The Adaptive City: 3 Steps to Achieving the Smart City of the Future

This is an updated version of a white paper originally published by the World Economic Forum.

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The Smart City of the future needs to become an Adaptive City to be able to respond dynamically to continuous change and disruption.

It's said that Rome wasn't built in a day, and there's a good reason for that. Cities are the most complex human-designed system on the planet. Today, 55% of the world's population lives in urban areas, with 68% projected to live in urban areas by 2050. In the United States, the number is already at 83% and projected to reach 89% by 2050.

As such, cities represent perhaps the most important opportunity for innovation and digital transformation for our entire society and the planet. Through this transformation we can deliver an urban future that is more sustainable and resilient, but also more adaptive.

Since cities are naturally complex, adaptive systems, at least from a human perspective, the key to their future digital transformation is in design and implementation that utilizes both digital and physical enablers of adaptation.

To achieve the smart city of the future, the Adaptive City needs to take the following 3 steps:

- **Establish the Vision** – Determine societal goals for the city and support dynamic optimization of the goals themselves to keep pace with continuous disruption and change
- **Design for Adaptability** – Focus the design or renewal across both digital and physical elements of the city architecture and infrastructure and its ever-changing needs and use cases
- **Build and Operate for Intrinsic Agility** – Pursue a platform business model approach with governance and orchestration of the digital and physical enablers of adaptability "engineered-in".

In this article, we explore the successes and failures of the built environment's digital transformation to date, why the Smart City concept is necessary but not sufficient, and 3 steps for achieving the Adaptive City of the future – one which works for everyone.

Adaptability is a powerful concept that can have real-world impact at a level even above that of sustainability and resilience. For example, whereas resilience is a risk management strategy, adaptability is both a risk management and an innovation strategy, since the Adaptive City can dynamically respond to both challenges and opportunities.

Successes and failures of infrastructure's digital transformation

While there have been some shining examples of industry transformation – such as Icon's work in permitted, 3-D printed housing; Move Nona's creation of the largest and longest autonomous vehicle network at one location in the U.S. (with five routes and eight shuttles connecting nearly 10 key destinations); as well as Virgin Hyperloop's successful passenger test runs – recent attempts at large-scale digitization of the urban landscape have stalled.

CISCO pulled back from their Smart City push in 2020, mostly due to the effects of the pandemic pressuring public budgets at the time. Alphabet-backed Sidewalk Labs pulled out of a billion-dollar smart city contract in Toronto. Katerra, who received $865M in venture capital investment in 2018 to target offsite and modular construction, filed for bankruptcy and auctioned off their assets and IBM, with their "smarter cities" campaign, invested millions before pulling back.

Some of the reasons for these growth stalls include market readiness and timing, but also ecosystem complexity. When there are hundreds of niche use cases and thousands of available solutions, it is hard for mega-vendors to come along and capture the market. The Internet of Things (IoT) ecosystem, for example, is much the same and is comprised of thousands of specialty vendors all competing for a share of the projected $278.9B market for global IoT solutions and services by 2024. Even the sub-segment related to Radio Frequency Identification (RFID) technologies is splintered into active and passive tags, readers, middleware, printers and a plethora of industry-specific applications.

The Smart City is not enough

While the concept of the smart city (coined back in the 2000s) has long been the future vision for cities, even this is necessary, but not sufficient. Management consultancies and tech firms have long pitched the notion of intelligent sensors capturing billions of real-time data points to help cities become smart and able to respond to their surroundings. Common use cases have included self-driving cars, smart lighting, and even smart trash cans. Sensors and data are indeed the building blocks, like cement, air, water, sand and gravel are for concrete, but represent raw ingredients not the final solution.

Digital twin technology, such as that used for planning in Wellington, New Zealand, helps to take the smart city concept one step further. Wellington has developed a digital twin that connects complex infrastructural, social, economic and environmental systems with the decisions being made by the council and their impacts on communities. The benefit of the digital twin platform – in this case a digital model of the past, present and future of the city – is that it supports development, planning, operations and citizen engagement and therefore spans all stages of the design, build, operate lifecycle. In the past five years the evolving digital twin has been used to assist in earthquake and pandemic response, the creation of Wellington's Resilience Strategy, urban planning, public engagement on climate change and social harm reduction.

Adaptive Cities continuously maximize desirable outcomes

This is a useful start, but the city of the future needs to go one critical step further. It needs to become an adaptive city able to respond dynamically to continuous change and disruption.

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In recent years, disruption in all its forms has moved from the exception to the norm. Today's continuous disruption comes in the form of both technological disruption like 3D printing, AI/ML, autonomous vehicles, digital twins and modular construction as well as business disruption such as pandemics, extreme weather events, climate change, acts of God and even wildly fluctuating governmental policies.

The smart city concept worked well for steady state conditions, but in a world of continuous disruption, a key requirement for the city is to be able to respond to change and do so with intrinsic agility across both digital and physical aspects of its operating model. Agility in the digital stack is nothing if the city remains brittle in its physical infrastructure.

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Much like the U.S. military's defense readiness condition (DEFCON) system, the ability to quickly respond to change and do so with pre-defined "go-to" operating conditions enables a city to continuously maximize its up-time and benefit for citizens without having to reinvent itself for every change or challenge.

An adaptive city balances lives and livelihoods with resilience and sustainability and all the political, economic, social, technological, legal and environmental (PESTLE) external conditions that need to be continuously analyzed and acted upon.

3 steps for implementing the Adaptive City

The path to the Adaptive City is a multi-year journey. Like digital transformation, it can gain quick wins along the way so that benefits are realized in every step of the journey. Three key steps along this path to implementation relate to establishing the vision, designing for adaptability and then building and operating for intrinsic agility as follows:

Step 1: Establish the vision for the Adaptive City

The vision for the adaptive city of the future starts with its strategic goals. They may include economic growth, quality of life, health and wellness, diversity and inclusion, safety and security, mobility, efficiency and resilience, and sustainability and environment. This is clearly different for each city. For example, Miami's needs in terms of resiliency are far different from those of Dallas. Adaptability is key since it becomes an enabler to better support all strategic goals of the city. It means you can hit more of your goals, more of the time, for more of your stakeholders.

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Figure 1 Adaptive City strategic goals: Dynamically optimized for all stakeholders

As an example, the concept of dynamic curb management enables city planners and building operators to smooth the flow of traffic and deliveries at the curbside using dynamic, data-driven curb management software and policies to make roadways more efficient and equitable. For example, two-hour parking spaces can become three-minute loading zones, or dynamically priced delivery zones, based on time of day or other factors.

Since the strategic goals for the city will be continuously changing, the Adaptive City will need to support dynamic optimization of the goals themselves so that goals which are sometimes in mutual tension with one another, such as traffic volume (i.e. mobility) and CO2 emissions (i.e. environment), can be pro-actively managed minute-by-minute.

Step 2: Design for adaptability

To design for adaptability, it is important to focus the design across both digital and physical elements of the city architecture. Software adaptability can be accomplished with approaches such as cloud computing, artificial intelligence and machine learning, hyperautomation, software-defined networks, smart contracts, digital twins and platform business models. Physical adaptability can be accomplished with approaches such as adaptive materials, modular design and construction, multi-functional design, robotics and drones, and techniques which support rapid integration and interoperability or dynamic provisioning (Table 1).

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Digital Enablers for Adaptability	Physical Enablers for Adaptability
AI/ML	Robotics & Drones
Cloud Computing	Modular Design & Construction
Smart Contracts	3D Printing
Digital Twins	Intelligent Sensors
Software-Defined Networks	Dynamic Provisioning
Platform Business Models	On-Demand Services
Open Innovation & Open Data	Adaptive Governance

Table 1 – Digital and physical enablers for the Adaptive City

By way of some examples, Ample's robotic battery swapping stations can swap out an electric vehicle's battery modules and packs in 10 minutes. "Plug and play urbanism" takes elements such as pedestrian bridges and makes them moveable as needed. An example is the City of Fort Worth, which made streetscape improvements with a moveable bridge across an 80-foot-wide creek. On a larger scale, Qatar's shipping-container football stadium can be taken apart and reassembled after a match.

Operational optimization in parking facilities means not only doing more with less (e.g. during the pandemic when demand was down by as much as 90%), but in finding alternative approaches such as converting garage levels to work-out facilities, providing space for pop-up retail or creating staging areas for restaurant take-out and food deliveries.

This physical adaptability extends to specific assets in the built environment as well as entire structures. Multi-functional streetlights, such as those in the New Haven planned development community in Ontario, California, are equipped with USB charging ports, environmental sensors, Wi-Fi, wayfinding and more.

As another example, dynamic road provisioning as well as dynamic road pricing can be used to allocate space both to and from private motorized vehicles to help improve the provision of bus services and encourage cycling and walking. Just like the "lot size of 1" in the Industry 4.0 vision for the future of manufacturing, this dynamic provisioning and pricing can move from today's blunt instruments, which are applied "en masse" to a broad swath of city traffic, almost down to the level of individual vehicles.

Step 3: Build and operate for intrinsic agility

To build out or renew this infrastructure, it will be important to utilize the new technological building blocks such as those outlined earlier. These digital and physical enablers will provide intrinsic agility, since by utilizing them during the construction or renovation process, as well as in daily use and operation, there is already adaptability by design.

In terms of integration, it will be important to pursue a platform business model approach where intellectual property from startups and other constituents in the Adaptive City ecosystem can plug and play into the platform's suite of services, much like the Apple App Store model.

The Adaptive City may own and operate this platform as a public service, but it also enables permissionless innovation so that others, including citizens, can easily innovate and build on top. The platform should be loosely coupled from one component to another and integrate only to the degree necessary to support the business rules (i.e. optimization of Adaptive City strategic goals) and ensure safety and security.

Public-private partnerships will be essential to this journey. For example, in a world of fully autonomous vehicles, cars will now be able to automatically take themselves in for a car wash or for scheduled maintenance without the need for human intervention. It may be as simple as a voice command on the smartphone, or the car may decide by itself when it is time. Private car washes as well as service and repair shops will need to be just as technically advanced with machine-to-machine (M2M) scheduling software and physical processes that can accommodate this form of driver-less, autonomous maintenance.

It's time to redefine the role of each asset, from buildings and roads to cars, and even to redefine the human role in the adaptive city.

As part of this journey, the natural environment needs to be more blended with the hard built environment. The blending of the green and grey. As a society, for too long, we have relied almost entirely on grey infrastructure without leveraging the benefits of the natural processes of green infrastructure which has natural attenuators built in.

The Adaptive City as a software company

With so many technical building blocks enabling so many use cases for the Adaptive City of the future, perhaps the main challenge will be in the governance and orchestration of the platform business model that brings all this to life. At this point, the Adaptive City will become its own software company, quite literally helping to make the world a better place.

It is said that “every company is a software company” and perhaps now is the time for every city to become a software company as well.

Of course, software companies as well as cities rely upon humans to make things happen and to embrace and implement any kind of change from the status quo. The vision of the Adaptive City won’t be attainable via digital and physical enablers of adaptability alone. It will require careful change management across all 3 steps outlined here so that tomorrow’s adaptive solutions can find their way from vision to reality. Humans will need to establish and agree upon the strategic goals of the city as well as their relative priority. Humans will need to play a key role in designing for adaptability and providing the business case for change. Finally, humans will need to build and operate the city’s civil infrastructure with a new focus on adaptability as a vital mission objective much like resilience and sustainability before.

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