and relatable problems that technology can potentially solve
- Existing initiatives — the identification and leverage of existing initiatives such as the open data program ensure that there is no repetition and inefficiency across departments and agencies

Smarter, more resilient cities are the result of a unified approach and not simply clever technological deployments.

Figure 7. The "Five C's" Approach to Collaborative Action. © TRBOT 2017

The "Five C's" approach sought to connect and collaborate with stakeholders to find clear and defined targets based on specific needs. It also promoted the involvement of citizens and businesses in smart city programs and called for digital inclusion to ensure that smaller tech firms and start-ups can participate better in procurement processes.

In order to achieve these, the following "Five C's" approach was adopted:

Collaborate with stakeholders — Identify all stakeholders across the broader city ecosystem and engage with them on specific needs obtaining clear and defined targets and outcomes.

Catalyze a data governance and analytics strategy — Build upon the city's open data initiative and address pockets of data in silos, particularly outside the municipality's management, such as those in academia.

Connect Toronto stakeholders — Engage residents and businesses so that they are aware of smart city initiatives. Foster digital inclusions and help smaller technology firms and start-ups to better participate in the procurement processes and ensure that return on investments can be properly measured.

Co-Create with key players to build solutions — Enhance partnerships with the industry, university and incubators to bring far more innovative solutions than traditional technology purchasing mechanisms.

Communicate a cohesive narrative — Develop awareness, attract investment and talent and include an international reach. In this case, not all solutions must be purchased, and strategic partnerships are possible if a common understanding of goals and a reference framework for measuring success is available.

Figure 6. Three key components that enable a Digital Strategy

Following this approach resulted in a concise framework which was proposed to the Mayor's Office and ultimately approved by the Council. This included a newly formed Chief Transformation Office taking charge of the smart city portfolio and picking an initial lane to tackle the affordable housing issue along with its associated digital literacy issues.

The timing of this also coincided with a federally run "Smart Cities Challenge" — a municipal level competition to win funding in order to accelerate the delivery of smart city concepts. Toronto did not succeed in the competition but had embarked on delivery of the program regardless. As of writing, however, this effort has been paused due to COVID-19 and internal city reorganization.

Sidewalk Toronto

While the Smarter Toronto initiative took a strategic top-down view of the digital city conundrum, momentum was growing with the project that came to be known as **Sidewalk Toronto**.

Sidewalk Labs was proposing a large-scale redevelopment of the East Portlands areas of the city, in a deal that was very much opposite to the SCWG work. The initial C$50 million investment was all fronted by Sidewalk Labs, in an inverse procurement of sorts. While the project eventually produced a "**Master Innovation and Development Plan**", initial announcements focused heavily on the potential of technology, data and sensors, and how they could create a "City as a Platform." This raised complex challenges, including data privacy, governance and privatization of key city principles, among others.

In May 2020, Sidewalk Labs officially canceled the project, citing an "unprecedented economic uncertainty."[10]

Sidewalk Toronto is a large-scale example of **vendor-driven** policy and innovation. For the average person, the project lacked a clear reason for existing and raised questions on its expected outcomes, particularly for the citizens. The narrative of sensors and data collection in order to solve problems also caused huge roadblocks in the adoption and approval process as it raised fundamental questions such as "**why are we collecting any data at all?**"[11]

It is also interesting to note that **Smarter Toronto** and **Sidewalk Toronto** operated almost entirely in two silos for various political reasons, and it can be argued that this did not help the delivery of either vision as it created "**too many strategies**" and the inability to integrate the programs, particularly in the eyes of the public. While not always the case, an overarching authority helps in rallying support for smart initiatives from the public and decision-makers. It can be owned, led or instigated by a city department or a similar authoritative vehicle, but must be empowered or communicated well so it is respected and accepted. Ultimately, beyond immediate ownership, it will need the political will to keep it going.
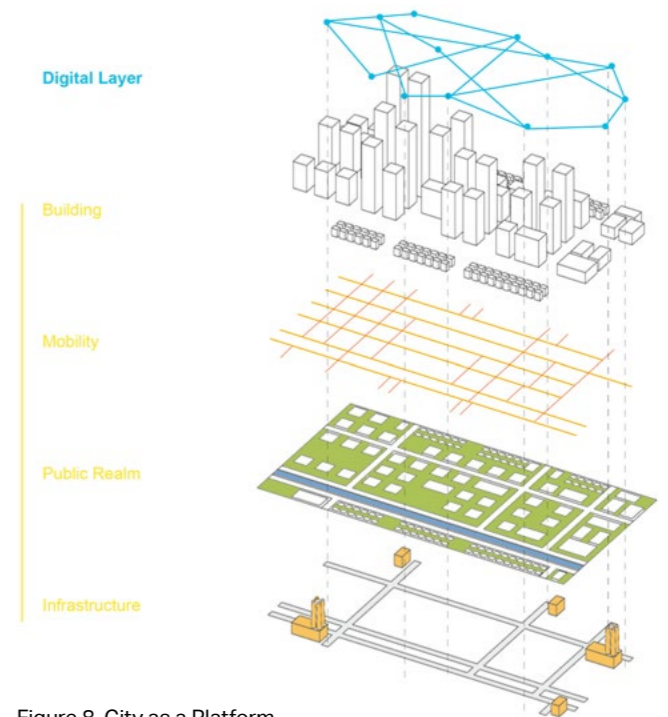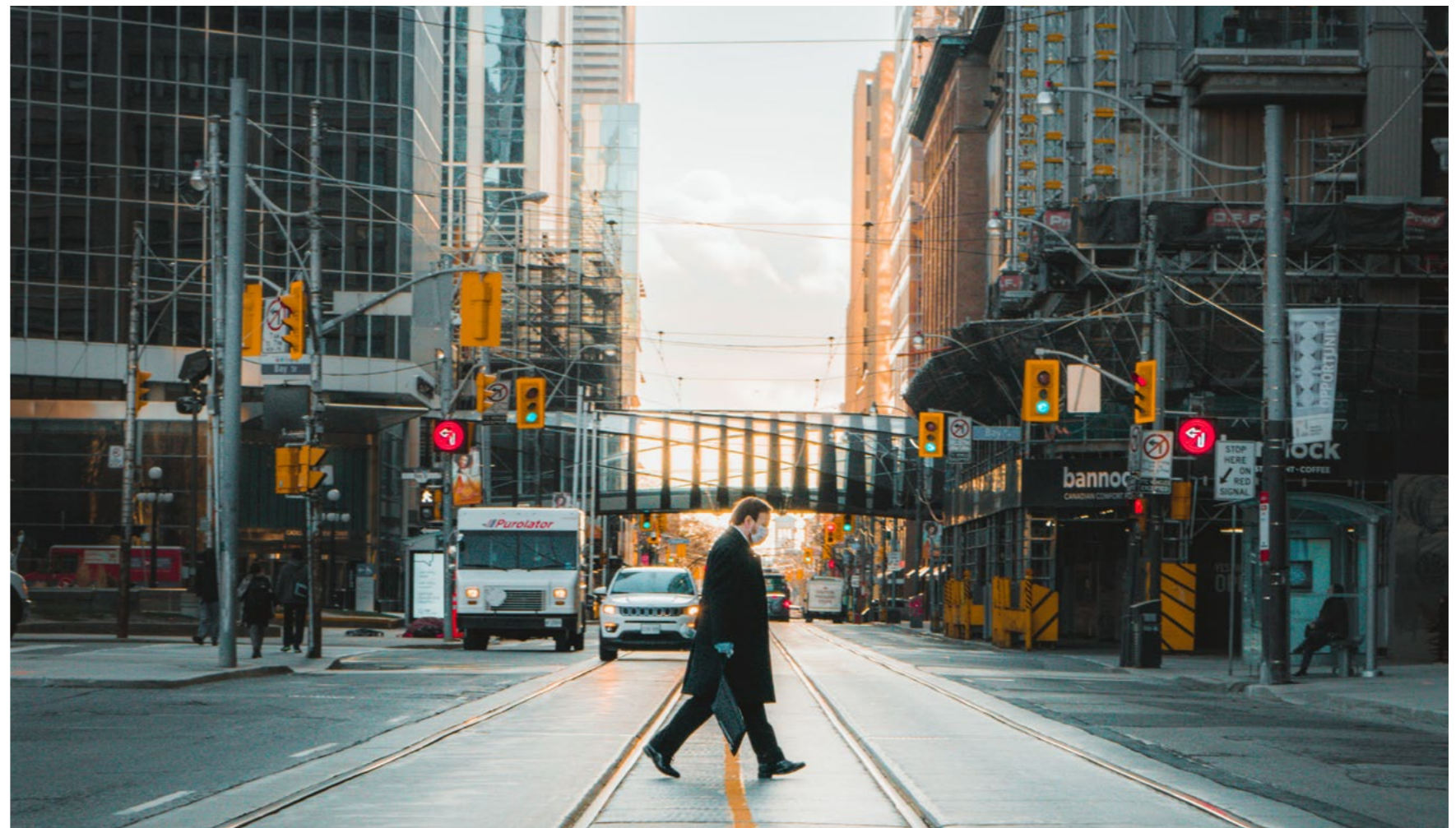

Figure 8. City as a Platform

Success and strategy

A key tenet of digital transformation is stakeholders' acceptance and adoption. Often the inhibitors to success are not technological but stakeholders-related. This also underscores the critical need for a clear overarching strategy, with consistent messaging and engagement. And while it is important to consider the opportunities new technology presents to cities, and explore that lens, it must be done under the auspice of city control, governance and a clearly articulated reason for doing so, with measurable results.

Successful delivery of digital city programs must also consider the domain knowledge of those delivering, not just the ability to handle the technology. In this instance, Sidewalk Labs was more than adept at delivering technology solutions, but where the project faltered was in a depth of understanding of the context — **a technology company is not typically familiar with the nuances of city** planning, development, funding and approvals. If outside expertise is sought in the digital cities space, then looking for those that bring that knowledge should also be considered. Such expertise and prior experience are integral in **navigating complex challenges** and help build a solid foundation in smart city planning through a strategic and pragmatic approach.

In the end, an overarching strategy, a defined governance, and ownership are key ingredients in driving a program's success. Without these and a 'reason' for the program, transformation can be challenging, if not futile, as there would be no baseline against which to refer or measure eventual success.

While it is important to consider the opportunities new technology presents to cities, and explore that lens, it must be done under the auspice of city control, governance and a clearly articulated reason for doing so, with measurable results.

Digital Cities: Future Differentiating Strategies

Smart Nation

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For two years in a row, Singapore has ranked first at the International Institute for Management Development (IMD) Smart City Index. From the launch of its Smart Nation program in 2014, Singapore has actively been addressing national challenges while driving transformation, particularly in the areas of health, education, transport, urban solutions and finance. As the Singapore government continues to take a collective approach in building a Smart Nation, harmonizing collaboration among stakeholders and making data accessible to all through secure and effective platforms are some of the key challenges that must be addressed.

Singapore has gone through a tremendous transformation in a condensed period of time, evolving from a port city into a major metropolitan urban town. Now, it is leading the global Smart City Index 2020[12]. Compared to more historic cities such as New York, London or Paris, the lack of an urban framework foundation, developed and validated over time, gave Singapore a major opportunity and a great challenge. Faced with limited land availability and the need for high-density development, it was critical that city leaders develop analytical and visualization tools to strategically plan and understand the future urban environment of the city. Looking back, these initial planning tools can be seen as the first step of the smart city journey, which stimulated Singapore to leverage data to deliver a better outcome for its complex urban environment.

More than just having the tools, Singapore's smart city initiatives started from the call to take sustainable action – with citizens, not technology, at its heart. Guiding each of their strategies for smart city development are four key priorities: developing leadership and governance, stakeholders and citizen focus, effective use of data and integrated ICT infrastructure[13].

In 2014, the Singapore government launched the Smart Nation program with the aim of enabling physical and digital space to drive growth for the city-state. The program envisions Singapore as an economically competitive global city and a liveable home. This whole-of-nation movement seeks to harness and integrate all technologies and possibilities to build a future Singapore, where citizens are empowered and given the opportunities to achieve their aspirations, and where businesses are encouraged to innovate and grow.

The Smart Nation program is coordinated by the Smart Nation and Digital Government Office of the Prime Minister's Office, and supported by other government agencies. The key domains of the program are **health, education, transport, urban solutions** and **finance.** Through this, the city-state seeks to address national challenges while driving transformation.

Singapore's smart city initiatives started from the call to take sustainable action – with citizens, not technology, at its heart.

Figure 9. Singapore Smart Nation Program
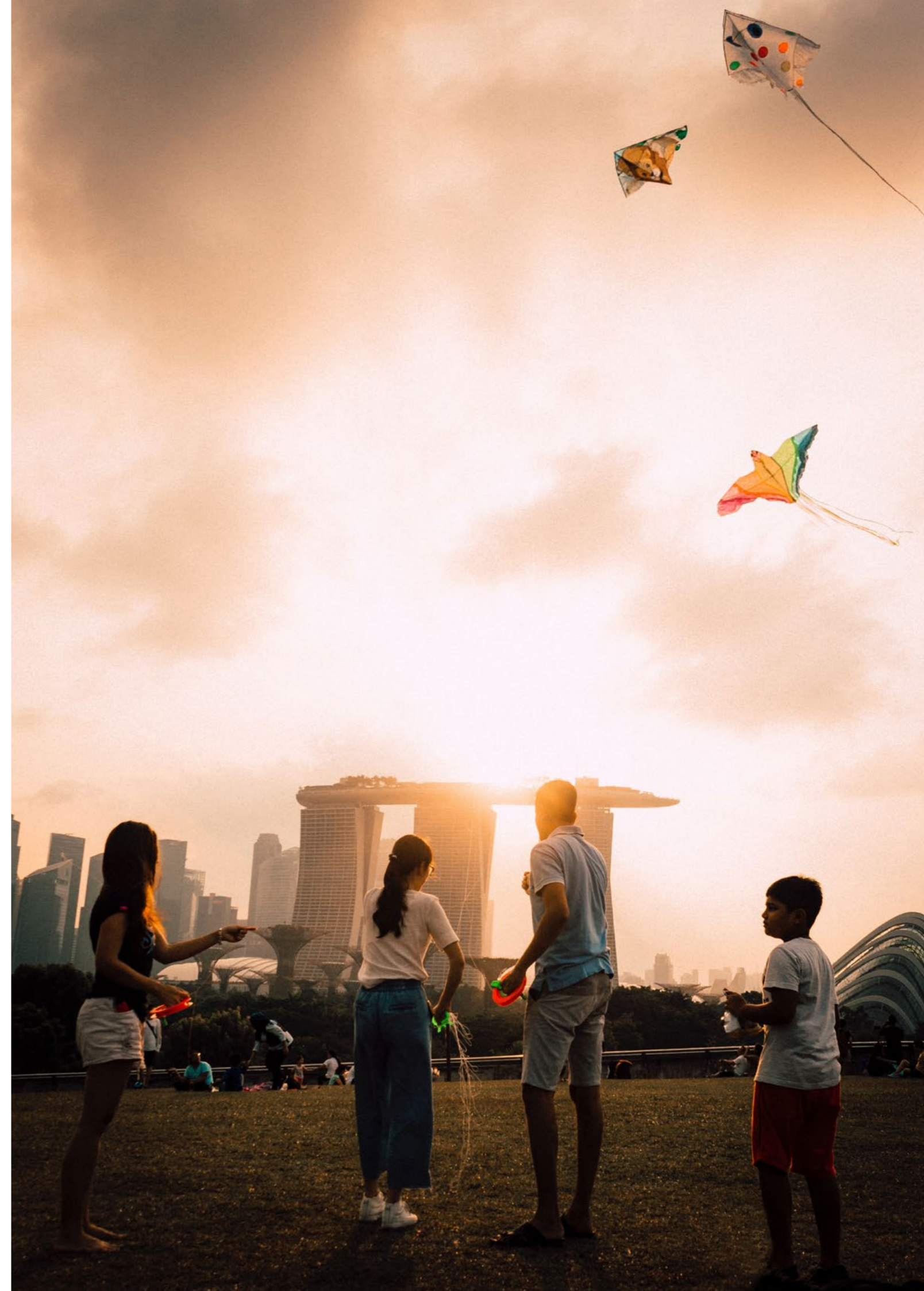
Enabling innovation

The Smart Nation program supports several specific initiatives for adopting new technology and alternative ideas, such as open data, living laboratories, cybersecurity and privacy and digital inclusion, to name a few.

Among those initiatives is Singapore's push for a smart cashless society with contactless payment. The government sandbox provides an environment for fintech groups, including financial institutions and non-financial players, to experiment and allow innovations a better chance to take root.

Singapore is also testing and implementing various innovative digital solutions embedding into better designs. Mobility as a service and self-driving vehicles are two main initiatives for optimizing land use for efficient, safe and reliable transportation.

Liveability and urban solutions

A major part of this transformation will include Singapore's real estate environment. Existing and future buildings and structures need to become smarter, work more efficiently, and adapt to users. The Building and Construction Authority (BCA) and the Ministry of National Development have been championing many key initiatives to create better and smarter buildings and infrastructure, but there is still room to advance.

A smarter built environment that uses technology solutions to provide intelligent control and management systems for energy, water, waste and security (physical and cyber) is starting to emerge. Such solutions are usually automated, and this makes the buildings more resource-efficient.

There are intangible benefits such as health, employee productivity, corporate social responsibility, educational excellence, and evidence that more intelligent performing buildings are translating into higher property values. However, the Singapore market is only beginning to consider operating or lifecycle costs in pricing models.

Several initiatives are focused on finding innovative solutions that improve urban living in Singapore estates and homes. This includes aspects that will leverage technology to enhance the urban environment and solutions that improve the way people live. In the urban environment, monitoring is being proposed to allow for access to real-time data that helps to understand Singapore's land, air and water environment.

All these bring digital tools and systems at the forefront of advancement and innovation. However, proper implementation and integration of these tools with the current environment cements the foundation of transformation.

> There are intangible benefits such as health, employee productivity, corporate social responsibility, educational excellence, and evidence that more intelligent performing buildings are translating into higher property values.
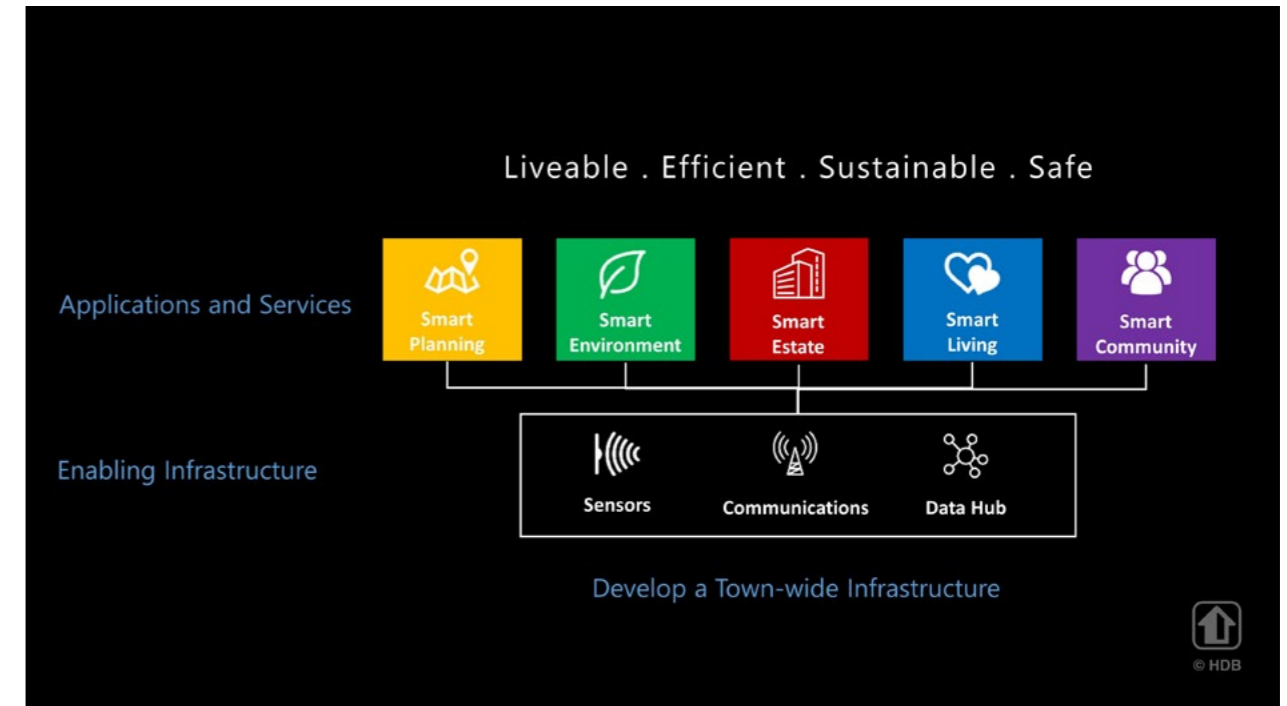

Figure 10. Smart HDB Town Framework. Image courtesy of the Housing & Development Board

Figure 11. Tengah master plan. Image courtesy of the Housing & Development Board

The Singapore smart towns

The Housing and Development Board (HDB) is the city-state's most prominent master planner and housing developer and carries out extensive research and development to build sustainable and smart towns that create a better living environment for residents. With approximately 80 percent of Singapore households living in public housing, various government agencies are working with industry players to develop and test smart home solutions in HDB estates. This includes the use of technology to help deliver more efficient, environment-friendly, vibrant and inclusive places with strong communities.

HDB uses 3D modeling software and environmental simulation tools at a district planning level to better understand how environmental conditions interact with the layout and design of the town to derive configurations that will create a comfortable living environment for residents. The software platform uses 3D city models to simulate the interaction of urban micro-climatic conditions such as wind flow, temperature fluctuations, and solar irradiance with one another, and their combined effects on the surrounding urban landscape.

In 2016, HDB announced the master plan for Tengah new town — a major milestone in its sustainable and smart journey. HDB also selected AECOM as part of a consortium led by NCS to deliver a "Smart Urban Habitat Masterplan."

Tengah new town is set to be a greenfield site with a whole-of-estate approach, incorporating HDB's largest smart and sustainable ideas. These include a "car-free" town center, dedicated walking and cycling paths for residents, and connections to the Jurong Region Rail Line.

Figure 12. Tengah pedestrian road view. Image courtesy of the Housing & Development Board

Digital Cities: Future Differentiating Strategies

The larger road networks in Tengah are designed to meet future needs, supporting future forms of mobility, such as autonomous or self-driving vehicles. Smart technology and sensors are embedded in facilities such as lighting, lifts, solar panels, water pumps and pneumatic waste systems and will be connected to the HDB Smart Hub. Information from sensors is collected and processed to enable predictive maintenance, reduce manpower and improve service reliability. The first homes will include digital infrastructure to enable communication with Internet of Things (IoT) devices with applications including telehealth services, energy management systems and elderly monitoring systems.

HDB is also developing field trials with new technologies in existing homes and a few new home developments. This aspect will allow agencies to assess existing demand from residents and provide sufficient scale to facilitate adoption/deployment of the identified technology solutions. Feedback from these trials will help commercial companies understand HDB residents' needs and refine their products for launch in the market.

In developing Tengah, AECOM planners, architects and engineers utilized tools to select the most cost-effective and optimal initiatives to achieve sustainability goals. These include analyzing key wind channels and the urban solar heat to optimize the building layouts and orientation to enhance wind flow and promote natural ventilation within the town.

The Singapore government laid the foundation of the Smart Nation program, developing infrastructure, facilitating innovation and creating a framework for the broader stakeholders group. The government's mission to unite and integrate intelligence from the citizens, industry players, research institutions and government bodies to solve the complex challenges of the city-state is ambitious. Opening data to public usage is a promising direction that requires the development of a governance framework, an accessibility structure and a maintenance methodology.

There are numerous challenges in dealing with such complex scenarios of multiple players, a multi-layered structure, several overlapping initiatives, and an extensive data set to manage. One of these challenges is harmonizing collaboration among stakeholders and making data accessible to all through secured and effective platforms. Doing so avoids placing developments and initiatives in silos, which tend to create fragmented strategies.

Only a well integrated and orchestrated approach can address such complexity of multiple and fast-evolving scenarios. Singapore's technological resources and digital systems promise many possibilities, but it takes the human capacity to implement and integrate these plans to truly reach its potential.

The Singapore government's mission to unite and integrate intelligence from the citizens, industry players, research institutions and government bodies to solve the complex challenges of the city-state is ambitious.

Understanding the new language of the digital city

Justin Trevan
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Cities contain many different spoken languages. But what is the language of the digital city?
The one question that tends to be asked in the digital city space is simply, "what does it mean to be a digital city?"

This a not new question, simply one with an ever-evolving answer. Cities have been pondering this as far back as the 1980s as we have seen in the Helsinki case study. It is the evolution of the answer that is particularly interesting.

In the early days, to be a digital, or 'smart', city was to be heavily technology-centric. The focus was solely on technology at the forefront and being the visible component. Today, however, it is more widely understood that the best digital cities are not overtly digital; they are organic cities, bustling with people and experiences, focusing on the citizen and providing the best services possible. They simply use technology and data to deliver these outcomes and to understand their own context better.

A digital city requires a focus on context and outcomes, delivered with the assistance of, but not solely by, technology. As we have seen through the examples in this report, each city has its own distinct interpretation of what that means to them. For the UK, it means addressing the need to integrate and share legacy data from estates to improve efficiency. Helsinki plans to use this process to map out entire cities in 3D in order to better understand the city fabric. In Toronto, the adoption of digital city aims to solve critical issues such as affordable housing and digital literacy, while Singapore aims to drive business growth and empower citizens through improved urban living.

Strategy as language

While we can perhaps learn from these examples, we cannot simply 'copy' digital city approaches. Different cities have different needs and different contexts. Everything from the physical fabric of a city and existing systems, all the way to softer dimensions such as citizen expectations and how consensus is achieved through governance, will affect potential success and therefore, must be thought through in a holistic manner. There is no one-size-fits-all approach in digital city.

Perhaps then city leaders should instead first ask themselves, "how can we be a digital city?" Answering this begins with defining the city's current state: from identifying the challenges it faces and what is being done about "them", to mapping out the vision for its citizens. This is not a one-off process — it is iterative, and cities may enter the process at various states of digital readiness. This way of thinking enables a baseline to be drawn from which progress can be measured, and important elements as we've seen in the case studies — a consensus strategy, inclusiveness framework and tech-neutral approach — can be articulated.

This definition is needed for the communication and inclusion of all stakeholders. It also enables the conceptualization, management and delivery of a portfolio of projects in a way that success can be understood, and failure corrected, across the gamut of people, process and technology.

This is what we've seen in all four use cases of digital cities. We may call it a 'strategy', 'principles,' a 'plan' or any other name, but it is simply the unique 'language' of the digital city and its corresponding digital ecosystem under consideration. All of the technical backgrounds, context and reasons are condensed into a single and easy-to-digest description. Such a description is part of what puts Singapore and Helsinki in first and second place in the Smart City Index 2020. Both cities deliver successful and innovative solutions but are planted on strong digital city strategic planning fundamentals.

Ultimately, this 'language' answers the question of 'why,' which is one every digital city should be able to answer before a single dollar is spent.

Perhaps then city leaders should instead first ask themselves, "how can we be a digital city?" Answering this begins with defining the city's current state: from identifying the challenges it faces and what is being done about "them", to mapping out the vision for its citizens.

Digital ecosystem: Driving the next evolution

Scott Dunn
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Significant progress has been made in scaling up digital twins and digital infrastructure especially in more developed and affluent cities. This acceleration is expected to continue, with ABI Research predicting more than 500 urban digital twins to be deployed by 2025[14], a significant increase from just a handful of early implementations in 2019.

However, we are still a long way from fully integrated digital cities. Only a few among millions of cities are currently getting the full benefits of such digital infrastructure — the ability to simulate future scenarios, to plan and adjust for better outcomes and to define alternative pathways with resilient solutions.
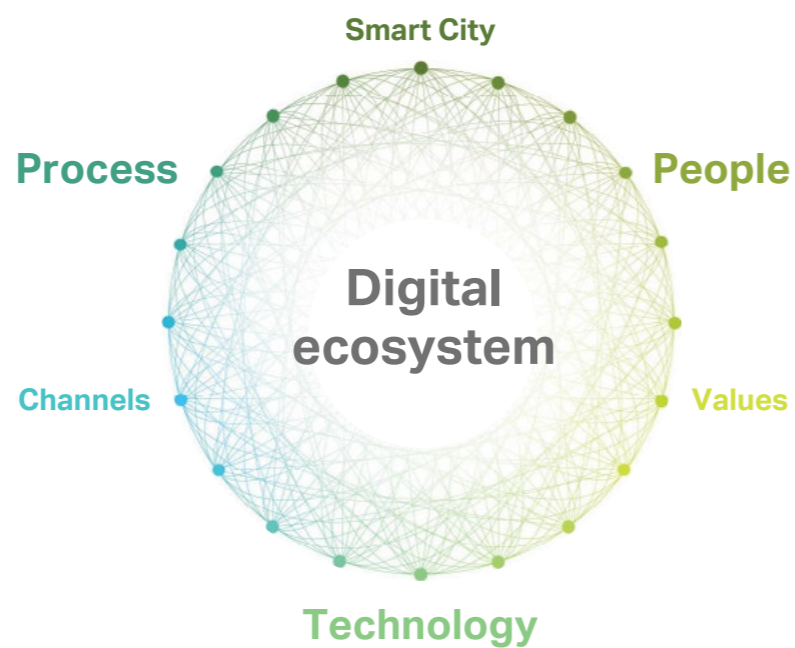
Figure 13. AECOM Digital ecosystem approach

A holistic approach towards digital ecosystems

Digital cities — like smart cities — are a portion of a broader ecosystem, which is evolving, growing, and transforming, and which must balance **People**, **Process** and **Technology** equally.

The digital ecosystem is not a prescribed set of specific technological solutions. It is a system that promotes an outcome-focused approach in which technology is woven into the fabric of society, economy, business and environment to respond and flexibly adapt to changing contexts and needs.

Data and analytics are fundamental for driving future sustainability and infrastructure efforts and enable the digital ecosystem. With effective coordination within a defined data management and governance framework, digital initiatives create exponential value by integrating data into an ecosystem where more and better data enables more quality outcomes to be achieved.

Cities of all sizes should be thinking about building a better tomorrow through policy and investment in the creation of secure interoperable ecosystems, where available data collected through various sources and media can be as open as possible.

This digital foundation is essential to maximize the value of every dollar invested in digital transformation plans, providing multiple optimized outcomes that benefit both the environment and society.

The value of integrators

As the case studies in this report show, integrators are key to the success of digital cities. Only a well-integrated and orchestrated approach can address such complexity of multiple and fast-evolving scenarios. This requires more than digital systems, as human capabilities to implement and integrate are crucial in focusing the discussion of digital cities, pulling together private and public sector stakeholders and amplifying the impact.

At AECOM we focus on offering integrated services and solutions that are outcome-driven, user-centric, create enabling networks, build business viability and provide a foundation of governance and resiliency for project developers. For us, this means asking the right questions and providing our project teams with the appropriate tools and systems to deliver value.

The digital ecosystem is not a prescribed set of specific technological solutions. It is a system that promotes an outcome-focused approach in which technology is woven into the fabric of society, economy, business and environment to respond and flexibly adapt to changing contexts and needs.

This then allows us to understand the project and create a strategy that looks towards the future, is not limited by the current technology and caters to the evolving needs of the project and the community it serves.

A digital ecosystem can propel a diversity of opportunities for generations to come. The right strategy and integrators can create a robust foundation in making sure that what we build today can be developed further and respond to the rapid changes in technology and our evolving society.

We would like to hear from you. Do you have an integrator story that is evolving the city digital ecosystem?

A digital ecosystem can propel a diversity of opportunities for generations to come.

AECOM

At AECOM, we're delivering a better world. Our vision is a world where infrastructure creates opportunity for everyone — uplifting communities, improving access and sustaining our planet. We are the world's premier infrastructure consulting firm — planners, designers, engineers, program and construction managers driven by a common purpose to deliver a better world. On projects spanning transportation, buildings, water, energy and the environment, our public- and private-sector clients trust us to solve their most complex challenges. Through our Think and Act Globally strategy, we are focused on extending our industry-leading, global expertise to each of our projects around the world, transforming the way we deliver work through technology and digital platforms, and enhancing our position as a leading Environment, Social & Governance (ESG) company.

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