McKinsey&Company

SMART CITIES IN SOUTHEAST ASIA

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DISCUSSION PAPER
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MCKINSEY GLOBAL INSTITUTE

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From established regional and multinational companies to startups and local disruptors, we serve a diverse client base, across industries. A longstanding trusted advisor on strategy, we are now recognised as a leader in implementation and digital. Increasingly, we use analytics and technology to build new businesses and transform existing ones. Despite how we have changed in recent years, we remain committed to regional impact. We partner with the public sector to translate the region's rich opportunities into transformative economic and social growth. At McKinsey, we care most about the impact we have—on our clients, our communities, and the people of Southeast Asia.

FOREWORD

Imagine the cities of the future. Will people navigate from place to place with ease, or will the streets be chaotic and gridlocked? Will cities be healthy and sustainable places to live, or will environmental problems spiral? Will cities be able to provide adequate housing, infrastructure, and services to keep up with the needs of surging populations?

These are urgent questions, not only within the Association of South East Asian Nations (ASEAN) but worldwide. While cities concentrate many societal and environmental problems, they also tend to be where solutions are forged. In the face of growing populations, resource constraints, and overburdened infrastructure systems, cities have to make better use of technology to do more with less.

Recently published research from the McKinsey Global Institute (MGI) suggests that cities are on the brink of doing just that. Technologies like the Internet of Things and machine learning have advanced, and mobile penetration is reaching critical mass. Sensors across the urban environment are adding a layer of intelligence to physical and social infrastructure systems. Real-time data and enhanced tech capabilities give agencies the ability to respond more effectively to what is happening at any given moment.

The drive to make cities smarter is not just about what governments do. It's also about creating environments where different players can bring innovation to bear on public issues. Many digital solutions that are changing the urban fabric, from e-hailing to telemedicine, come from the private sector. These have enormous potential across Southeast Asia, where urbanisation is happening at a breakneck pace.

This is a critical turning point for the region: If growth is well managed, it can be a force for progress in human development. But if it is not, many social ills may take root, diminishing the quality of life and the environment along with it. Southeast Asia has a window of opportunity to set its smaller cities on a more sustainable development path and to address the growing pains of its largest cities before they become intractable problems.

Smart solutions will not provide an easy fix for all of these problems, but they can give cities a set of powerful and cost-effective tools. Recognising this potential, the ASEAN Smart Cities Network has been launched with 26 locations across the region signing on as pilot cities. If they successfully set standards, share best practices, develop action plans, and launch some solutions on a regional scale, they could take significant steps forward.

There is no universal road map for cities to become "smarter." Southeast Asia does not have to replicate a generic global template. Cities across the region can forge a new model that reflects their own challenges and priorities. This report offers an overview to help cities understand the promise and limitations of the new technologies at their disposal—and to help private-sector companies and citizens themselves anticipate the coming wave of change.

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EXECUTIVE SUMMARY

Southeast Asia's future is inextricably tied to the fate of its cities. Today, the region's urban areas (with more than 200,000 residents) are home to one-third of its total population, but they generate more than two-thirds of the region's GDP. Urbanisation is fuelling economic growth, but the breakneck pace has left many cities struggling to provide adequate housing, infrastructure, and services to meet the needs of a surging population.

While the urban challenges across Southeast Asia have been growing in scope, new technologies that could tackle some of these issues have reached maturity. Hundreds of cities around the world, including some pioneers in Southeast Asia, are deploying these solutions to become "smarter." The region as a whole can build on these early efforts, benefit from the lessons learned, and make better use of technology to make the urban environment work for the people who inhabit it.

A smart city incorporates data and digital technologies into infrastructure and services—all with an eye to solving specific public problems and making the urban environment more liveable, sustainable, and productive. Cities still need to invest in fundamental systems and services, but they can use smart solutions to get more capacity and lifespan out of their infrastructure assets and deliver for their residents in a more effective way.

GOVERNMENTS, COMPANIES, AND RESIDENTS ARE TURNING CITIES AROUND THE WORLD INTO SMARTER ECOSYSTEMS

Cities are complex environments with millions of moving parts, and managing them is no small task. But cities now have data and digital tools at their disposal to tackle a wide range of public problems. Sensors, cameras, and smartphones add a layer of digital intelligence over a cityscape, capturing a stream of real-time data on everything from traffic and transit to air pollution, weather, crime, energy use, and much more. Analytics systems and mobile apps translate this data into alerts, insights, and tools. This allows users to make better decisions—and when millions of those decisions add up, they positively impact the city's overall performance. Less time is wasted in traffic and queues, and health and safety improve. Energy, resources, space, and investment are used more efficiently.

While good management is a critical element in a smart city, governments are not the only actors. Smart cities are not just top-down initiatives; they actively engage corporations and residents in making the overall ecosystem more efficient. In fact, many of the innovations that are changing the fabric of cities worldwide, such as e-hailing and smart office buildings, are revenue-generating ventures introduced by private-sector companies. Companies operating effectively in this space have identified public problems and come up with digitally enabled solutions, many of which can be introduced quickly and cost-effectively.

Recent MGI research examined how the current generation of smart city technologies can perform in a variety of urban settings worldwide. It found that they can improve many quality-of-life indicators by 10 to 30 percent. They can save time, improve public health and safety, create a cleaner and more sustainable environment, and foster a sense of community and civic engagement. This paper takes a more focused regional view of smart cities and their potential in Southeast Asia.

SMART CITIES ARE POISED TO HAVE SIGNIFICANT AND BROAD-BASED IMPACT IN SOUTHEAST ASIA

Cities across Southeast Asia are primed to take advantage of smart solutions. Spending power, digital literacy, and smartphone penetration have improved across the region. Many cities now have the backbone information and communications technology (ICT) infrastructure in place and have begun the process of digitising some government departments and public-facing services. At the same time, many fast-growing cities are a blank canvas where infrastructure can spread, unhindered by outdated technology.

Dozens of smart solutions are available today focusing on every domain of city life: mobility, social infrastructure, the built environment, utilities, security, community, and the economy. As they begin their smart transformation, each city is setting its own priorities regarding which solutions to deploy. Although national and local governments across the region have real financial constraints, private investors, development finance institutions, and donor agencies can fill the gaps. Furthermore, some solutions offer opportunities to generate revenue, which opens the door to private-sector providers or public-private partnerships.

Building on MGI's previous work, this paper examines how smart cities could evolve in Southeast Asia—and, most important, how they could improve the urban quality of life. We find substantial potential for impact (Exhibit E1). Smart solutions could remove up to some 270,000 kilotons of greenhouse gas (GHG) emissions annually. Some 5,000 lives lost each year to traffic accidents, fires, and homicides could be saved through mobility solutions, crime prevention, and better emergency response. Intelligent traffic and transit solutions could save up to eight million man-years in annual commuting time. Smart healthcare solutions could reduce the region's disease burden by 12 million disability-adjusted life years—in other words, not only extending overall life expectancy but adding years of good health. By creating more efficient and productive environments for business and hiring, Southeast Asia could add almost 1.5 million jobs. Residents could also save as much as $16 billion annually as smart solutions contribute to better housing options and lowering energy bills. However, the scope and shape of impact will vary in different cities across the region.

Exhibit E1

Smart cities in Southeast Asia can deliver real quality-of-life improvements.

260k–270k Kilotons of GHG emissions avoided
Equal to the total emissions produced by Laos

4,900–5,000 Unnatural deaths averted annually
Equivalent to 50% of Malaysia's yearly total

8M–12M Disability-adjusted life years (DALYs) reduced
More than the total DALYs for all of South Korea

1.2M–1.5M New jobs created
Equivalent to 20–30% of the workforce in Jakarta, Bangkok, Manila

$9B–16B Savings on the cost of living
Equivalent to 2–4x Brunei's total household expenditure

6M–8M Man-years saved in commuting time
2x more than Singapore's workforce spends commuting

SOURCE: McKinsey Global Institute analysis

CITIES ACROSS SOUTHEAST ASIA HAVE VERY DIFFERENT STARTING POINTS AND PRIORITIES THAT WILL SHAPE THEIR DEPLOYMENT OF SMART SOLUTIONS

Although the ten nations of ASEAN are working to achieve deeper economic integration, the hallmark of the region remains its diversity—and not only in terms of language, culture, and ethnicity. Each country has widely varying forms of government, economic systems, levels of technological maturity, and human development indicators. Some nations have young and growing populations, while others are ageing. Per capita income can differ up to 50 times between various countries.

The region's cities similarly resist easy categorisation. Comparing cities or drawing conclusions about how they can approach a major transformation is harder across Southeast Asia than across Europe or South America. Nor can smart cities be assessed in broadly linear "tiers" of cities like those in China and India, where governments are implementing national visions that have set priorities for hundreds of cities.

One key finding from MGI's global research on smart cities is how heavily each city's unique characteristics influences the impact various smart solutions could deliver. The state of its legacy infrastructure systems, its physical layout, and its baseline indicators (such as crime rates and commuting times) play a huge role. This underscores the importance of each city's starting point. The four archetypes below reflect these differences in Southeast Asia:

- **Smart city sandboxes.** Once a city becomes a smart city sandbox, it has already built robust and comprehensive high-speed communication networks and implemented dozens of smart applications covering every domain of urban life. These cities can now turn to developing next-generation technologies and creating new and better experiences for residents. Today Singapore is the only city in the region that fits this category. It is not only a standout in Southeast Asia but also ranks among the most advanced smart cities globally.

- **Prime movers.** These are the region's largest primary cities, and they have the potential to touch millions of lives. Major physical and social infrastructure systems are in place, but they are often strained beyond capacity and in need of costly retrofits and expansions. There are big inefficiencies affecting the quality of life, and these cities can capture big wins from applying smart solutions to these issues. The sheer scale of these cities makes smart city initiatives more easily viable even at modest levels of adoption.

- **Emerging champions.** These are midsize cities with infrastructure that can benefit from more integrative solutions to deliver high-value, cost-effective impact and expand access to services. These cities tend to need large-scale investment to get to the next phase of growth and development, but their financial capacity is typically constrained because of their relatively smaller scale.

- **Agile seedbeds.** With less than a million people each, these cities can be nimble in piloting and scaling up targeted smart city applications. Some are on the cusp of rapid growth, and smart planning can manage that process sustainably.

CAPTURING THE POTENTIAL OF SMART CITIES IN SOUTHEAST ASIA WILL TAKE BOLD ACTION FROM BOTH THE PUBLIC AND PRIVATE SECTORS

Urbanisation can be a critical factor propelling Southeast Asia to the next level of economic and human development, but only if growth is managed well. Cities need to act now to address growing environmental stresses, particularly to combat climate change and improve their resilience as its effects become apparent.

Private-sector companies that find ways to contribute to these public goals can find substantial market opportunities across Southeast Asia. We estimate that the market for smart mobility applications could be as large as $70 billion, while opportunities to make the built environment smarter could be worth up to $26 billion. But operating within smart cities is not like operating in any other market. Companies may need to change their approaches, capabilities, and willingness to partner.

The three imperatives below can shape the strategies of both public- and private-sector organizations.

- **Plan.** The smart city starts with articulating a strategic vision and goals—and since the entire point is to respond more effectively and dynamically to the needs and desires of residents, any strategy has to start with people rather than technology. Engaging the public from the outset rather than after smart solutions are introduced can secure community buy-in. Cities also need to consider how to pair smart technologies with complementary policies and investment in hard infrastructure. While it is important for city governments to outline a vision for the future, the rapid pace of technological change means that they have to retain some flexibility to experiment and recalibrate. Taking a data-driven approach that continually measures progress against clear quality-of-life goals can guide that process.

  Companies with aspirations to become urban solution providers need to navigate a dynamic and complex ecosystem, including different layers of government and multilateral institutions that often fund such initiatives. The need to tailor solutions to each city's context, combined with the unwieldiness of dealing with multiple stakeholders and agencies, makes it challenging for many providers to enter the smart city market in a viable way. The trick will be balancing each city's desire for custom solutions while achieving the scale needed to build a solid business case. Companies may also need to add new government relations capabilities to understand how the public sector works and devote time to engaging thoughtfully with local leaders about how to meet their city's needs.

- **Provide.** Cities can no longer think of data and smart city tools as costly capital expenditures. They are increasingly necessary operational investments. Even when fiscal resources are scarce, there are ways to devise sustainable models for applications to take off, for example by monetising data, offering development rights, modifying zoning restrictions, or coming up with creative models that can generate revenue for private-sector providers. Low-income cities may be able to jump-start progress by creating open data portals, which make raw information available for private-sector innovation that does not require any public investment but nevertheless could improve the quality of citizens' lives. Cities facing tough choices will have to prioritise the practical over the flashiest new technologies. Installing digital systems behind the scenes to manage traffic, coordinate networks of hospitals, or cut down on bureaucratic paperwork may yield more impact than highly visible touchscreens on the street.

Companies need an intimate understanding of a city's context so they can anchor their offerings and value proposition to the real needs of residents. They may need to steer their potential government customers toward solutions that can make a visible difference in their constituents' lives—and away from gimmicks that garner headlines but ultimately fail to create headway thereafter. Simple and scalable solutions tend to gain traction and users, enhancing value for citizens and solution providers alike.

- **Partner.** Neither the public nor the private sector can build smart cities alone. Many of the critical services are public goods for which the public sector is the natural owner. But city government does not have to be the sole funder and operator of every type of service and infrastructure system. Technology is reconfiguring traditional roles and divisions of labour between government agencies and private providers. It makes sense to identify those areas where city agencies can step back and make room for other players, including private-sector companies, state-owned utilities, universities, foundations, and nonprofits. Some cities actively cultivate the ecosystem approach by creating consortia, partnerships, and even physical collaboration spaces.

  Companies may need to become more open to partnering with players from other industries. Some companies manufacture smart city products or components, while others provide digital platforms, integrate systems, or even orchestrate activity across the broader ecosystem with a network of partners. An ecosystem requires not only cooperation but also technical compatibility. Forming alliances, setting industry standards, and shifting toward open interfaces may help the entire industry move forward.

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Despite their varied starting points, priorities, and capabilities, cities across Southeast Asia can cooperate to deploy smart solutions on a much bigger scale. Solutions become more valuable as they add active users and the stores of data grow. Just as trade and digital flows link the region, smart cities are yet another area where integration can speed progress through the sharing of data, best practices, and open-source tools. The most advanced cities may be able to assist others in developing technological capabilities and specific apps, but it will also be valuable for the region's lower-income cities to share with one another what they are learning about where digital innovation can yield the greatest impact. Green shoots are already visible, and the recently launched ASEAN Smart Cities Network can provide a vehicle for accelerating progress.

1. SMART CITIES CAN TRANSFORM SOUTHEAST ASIA

Cities are the dynamos of Southeast Asia, fuelling its economy and generating most of its production, consumption, and trade. Today there are more than 230 cities across the region, each with more than 200,000 people—and they contain a multitude of languages, ethnicities, religions, and cultures. They collectively contain one-third of the region's population and drive more than two-thirds of its economic growth.[1] While Southeast Asia has hundreds of smaller but fast-growing "middleweight" cities, its larger primary cities play a more outsize role in each nation than tends to be true in other parts of the world. The economies of the region's megacities are comparable in size to those of entire nations. The GDP of Jakarta, for instance, is comparable to that of Sweden.

Urbanisation can be a powerful force for economic and human development, but it is happening across Southeast Asia at an unprecedented pace. Many booming cities are struggling to keep up with growing demands for decent housing, electricity, water, transit, healthcare, and education. In many places, the result is crippling gridlock, pollution, slums, and stress.

While the urban challenges across Southeast Asia have been growing in scope, technologies that could help to tackle some of these issues have reached maturity. Hundreds of cities around the world, including some pioneers in Southeast Asia, are deploying these solutions to become "smarter." The region as a whole can build on these early efforts to make the urban environment work for the people who inhabit it. If Southeast Asia can use the new tools at its disposal to manage urban growth and make the urban environment operate more efficiently, it can continue to make significant strides in economic and human development, delivering a better quality of life to hundreds of millions of people.

AS SOUTHEAST ASIA RAPIDLY URBANISES, ITS PRIMARY CITIES ARE PLAYING AN OUTSIZE ROLE

Southeast Asian cities are expanding rapidly, at a quicker pace than the global average or the rest of Asia on average. By 2030, another 90 million people are expected to move to cities across ASEAN.[2] That would be more than 2.5 times the growth rate of population expected for the region, indicating that cities will become even more central to Southeast Asian economies and societies.

Despite their rapid growth to date, the urban share of the total population in six out of the ten countries in ASEAN remains below the global average of 54 percent. This indicates that the shift from countryside to city may continue to play out for years to come—and because Southeast Asia is still catching up, it has the opportunity to learn from the best practices of fast-growing cities in other parts of the world and avoid their missteps.

To a much greater degree than in other parts of Asia, Southeast Asia's wave of urbanisation is heavily driven by rapid growth in seven primary cities (Jakarta, Manila, Yangon, Ho Chi Minh City, Bangkok, Kuala Lumpur, and Singapore). These cities are the largest population centres within their respective countries, and they play an outsize role in their economies (Exhibit 1).
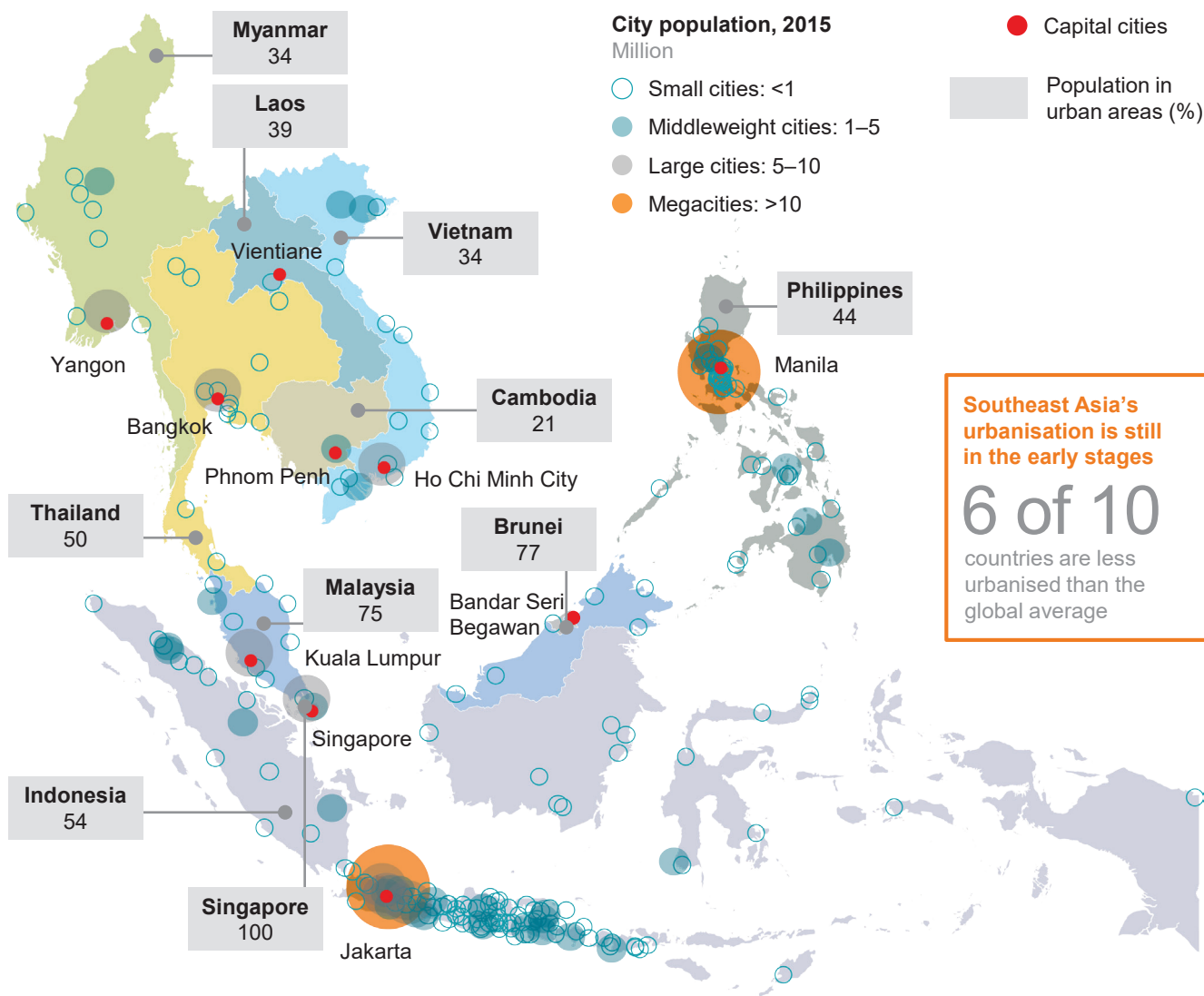
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[1] Based on McKinsey Cityscope data and projections; calculated as the proportion of expected growth in these cities to total regional growth.
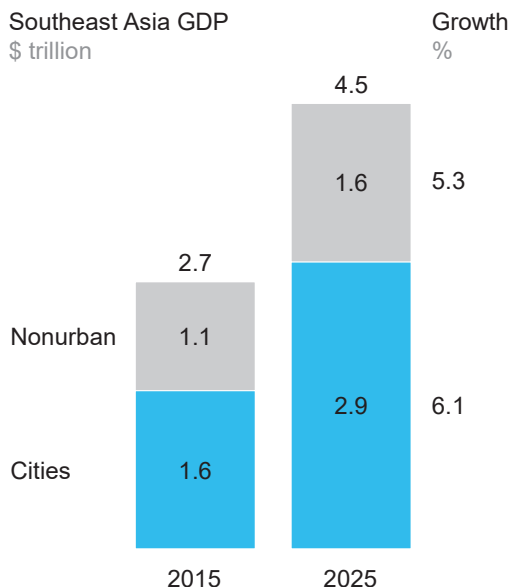
[2] *Southeast Asia at the crossroads: Three paths to prosperity*, McKinsey Global Institute, November 2014.
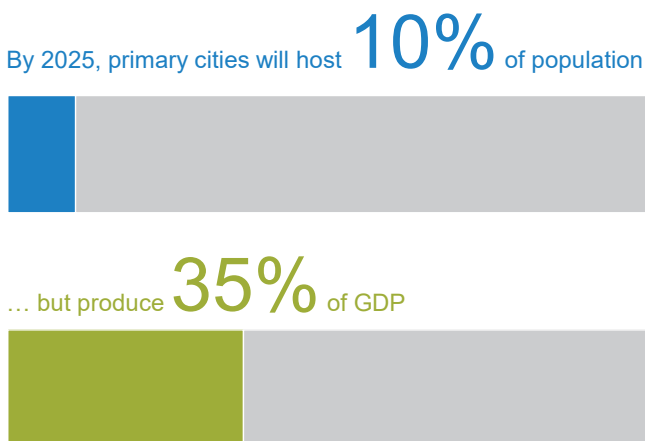
Exhibit 1

Southeast Asia: A tale of cities

City population, 2015
Million

○ Small cities: <1
● Middleweight cities: 1–5
● Large cities: 5–10
● Megacities: >10

● Capital cities

Population in urban areas (%)

Myanmar 34
Laos 39
Vietnam 34
Vientiane
Yangon
Bangkok
Phnom Penh
Ho Chi Minh City
Cambodia 21
Thailand 50
Malaysia 75
Brunei 77
Bandar Seri Begawan
Kuala Lumpur
Singapore
Indonesia 54
Philippines 44
Manila
Singapore 100
Jakarta

Southeast Asia's urbanisation is still in the early stages
6 of 10
countries are less urbanised than the global average

Cities are the engines of the economy…

Southeast Asia GDP
$ trillion

Growth
%

4.5
1.6 — 5.3
2.7
1.1
Nonurban
2.9 — 6.1
1.6
Cities

2015   2025

… and the region's primary cities play an outsize role

By 2025, primary cities will host **10%** of population

… but produce **35%** of GDP

SOURCE: McKinsey Global Institute analysis

URBAN GROWTH HAS BROUGHT ON MULTIPLE CHALLENGES

Urbanisation generally goes hand in hand with rising affluence. Additionally, it is easier to deliver infrastructure and public services to a more densely concentrated population, which can lead to gains in educational attainment and access to healthcare.

But particularly in the region's largest cities, rapid growth has led to growing pains. Cities are coming under strain, and in many places, the quality of life has taken a hit. Residents spend hours each day stuck in traffic or stuffed into overcrowded trains and buses. They struggle to find decent affordable housing, and millions make do with slum dwellings. Air quality is poor, and sanitation services cannot keep up with the amount of waste being generated. Effective management of city operations and agencies is not always a given.

These issues are common to urban areas across the developing world, but the cities of Southeast Asia are also uniquely exposed to the effects of climate change.[3] The region's low-lying coastal cities—including Bangkok, Ho Chi Minh City, Jakarta, Manila, and Yangon—are frequently hit by tropical storms and catastrophic flooding that claim lives and cause displacement as homes and businesses are damaged. The urban poor, who typically live in substandard housing, are at high risk. One study estimates that some 115 million urban residents across Southeast Asia will be vulnerable to coastal flooding.[4]

The speed of urbanisation across Southeast Asia has generally outpaced planning and investment, causing significant gaps in infrastructure and services. Previous MGI research has estimated that Southeast Asia needs some $7 trillion in infrastructure, housing, and real estate investment to support sustainable growth.[5] Cities would have to increase their annual spending substantially to meet this target. In addition, changing social factors such as ageing populations will shift the demands on public services. Investing boldly—and getting the most out of every dollar invested—will determine whether cities develop in a liveable and sustainable way. City governments and the private sector alike need to explore every option at their disposal to meet these needs, improve the urban quality of life, and do more with less.

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[3] *Climate change 2014: Impacts, adaptation and vulnerability*, Intergovernmental Panel on Climate Change, March 2014.

[4] Guanghua Wan and Matthew Kahn, "Green urbanisation in Asia," in *Key indicators for Asia and the Pacific 2012*, Asian Development Bank, 2012.

[5] *Southeast Asia at the crossroads: Three paths to prosperity*, McKinsey Global Institute, November 2014.

SMART SOLUTIONS CAN HELP TO ADDRESS THE REGION'S URBAN CHALLENGES

Cities across Southeast Asia have much to gain by becoming "smarter" in their use of technology. Today the needs and aspirations of residents often exceed the public sector's capacity to provide infrastructure and services. But smart solutions offer a way to scale up the capacity, reach, and quality of these systems and services. They can change the economics of infrastructure, giving cities the ability to add new services faster and at a lower cost. Although they are only one part of the full tool kit available to cities, digital solutions are the most powerful and cost-effective additions to that tool kit in many years.

We define smart city solutions as the practical use of data and digital technologies to deliver infrastructure or services in the urban setting, all with the goal of improving outcomes that relate to liveability, sustainability, and productivity. In other words, it is about putting technology to work so that urban residents can have a better quality of life.

Dozens of tools are available in every domain of urban life: mobility, social infrastructure, the built environment, utilities, security, community, and the economy (Exhibits 2 and 3). These domains relate to how citizens live, work, play, and interact with other people and their physical space. The individual applications in each of these areas can take a wide variety of forms. They may involve hardware, software and systems, mobile apps, and sensors. They may capture readings about conditions in the physical world, combine data from different sources, or use data in planning, building, and operational management. Some of them are tools for city government, while others involve private-sector companies bringing new, digitally enabled business models into urban settings. The use cases range from discrete one-off projects to holistic solutions that become woven into the day-to-day fabric of the city.

Some of the innovations currently available or just over the horizon in smart cities involve advanced, cutting-edge breakthroughs such as autonomous vehicles. But cities can often create significant progress by applying relatively simple and basic digital systems in targeted ways, such as capturing data on traffic patterns or digitising time-consuming, paper-based business licensing processes. It is also important to consider how digital systems might work in the spatial context of the city—that is, how digital tools could integrate with buildings, parks, streetscapes, transit stops, and other spaces, whether enhancing them or improving the way they are planned and built.

Exhibit 2

Smart cities address seven domains of urban life

Economy

Infrastructure and services that support industry, innovation, and productivity

ASEAN-6 needs to boost productivity by **50–170%** through 2030 to maintain historical growth; infrastructure investment needs to increase up to **6 times** in Indonesia to keep pace with growth

Mobility

Infrastructure and services that enable free and convenient physical movement of residents and goods within cities

Congestion on roads costs **2–5%** of GDP every year; in Kuala Lumpur this is equivalent to **RM3,100** per resident

Utilities

Infrastructure and services that manage water, waste, and energy

Air pollution up **>5%** from 2008 to 2013 in more than **2/3** of cities; **96%** of residents in Jakarta have no access to wastewater treatment

Community

Civic and social infrastructure and services that give residents and visitors greater connectivity within the community and with local governments

Social infrastructure

Infrastructure and services to support the social needs of residents, including education, health, a sustainable environment, and quality streets and public spaces

Security

Monitoring and coordinating infrastructure and services to protect residents from external and internal threats

Built environment

Commercial, residential, and industrial buildings and infrastructure assets

28% of the urban population lives in substandard housing across the region; in Laos and Cambodia, that share is **80%**

Obesity up **28%** on average in the ASEAN-6 between 2010 and 2014; elderly share of population expected to **double** between 2015 and 2035

>80 cities and **>25%** of the population in low-elevation coastal zones; in Manila, **3 million** residents face flood/landslide risk
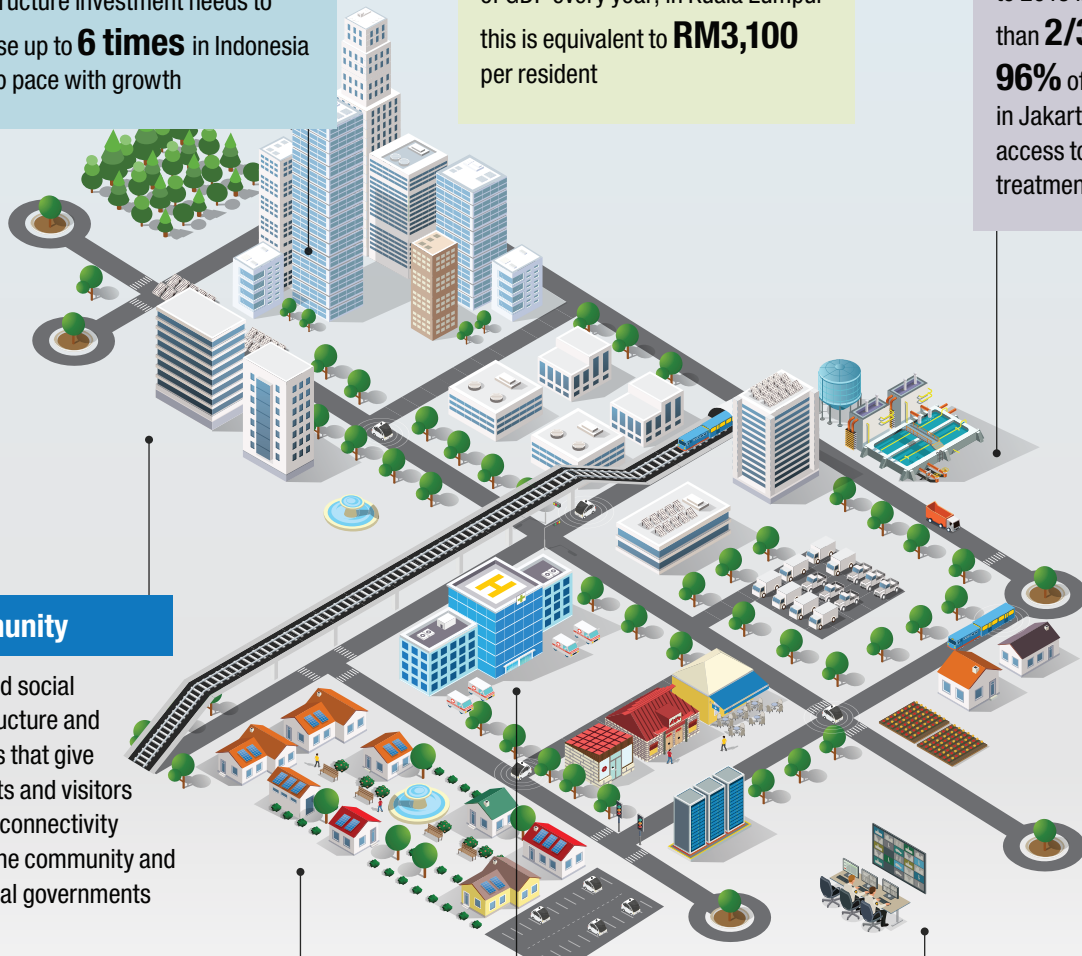
SOURCE: McKinsey Global Institute analysis

Exhibit 3

Our research looked at dozens of smart applications that will be relevant for cities through 2025

Social infrastructure

Data-based public health interventions for maternal and child health

Data-based public health interventions for sanitation and hygiene

First aid alerts

Infectious disease surveillance

Integrated patient flow management systems

Lifestyle wearables

Online care search and scheduling

Real-time air quality information

Remote patient monitoring and telemedicine

Smart streetlights

Free public Wi-Fi

Utilities

Distribution automation systems

Dynamic electricity pricing

Waste collection route optimisation

Leakage detection and control

Smart drainage

Smart grids

Kinetic floor tiles

Smart meters

Water quality monitoring

Economy

Digital business licensing and permitting

Digital business tax filing

Local e-career centres

Online retraining programs

Personalised education

Built environment

Precast, prefab, 3-D printing

Drone surveys of construction sites

5-D BIM

IoT-enabled construction sites

Digitised project collaboration

Sustainable building materials

Eco-digesters

Smart bins

Automated cleaning robots

Digital tracking and payment for waste disposal

Building management systems

Home energy automation systems

Home energy consumption tracking

Gamification and nudge-based analytics

Behavior-based water consumption tracking

Digital land-use and building permitting

Open cadastral database

Peer-to-peer accommodation platforms

Security

Body-worn cameras

Crowd management

Data-driven building inspections

Disaster early-warning systems

Emergency response optimization

Gunshot detection

Personal alert applications

Predictive policing

Real-time crime mapping

Security command and control centres

Smart surveillance

Mobility

Traffic command and control centres

Intelligent traffic lights

Real-time road navigation

Dynamic smart parking

Dynamic congestion pricing

Public transit information and management

Car and bike sharing

E-hailing

Mobility as a service (multimodal public transit)

Demand-based microtransit

Digital public transit payment

Dynamic speed limits

Predictive maintenance

Shared and autonomous driving

AV remote control centres

Driverless trains

Parcel load pooling

Smart parcel lockers

Self-driving trucks

Truck platooning

Logistics consolidation centres

Community

Digital citizen services

Local civic engagement applications

Customer service robots

Local connection platforms

Of particular note for Southeast Asia, MGI's recently published global research finds that the current generation of smart applications can help cities make significant or moderate progress toward meeting 70 percent of the UN Sustainable Development Goals. Smart solutions can contribute to a wide range of outcomes. They can save lives, prevent crime, improve the flow of traffic and transit, and reduce disease burden. They can be used to improve air quality, reduce carbon emissions, cut water consumption, and reduce waste. Digitising government functions can create a more efficient business environment, removing some of the barriers that hinder startups and housing development. In Southeast Asia, governments and the public alike are also beginning to understand the potential for these tools to enhance transparency and improve governance.

Smart cities are no longer a conceptual idea put forth by technologists or buzzwords spouted by hardware providers and property developers. Hundreds of cities worldwide are deploying smart solutions and producing tangible results.

Consider some examples from other parts of the world. Moscow, for instance, implemented a variety of intelligent traffic management tools to deal with its gridlock—and although it has absorbed more than a million additional private cars in recent years, average travel speeds through the city are still up by 13 percent. Mexico City had no route map of the microbuses (peseros) that transport millions of people every day, but an app created a competitive game that engaged thousands of riders in compiling data on their routes. New York introduced a network of public Wi-Fi kiosks on its streets with charging stations and information portals connecting people to social services; the kiosks themselves are a vehicle for advertising revenue to offset the capital costs. To complement the city's existing transit network, Berlin's public transportation provider is piloting an on-demand ride-sharing van service through a public-private partnership. Beijing reduced deadly airborne pollutants by roughly 20 percent in less than a year by using air quality sensors to track specific sources of pollution and regulate traffic and construction accordingly.

These are only a few examples, but they give a sense of how cities are creatively applying technology to public life. As cities across the region pursue their own efforts, Southeast Asia can also find success stories closer to home (see Box 1, "Smart cities in action in Southeast Asia").

Box 1. Smart cities in action in Southeast Asia

Da Nang: Redefining resilience

Da Nang is a hub for transportation, services, and tourism in central Vietnam. The city sits along a long section of low-lying coastline where it is exposed to flooding and storms. In 2013, Typhoon Nari flattened 4,000 regularly constructed homes, but homes constructed under a resilience project withstood the storm in good condition. These national housing investments pose valuable lessons for other Southeast Asian cities that are vulnerable to climate change and disasters.

The city has developed models that employ data to assess climate risk and shape its strategies through the Climate Change Coordination Office. The office has devised innovative solutions, including early flood warning systems and hydrological data to project water levels and areas that would be affected. These projects use and collect data to monitor and predict potential risks, which informs urban planning as the city's various agencies and entities partner to build more resilient housing units for low-income residents. This type of integrated effort allows for the kind of scale that makes projects viable and attractive to investors—and it enables them to use new materials and incorporate smart, energy-efficient technology.

The city's Climate Change Coordination Office has worked with global insurance company Swiss Re to develop an open data–driven flood risk map to increase awareness of problem areas. Open data maps help inform communities of potential storms and disasters, and they are accessible to low-income households, whose houses are most prone to disasters. Other ASEAN cities and citizens, especially those in areas that are prone to climate hazards, can benefit from similar initiatives on improving accessibility of climate-related data to the public.

Phuket: Focusing on sustainable tourism

An idyllic island off the west coast of Thailand, Phuket is well known to international travellers. The island attracts more than eight million international visitors each year, and there are ambitious plans to increase that number to 13 million. But destinations around the world sometimes struggle with becoming too popular for their own good; a heavy influx can harm the quality of life for locals and the experience for visitors themselves. Since tourism comprises 97 percent of the island's GDP, it is vital to manage its growth carefully.

Thailand's government designated Phuket as the country's first smart city, with a clear focus on the main theme of tourism. Phuket has outlined a multipronged Smart City Action Plan covering tourism, safety, the environment, the economy, governance, education, and healthcare. Having the plan in place has enabled the city to prioritise applications against the intended outcomes. If it can manage to grow in a smart and sustainable way, Phuket could serve as a potential blueprint for other Southeast Asian cities that are dependent on tourism but in danger of being overrun by it.

One of the first steps in Phuket was rolling out a public Wi-Fi system that today has more than 1.3 million accounts. While the service is free for users, Phuket intends to use the data it generates in the future for other applications. This detailed data is collated on a centralised platform where it provides the fuel for app development; it can also be analysed to understand tourist behaviour and preferences.

Phuket intends to build a closed-circuit TV network with "eagle eyes" over the city. Today, it has deployed 700 of 1,300 "publicly owned" CCTVs from police and local agencies. However, the city has embarked on a program to incorporate thousands of feeds from private business to make the network more comprehensive. In return for participation, the city will provide the business owners with access to the pooled data. This approach to partnerships will have the potential to expand coverage beyond what the original resources could achieve.

Southeast Asian cities have the necessary building blocks at hand:

- **Infrastructure.** Smart cities need a robust technology base, including high-speed communication networks, sensors, meters, cameras, and open data portals. While many parts of the region have further work to do in expanding and upgrading their fibre broadband, digital subscriber line, and wireless networks, current infrastructure is already sufficient in most major cities to support a broad range of applications. Almost two-thirds of the region has 4G networks, and coverage is significantly better in cities. The lower-income cities currently lacking backbone digital networks are "blank slates" that may be able to catch up and overtake since they are not limited by previous generations of technology.

- **Political will and support.** Both national and city governments across the region see the potential of using smart solutions to create positive impact for citizens. The ASEAN Smart Cities Network is a forum for 26 pilot cities to share cross-cutting lessons and resources. Singapore is well advanced, and Thailand has indicated its ambition to develop 100 smart cities in the next two decades.

- **Investment.** Financial constraints are a major concern for city governments, but multilateral organizations and private companies have significant appetite to step in and participate. The Keppel Corporation, for example, a Singapore-based engineering and construction firm, set up Keppel Urban Solutions in late 2017 to focus on building large-scale smart developments. Its first flagship project was the Saigon Sports City, a smart township in Ho Chi Minh City. Smart cities offer significant opportunities for real estate developers, tech firms, telecoms, utilities, and transportation companies.

- **People.** Being smart requires people to adopt and use these technologies productively in the day-to-day life and business of the city. In smart cities, residents are not merely the passive recipients of services; they are active participants in shaping how their city operates and uses its resources. In many cases, smart apps put more transparent real-time information at the fingertips of residents so they can act on it. Many smart city applications succeed only if they are widely adopted, so a connected population is a critical enabler. Mobile penetration across Southeast Asia has grown by 15 percent annually over the past decade.[6] Even countries that were slower to adopt have been catching up rapidly. Myanmar, for instance, went from essentially zero to more than 95 percent penetration in a decade.[7]

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Becoming a smart city is not a goal in and of itself. Smartness is simply a tool to help cities better serve the people who live and work in them. It is therefore important to understand how it can improve the quality of life in tangible ways. The next chapter considers what kind of progress Southeast Asian cities could achieve, including a more detailed look at opportunities to transform mobility and the built environment.

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6   Based on Indonesia, Malaysia, Myanmar, the Philippines, Singapore, and Thailand, from International Telecommunication Union data.
7   International Telecommunication Union.

2. THE POTENTIAL AT STAKE FOR CITIES IN SOUTHEAST ASIA

Recent MGI research examined how the current generation of smart city technologies can perform in a variety of urban settings worldwide. It found substantial potential for these tools to improve many quality-of-life indicators, saving time, improving public health and safety, creating a cleaner and more sustainable environment, and fostering a sense of community and civic engagement.

This paper applies a more focused lens to look at what kind of progress Southeast Asia's cities can achieve by becoming smarter. Each will have its own priorities and take its own path, and the potential impact will be highly influenced by each city's unique context and starting point. We consider several city archetypes to show how these differences might affect their choices and their journey. Finally, we take a deeper look at how smart solutions could reshape mobility and the built environment in the urban environment of Southeast Asia.

WE FIND SUBSTANTIAL POTENTIAL FOR SOUTHEAST ASIAN CITIES TO DELIVER A BETTER QUALITY OF LIFE

Building on MGI's previous global research, we consider the potential outcomes if cities across the entirety of Southeast Asia employ a full range of smart solutions effectively. The results of our analysis show that technology can have far-reaching impact in many aspects of the quality of life (Exhibit 4).

Smart solutions could remove up to 270,000 kilotons of greenhouse gas emissions annually. Some 5,000 lives lost each year to traffic accidents, fires, and homicides could be saved through mobility solutions, crime prevention, and better emergency response. Intelligent traffic and transit solutions could save up to eight million man-years in annual commuting time. Smart healthcare technology could reduce the region's disease burden by 12 million disability-adjusted life years—in other words, not only extending overall life expectancy but adding years of good health. By creating more efficient and productive environments for business and hiring, Southeast Asia could add almost 1.5 million jobs. Residents could also save up to $16 billion annually as smart solutions contribute to better housing options and lower energy bills.

Exhibit 4

Smart cities in Southeast Asia can deliver real quality-of-life improvements.

260k–270k Kilotons of GHG emissions avoided
Equal to the total emissions produced by Laos

4,900–5,000 Unnatural deaths averted annually
Equivalent to 50% of Malaysia's yearly total

8M–12M Disability-adjusted life years (DALYs) reduced
More than the total DALYs for all of South Korea

1.2M–1.5M New jobs created
Equivalent to 20–30% of the workforce in Jakarta, Bangkok, Manila

$9B–16B Savings on the cost of living
Equivalent to 2–4x Brunei's total household expenditure

6M–8M Man-years saved in commuting time
2x more than Singapore's workforce spends commuting

SOURCE: McKinsey Global Institute analysis

FOUR ARCHETYPES SHOW DIFFERENT SHAPES OF SMART CITIES ACROSS SOUTHEAST ASIA

The impact numbers above indicate the size of the aggregate opportunity across the region. But the speed and scope of impact will vary greatly from place to place, reflecting Southeast Asia's remarkable diversity.

Although the ten nations of ASEAN are pursuing deeper economic integration, they represent a multitude of languages, cultures, and ethnicities. They have widely varying forms of government, economic systems, levels of technological maturity, and human development indicators. Some nations have young and growing populations, while others are ageing. Per capita income can differ up to 50 times between various countries.

The region's cities similarly resist easy categorisation. Comparing cities or drawing conclusions about how they can approach a major transformation is harder across Southeast Asia than across Europe or South America. Nor can smart cities be assessed in broadly linear "tiers" of cities like those in China and India, where governments are implementing national visions that have set priorities for hundreds of cities.

One key finding from MGI's global research on smart cities was how heavily each city's unique characteristics influenced the performance of specific applications. The state of its legacy infrastructure systems, its physical layout, and its baseline indicators (such as crime rates and commuting times) play a huge role. This underscores the importance of each city's starting point. The four archetypes below capture some of these differences in Southeast Asia, and Exhibit 5 shows how the size of the impact potential can vary.

Smart city sandboxes

When a city reaches this stage, it is typically focused on improving productivity and designing new types of citizen experiences rather than filling major gaps in public infrastructure or expanding services to previously unreached segments of the population. The next steps may be pioneering autonomous driving innovation to revolutionise mobility or installing more building automation systems to achieve bigger reductions in emissions.

Today Singapore is the only city in Southeast Asia that fits this category—although it is feasible for other regional leaders to get there in the future. Singapore actually ranks among the most advanced smart cities globally. It has installed ultra-high-speed communication networks and implemented dozens of smart applications covering every domain of urban life. Thanks to its head start, Singapore is now a sandbox for next-generation technologies and novel implementation approaches, with advantages in its relative affluence, density, and significant public engagement.
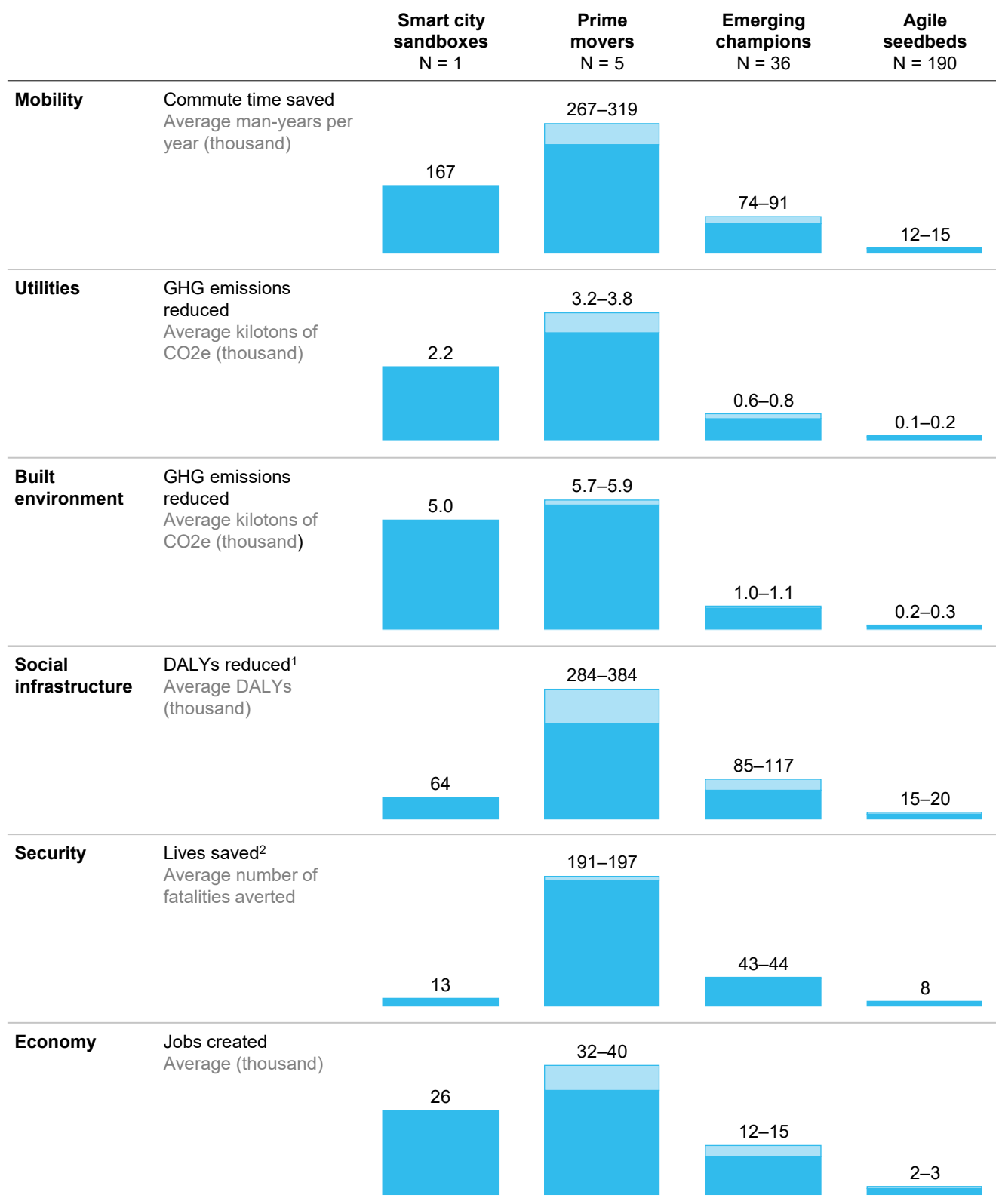
Prime movers

Bangkok, Ho Chi Minh City, Jakarta, Kuala Lumpur, and Manila are among the region's primary cities, all with populations of 6.5 million or more. Major physical and social infrastructure systems are in place, but they are often strained beyond capacity. The biggest priority is expanding systems and services to serve more people, which includes reaching segments of the population who lack access today and planning ahead to absorb future growth. Retrofitting existing infrastructure systems with smart technologies (for example, using Internet of Things (IoT) sensors for predictive maintenance on metro lines) can optimise their performance and get more capacity and lifespan out of them.

The sheer scale of these cities makes smart city initiatives financially viable even at modest levels of adoption. When prime movers implement smart solutions successfully, they can capture big wins and touch millions of lives.

Exhibit 5

The impact of smart city solutions will differ sharply across city types.

Average by city type

		Smart city sandboxes N = 1	Prime movers N = 5	Emerging champions N = 36	Agile seedbeds N = 190
Mobility	Commute time saved Average man-years per year (thousand)	167	267–319	74–91	12–15
Utilities	GHG emissions reduced Average kilotons of CO_2e (thousand)	2.2	3.2–3.8	0.6–0.8	0.1–0.2
Built environment	GHG emissions reduced Average kilotons of CO_2e (thousand)	5.0	5.7–5.9	1.0–1.1	0.2–0.3
Social infrastructure	DALYs reduced[1] Average DALYs (thousand)	64	284–384	85–117	15–20
Security	Lives saved[2] Average number of fatalities averted	13	191–197	43–44	8
Economy	Jobs created Average (thousand)	26	32–40	12–15	2–3

1 Disability-adjusted life years.
2 Mobility applications also save lives; not shown in this total.

SOURCE: McKinsey Global Institute analysis

Emerging champions

These are midsize cities (such as Cebu, Davao, Hanoi, Phnom Penh, and Yangon) that can benefit from integrating infrastructure, hardware, and software to deliver high-value, cost-effective impact. These solutions can expand access to services, reaching residents who were once left out.

These cities tend to need large-scale investment to get to the next phase of growth and development, but their financial capacity is typically constrained because of their relatively smaller scale. Large-scale projects to develop entire smart districts could attract private-sector partners.

Agile seedbeds

With less than a million people each, cities such as Bandar Seri Begawan, Banyuwangi, Da Nang, Luang Prabang, Phuket, Siem Reap, and Vientiane can be nimble in piloting and scaling up targeted smart city applications. Some are on the cusp of rapid growth, and smart planning can manage that process sustainably. If these cities are dominated by one industry (such as tourism or manufacturing), focusing on applications that can support a sustainable future for that industry should be part of the planning. Because these cities may have swaths of greenfield land, master-planned districts that are built smart from the start can help set a strong foundation.

Comparing the results that can be achieved within each domain, we see clear variations across these categories. Once a city becomes a smart city sandbox, it has already captured many of the quick wins. Prime movers and emerging champions, by contrast, have big potential to deliver results and touch millions of lives.

•••

Smart cities address multiple aspects of the quality of life. In addition to improving key indicators that matter to the lives of residents, they may also change the fabric of cities and the way they function. In the following chapter, we take a deeper look at how two urban domains may evolve in the future.

3. SMART CITIES IN ACTION: MOBILITY AND THE BUILT ENVIRONMENT

Smart cities deploy data and new technologies in every domain of urban life: mobility, social infrastructure, the built environment, utilities, security, community, and the economy. These domains relate to how residents live, work, play, and interact with other people and their physical space.

This chapter takes a deeper look at two of these seven domains. Mobility and the built environment are both fundamental to the way people experience a city. We examine the scope of tools and approaches available to smart cities in both of these areas—and in doing so, we offer a glimpse into how smart cities may function in the future and how the look and feel of the urban fabric may evolve.

MOBILITY: SMART SOLUTIONS IMPROVE COMMUTES AND THE ENVIRONMENT

Mobility is the flip side of congestion. Today, congestion is one of the key productivity drains in Southeast Asia, exacting a toll that has been estimated at 2 to 5 percent of each country's GDP. This is an issue in every major city across the region—and a recent index ranked Bangkok and Jakarta as two of the three cities with the worst traffic gridlock in the world.[8] As urban populations soar, traffic often slows to a crawl, and taking public transit may involve navigating a crush of people.

Commutes are also a major factor shaping the quality of life for most city residents. Studies have shown that longer daily commutes are correlated with lower life satisfaction and even increased risk of anxiety, poor fitness, obesity, high blood pressure, and other physical maladies.[9] Moreover, when cars spend a large proportion of time idling, they generate GHG emissions and air pollution. Poorly managed traffic is also a safety risk, and in cities without good public transit options, the cost of maintaining a private vehicle can add significantly to the cost of living.

Cities can seize on the current wave of innovation in mobility to address commuting times, create a less stressful commuting experience, and add new options for getting around. There are four main types of approaches:

- **Traffic and parking optimisation.** The main aim of these applications is to smooth the flow of vehicles on the road. Intelligent syncing of traffic signals, for example, prevents backups at intersections. Smart parking apps point drivers directly to available spots, eliminating time spent fruitlessly circling city blocks—an effect that reduces congestion for everyone. Cities in which buses are the primary mode of public transit also stand to gain from these traffic measures.

- **Public transit optimisation.** Shifting people out of private vehicles is key to alleviating traffic, but cities have to provide access to good public transit alternatives in order to do that. Smart city technologies can help cities get more out of their existing transit assets, and intelligent systems can be embedded into expansions and new assets. Adding IoT sensors to existing infrastructure can help crews perform predictive maintenance on equipment, fixing problems before they turn into breakdowns and delays. Collecting

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8 TomTom Traffic Index, "Measuring Congestion Worldwide", TomTom Traffic Index, https://www.tomtom.com/en_gb/trafficindex/list?citySize=LARGE&continent=ALL&country=ALL.

9 See, for example, Margo Hilbrecht, Bryan Smale, and Steven E. Mock, "Highway to health? Commute time and well-being among Canadian adults," *World Leisure Journal*, volume 56, number 2, 2014; Christine M. Hoehner, Carolyn E. Barlow, Peg Allen, and Mario Schootman, "Commuting distance, cardiorespiratory fitness, and metabolic risk," *American Journal of Preventive Medicine*, volume 42, number 6, June 2012; and Alois Stutzer and Bruno S. Frey, "Stress that doesn't pay: The commuting paradox," *The Scandinavian Journal of Economics*, volume 110, issue 2, June 2008.

and analysing data on public transit usage can also help cities make better decisions about routes, intervals, and where to invest. Singapore's Land Transport Authority (LTA) used anonymised data from commuter fare cards to identify hot spots and better track and manage bus fleets, making adjustments that have reduced the number of bus services with crowding issues by 92 percent. Apps offering information about multiple modes of transit in one view give people the ability to avoid delays and find the fastest route before they even set out. Digital ticketing can also speed boarding. Helsinki is pioneering the Whim smartphone app, which allows users to enter a destination, find the fastest route there by any combination of transportation modes, and pay for the trip in one transaction.

- **New transit modes.** Cities around the world have new types of digitally enabled transit options, including bike sharing, personal mobility devices, on-demand minibus services, and e-hailing. Some of these have come from private-sector companies, while others are provided by local governments or public-private collaborations. Multiple companies are racing to develop autonomous vehicles, which could someday form the bulk of shared fleets and radically change urban mobility in the years ahead. Even more futuristic developments like "hyperloops" and drone taxis could be on the horizon.

- **Enhanced logistics.** Central logistics hubs and parcel load pooling (which dynamically matches available truck capacity with delivery needs) can cut down on the number of delivery trucks clogging urban streets.

Giving everyone transparent, real-time information helps to improve circulation in the city. When a resident looks at her phone and sees a traffic jam, she may choose an alternate route or set out at a less busy time, thus avoiding adding another car to the road and worsening congestion for everyone. When a company sees a revenue-producing opportunity to offer mobility services, residents in underserved neighbourhoods suddenly have new ways to get to work. It is still critical for cities to build and maintain traditional road and mass transit infrastructure, but digital systems can make sure these assets are used in the most efficient way possible.
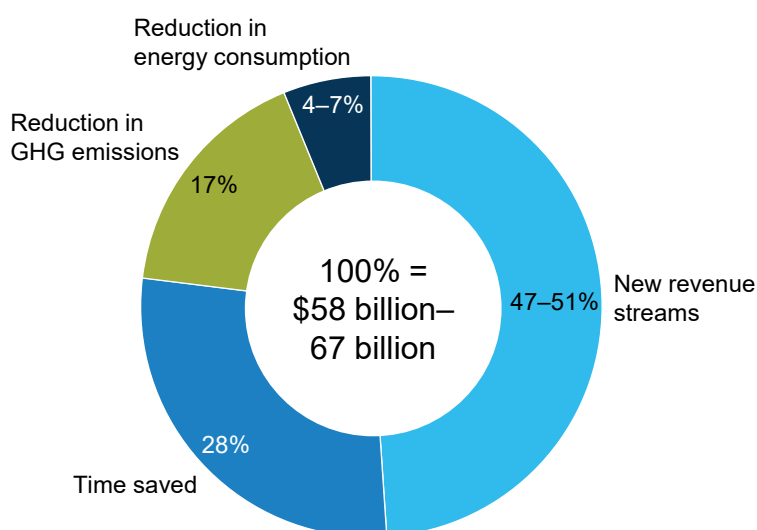
Smart mobility can create up to $70 billion in value across Southeast Asia

When millions of people share a limited space, their ability to move and circulate freely is critical to the way they experience the city. MGI's global research found that the mobility domain has the greatest number of applications being developed and introduced into real-world settings globally.

Mobility solutions can also create real economic value in multiple ways (Exhibit 6). There are multiple channels, which we estimate could reach roughly $60 billion to $70 billion annually across Southeast Asia. Some of this value stems from the time savings created by reducing congestion—a factor that creates a more productive and attractive business environment as well as freeing up more of the day and making life less stressful for individual workers. But the biggest share could come from new revenue streams as various players find ways to monetise new types of mobility solutions.

Exhibit 6

Mobility applications can create almost $70 billion in value across Southeast Asia.

Reduction in energy consumption: 4–7%

Reduction in GHG emissions: 17%

Time saved: 28%

New revenue streams: 47–51%

100% = $58 billion–67 billion

Examples

Singapore
- Implemented dynamic congestion pricing through the Electronic Road Pricing system
- Traffic congestion is down by 15% since its introduction in 1990
- Public transit has gone from 45% to 65% of the city's commutes

Malaysia
- Grab acquired Uber's Southeast Asia business in 2018. It provides up to 2.5 million rides daily

Indonesia
- Ride-hailing company Go-Jek currently has a fleet of more than a million cars and motorcycles

SOURCE: McKinsey Global Institute analysis

Mobility has become a much more crowded playing field as cities get smarter. Value is rapidly shifting, and the outcome remains uncertain (Exhibit 7). More change lies ahead as e-hailing and public transit fleets shift to electric and eventually autonomous vehicles—a shift that will require large capital investment for infrastructure such as smart metering and electric vehicle charging stations. Public utilities, such as telecom or electricity suppliers, will likely experience an increase in demand.

For decades, car manufacturers and public transit companies owned the interface to the customer, but the rise of digital mobility services such as e-hailing has expanded the value chain, enabling companies to assume new roles. Some customer-facing mobility platforms are not fully profitable yet but promise high future margins. Many of these are offered by digital native firms, but traditional automakers and even public transit operators are also pushing into this space by offering multimodal platforms or their own ride-sharing services.

Traditional auto manufacturers are already looking ahead to what could be a major shift from private vehicle ownership to shared mobility in cities, and they run the risk of being significantly disrupted if they do not shift their business models. When autonomous transportation services eventually break through, it remains to be seen whether automakers will simply make and sell the required fleets, operate them as a service for other companies and cities, or successfully position their own mobility platforms to move into the highest-margin part of the value chain.[10]

Exhibit 7

Smart solutions are shifting value in the ecosystem: Mobility example

Impact on value

| | Negative | | Indeterminate | | Positive | | n/a |

		Traffic command and control centers	Intelligent traffic information	Intelligent traffic lights	Public transit information and man-agement	E-hailing	Predictive mainte-nance of public transit	Autono-mous and shared cars
Traditional auto industry	Car dealers	n/a	n/a	n/a	Negative	Negative	n/a	Negative
	Automakers	n/a	n/a	n/a	Negative	Negative	Negative	Indeterminate
	Fuel suppliers	n/a	n/a	n/a	Indeterminate	Indeterminate	n/a	Indeterminate
	Vehicle-parts suppliers	n/a	n/a	n/a	Negative	Indeterminate	Negative	Indeterminate
Tech-enabled companies	Tech solutions firms	n/a	n/a	Positive	Positive	n/a	Positive	Positive
	Software firms	Positive	Positive	Positive	Positive	Positive	Positive	Positive
	Cyber-security	Positive	Positive	Positive	Positive	Positive	Positive	Positive
Public utilities	Telecommu-nications firms	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate
	Electricity suppliers	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate
Transport services	Public transit operators	Positive	Positive	Positive	Positive	Negative	Positive	Positive
	Mobility ser-vice providers	Positive	Positive	Positive	Indeterminate	Positive	Indeterminate	Positive

SOURCE: McKinsey Global Institute analysis

Smart mobility requires three core enablers

Orchestrating the movement of millions of people and vehicles through a city on any given day involves capturing and processing tremendous volumes of data. Autonomous vehicles will eventually require even more advanced networking with other cars on the road and with their surroundings. Three enablers are crucial to smart mobility (and to many other domains in a smart city):

- **Open data and data standards.** Developing clear standards and consistent guidelines for data sharing can jump-start innovation.

- **IoT sensor networks.** Smart mobility requires more "eyes" on the roads and comprehensive low-power wide-area networks to support this infrastructure.

- **Cybersecurity.** The smart sensor networks and connected hardware constituting the IoT provide much more "surface area" that is vulnerable to hackers. Compromised systems or self-driving cars could pose serious safety risks. Developing industry-wide security standards for the IoT will be critical to ensuring progress.

It is worth noting that current infrastructure, such as 4G or broadband, is sufficient for many applications to get off the ground. Cities do not have to wait for next-generation technologies; they can make headway with many solutions available today.

THE BUILT ENVIRONMENT: SMARTER SOLUTIONS FOR COST SAVINGS AND ENERGY EFFICIENCY

A city's built environment needs to evolve along with the needs of its population. Across Southeast Asia, there is a pressing need to build more housing and infrastructure—and to do so quickly, cost-effectively, and sustainably. Making the built environment smarter starts with using modern construction approaches, tools, and methods for higher productivity. It also involves managing properties and their utility consumption more effectively. Data and technology tools can help various stakeholders build cheaply and quickly without compromising on quality or environmental impact. There are three main types of smart solutions in this domain:

- **Construction productivity.** It is all too common for construction projects to run over schedule and over budget. But technology solutions, tools, and platforms can help digitise slow, paper-driven processes and optimise the use of labour, equipment, and materials.[11] For example, using prefabricated, prefinished volumetric construction modules involves assembling the components of a structure at a factory, completing fit-outs and finishes, and then transporting them as a block or module to the construction site to streamline project timelines, minimise wasted materials, and achieve much higher standards of quality, safety, and cleanliness. Singapore's Housing and Development Board estimates that a public housing project that would once have taken three or four years to build could be completed using this technique in 27 months. The production of traditional concrete materials generates about 5 percent of global CO_2 emissions, but switching to greener building materials can minimise that effect. The use of IoT networks and digital tools on construction sites can track and optimise equipment performance, digitise and coordinate workflows and labour movements, enable collaboration between field and office, and optimise project costs and schedules overall. Data and analytics can help developers and contractors manage performance for construction projects more effectively and help predict and prevent accidents, disruptions, and other events that could impact project progress.

- **Resource-efficient building management.** Buildings are a huge source of GHG emissions. A great deal of energy is wasted in homes and commercial buildings alike simply by heating, cooling, and lighting empty rooms. Building automation systems address these inefficiencies by incorporating features such as smart thermostats and optimised lighting that use timers or detect when rooms are occupied—and systems can now optimise across an entire portfolio of buildings. Savings can be passed on directly to consumers or enhance profits of asset managers. When Singapore's public utility piloted a new home energy management system that led to a 20 percent reduction in average monthly household electricity consumption, it brought down monthly bills.

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[11] For more on this topic, see *Reinventing construction: A route to higher productivity*, McKinsey Global Institute and McKinsey's Capital Projects & Infrastructure Practice, February 2017.
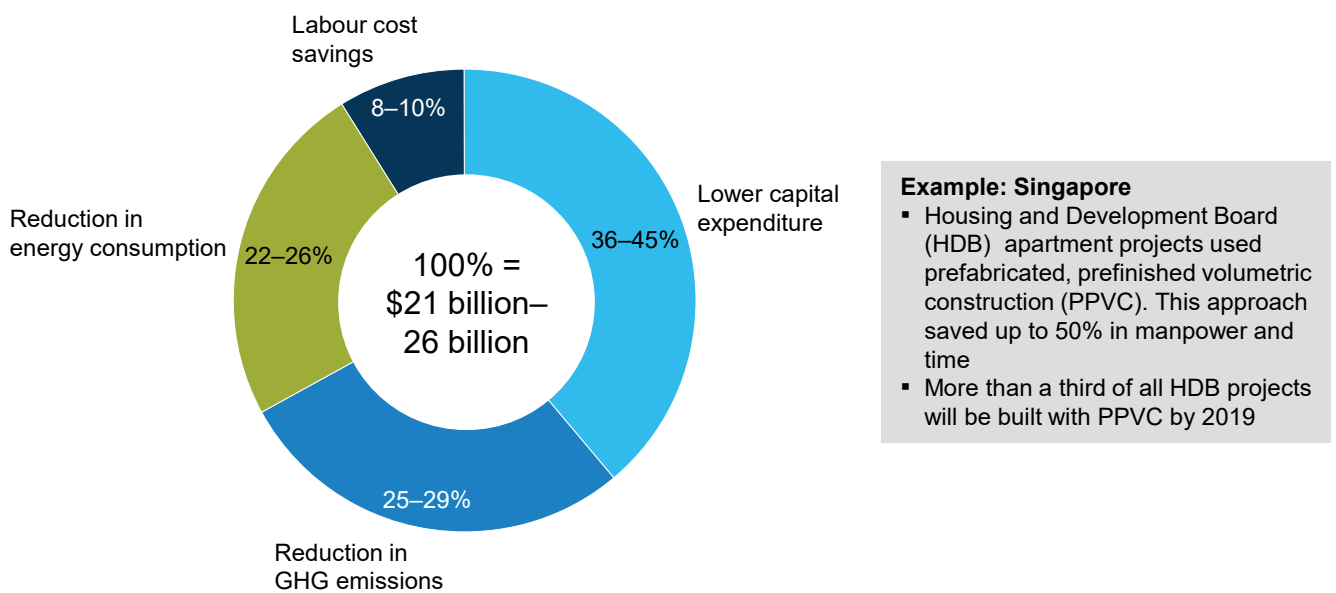
- **Digitising land acquisition, approvals, and permitting.** In many cities, extensive bureaucracy slows land acquisition, environmental studies, design approvals, and permitting. Delays and inefficiencies increase the risk premium associated with building projects, which are passed along to renters and would-be homeowners—and they prevent some projects from being undertaken at all. Digitising and automating the land-use and permitting process can reduce this risk. In addition, most cities have a surprising amount of land sitting idle, including vacant lots in the urban core where infill housing could be built. Creating open-source cadastral databases can help identify land parcels for development. Malaysia's e-Tanah is an integrated land administration and management system with a public portal that allows anyone to make online inquiries, search for titles, and pay taxes online.

Smart solutions in the built environment represent an opportunity exceeding $25 billion across Southeast Asia

The value from using smart solutions in the built environment will be captured by both businesses and consumers. Businesses stand to benefit from reduced capital and operating costs, while consumers can potentially lower their cost of living by reducing their energy consumption. These potential savings present an opportunity of more than $25 billion. Exhibit 8 illustrates an estimated breakdown.

Exhibit 8

Smart solutions for the built environment can create more than $25 billion in value.

Labour cost savings
8–10%

Lower capital expenditure
36–45%

Reduction in energy consumption
22–26%

100% = $21 billion– 26 billion

Reduction in GHG emissions
25–29%

Example: Singapore
- Housing and Development Board (HDB) apartment projects used prefabricated, prefinished volumetric construction (PPVC). This approach saved up to 50% in manpower and time
- More than a third of all HDB projects will be built with PPVC by 2019

SOURCE: McKinsey Global Institute analysis

Exhibit 9 shows how the adoption of smart solutions in building construction and management could shift value. The tech-enabled firms that produce these solutions are not the only ones in a position to win. Traditional architecture and engineering firms, property management and building services firms, and engineering, procurement, and construction firms stand to make real gains by adopting these tools and approaches. They can realise substantial cost savings, for example, through digital design and collaboration tools that can minimise rework and increase transparency and coordination at every stage of complex projects. Property developers that incorporate smart systems into their buildings may be able to charge a premium to buyers and tenants. The makers and suppliers of traditional construction materials and basic equipment could eventually be disrupted, along with construction players that do not evolve and modernise. This may take time to unfold,

however, since only the most advanced companies are embracing new technologies such as 3-D printing of buildings and the use of IoT sensor networks on sites. Utilities may also see a decline in revenue due to decreased energy consumption, although this shift depends largely on whether smart applications manage to change consumer behaviour.

Exhibit 9

Smart solutions are shifting value in the ecosystem: Built environment example

Impact on value

🟥 Negative 🟨 Indeterminate 🟩 Positive ⬜ n/a

		Precast/ prefab/ 3-D printing	IoT-enabled construction sites	Digitised project collaboration and mobility	Building management systems	Home energy automation systems	Digital land use and building permitting
Traditional players	Suppliers of traditional construction materials	Negative	n/a	n/a	n/a	n/a	n/a
	Basic equipment OEMs (eg, HVAC)	n/a	n/a	n/a	Negative	Negative	n/a
	Architecture firms	Positive	Positive	Positive	n/a	n/a	Positive
	Property developers	Positive	Positive	Positive	n/a	n/a	Positive
	Property management and building services	n/a	n/a	n/a	Positive	n/a	n/a
	Engineering, procurement, and construction	Positive	Positive	Positive	n/a	n/a	Positive
Tech-enabled companies	Suppliers of innovative materials	Positive	n/a	n/a	n/a	n/a	n/a
	Smart equipment OEM (eg, smart windows)	n/a	n/a	n/a	Positive	Positive	n/a
	Tech solution providers	n/a	Positive	Positive	Positive	Positive	n/a
	Consumer tech firms	n/a	n/a	n/a	n/a	Positive	n/a
	Cyber-security	n/a	Positive	Positive	Positive	Positive	Positive
Public utilities	Power utilities	n/a	Indeterminate	Indeterminate	Indeterminate	Indeterminate	n/a

SOURCE: McKinsey Global Institute analysis

Making the built environment smart requires some core enablers

Previous MGI research has found that construction is one of the least digitised—and least productive—industries. It involves many highly manual processes and deeply entrenched ways of doing things. Most customers also want customised designs, which adds to the difficulty of achieving economies of scale. But the value of injecting more innovation and digital technology into such a critical industry could be considerable, creating significant impact in cities where the need for more modern space is acute.

Three enablers will be key:

- **Data digitisation and standardisation.** Much of the data that is relevant to the property sector, including plans, drawings, and permits, is manually created and reproduced. Data that does exist is often nonstandard and incompatible for use across existing technology platforms. Digitising and standardising this data will not only ensure that information is archived properly but also save the ecosystem a significant amount of time and manpower in processing and collaborating. Singapore's Building and Construction Authority, for example, created CORENET (Construction & Real Estate Network), an online platform for building professionals that has centralised 3.54 million electronic submissions since its launch in 2001.

- **Advanced analytics.** Advanced analytics enabled by the IoT can improve on-site monitoring of materials, labour, and equipment productivity. On-site productivity can be greatly increased by using cloud-based control towers that rapidly assemble real-time data in both backward-looking and predictive ways, accounting for many variables. Consolidated Contractors Company, a large construction company in the Middle East, cut annual expenditures by $15 million globally by implementing predictive maintenance to reduce the downtime and extend the asset life of its equipment.

- **Process digitisation.** Much of the time and cost savings that can be realised in the built environment space relies on the flow of information or output from one stakeholder to another, whether it involves designers sharing changes to a construction blueprint with the right subcontractor or a utility sending feedback to a consumer about their electricity consumption. These flows become faster and less prone to error when they are done digitally. Platforms such as 5-D BIM can make design changes, cost parameters, and project status transparent to all collaborators and stakeholders. Digital collaboration and mobility tools (such as construction management apps loaded on mobile devices) can track progress on site in real time.

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Smart solutions, if deployed well, can make a city more responsive, productive, and liveable. The effort requires all hands on deck: city leadership and public employees, private-sector companies, financiers, social-sector organizations, and residents. The following chapter explores the smart management and execution required to turn these aspirations into reality.

4. REALISING THE SMART CITY OPPORTUNITY

Urbanisation can be a critical factor propelling Southeast Asia to the next level of economic and human development, but only if growth is managed well. Cities need to act now to address growing gridlock, create more productive environments, meet housing and healthcare needs—and particularly to combat climate change and improve their resilience as its effects become apparent.

Governments have a dual role to play. In addition to digitising their own processes and deploying some intelligent solutions on their own, they have to help the broader ecosystem evolve. It often makes sense to involve the private sector, which can provide different types of expertise and capabilities. But governments are in a unique position to provide and track data, bring stakeholders together, spur innovation, and address unintended consequences.

For companies and financiers, smart cities represent major opportunities, given that some of Southeast Asia's urban markets are larger than entire nations (see Box 2, "Singapore: Smart city in a box"). In order to partner with cities and operate effectively there, companies will need to adopt the mindset of serving people, not just a market. They may be able to find new business models by looking for specific ways to help cities deliver a better quality of life.

Box 2. Singapore: Smart city in a box

Singapore is a unique case in Southeast Asia, given its relative prosperity and its highly coordinated government system. Nevertheless, its Smart Nation initiative can yield valuable lessons for other cities across the region. Its experience shows that technology systems alone are seldom enough to make a city truly liveable; it also takes good execution and an understanding of how to adapt and integrate systems to deliver outcomes.

■ **Coordinate.** The Smart Nation Programme Office (SNPO) was set up in 2014 under the Prime Minister's Office with the mandate to coordinate digital strategies across government agencies.[1] The office was also put in charge of developing standards, policies, and platforms. One of the results is the OneService app, which solved what had been a pain point for residents: the confusion of dealing with multiple government agencies for municipal issues. By consolidating both back-end architecture and front-end services, the app brought together the services of 11 partner agencies and 16 town councils, creating more efficient tracking and oversight of complaints. Residents now have one touchpoint for reporting their concerns, and the agencies themselves can pool resources and collaborate more closely.

■ **Build open.** Singapore's Smart Nation rests on an open data ecosystem where the guiding principle is that data is a useful resource to be widely shared and mined for insights. Data sets gathered by government agencies have been made available and accessible to the public through online portals. Releasing a giant store of information encourages experimentation and engages businesses and the public in putting it to work in devising new apps and solutions that will benefit more people. The Land Transport Authority's DataMall, for example, made some 100 data sets available, resulting in the development of more than 40 mobile apps and services. One of them, built by a resident, is the Bus Uncle app, a bus arrival timing app with a strong local personality. By creating open data platforms, any city across Southeast Asia can unleash this kind of crowdsourced innovation.

■ **Support people.** Young and digital-savvy populations are natural users of smart apps, but older and poorer demographic groups on the wrong side of the digital divide may be left out of the benefits. A centralised approach to citizen engagement that specifically includes offline populations can be crucial to making a smart city more inclusive and equitable. Singapore has made a sustained national effort to systemically educate and promote the whole population and encourage pervasive technology use. Cities across Southeast Asia will have to make similarly conscious efforts to build cities that are smart for all.

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[1] While the SNPO was set up in 2014 under Prime Minister's Office, as of 2017 it was restructured and the Smart Nation and Digital Government Office with the Government Technology Agency as the technical arm supporting its implementation work. Centre for Liveable Cities, Singapore, *Urban systems studies—Technology and the city: Foundation for a Smart City*, 2018

THREE IMPERATIVES CAN SHAPE THE SMART CITY JOURNEY

In addition to these three principles, Exhibit 10 poses some starter questions to help various stakeholders think through the roles they can play in a smart city.

Exhibit 10

Important questions for key players in the ecosystem

Public sector	National governments	- Is there a national agenda based on what people value? Can budget be committed? - What sort of national government data should be shared on an open platform? - Can the government help bridge partnerships with other countries or organisations?
	Cities/mayors	- What kind of platforms can you create to keep residents informed and gather their opinions? - How will you set budget priorities? - Can you pool resources with other cities? - How should you attract and partner with private-sector players? - What new capabilities do you need?
Private sector	Solutions providers	- Do you see a way to use technology and data to solve the real problems of real people in cities? - How will you find a sustainable commercial model? What data can you monetise? - How can you work with physical infrastructure owners to adapt and scale up your solution? - Do you need to add capabilities in urban planning, architecture, or design?
	Real estate developers	- Can you retrofit existing properties? Will tenants be willing to pay for those upgrades? - How do you integrate technology in your planning, design, and building processes? - Do you have the right tech talent?
	Mobility developers and operators	- How can you use smart solutions to shift traffic and transit patterns? - How can technology improve traditional ways of getting around? - How do you monetise new transit modes? How do you adjust to asset-light models?
	Contractors/operators/ service firms	- How can you improve processes through digitisation? - How can you partner with planners or developers for end-to-end infrastructure planning and construction?
	Infrastructure investors	- How can you more effectively assess the returns on smart city infrastructure? - How can you help to bridge tech firms, infrastructure developers, and operators to create more holistic products?
	Principal investors	- How can you identify Southeast Asian champions and scale solutions across the region? - How can you more effectively assess potential returns?

SOURCE: McKinsey Global Institute analysis

Plan

The smart city starts with articulating a vision and goals—and since the entire point is to respond more effectively and dynamically to the needs and desires of residents, any strategy has to start with people. Many smart city initiatives have failed when they focused on the technology instead of on what people want and how they behave. Engaging the public from the outset, not just after specific solutions suddenly appear, can secure community buy-in. In India, Pune undertook nine phases of public engagement to get input from more than half of the city's population in the design of its smart city agenda.[12]

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[12] Smartnet, *Smart Pune: Creation of a vision community*, December 2015, https://smartnet.niua.org/content/99ac9eaf-513e-4669-82c4-0c8af2b4a5df.

Cities also need to consider how to pair smart technologies with complementary policies and investment in hard infrastructure. There is no getting around the need for hard assets and maintenance. Smart technologies cannot compensate for inadequate infrastructure investment, but they can help investment go further by adding new capabilities as core components are upgraded.

While it is important for city governments to outline a strategic vision for the future, the rapid pace of technological change means that they have to retain some flexibility to experiment and recalibrate. Taking a data-driven approach that continually measures progress against clear quality-of-life goals can guide that process and help to set priorities.

Companies with aspirations to become urban solution providers need to navigate a dynamic and complex ecosystem. In the public sector, national governments and local governments vary in their administrative reach over different cities. Furthermore, major quasi-public-sector organizations, such as the World Bank, Japan International Cooperation Agency, and Asian Development Bank, have a presence and participation in different cities. Transit and mobility solutions may entail coordinating with multiple operators; in many part of Southeast Asia, bus operators are separate from light rail, BRT, or metro operators. In the private sector, large multinationals often go up against local champions, pitting their technological capabilities against local know-how.

The need to tailor solutions to each city's context, combined with the unwieldiness of dealing with multiple stakeholders and agencies, makes it challenging for many providers to enter the smart city market in a viable way. The trick will be balancing each city's desire for custom solutions with the reality that a certain level of scale is needed to build a solid business case.

Companies may need to add new government relations capabilities to understand how the public sector works and devote time to engaging thoughtfully with local leaders about how to meet their city's needs. Since many solutions require developing plans that combine the physical world with digital technology, traditional players (such as real estate developers and infrastructure providers) may need to add new types of tech talent to compete.

Provide

Cities can no longer think of data and smart city tools as costly capital expenditures. They are increasingly necessary operational investments. Even when fiscal resources are scarce, there are ways to devise sustainable models for applications to take off, for example by monetising data, offering development rights, modifying zoning restrictions, or coming up with creative models that can generate revenue for private-sector providers. One key instrument the public sector has at its disposal is the "government as a buyer" model, which can support the development of new technologies. The Indian government extended grants under the FAME India scheme to support cities procuring electric vehicles for mass transport, a move that supported both the faster adoption of electric vehicles and multimodal transit solutions.

Technology continues to accelerate and expand our idea of what is possible. But cities do not need to wait for self-driving cars and flying taxis to appear before they take action. Many relatively simple digital systems and proven, open-source apps are in use in cities around the world today, and they can produce real results. Cities facing tough choices will have to prioritise the practical over the flashiest new technologies. Installing digital systems behind the scenes to manage traffic, coordinate networks of hospitals, or cut down on bureaucratic paperwork may yield more impact than highly visible touchscreens on the street. Low-income cities may be able to jump-start progress by creating open data portals, which make raw information available for private-sector innovation that does not require any public investment but nevertheless could improve the quality of citizens' lives.

Sometimes modest innovations can have massive payoffs in operational impact, far outweighing the cost of the initial outlay. The genesis of Malaysia's iClean Selangor app, for example, came not from technology but from a survey of almost 10,000 respondents. Respondents clearly prioritised a waste collection system, and the iClean Selangor app addressed that. Residents submitted pictures of rubbish in specific locations, enabling more precise deployment of sanitation services to clean up. Within three months, the frequency of reports had declined from a high of 50–60 per day to two per day. One of the areas covered, Kampung Delek, went from being one of the dirtiest kampungs (villages) in the state to winning an award for being the cleanest after this app debuted.

Companies need an intimate understanding of a city's context so they can anchor their offerings and value proposition to the real needs of residents. They may need to steer their potential government customers toward solutions that can make a visible difference in their constituents' lives—and away from gimmicks that garner headlines but ultimately fail to create headway thereafter. Simple and scalable solutions tend to gain traction and users, enhancing value for citizens and solution providers alike.

Partner

Neither the public nor the private sector can build smart cities alone. Creative and collaborative partnerships involving governments, private-sector companies, social-sector institutions, and the public alike will create better solutions and value. Various stakeholders can bring different things to the table, whether it is financing, urban planning experience, technical expertise, operational capabilities, or knowledge of the local landscape.

Many of the critical services are public goods for which the public sector is the natural owner. Government also needs to take a leading role in putting enabling infrastructure and policies in place to open data sets, provide foundational networks and platforms, and expand digital access and literacy among the population. But the city government does not have to be the sole funder and operator of every type of service and infrastructure system—and it is particularly not equipped to do so in the technology arena, which is constantly evolving. It makes sense to identify those areas where city agencies can step back and make room for other players, including private-sector companies, public-sector utilities and transport firms, universities, foundations, and nonprofits. Some cities actively cultivate the ecosystem approach by creating consortia, partnerships, and even physical collaboration spaces.

Technology is reconfiguring traditional roles and divisions of labour between government agencies and private providers. Increasingly the lines between public- and private-sector players are blurring. Public-private partnerships are crucial today, but over time, this distinction may be less significant. For example, Beeline, an on-demand transit service in Singapore, was initiated through a government unit and piloted by the government. But it was rapidly spun off to be operated by private service providers, with minimal impact on users. In Thailand, Phuket Eagle Eyes, an initiative to collect video feeds from a wide CCTV network, is supported by 700 CCTV feeds from public agencies (police and local agencies), but it has the potential to be supercharged by incorporating the CCTV feeds of private security systems.

Makassar, Indonesia's fifth-largest city, signed a memorandum of understanding with International Enterprise (IE) Singapore in 2016. It enables the city government to work closely with Singapore companies to deliver its smart city plan, drawing on their expertise in technology and implementation.[13] Clark Green City in the Philippines also built a strong series of partnerships as pa=rt of its smart city strategy. The Bases Conversion

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[13] *Urban Systems Studies – Technology and the City: Foundation for a Smart City*, Centre for Liveable Cities, Singapore, 2018.

and Development Authority, which manages the development of Clark Green City, has partnered with the Japan Overseas Infrastructure Investment Corporation for Transport & Urban Development to develop a comprehensive master plan, and with Surbana Jurong, an infrastructure and urban master planning firm, for support on drafting a management framework.

Companies, too, may need to become more open to partnering with players from other industries. Some manufacture smart city products or components, while others provide digital platforms, integrate systems, or even orchestrate activity across the broader ecosystem with a network of partners. Keppel Urban Solutions, a Singapore company, is partnering with Microsoft to offer smart services such as an intelligent command-and-control centre and an integrated resident services app in its Ho Chi Minh City smart development. An ecosystem requires not only cooperation but also technical compatibility. Forming alliances, setting industry standards, and shifting towards open interfaces may help the entire industry move forward.

Residents are also fundamental partners in the smart city. Being smart requires the public to adopt and use these technologies productively in the day-to-day life and business of the city, actively shaping how their city operates and uses its resources. Cities can use technology to take the pulse of public opinion on a wide range of issues, enabling residents to weigh in on many planning decisions. They can also use public feedback as the basis for making continuous improvements to the system. Smart cities encourage people to use transit at off-peak hours, to change routes, to use less energy and water and to do so at different times of day, and to reduce strains on the healthcare system through preventive self-care. Apps and interactive platforms that invite anyone to gather data and report problems give cities millions of additional data points and eyes on the street.

While its hallmark is diversity, Southeast Asia can also draw on its commonalities to make progress, extracting lessons that apply across different cities. The ASEAN Smart Cities Network has been launched with 26 locations across the region signing on. If these cities successfully set standards, share best practices, develop action plans, and launch some solutions on a regional scale, they could take significant steps forward. Initiatives like the network are crucial to building a strong base of collaboration across the region.

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Smart cities are already enabling the next wave of public investment and spurring private-sector innovation around the world. City governments will have to find the right combination of technologies, investment, policies, and partners to suit their own starting points and their own residents' priorities. They will also have to step back and leave ample room for private-sector innovation to fill in some of the blanks. Cities never stop evolving and reinventing themselves—and smart urban solutions will only accelerate the pace of change.

# APPENDIX

1. CITY ARCHETYPES

The diversity of the nations of ASEAN makes characterising their cities difficult, but they exhibit enough similarities to make it possible to categorise them according to four archetypes: smart city sandboxes, prime movers, emerging champions, and agile seedbeds (Exhibit A1).

Exhibit A1

City archetypes across Southeast Asia

● ASEAN Smart Cities Network cities

Population
Million
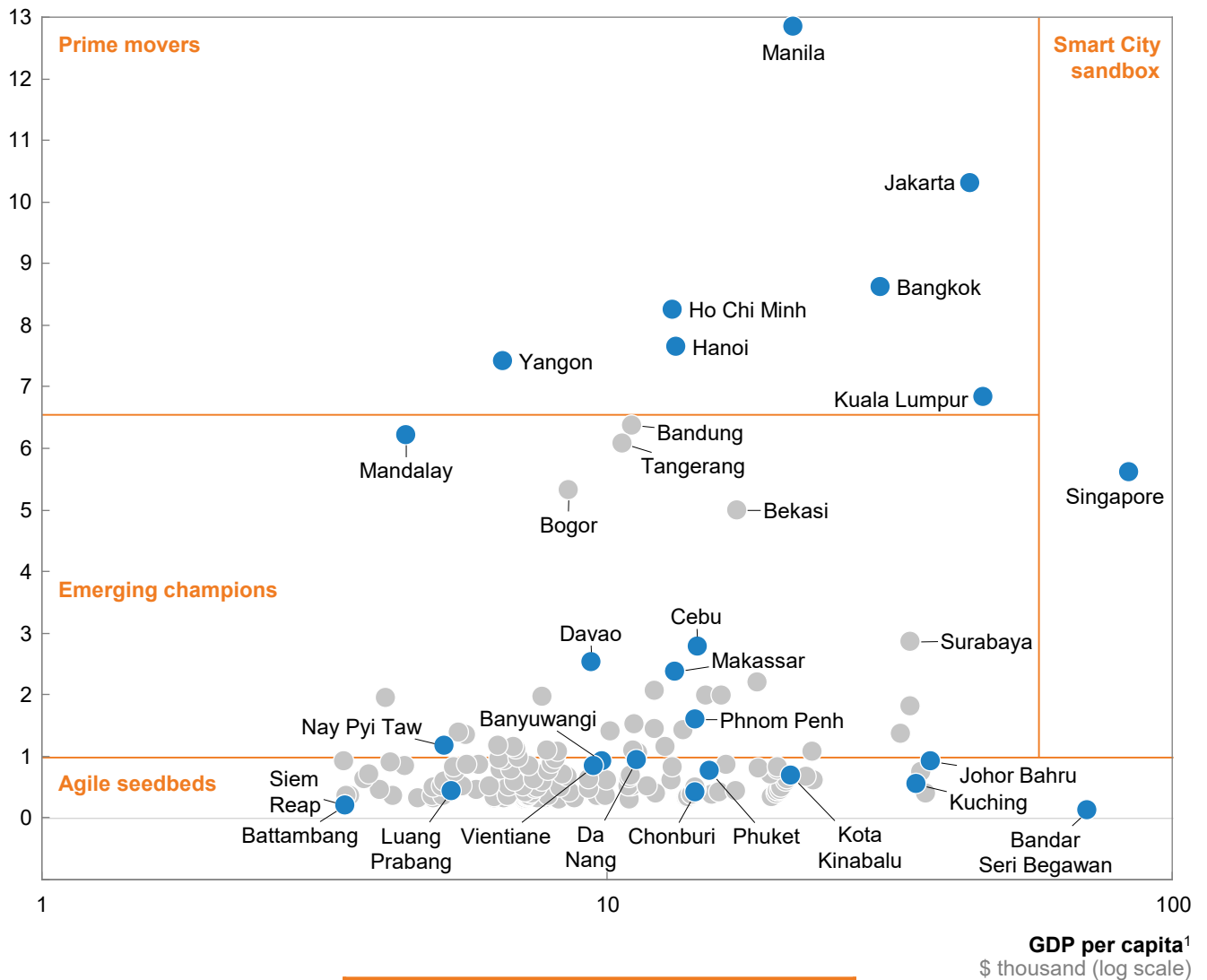
City type	Population growth rate (%)	
	Average	Range
Smart City sandbox	1.2	1.2–1.2
Prime mover	2.0	1.6–2.4
Emerging champion	2.5	1.6–4.9
Agile seedbed	2.3	1.6–4.4

1 National GDP per capita figures used for Bandar Seri Begawan, Battambang, Siem Reap, Luang Prabang, and Phuket due to limited data availability.

SOURCE: MGI CityScope database; McKinsey Global Institute analysis

2. GLOSSARY

Seven domains of public infrastructure and services

- **Mobility.** Infrastructure and services that enable free and convenient physical movement of residents and goods within cities.

- **Social infrastructure.** Infrastructure and services to support social needs of residents and maintain streets and public spaces, including quality environment, education, health, and well-being.

- **Built environment.** Commercial, residential, and industrial building and built infrastructure within which residents live, work, and play.

- **Utilities.** Infrastructure and services that manage water, waste, and energy resource for the city.

- **Security.** Monitoring and coordinating infrastructure and services that protect residents and residents from external and internal threats (e.g., policing, disaster resilience).

- **Community.** Civic and social infrastructure and services that foster greater connectivity between residents, and with visitors, their community, and local governments.

- **Economy.** Infrastructure and services that directly enable economic well-being of residents through industry and innovation.

Smart applications in mobility

- **Traffic command and control centre.** Implementation of a central facility for cities or districts that integrates and displays multiple sources of real-time information to provide effective monitoring of traffic quality and service levels. Sources can include real-time GPS tracking systems, CCTV surveillance, vehicle monitoring systems, and more.

- **Intelligent traffic lights.** Installation or retrofit of traffic lights with sensors and controls to implement dynamic optimisation of timing, leading to higher average speeds on roads and less frequent stop-and-go conditions. Includes traffic light pre-emption technology, which gives priority to emergency vehicles, public buses, or both.

- **Real-time road navigation.** Development of real-time navigation tools that can be made available to individuals and companies for choosing driving routes, with alerts for construction, detours, congestion, and accidents. These tools will allow users to choose the most time-efficient routes.

- **Dynamic smart parking.** Installation of IoT-based system for consolidation of parking availability across multiple locations, publishing of live status of individual spaces, and provision of parking reservations. A dynamic smart parking system can also be integrated with payment systems to implement dynamic pricing.

- **Dynamic congestion pricing.** Charging of fees for private car usage in certain areas, during times of peak demand, or both, adjusted dynamically according to prevailing road conditions based on ideal average road speeds. Uses a system of transponders, automated gates, and digital payment systems in conjunction with a charge-determining algorithm.

- **Public transit information and management.** Collection and dissemination of real-time information about price, arrival and departure times, and availability of transportation options across many modes such as APIs, mobile applications, and in-person signboards. Open access to data through APIs will also enable private-sector innovation.

- **Car sharing.** Access to short-term car use without a driver or full ownership; can be round-trip (station-based), one-way (free-floating), peer-to-peer, or fractional.

- **Bike sharing.** Availability of public-use bicycles, either in docking hubs or free-floating, to provide an alternative to driving, public transit, and private bike ownership. This option can bridge the first-mile/last-mile segment when public transit does not take a commuter door-to-door.

- **E-hailing.** Availability of real-time, on-demand ordering of point-to-point transportation through a mobile device. Can also include pooled e-hailing where separate ride requests with compatible routes are matched dynamically to increase vehicle utilisation.

- **Mobility as a service (multimodal public transit).** Development of a digital platform that allows seamless end-to-end trip planning, booking, ticketing, and payment services across all available modes of transportation.

- **Demand-based microtransit.** Development of ride-sharing services with fixed routes, fixed stops, or both, often supplementing existing public transit routes. Algorithms use historical demand to determine routes, vehicle size, and trip frequency. May include options to reserve seats.

- **Digital public transit payment.** Implementation of digital and touchless payment systems in public transportation that allow for prepayment and faster boarding. Includes smart cards and mobile payments.

- **Dynamic speed limits.** Implementation of system where speed limits applicable on city roads vary dynamically based on traffic conditions and are displayed on electronic signboards. Algorithm takes in real-time information from sensors and other data sources to calculate ideal speed limits based on current vehicle speeds, congestion information, and traffic flow rates.

- **Predictive maintenance.** Use of sensor-based monitoring of the condition and potential failure points of public transit and related infrastructure (such as rails, roads, and bridges) so that predictive maintenance can be performed before breakdowns and disruptions occur.

- **Shared and autonomous driving.** Availability of a shared car fleet capable of sensing the environment and navigating without human input. Transportation via these cars can be ordered through a mobile device or other digital touchpoint.

- **AV remote control centre.** Installation of a command post or retrofit of an existing command centre that allows for the remote operation of autonomous vehicles on the road.

- **Drone transportation.** Availability of autonomous door-to-door transport using an unmanned aerial-only vehicle.

- **Driverless trains.** Implementation of International Association of Public Transport Grade of Automation 4 trains capable of operating automatically at all times, including door closing, obstacle detection, and emergency situations.

- **Parcel load pooling.** Availability of analytics platform for online matching of demand for deliveries with the available supply of trucking capacity. By maximising vehicle utilisation, fewer trucks make a greater number of deliveries.

- **Smart parcel lockers.** Installation of on-site drop boxes at locations where packages can be picked up using individual access codes sent to mobile devices or other personal authentication method.

- **Self-driving trucks.** Availability of trucks for the transport of goods with the capability of sensing the environment and navigating without human input through use of technology such as GPS, radar, and LIDAR.

- **Truck platooning.** Implementation of technology that links two or more trucks in convoy, behind a human-driven lead truck, using connectivity technology and automated driving support systems to allow for more efficient transportation of goods.

- **Logistics consolidation centre.** Construction of a central hub for consolidation of goods from commercial delivery vehicles to maximise truck load, and timed operation of trucks to minimise impact to traffic. Enabled by technology smart mobilities technology such as ITS, real-time road navigation, etc.

Smart applications in the built environment

- **Precast, prefab, 3-D printing.** Assembly of components of a structure in a factory or other manufacturing site and transporting complete assemblies or subassemblies to the construction site for quick setup.

- **Drone-enabled construction survey.** Survey and inspection of difficult and inaccessible terrain by overlaying civil engineering plans to 3-D model to track progress of civil work, track movement of critical equipment, and allow cheaper delivery of some items.

- **5-D BIM.** Adopting technical tools to display the physical and functional aspects of a project in a five-dimensional way: 3-D CAD components linked with schedule constraints (4-D) and cost-related information (5-D).

- **IoT-enabled construction site.** Incorporation of a network of sensors into physical devices and equipment used in construction sites to allow connectivity and exchange of data. Use cases include equipment monitoring (predictive maintenance), smart structures (e.g., sensors to test strength and reliability of structure), GPS tracking (to track materials and trucks), electronic time logs, etc.

- **Digitised project collaboration.** Planning and tracking of construction projects through digital means; can be used for progress reporting, productivity tracking, access expertise, etc.

- **Sustainable building materials.** Substitution of traditional construction materials for materials that have low embodied energy and environmental impact. Includes ETGE, geopolymer cement concrete, nanomaterials, graphene, and CLT (created by binding layers of timber with structural adhesives to produce solid panels).

- **Eco-digester.** Installation of a wholly self-contained disposal system able to convert solid organic waste to reusable water.

- **Smart bins.** Installation of solar-powered smart bins for general waste and recyclables; incorporates sensors that alert waste collection firm when capacity limits are reached.

- **Automated cleaning robots.** Deployment of technologically enabled robots that are able to perform basic cleaning tasks through programmed reactions to environmental stimuli.

- **Digital tracking and payment for waste disposal.** Installation of digitally enabled pay-as-you-throw systems; includes feedback to users to increase awareness and reduce waste.

- **Building management systems.** Deployment of smart systems that optimise energy and water use in commercial and public buildings by leveraging sensors, meters, and analytics to monitor and manually or remotely/automatically eliminate inefficiencies.

- **Home energy automation systems.** Installation of smart meters and other sensors to optimise home energy consumption using smart thermostats, programmable and remote controllable electronic devices (smart home), and standby electricity control.

- **Home energy consumption tracking.** Installation of smart meters and other sensors to track residential electricity consumption with feedback delivered to the user via mobile app, email, or text to increase user awareness and encourage conservation.

- **Gamification and nudge-based analytics.** Use of real-time environment impact data to reward best savers and punish high users combined with nudge-based analytics for evidence-based sustainable strategies.

- **Behaviour-based water consumption tracking.** Provide feedback (via mobile app, email, text, etc.) on a resident's water consumption to increase awareness and reduce consumption.

- **Digital land-use and building permitting.** Digitisation and automation of the application process for land-use and construction permitting, reducing approval time and increasing transparency.

- **Open cadastral database.** Provide a complete database of land parcels in the city, open to the public; enables a more efficient land market by creating transparency of available land and lowering the cost of land parcel registration.

- **Peer-to-peer accommodation platforms.** Creation of digital marketplaces where individual hosts can list and rent out short-term accommodations.

Smart applications in utilities

- **Distribution automation systems.** Installation of different types of smart grid technologies, including FDIR, M&D, Volt/Var, and substation automation, to optimise energy efficiency and the stability of the power grid.

- **Dynamic electricity pricing.** Implementation of dynamic adjustment of electricity prices to shave peak-time demand and reduce electricity generation cost. By reducing peak demand, cities can reduce the number of power plants that operate during peak hours.

- **Waste collection route optimisation.** Use of sensors inside trash bins to measure trash volume and direct the routes of garbage trucks. This application keeps garbage trucks from travelling to trash bins with little waste volume.

- **Leakage detection and control.** Monitoring of pipe conditions from a remote location using sensors, and control of pump pressure to reduce or prevent water leakage. The early identification of leaks can prompt follow-up actions from relevant city departments and utility companies.

- **Smart drainage.** Installation of sensors to detect blockage or clogging inside underground drainage channels, indicating the exact area and place of problem.

Sensors also allow monitoring of water flow data so control centre is able to open and close drainage channels as needed.

- **Smart grids.** Utilization of sensors and technology in an electricity supply network to detect and react to local changes in usage. Ensures properly distributed supply and storage of energy.

- **Kinetic floor tiles.** Generation of power from material laid on ground through conversion of kinetic energy to electrical energy.

- **Smart meters.** Installation of sensors to monitor usage patterns of electricity or water, including remote/automated control in certain instances.

- **Water quality monitoring.** Monitoring of water quality in real time (in mains, rivers, oceans, and so forth) with alerts delivered to the public via channels such as mobile app, email, text, or website. This warns the public against consuming or coming into contact with contaminated water and prompts cities and utilities to follow up promptly.

Smart applications for the economy

- **Digital business licensing and permitting.** Switch to digitised process (such as an online portal) for businesses to obtain operating licenses and permits.

- **Digital business tax filing.** Creation of channel for businesses to complete tax filing online.

- **Local e-career centres.** Creation of online platforms for posting job openings and candidate profiles; may use algorithms to match compatible candidates with available jobs. Reduces job-hunting time and increases net new employment.

- **Online retraining programs.** Delivery of lifelong learning opportunities through a digital format, especially to help individuals who are unemployed or at risk of becoming unemployed gain new skills.

- **Personalised education.** Use of student data to identify individuals who need additional attention or resources; potential to tailor learning environments for individual students.

Smart applications to build community

- **Digital citizen services.** Digitisation of citizen-facing government administrative services such as income tax filing, car registration, and applying for unemployment benefits. Includes digitisation of the user journey as well as back-end support functions as needed.

- **Local civic engagement applications.** Use of digital apps to encourage public engagement in city affairs. May include reporting nonemergency nuisances and maintenance needs (for instance, reporting on trash via a municipal app), giving input on policy decisions, participating in digital city initiatives (such as open data hackathons), and interaction with city officials and departments on social networks.

- **Customer service robots.** Deployment of robots equipped with natural language processing and capable of operating independently in people-facing situations at government bodies to increase productivity and improve experience.

- **Local connection platforms.** Promotion of connection and potential meetups within a community through websites or mobile apps. May be used to find people with similar interests and hobbies, to connect with neighbours, and so on.

- **Body-worn cameras.** Utilisation of wearable audio, video, or photographic recording systems by police officers to record incidents and police operations for audit.

- **Crowd management.** Utilization of RFID, sensors, drones, and other technology to monitor and, where necessary, direct crowds to ensure safety.

- **Data-driven building inspections.** Incorporation of data collection and data analytics in building inspections so as to focus on buildings with the greatest potential risks.

- **Disaster early-warning systems.** Deployment of sensors, cameras, and monitoring systems with data collection and analytics designed to predict and mitigate the effects of natural disasters such as hurricanes, earthquakes, floods, and wildfires.

- **Emergency response optimisation.** Deployment of in-home/in-vehicle sensors, GPS, and other devices to collate data and use analytics and technology to optimise emergency response call processing and field operations, such as the strategic deployment of emergency vehicles.

- **Gunshot detection.** Implementation of acoustic surveillance technology that incorporates audio sensors to detect, locate, and alert police agencies to gunfire incidents in real time.

- **Personal alert applications.** Development of applications that respond to emergencies by alerting emergency response services, loved ones, or both. Devices (such as personal safety wearables, car crash detectors, and fall alert systems) may transmit location and voice data.

- **Predictive policing.** Deployment of big data and analytics (including social media monitoring) in police stations and systems to predict where and when crimes are likely to happen with greater precision. These systems are used to deploy police patrols and target prevention efforts.

- **Real-time crime mapping.** Development and adoption of technology used by law enforcement agencies to map, visualise, and analyse crime incident patterns. Information and intelligence gathering serves as a management tool for allocating resources effectively and creating accountability among officers.

- **Security command and control centre.** Implementation of a central facility for cities or districts that integrates and displays multiple sources of real-time information to provide effective monitoring of security. Sources can include real-time GPS tracking systems, CCTV surveillance, GIS mapping, etc.

- **Smart surveillance.** Integration of intelligent monitoring to detect anomalies based on visual feeds including facial recognition, smart closed-circuit TVs, and license plate recognition.

- **Flood water management systems.** Deployment of monitoring capabilities and technologies e.g., water level monitors, soil quality sensors, etc., that can monitor potential flooding and run-off conditions within the city, to support early warnings in times of flood and infrastructure planning for water management.

Smart applications in social infrastructure

- **Data-based public health interventions for maternal and child health.** The use of analytics to direct highly targeted health interventions for at-risk populations (in this case, identifying expectant and new mothers to drive educational campaigns about pre- and postnatal care).

- **Data-based public health interventions for sanitation and hygiene.** The use of analytics to direct highly targeted interventions, such as understanding where to increase rainfall absorption capacity or collecting crowdsourced data on gaps in sanitation systems.

- **First aid alerts.** Deployment of technologies that alert bystanders trained in CPR so that cardiac arrest victims receive prompt and critical care, e.g., mobile applications.

- **Infectious disease surveillance.** Implementation of data collection, analysis, and response to prevent spread of infectious and epidemic diseases. Includes awareness and vaccine campaigns (for example, for HIV/AIDS). Integrated patient flow management systems: real-time hardware and software solutions that provide visibility into where patients are in the system to improve hospital operations and coordinate utilisation on a city or multiple-facility level.

- **Lifestyle wearables.** Public dissemination (free or subsidised) of wearable devices that collect data on lifestyle and activity metrics and inform the wearer; may promote exercise or other aspects of a healthy lifestyle.

- **Online care search and scheduling.** The deployment of tools that assist in selecting payors and providers with financial and clinical transparency, especially through online platforms.

- **Real-time air quality information.** Installation of sensors to detect and monitor the presence of air pollution (outdoor, indoor, or both) in real time. Individuals can view the information online or on a personal device and choose to modify their behaviour accordingly.

- **Remote patient monitoring and telemedicine.** The use of technology, including audiovisual communication, and devices to monitor vitals in order to receive healthcare and interact with carers remotely, outside of a healthcare facility or in a different location from the healthcare professional. Includes medication adherence technologies that assist patients in taking medications as recommended by their healthcare provider.

- **Smart streetlights.** Installation of sensor-equipped and connected energy-efficient streetlights (including LED) that optimise brightness and reduce maintenance needs. Smart streetlights can be equipped with speakers, gunshot detection sensors, and other features to enhance functionality.

Each domain offers opportunities for both immediate and longer-term impact

Domain	Quick wins	Priorities for the future
Built environment	▪ Encourage digitisation in the construction industry by setting regulatory standards or providing subsidies ▪ Set baseline standards and guidelines for the use of technology and modern techniques (eg, 5-G BIM, prefabrication) in public projects	▪ Install sensors to enable fully connected construction sites (eg, sensors, wireless connectivity, wearables) and incorporate automation and consumption tracking tech into all new buildings by setting building standards ▪ Implement advanced analytics on project, firm-level, and sector-wide data to improve accountability on costs
Mobility	▪ Prioritise technology to ease congestion or increase transit capacity with government as a buyer, especially if revenue generating ▪ Improve clarity on traffic conditions through collection and sharing of data, eg, install trackers on taxis to monitor traffic ▪ Implement regulations to support shift from private vehicles, eg, facilitate regulatory framework for new modes like e-hailing	▪ Proactively engage with the private sector on the testing and regulatory framework for autonomous vehicles ▪ Engage with the private sector on long-term transit planning that allows for future innovations (eg, hyperloop, car taxis) ▪ Prioritise cybersecurity
Utilities	▪ Use the Internet of Things to monitor systems and prevent waste (eg, water leakage sensors, smart energy meters) ▪ Track usage and provide feedback to nudge citizen behaviour	▪ Utilise advanced analytics in conjunction with sensor networks to dynamically optimise delivery of utilities (eg, dynamic electricity pricing, distribution automation systems) ▪ Incorporate distributed generation and work toward the goal of city-wide smart grid coverage
Economy	▪ Digitise business-facing government services and use regulation to encourage businesses to digitise their own processes ▪ Invest in developing e-career centres	▪ Work with the private sector and educational institutions to provide short, personalised learning courses to help workers gain the skills that are in demand
Security	▪ Invest to build robust cybersecurity capabilities within public and private sectors ▪ Implement city-wide early warning systems (eg, flood water management system ▪ for many cities that typically suffer flash flooding)	▪ Establish guidelines for data sharing across multiple government agencies, and use advanced analytics and sensor technology to improve coordination and responsiveness
Community	▪ Digitise citizen-facing government services (eg, tax filing, application for benefits) ▪ Establish a norm of interactive governance (eg, create platforms to gather public opinion) ▪ Gain crowdsourced intelligence by giving citizens easy-to-use apps for reporting local problems	▪ Develop "one-touch" services in which multiple government agencies collaborate and synchronise back-end systems but individuals go to one easy-to-use portal
Social infrastructure	▪ Adopt "government as a buyer" model to incorporate technology in public hospitals and universities, eg, patient management flow systems and digital personalised education ▪ Identify and support applications that can deliver healthcare to the underserved	▪ Mobilise public-sector analytical capabilities to design and run targeted, tech-enabled, end-to-end campaigns for most critical public health themes ▪ Improve digital literacy and access, especially for the poor and the elderly, so they can share in the benefits of a smarter city