CITIES OF TOMORROW: REIMAGINING URBAN INFRASTRUCTURE

PATHWAYS TOWARD INTEGRATED AND ADAPTIVE URBAN INFRASTRUCTURE SYSTEMS BY 2050

VAUBAN INFRASTRUCTURE PARTNERS
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A leading think tank for the infrastructure sector, InfraVision was created in March 2024, leveraging on four years of research, and is now open to all stakeholders. This initiative brings together companies, investors and individuals looking to strengthen the position of the infrastructure asset class and make it a building block for tomorrow's world.

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Vauban Infrastructure Partners is a leading infrastructure asset manager focused on the core infrastructure market. Headquartered in Paris, Vauban employs 75 professionals and targets predominantly European brownfield mid-market assets, and pursues a long-term, yield-driven strategy matching the underlying nature of the assets and long-term commitment to all stakeholders' interests through a strong focus on creating sustainable value and a unique ESG approach. To date, Vauban has raised over USD 10bn across seven funds in core infrastructure, and has invested in the mobility, energy transition, social infrastructure, and digital infrastructure sectors spanning 12 different geographies.

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FOREWORD

Since its creation, Vauban Infrastructure Partners has sought to invest in essential public infrastructure that provides long-term sustainable solutions to local communities: clean water, efficient waste management, safe and low-carbon transportation, very high-speed communication networks, and a broad range of social services around education, health, justice and leisure. We believe that it is our duty to act in the best interests of investors and society, to help build and maintain vital infrastructure systems so that communities can thrive in a sustainable environment.

Launched in 2024, the InfraVision think tank laid the groundwork for a new platform of thought leadership and knowledge exchange on the future of infrastructure. In 2025, we sought to accelerate its momentum – expanding research, convening new dialogues, and highlighting practical solutions.

With this in mind, our focus turned to cities as the frontline where today's most urgent challenges converge. While our earlier work explored how climate change threatens their ability to remain sustainable, circular, and inclusive, we now extend the lens to encompass rapid population growth, the strains of aging infrastructure, and the growing complexity of urban systems. By doing so, we aim not only to frame the scale of the issues ahead, but also to explore the practical levers cities can draw upon to respond.

Guided by this ambition, we have brought together diverse voices to reflect on the changing realities of urban life and infrastructure – hosting a panel on innovative infrastructure solutions and producing a podcast series on themes of interdependence, adaptability, and governance in cities. Among these, nature-based solutions stand out as a critical avenue for adaptation and resilience. By integrating such approaches into the urban fabric, we hope to advance the conversation on how cities can evolve to meet the needs of tomorrow while remaining equitable, sustainable, and liveable for generations to come.

In addition, InfraVision launched its inaugural student competition, 'The City as a Network: Reimagining Urban Infrastructure', which invited bright young minds to propose innovative solutions for the future of cities. Over 100 submissions were made, and we are pleased to present the three laureates here, hoping they will inspire our readers as much as they have inspired us.

Gwenola Chambon,
CEO, Founding Partner

Mounir Corm,
Deputy CEO, Founding Partner

EXECUTIVE SUMMARY

From the earliest clusters of human settlement in the Neolithic period, infrastructure has been more than a practical necessity; it has been **the "structuring power" behind the rise of cities.** Far from being a silent backdrop, infrastructure has always actively shaped the spatial layout and the social and economic practices of urban life. If cities are crucibles that concentrate the human condition, infrastructure is the network of conduits that enables that concentration and fuels exchange.

Over the next decades, **cities will need to navigate overlapping challenges with far-reaching implications.** One of the most pressing is the rapid pace and vast scale of urban population growth, which places tremendous pressure on cities to accommodate new residents. Overall, according to the UN, 55% of the world's population lived in cities in 2018, a figure projected to rise to 68% by 2050. At the same time, climate change is emerging as a powerful external stressor: today, nearly 60% of cities with at least 300,000 inhabitants are already at high risk of exposure to at least one type of natural disaster. Compounding these risks are persistent gaps in access to urban infrastructure, which contribute to inequality, fuel economic deprivation, and heighten social instability. Other systemic strains include waste accumulation, which undermines urban livability, and growing pressure on water resources, which poses an existential risk for many cities worldwide.

Importantly, **these pressures are mutually reinforcing and, if left unaddressed, could trigger cascading 'breakdowns of urban metabolism'**, where the failure of one system spreads across others.

In this high-pressure environment, **infrastructure stands at the frontline** —both as a potential point of failure and as a powerful lever for building urban resilience.

Cities will need to maintain and transform existing assets, many of which were built in the mid-20th century and are now nearing the end of their typical 50- to 80-year lifespan. In China, for example, infrastructure built before the 2000s has average service lives ranging from just 10–20 years for marine ports (prior to major upgrades) to 30–40 years for civil structures.[1] Investing in maintenance will then be essential to keep existing infrastructure fully operational, particularly as decarbonization and digitalization drive system-wide transformation.

Cities will have to meet rising demand for new infrastructure. Approximately 50% of the urban environment that will be needed by 2050 has not yet been built, and urban land is projected to grow from about 0.6m km² in 2000 to between 1.1m 3.6m km² by 2100.[2]

The challenge is clear, yet it presents an unparalleled opportunity to **rethink how infrastructure is conceived, financed, and delivered.** What are currently points of failure in urban infrastructure hold the potential to become foundations for a more resilient and sustainable future. To unlock this value, a deliberate effort of projection is needed, both at the macro level and within individual cities, to **anticipate long-term needs and align infrastructure strategies accordingly.** The stakes are high: the World Bank estimated in 2016 that without adaptive measures, climate-related disasters could cost cities up to USD 314bn annually by 2030.[3] In India, urban flooding already causes USD 4bn in damages annually, projected to rise to up to USD 30bn by 2070 without intervention.[4]

1 - Van Breugel K., *Societal burden and engineering challenges of ageing infrastructure*, Procedia Engineering, 171, 2017

2 - Gao J., O'Neill B., *Mapping global urban land for the 21st century with data-driven simulations and Shared Socioeconomic Pathways*, Nature Communication, 11(1), 2020.

3 - WB, World Bank: Investing in Urban Resilience Can Save the World's Cities Billions Each Year and Keep Millions out of Poverty, 2016.

4 - World Bank, Towards resilient and prosperous cities in India, 2025

In this context, **scenario planning stands out as a critical tool for shaping the cities of tomorrow, helping forecast possible futures and inform decision-making.** At the macro level, the future of cities will be defined by two critical factors: the resource management strategy (ranging from proactive abundance and efficiency to reactive scarcity and strain) and governance models (spanning from centralized, hierarchical structures to decentralized, community-led arrangements). As part of the research carried out for this report, four distinct scenarios emerge, notably based on the decisions cities make along these two dimensions:

- **Hyper-connected and centralized smart metropolis** (proactive resource management + centralized governance): urban infrastructure operates through seamless digital technology integration under top-down governance.

- **Resilient, regenerative, community-led city** (proactive resource management + decentralized governance): cities achieve self-reliance through circular economies and localized governance.

- **Resource-strained, fragmented urban landscape** (reactive resource management + decentralized governance): cities become patchworks of vulnerable communities, trapped in linear consumption patterns without adequate systems-level response.

- **Controlled, efficiency-driven survival cities** (reactive resource management + centralized governance): cities respond to resource pressures through strong centralized coordination enabling efficient allocation and emergency preparedness.

These cities are archetypes, not reality, neither present nor future. While the four scenarios highlight distinct pathways, **real urban development will be hybrid, mixing elements from multiple models.** Centralized, tech-driven systems may ensure efficiency in energy, transport, or emergency services, while decentralized, community-led approaches support local engagement and resilience. Resource models will vary similarly, reflecting local constraints and priorities.

This blending of approaches underpins the concept of adaptive cities. Rather than aligning exclusively with any single scenario, adaptive cities embody a pragmatic ambition: to selectively combine the strengths of each model while mitigating their respective vulnerabilities. They aim to integrate the hyper-connected metropolis's efficiency, the resilient city's community cohesion, lessons on preparedness from resource-strained areas, and the controlled city's capacity for coordination and resilience. At the heart of these cities is adaptive infrastructure, **the physical and digital backbone of urban systems**, designed to dynamically adjust operations and configurations in response to changing conditions.

The solutions to move toward those adaptive cities are well-identified and infrastructure stakeholders can already focus on several key levers:

- **Acting on short-term levers.** Future-proofing infrastructure must start with ensuring the best practices are used today across systems to ensure their proper maintenance. Adopting a lifecycle approach is critical to secure the long-term reliability of infrastructure assets. Focusing on high-impact and ready-to-implement solutions is also a winner for cities: circular economy principles can deliver immediate and lasting value.

EXECUTIVE SUMMARY

- **Leveraging on innovative technologies** from smart infrastructure and services to data-driven governance. Urban innovations enable cities to anticipate and respond to emerging needs, rather than reacting to crises after they occur, encouraging the use of modular, multi-use infrastructure that can be repurposed as needs change, ensuring that investments remain relevant over time.

- **Adopting nature-based solutions.** Harnessing ecosystem services such as flood protection strengthens urban resilience while delivering long-term cost savings and social benefits. Sponge cities like Wuhan illustrate how nature-based strategies can already outperform traditional gray infrastructure in managing climate risks and enhancing livability.

- **Integrating infrastructure systems.** Cities can unlock long-term value by coupling sectors such as energy, transport, water, and digital networks, and by ensuring interoperability across systems. Overall, analysis of EU energy markets has shown that sector coupling could lead to a 60% decrease in emissions from the transport, building, and industry sectors by 2050—a 71% reduction relative to 1990 emission levels.

- **Investing in regulatory innovation.** Regulatory sandboxes, longer and more flexible models of public-private partnerships, smart procurement mechanisms (performance-based specifications, etc.), and faster approval of projects are all tools that can be deployed by cities.

To accelerate progress and **overcome the current "tragedy of the horizon"**—the tension between short-term political cycles and the long-term demands of infrastructure and climate adaptation —**strong governance and a long-term vision for urban infrastructure planning are indispensable.** Traditional approaches, rooted in predictability and functional efficiency, often fail to anticipate the ripple effects and cascading risks inherent in complex cities. Recognizing cities as Complex Adaptive Systems (CAS) enables planners and policymakers to adopt flexible strategies. Advances in analytical tools and adaptive planning methods are increasingly supporting this shift, helping urban systems navigate complexity while enhancing their capacity to respond to both immediate and long-term challenges.

The present report seeks to **provide actionable operational tools by offering three comprehensive playbooks tailored for cities, governments, and investors**, guiding them in strategic decision-making and effective implementation. These protocols are designed to reflect the distinct priorities and incentive structures of each stakeholder group while defining shared goals that foster alignment across them. Together, they provide a framework for building future-ready infrastructure that is adaptive and fit for the cities of tomorrow:

- **At the city level, strategies should be differentiated by urban typology to ensure targeted, effective interventions.** For instance, low-income cities could focus on strengthening local institutions and unlocking basic finance for infrastructure projects, while middle-income cities can prioritize multi-benefit projects such as integrated water-waste systems or green corridors. High-income cities may put the focus on streamlining permitting processes and overcoming NIMBYism through community engagement.

- **National governments hold the key to catalyzing urban transformation** by establishing long-term policy frameworks, mobilizing finance at scale, setting infrastructure standards, and investing in innovation while embedding inclusivity into urban policy. Possible measures for high-income countries include mandating minimum green performance standards and funding research of advanced technologies, while middle-income countries can enhance creditworthiness by developing flexible, long-term public-private partnerships and by strengthening municipal bond markets. In low-income contexts, governments can prioritize building foundational legal frameworks and securing international climate finance and direct to city priorities (grants, blended finance).

- **The financial community carries a special responsibility,** as investors are actors who can bridge the global infrastructure gap, enabling the financing needed to transform urban systems. With global infrastructure investment needs estimated at USD 94tn by 2040,[5] strategic investment is critical to ensure that projects are not only bankable but also aligned with long-term urban development goals.

In a time of rapid political and economic change, with elections approaching in major countries and regulatory uncertainty surrounding infrastructure, InfraVision serves as a unique platform connecting diverse infrastructure stakeholders—including operators and investors—with local authorities and international institutions such as such as the European Commission, the European Parliament, and the OECD. By fostering collaboration between industry leaders, researchers, policymakers, and investors, InfraVision enables the exchange of best practice and innovative solutions. This cross-sector network ensures knowledge flows seamlessly from local to European levels, supporting future-ready urban infrastructure.

5 - Global Infrastructure Hub, *Global Infrastructure Outlook*, 2017.

METHODOLOGY

A report combining academic expertise and business insights

The present report aims to provide stakeholders in the infrastructure market with a forward-looking approach to the future of cities and infrastructure. This study has been conducted with the sponsorship of Vauban IP and with the participation of Infravision corporate members and additional stakeholders, and in collaboration with Altermind, a consulting firm enhanced by insights from the international academic world.

Reflecting the DNA of both Vauban IP and Altermind, the report combines academic expertise with business insights, relying on the review of existing literature and the outcomes of a series of thematic events:

A **webinar** titled "Cities of Tomorrow: Reimagining Urban Infrastructure" featuring a discussion moderated by Laurene Mahon (Former Vice Chair, CIBC Capital Markets) on the urgency for infrastructure stakeholders to act now in order to build future-proofed cities; a presentation by Elisa Ferreira (Former EU Commissioner for Cohesion and Reforms) on the role of cities in driving competitiveness and cohesion in Europe; a contribution from Joanne Anderson (Former Mayor of Liverpool) on inclusive urban development and social impact in Liverpool; and insights from Andrew Karvonen (Professor of Urban Design and Planning, Lund University) on climate adaptation, energy transformation, and mobility innovation in cities.

A **breakfast panel** hosted at Vauban IP's offices, dedicated to exploring emerging solutions to upgrade and boost the development of urban infrastructure. Following an introductory keynote by Paulo Moura (Deputy Director at the Université Côte d'Azur IMREDD) on innovation and urban infrastructure, with a deep dive on autonomous vehicles, the discussion featured: Virginijus Sinkevičius (Member of the European Parliament), Carine Staropoli (Economist at the Paris School of Economics), Jérôme Stubler (CEO of Equans), Joyce Abou Moussa (Head of Organizational Performance at Groupe ADP), and Yves Lederer (President of Groupe Coriance). Moderation was delivered by Matthew Bishop (Former US Business Editor and New York Bureau Chief at The Economist), with opening and closing remarks by Gwenola Chambon (CEO and Founding Partner of Vauban Infrastructure Partners).

A **keynote speech** by Dario Nardella (Member of the European Parliament and former Mayor of Florence) entitled "Empowering Cities: the critical role of urban governance in shaping Europe's future", delivered during **Vauban IP Investors and CEOs Day**. He emphasized the urgency and opportunity of rethinking urban models, from climate resilience to territorial inclusion.

A series of three podcasts as part of a series titled "Cities of Tomorrow", hosted by Laurene Mahon, exploring the future of infrastructure and cities through three lenses:

Interdependence of infrastructure: the discussion highlights the complex and interconnected systems of urban infrastructure, with Antoine Tréboz (CEO at ALiS and ALBEA), Bergþóra Halldórsdóttir (Chief of Staff at Borealis Data Center) and Adam Abdin (Associate Professor at Centrale Supélec, University of Paris-Saclay).

Adaptive cities: the second episode explores the need for both resilience and agility in urban operating models with Fernando Lozano Ruiz (CEO at Metro de Malaga), Charles-Antoine Blanc (CFO at Paprec) and Timothy J. Dixon (Professor at the universities of Reading and Oxford). It covers technological and policy shifts shaping adaptive cities, including urban transportation and waste management.

Urban governance: the final episode focuses on new models for urban governance with Reuven Carlyle (Former Washington State Senator) and Cecilia Wong (Professor at University of Manchester), addressing challenges like ageing infrastructure, digitalization, and climate risks, and emphasizing the need for smarter and sustainable governance.

In 2025, **InfraVision also launched its inaugural competition, "The City as Network: Reimagining Urban Infrastructure"**, inviting students and recent graduates from around the world to propose innovative strategies for transforming urban systems into resilient and human-centered networks.

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Key takeaways

→ From the earliest clusters of human settlement in the Neolithic period, infrastructure has been more than a practical necessity: it has consistently been the “structuring power” behind the rise of cities, shaping not only the physical layout of urban areas but also their core functions

→ Cities are currently facing a convergence of challenges: demographic pressures (massive urbanization and population growth in the Global South, aging populations in the OECD), escalating climate risks, and widening inequalities and social divides (within and between countries)

→ Infrastructure is at the frontline of these interconnected challenges, which can cause failures in urban systems, with possible ripple effects on other systems, the costs of adaptation are lower than the costs of inaction, as the ‘price of standing still’ is prohibitive

→ The world needs to build roughly 50% of its future urban environment by 2050, which presents cities with a double-edged reality: pressure on resources and ecosystems, but also an opportunity to rethink how infrastructure is conceived, financed, and delivered

→ However, a fundamental temporal mismatch exists between the decades-long planning horizons needed for infrastructure and the shorter timeframes of political mandates (a ‘tragedy of the horizon’), requiring institutional adaptation and stakeholder engagement

→ Success requires concerted action from local officials, governments, NGOs, the private sector, and citizens and a commitment to ‘future-proofed’ infrastructure development

Cities under pressure: infrastructure at the frontline of compounding crises

Infrastructure and the making of cities: shaping space and society

THE ‘STRUCTURING POWER’ OF INFRASTRUCTURE IN CITIES

From the earliest clusters of human settlement in the Neolithic period, infrastructure has been more than a practical necessity—it has been the ‘structuring power’ behind the rise of cities.

Far from being a silent backdrop, infrastructure actively shaped the spatial layout and the social and economic practices of urban life. In the words of Michael Neuman, “as cities are crucibles that concentrate the human condition, infrastructures are conduits that enable that concentration and empower human achievement.”[6]

Uruk, around 4000 BCE, grew from a modest settlement into one of the first great cities by developing an intricate system of irrigation canals. These not only ensured agricultural surpluses but also allowed for population growth, occupational specialization, and the emergence of centralized governance.[7]

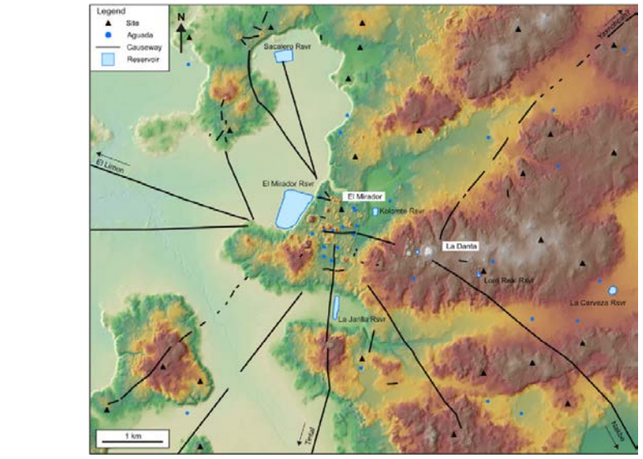
While pyramids like Calakmul in Campeche, Mexico, stand as iconic symbols of Maya architecture, it was their extensive road systems that formed the backbone of Maya civilization. In 2023, using LiDAR technology, researchers uncovered one of the earliest large-scale networks of highways between 417 ancient cities dating from around 1000 BC – 150 AD.[8] As part of the study, which extends from Guatemala’s northern Petén jungle to Mexico’s southern state of Campeche, researchers have also identified ball courts and hydraulic works, including reservoirs and dams.

Infrastructure has progressively consolidated this ‘structuring power’. The form cities take is largely determined by early infrastructure choices, which ripple through time and imprint on the skyline. The large spatial variations in built-up heights can be attributed to various factors such as land-use histories and policies, especially with regard to early infrastructure investments, zoning, building codes, and height restrictions. This is reflected in the global atlas of urban built-up heights developed by Zhou Y. and al. in 2022, which maps substantial spatial variation across continents.[9]

FIGURE 1

‘Super highways’ in Ancient Maya cities: representation of inter-urban networks[10]

Sources: Hansen R. et al., 2023 (top), Reuters (bottom)



INFRASTRUCTURE AND CITIES: A CONSTANT DIALOGUE

The structuring power of infrastructure does not imply rigidity. Rather, **infrastructure serves both as a canvas and a catalyst for urban life**, enabling the ongoing co-evolution of a city’s physical form and its social fabric. Infrastructure and urban activity exist in a continuous dialogue, each influencing and reshaping the other. Cultural trends, political priorities, and technological innovations drive infrastructure transformation, while these systems, in turn, shape the rhythms and patterns of everyday urban life.

This thesis is supported by the French urbanist Alain Bertaud, who sees cities not merely as groups of buildings or infrastructure, but as **living systems that are continuously shaped by human activity.** The essence of a city lies in the interactions between its inhabitants and their environment: the urban fabric is not static; it grows and transforms in response to the behavior of the people who inhabit it.[11]

EXPERT POSITION 1

Antoine Tréboz— Highways : the urban arteries enhancing city connectivity

“Highways are increasingly emerging as critical structuring elements within intermodal transportation systems, shaping how cities organize and facilitate mobility. In Madrid, for example, highways enable numerous coaches to converge efficiently in the city center and at railway stations, providing seamless transfers that significantly improve commuter accessibility. This illustrates how highways can function not merely as transit corridors but as integrative frameworks that connect multiple transport modes. A similar approach can be observed in France along the A10 motorway near Paris in the Essonne department, which embodies innovative and future-oriented mobility concepts. There, a purpose-built highway bus station is integrated with a large-scale car-sharing facility, offering high-quality coach services that directly link Paris with suburban railway stations. Such cases demonstrate how highways, when strategically designed and connected, can evolve beyond their traditional role of facilitating long-distance traffic to become pivotal enablers of intermodal connectivity and sustainable mobility futures”

Antoine Tréboz
CEO of ALiS and ALBEA

FOCUS 1

Urban form and infrastructure: a global atlas of variations in urban built-up heights

Global data on urban built-up heights is essential for assessing how urban form and infrastructure influence the environment, the economy, and human well-being. In 2022, a study presented a worldwide atlas of urban built-up heights, revealing substantial spatial variation across continents, countries, and cities. The atlas helps better understand the effects of urbanization on raw material demand, embodied and operational energy use, and urban development intensity.[12]

Overall, urban areas are dominated by low density and expansive development with low urban built-up heights—building heights peaking in the core and tapering off toward the periphery. Yet, built-up heights show large spatial variations across cities and regions: (i) cities with high levels of verticality are predominantly located in East Asia and Western Europe; (ii) China and the US have the largest total urban extents, but their skylines differ—China's average built-up height is twice that of the US (Figure 2).

6 - Neuman M., *Infrastructure is key to make cities sustainable*, Sustainability, 12(20), 2020.

7 - Algaze, G., *The End of Prehistory and The Uruk Period*, in: The Sumerian World, edited by Crawford, H., Routledge, 2013; Algaze, G., *Ancient Mesopotamia at the Dawn of Civilization: The Evolution of an Urban Landscape*, University of Chicago Press, 2008; Wittfogel, K.A., *Oriental Despotism: A Comparative Study of Total Power*, Yale University Press, 1957; Selz, G.J., The Uruk Phenomenon, in: The Oxford History of the Ancient Near East: Volume I: From the Beginnings to Old Kingdom Egypt and the Dynasty of Akkad, edited by Radner K. et al., Oxford University Press, 2020.

8- Hansen, R. D., Morales-Aguilar, C., Thompson, J., Ensley, R., Hernández, E., Schreiner, T., Suyuc-Ley, E., & Martínez, G., *LiDAR analyses in the contiguous Mirador-Calakmul Karst Basin, Guatemala: An introduction to new perspectives on regional Early Maya socioeconomic and political organization*, Ancient Mesoamerica, 34(3), 2023.

9 - Zhou Y. et al., *Satellite mapping of urban built-up heights reveals extreme infrastructure gaps and inequalities in the Global South*, Proceedings of the National Academy of Sciences, 119(46), 2022.

10- Hansen, R. D., Morales-Aguilar, C., Thompson, J., Ensley, R., Hernández, E., Schreiner, T., Suyuc-Ley, E., & Martínez, G., *LiDAR analyses in the contiguous Mirador-Calakmul Karst Basin, Guatemala: An introduction to new perspectives on regional Early Maya socioeconomic and political organization*, Ancient Mesoamerica, 34(3), 2023; Reuters, *Ancient Maya cities, 'super highways' revealed in latest survey*, 2023.

11 - Bertaud, A., *Order without design, Order without Design: How Markets Shape Cities*, The MIT Press, 2024

12 & 13 - Zhou Y. et al., *Satellite mapping of urban built-up heights reveals extreme infrastructure gaps and inequalities in the Global South*, Proceedings of the National Academy of Sciences, 119(46), 2022.

FIGURE 2

Global urban built-up heights derived from satellite observations[13]

Source: Zhou Y. et al., 2022

Some cities—such as Cape Town, South Africa, and New Delhi, India—feature multiple urban centers, each marked by its own peak in built-up height. In certain cities, such as New Delhi, where building height is limited by policy, both density and overall building heights tend to be low. Some expansive, low-rise cities—like Atlanta, Georgia, in the US—contain high-rise buildings in their urban cores, though these make up only a small share of the total building stock. Other cities, including Seoul in the Republic of Korea (South Korea) and several European cities such as Munich, Germany, have extensive areas of tall buildings located outside their primary urban centers.

Based on the patterns observed, Zhou et al. have classified cities into six distinct categories:

Sparse and homogeneously low: known for its sprawling suburbs and low-density development, Atlanta relies on highway networks for connection, contributing to its car-dependent culture.

Dense and homogeneously low: a planned city with a grid layout, Belo Horizonte features higher population density in its central areas with predominantly low-rise buildings, while balancing urban growth with its original human-scaled design.

Sparse and heterogeneously low: new Delhi combines planned low-density sectors with densely packed residential areas, showcasing a complex urban form where monumental government buildings contrast with historical low-rise zones.

Dense and heterogeneously low: Cape Town's high-density development is characterized by a mix of low-rise buildings that reflect both its colonial architecture and recent urban growth.

Sparse and homogeneously high: Seoul's low-density development is punctuated by uniformly tall, modern buildings, a testament to its economic growth and transformation from a war-torn city into a global economic powerhouse.

Dense and homogeneously high: one of the largest cities in the world, Mexico City has a skyline dominated by uniformly tall buildings that house its dense population, reflecting both its rapid urbanization and the challenges of managing growth in a megacity.

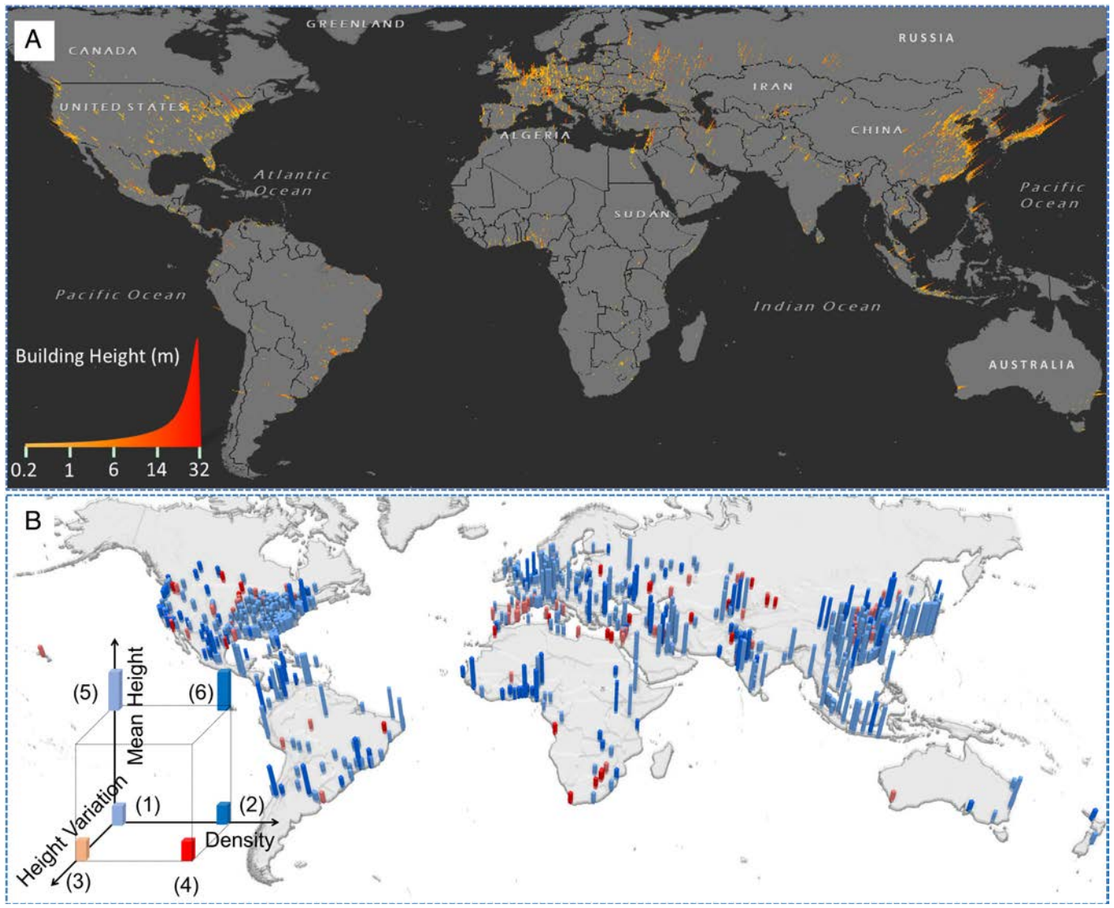
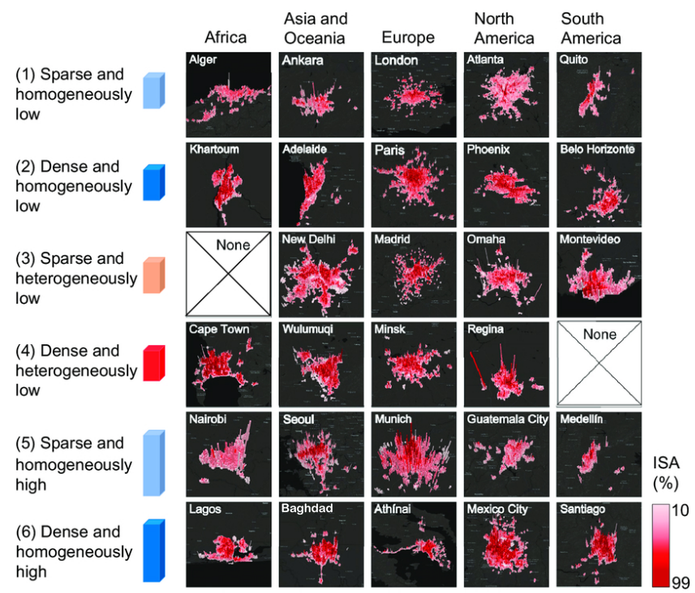


FIGURE 3

A 3D view of representative cities for the six types of urban forms

Source: Zhou Y. et al., 2022



COMPLEX AND UNPREDICTABLE SYSTEMS

The flip side of cities' constantly evolving nature is that **they become increasingly complex**, as infrastructure interacts with social activities and economic flows in dynamic and often unpredictable ways. The interdependence of urban systems is a defining feature of this complexity, producing both benefits and drawbacks depending on perspective:

Cities consume resources and have multiple impacts **through infrastructure systems that operate across multiple scales and timeframes**, creating complex feedback loops where solutions in one area can generate unintended consequences elsewhere. Upgrading stormwater infrastructure may improve flood resilience in one area but create vulnerabilities elsewhere, increasing long-term flood risk and damaging riverine ecosystems.[14]

Cities are also **interconnected global nodes requiring increasingly specialized infrastructure** to support diverse economic activities. Edward Glaeser in Triumph of the City shows how urban density enables knowledge spillovers between different sectors, creating economic complexity where a financial district, research universities, creative industries, and manufacturing can all interact through shared infrastructure systems.[15]

Efforts to make cities more sustainable sometimes struggle with these dynamics: we expect our cities to be engines of opportunity as well as places of belonging. Yet, we also demand that they are clean, sustainable, equitable, and resilient—demands that are often in tension—which require infrastructure that can adapt as quickly as the societies it serves. Cities must not only provide the scaffolding for daily life: they must anticipate futures that are uncertain and often contradictory.

EXPERT POSITION 2

Joyce Abou Moussa—Airports as circular nodes in the urban nervous system

"Urban infrastructure is the backbone of cities, but increasingly it is also becoming its nervous system: complex, connected and intelligent and constantly responding to change. Airports are a clear reflection of this evolution. We believe that airports are no longer isolated gateways or fixed assets, but integrated ecosystems and adaptive platforms acting as energy hubs, multimodal nodes, and urban laboratories supporting innovation. At Groupe ADP, where we operate more than 20 airports worldwide, we are witnessing this shift that has been driven by the convergence of digital infrastructure, energy systems and mobility networks. Our airports are becoming multimodal transport hubs, energy generators and platforms for data-driven decision-making, with a clear intent to move away from expanding infrastructure toward optimizing and upgrading it through smarter and more sustainable means. With travel demand rising, airports have a central role to play in decarbonizing its infrastructures and operations, not just in enabling this transition but in accelerating it. From Orly 2035 to CDG 2050, we are actively working on deploying this new model"

Joyce Abou Moussa, Head of Organizational Performance at Groupe ADP

Tackling the compounding and interconnected challenges of the 21st century

AN INEVITABLE BREAKDOWN OF URBAN METABOLISM?

Today's urban challenges are deeply interconnected, creating a complex web of mutually reinforcing pressures: climate change intensifies strain on energy infrastructure, precisely as escalating consumption heightens the urgency for decarbonization; rapid population growth and widening inequalities exacerbate deficits in housing, water, and transportation, disproportionately exposing vulnerable populations; meanwhile, aging demographics reshape demand patterns, further burdening fragile urban systems already stretched to their limits. The culmination of these individual system failures may lead to the so-called "**breakdown of the urban metabolism**": the failure of one system is not an isolated event but a catalyst for the failure of others.

URBAN DEMOGRAPHY: THE 'ELEPHANT IN THE ROOM'

Urbanization has been and will remain one of the most powerful mega-trends of the 21st century. While a potent engine for economic growth and innovation, the rising size of cities in terms of demography and spatial spread simultaneously intensifies critical challenges such as environmental degradation and infrastructure vulnerability.

Over the next three decades, **cities will have not only to accommodate their current populations but also absorb all net global population growth.**

Urban population growth has accelerated over the past 20-30 years and this trend is expected to intensify in the coming decades between 2018 and 2050, the urban population will rise by 2.5bn persons, from 4.2bn to 6.7bn—with 90% of this growth concentrated in Asia and Africa[16]—while the total world population will grow more slowly (from 7.6bn in 2018 to 9.8bn in 2050).[17] Overall, according to the UN, 55% of the world's population lived in cities in 2018, a figure projected to rise to 68% by 2050.[18] The world's urban land cover will soon have nearly doubled from 652,825 km² in 2000 to 1,210,475 km² by 2030.[19]

The scale of this demographic transition places **immense strain on existing infrastructure systems:**

Cities across the Global South are facing mounting challenges as **population growth often outpaces infrastructure development**, leading to persistent gaps in transport, energy, water, sanitation, and communication services.[21] These deficiencies fuel public health crises, environmental decline, and missed economic opportunities, reinforcing cycles of poverty and underdevelopment;

In most OECD countries, where population growth is slower, cities face distinct demographic pressures, such as **aging—and sometimes declining—populations and the rise of single-person households.**[22] In the UK alone, the number of people aged 65 and older is projected to rise dramatically—from 11.6m in 2015 to 19.4m by 2050—accounting for over 60% of the nation's total population growth during this period.[23] In the metropolitan and surrounding areas of 29 OECD countries, the share of people over 65 is projected to rise from about 20.9% in 2020 to 27.9% by 2040.[24] At the same time, in many regions across OECD countries, especially in smaller cities or towns, population is projected to decline, with some regions expected to lose 20% or more of their population by 2050.[25] This evolving demographic landscape shapes the demands placed on urban infrastructure. Older people require greater investment in healthcare, social services, and age-friendly public spaces, while some infrastructure—such as urban transit systems—needs to be rethought to improve accessibility. They generally live in smaller households, a trend reflected in the UK's declining average household size—from 2.35 persons in 2014 to an estimated 2.21 by 2039—which drives higher per-capita demand for energy and water.[26]

One of the defining aspects of accelerating urban population growth is the rise of megacities—urban agglomerations exceeding 10m inhabitants—which are growing globally and bringing their own challenges of density, congestion, and

FIGURE 4

Average annual rate of population change, 2024-2054[20]

Source: UNFPA

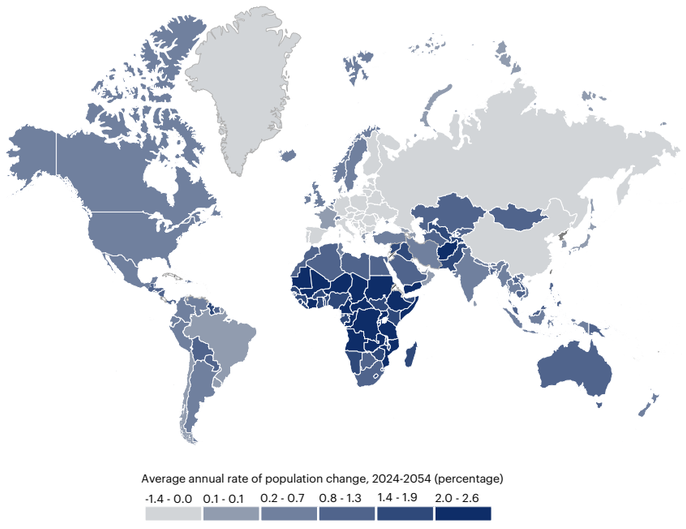


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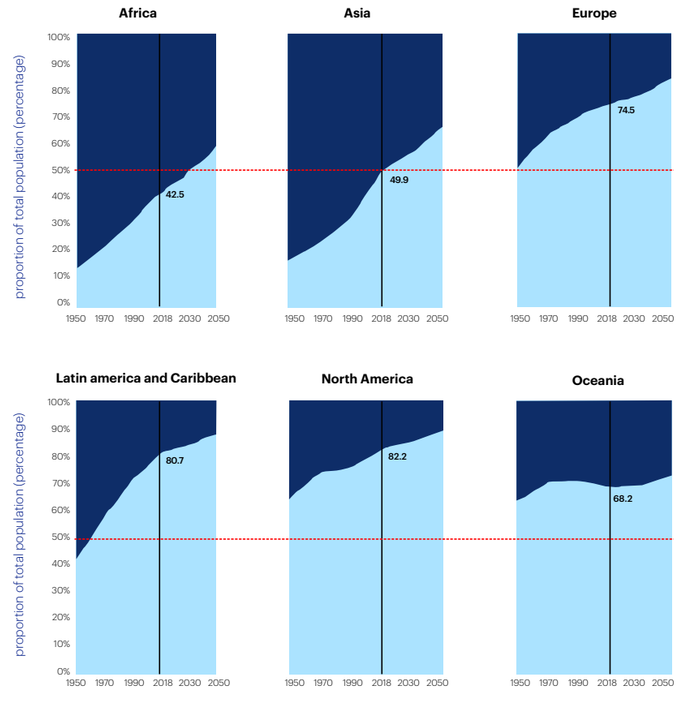
FIGURE 5

Urban and rural population as proportion of total population, by geographic region, 1950-2050[27]

Source: United Nations, 2018



infrastructure strain. The number of megacities is projected to climb from 33 in 2018 to 43 by 2030, with the largest concentrations in China and a rapidly emerging cohort in Africa, including Luanda, Dar es Salaam, and Kinshasa.[28] Pressure will be particularly acute on securing reliable and sustainable energy, as escalating demand is set to far outpace the capacity of renewables alone, underscoring the urgent need for diversified and resilient energy systems to sustain their growth.

WASTE ACCUMULATION: LEAVING THE LINEAR MODEL BEHIND

As urbanization continues to accelerate, the challenge becomes both more critical and more complex: rapidly growing populations will intensify demands on materials, infrastructure, and ecosystems. Cities already account for around **75% of global resource consumption**, up to 80% of energy use and 70% of carbon emissions.[29]

Without investment in circular infrastructure, cities risk locking themselves into unsustainable patterns of material management, while missing out on the economic and social opportunities of a circular transition. According to the International Resource Panel (IRP), if current trends continue, urban material consumption is projected to rise from 40bn tonnes in 2010 to nearly 90bn tonnes by 2050.[30]

CLIMATE CHANGE: A THREAT MULTIPLIER FOR ALL

Climate change acts as a powerful external shock and stressor that exacerbates the inherent complexity of urban systems. The existing urban built environment, which is responsible for approx. **60-70% of carbon emissions**,[31] was largely not designed to withstand climate change impacts, and its aging infrastructure is vulnerable to extreme weather events that are becoming more frequent and intense.

The figures tell a clear story. The number of natural disasters worldwide has risen sharply over recent decades, with more than 9,400 extreme events recorded since 1993, causing more than 765,000 deaths and close to USD 4.2tn in losses (inflation-adjusted).[32] Today, nearly 60% of cities with at least 300,000 inhabitants are already at high risk of exposure to at least one type of natural disaster, including extreme heat (Paris recorded a high temperature of 46°C in 2019), cyclones, droughts, floods, earthquakes, landslides, and volcanic eruptions.[33]

Looking ahead, **exposure will worsen:**

- C40 projects that the number of cities facing extreme heat will nearly triple by 2050, putting 1.6bn urban residents at risk,[34]
- Over 2bn city dwellers could face an additional temperature increase of at least 0.5°C by 2040,[35]
- Global mean sea level is projected to rise roughly 0.28-0.55 m (low emissions) to 0.63-1.01 m (very high emissions) by 2100 (relative to 1995-2014), driving far more frequent coastal extreme water levels that overwhelm today's defenses.[36] Cities experiencing rapid land subsidence, such as Jakarta, are particularly at risk: the Indonesian metropolis is sinking at an estimated average rate of 6 centimeters per year.[37]

Vulnerable populations (low-income groups, informal settlements) will be disproportionately exposed: in cities like Mumbai, informal housing in flood-prone zones is most at risk from sea-level rise.[38]

The impact of climate change extends well beyond acute disaster events to encompass **chronic stresses that gradually degrade infrastructure performance and reliability**. The interconnected nature of infrastructure systems means that those climate impacts can cascade across multiple sectors. Power outages during extreme heat events can compromise water treatment and distribution systems, while transportation disruptions can impede emergency response and infrastructure maintenance (see section #4).

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FIGURE 6

Cities' risk of exposure to natural disasters[39]

Source: United Nations, 2018

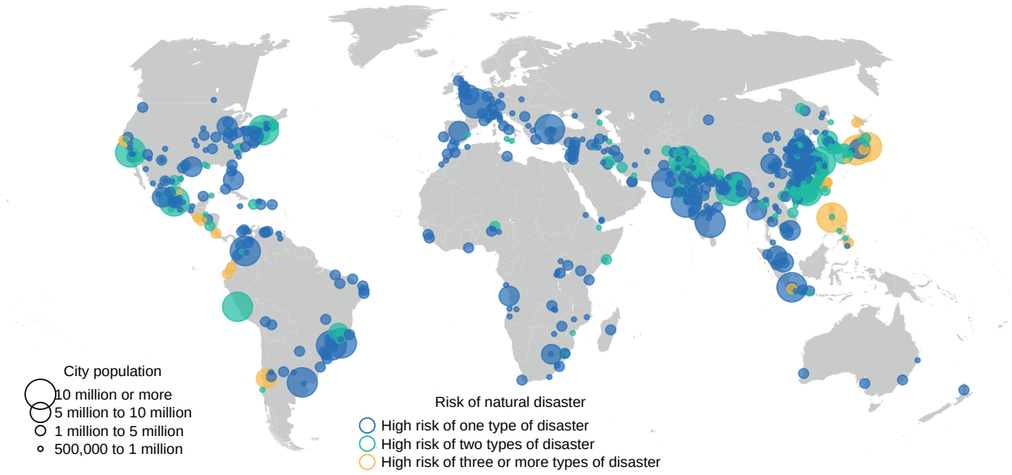
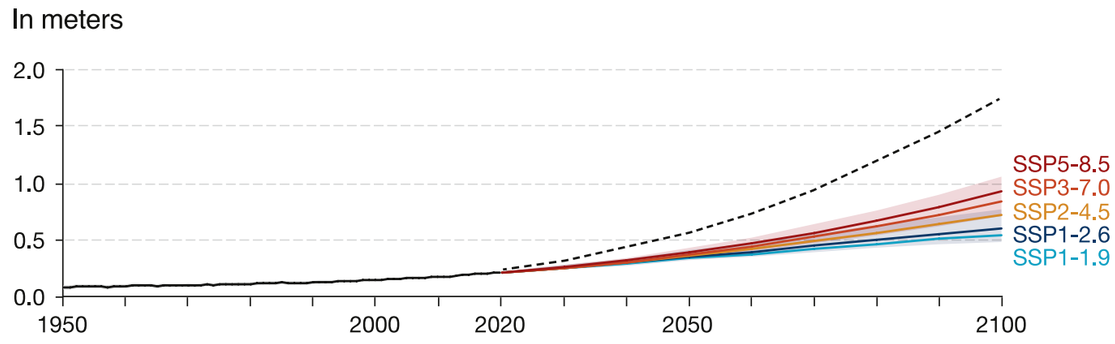


FIGURE 7

Sea level evolution according to IPCC scenarios (projected mean seal level rise relative to 1900), in meters[40]



Note: Solid lines show median projections. Shaded areas show probable ranges for SSP1-2.6 and SSP3-7.0. The dotted line (83rd percentile) indicates a max., albeit low-probability, impact of the SSP5-8.5 scenario on sea levels.

Source: IPCC, 2021

ENSURING ACCESS TO WATER: ADDRESSING ESCALATING PRESSURES

Urban water security is increasingly threatened by climate change, rapid urbanization, and aging infrastructure. Currently, roughly half of the world's population experiences severe water scarcity throughout the year,[41] while 2.2bn people lack access to safely managed drinking water.[42] In urban areas, progress has barely kept pace with population growth. By 2050, the number of people living in urban areas and experiencing water scarcity worldwide is expected to increase significantly, rising from 930m in 2016 to between 1.7bn and 2.4bn.[43]

RISING GAPS IN TERMS OF INFRASTRUCTURE QUALITY AND ACCESS

Urban poverty is concentrated where infrastructure is the weakest. Yet, access and quality of essential infrastructure and services continue to fall short globally, and the most vulnerable communities face the highest risk from infrastructure failures, as urban poverty increasingly concentrates in the most exposed areas. In 2017, less than half of the global population had access to essential healthcare services, 2.2bn people lacked safely managed drinking water, while 4.2bn lacked safely managed sanitation.[45]

Urban slum dwellers represent the most extreme manifestation of infrastructure-related inequality. The majority of slum dwellers are concentrated in three regions: eastern and south-eastern Asia (332m), central and southern Asia (197m), and sub-Saharan Africa (189m).[46] Despite improvements in some regions, the absolute number of people living in slums increased from 807m to 883m between 2000 and 2014, as new home construction and infrastructure development lagged far behind urban population growth. This increase occurred even as the proportion of urban populations living in slums declined from 28.4% to 22.8%, indicating that infrastructure development, while improving in relative terms, has failed to keep pace with the absolute growth in urban populations.[47]

Disparities are also marked in terms of infrastructure access and quality in high-income countries, although these may be less visible than conditions in low-income countries. For instance, in New York City, disparities in essential infrastructure can be seen both in healthcare and digital access.

Queens, New York, has only 1.65 hospital beds per 1,000 residents, compared to 5.7 per 1,000 in Manhattan.[49] This imbalance is partly the result of more than 40 hospital closures in New York State since 2000, which have eliminated 21,000 hospital beds statewide.[50]

Similar inequalities are found in broadband internet access: in 2023, 36.7% of households in the Bronx lacked a broadband subscription—far higher than in other boroughs.[51] Affordability worsens the divide: in the Bronx and in Brooklyn, the average price for broadband as a share of median household income is over 40% of the average cost of electricity for households.[52]

FIGURE 8

Decline of fresh water in the 2050s[44]

Source: IPCC, 2014

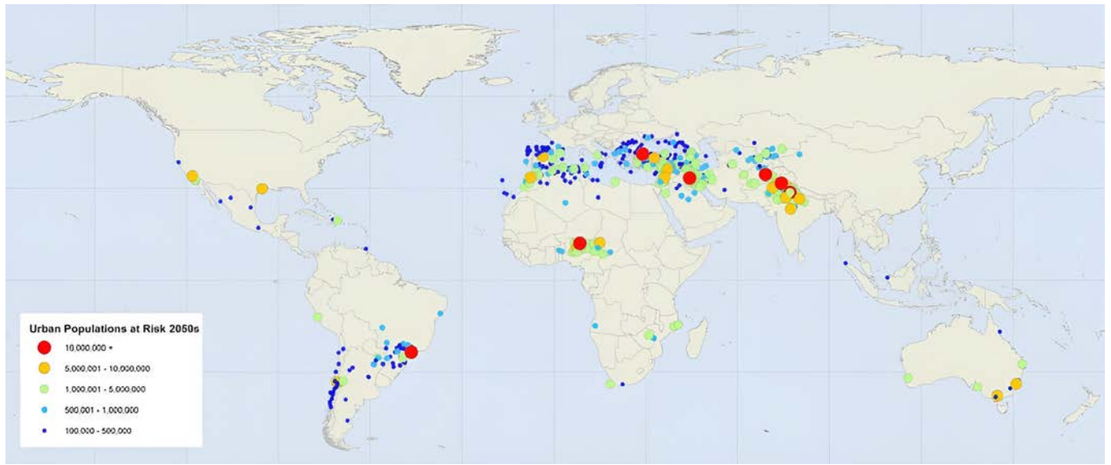


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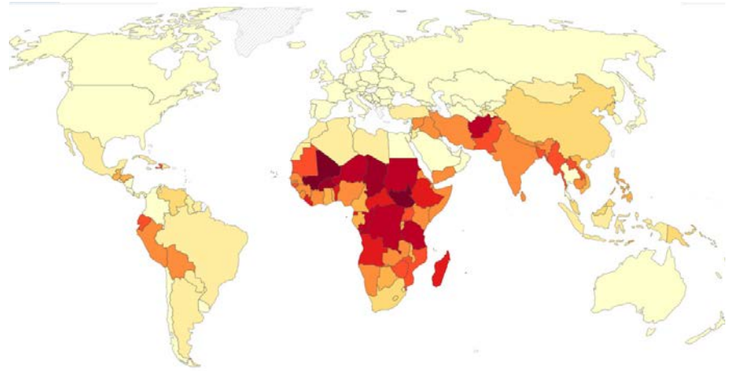
FIGURE 9

Share of the urban population living in slums, 2022[48]

Source: Our World in Data, 2024



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CASE STUDY 1

Embedding inclusion in urban transit expansion: the Málaga Metro example

The Metro de Málaga is a light rapid transit system serving the Andalusian city of Málaga, Spain. Opened in 2014, it plays a central role in improving connectivity between key urban districts, relieving road congestion, and offering residents a reliable alternative to car travel. Its network continues to expand in phases, with current projects aimed at deepening integration across the metropolitan area.

The extension of Málaga Metro Line 2 involves construction works and infrastructure spanning 1.8 km of underground track between Guadalmedina and Hospital Civil.[53] It includes the development of three new underground stations, enhancing access and connectivity within the city. This physical extension is necessary to ensure a continuity in the supply of transport services: the extension is expected to enable an additional 4.7m journeys across Málaga's metro network each year.[54] The extension enhances the metro's appeal by improving accessibility and reducing reliance on private vehicles, facilitating a modal shift toward public transit.

"In 2023, Metro de Málaga inaugurated its long-awaited city center extension, a two-kilometer addition that expanded the system by 20% and significantly transformed urban mobility. The extension immediately doubled ridership, demonstrating the impact of strategic investment in accessibility, integration, and affordability. All new and existing stations are 100% accessible, ensuring that people with reduced mobility, parents with strollers, and elderly passengers can navigate the network with ease. The extension also reinforced Málaga's integrated mobility ecosystem. Seamless interchanges between lines, connections with commuter trains, bike-sharing services, and e-scooter networks allow passengers to move across the city without barriers between modes. Affordability has been another cornerstone of success. Through fare discounts and competitive pricing strategies, the metro offers a cost-effective alternative to driving. Combined with faster travel times into the city center, the metro has become the logical choice for thousands of residents and visitors alike."

Fernando Lozano Ruiz,
CEO of Metro de Málaga.

A CALL TO ACTION: FUTURE-PROOFING URBAN INFRASTRUCTURE

Reimagining how cities design, build, transform and operate infrastructure

'THE PRICE OF STANDING STILL': QUANTIFYING THE COSTS OF INACTION

As cities face unprecedented challenges, the need for action is urgent, as the 'price of standing still' is prohibitive. In 2016, the World Bank estimated that without adaptive measures, damages from climate-related disasters could cost cities up to USD 314bn annually by 2030.[55] In India, urban flooding already causes USD 4bn in damages annually, projected to rise to up to USD 30bn by 2070 without intervention.[56]

Traffic congestion offers a particularly revealing illustration of the compounding costs of inaction. In Manila, the economic cost of traffic congestion has been estimated at approximately USD 57m per day in lost potential income. Projections indicate that, without intervention, this figure could rise to USD 142m per day by 2030.[57] Comparable challenges are evident elsewhere: in São Paulo, traffic congestion is estimated to impose an annual burden of USD 17.8bn, stemming from reduced productivity, increased fuel consumption, and the negative health impacts of vehicle emissions.[58] Karachi loses an estimated USD 688m annually (around 2% of national revenue) to congestion[59] and in the US, traffic congestion represented a productivity drain and cost over USD 88bn in 2019.[60]

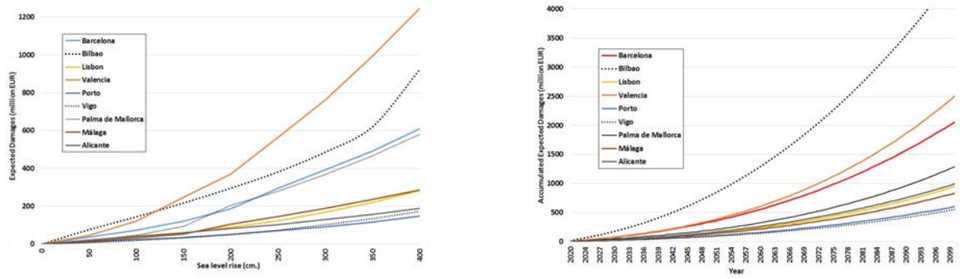
Climate is also a case in point. A study led by Abadie, Sainz de Murieta, Galarraga in 2020 estimates potential economic damage from 2020 to 2100 in 62 Iberian coastal cities (Spain and Portugal) due to regional sea-level rise.[61] Overall, accumulated average damage exceed EUR 1.7bn in 2030. Both the sea-level rise percentiles and the damage grow rapidly overtime, particularly in the second part of the century. Figure 10 illustrates the annual damage depending on local sea-level rise in nine of the cities analyzed: Bilbao, Valencia and Barcelona are the coastal cities with the largest expected accumulated damage in the case of inaction.

A key takeaway from this analysis is that, in the long run, **the costs of adaptation are significantly lower than the rising expenses associated with inaction.** The result is that investing in adaptation becomes a strategic necessity when evaluating the costs and benefits of potential actions. It is therefore essential to thoroughly assess the full probability distributions of sea-level rise and the resulting economic damages across cities, emission scenarios, and timeframes. Failing to account for these factors could lead to investment choices that underestimate future risks and are unable to adequately address them.

FIGURE 10

Damage curves for nine cities (left) / Accumulated expected damage in nine cities (right)[62]

Source: Abadie L. et al., 2020



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THE CHALLENGE OF TRANSFORMING AGING INFRASTRUCTURE

Much of the world's urban infrastructure, built during the mid-20th century, struggles to meet modern demands. A large part of existing infrastructure was built between the 1950s and 1980s and is now nearing the end of its of its lifespan, which is often 50 to 80 years (Figure 11) . In emerging economies, construction quality and durability varies and service life can be shorter[63]: for instance, in China, infrastructure built before the 2000s has average service lives ranging from just 10-20 years for marine ports (prior to major upgrades) to 30-40 years for civil structures.[64]

Overall, **the potential for improvement is huge:** in the US only, the American Society of Civil Engineers gives an overall grade of C- for urban infrastructure, noting that deferred maintenance and piecemeal investments cost USD 160bn annually (due to delays, inefficiencies, and safety risks associated with deteriorating systems).[66]

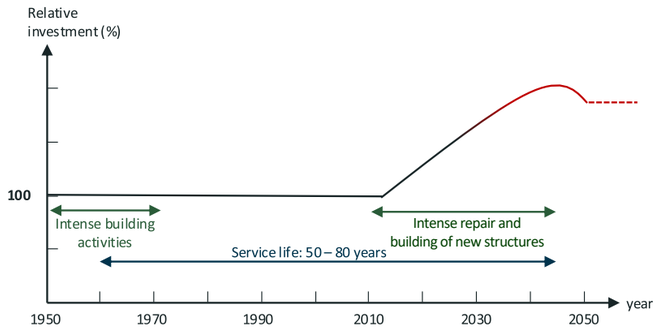
Transforming existing infrastructure still remains a complex endeavor, as it requires navigating physical, institutional, and financial constraints that can significantly hinder progress:

- Upgrades must often occur while systems remain in use, in many cases in dense urban settings with limited room to maneuver. In Tokyo, which has one of the world's busiest rail systems, the renovation of the Ginza Line happened at night in short windows to avoid disruption.[67]
- Infrastructure networks are tightly linked: modifying one can disrupt others, increasing complexity and risk. The development of the Guangzhou Smart City project took into account the impact on interconnected systems, such as power grids, communication networks, and municipal sewage and waste management.[68]
- Many assets were not built to modern standards, and poor documentation hinders effective planning. In the state of New York, in 2008, aging wastewater infrastructure systems were failing, necessitating USD 36.2bn in upgrades over 20 years.[69]

FIGURE 11

Stages in the building lifecycle: many structures are approaching the end of their lives[65]

Source: Van Breugel K., 2017



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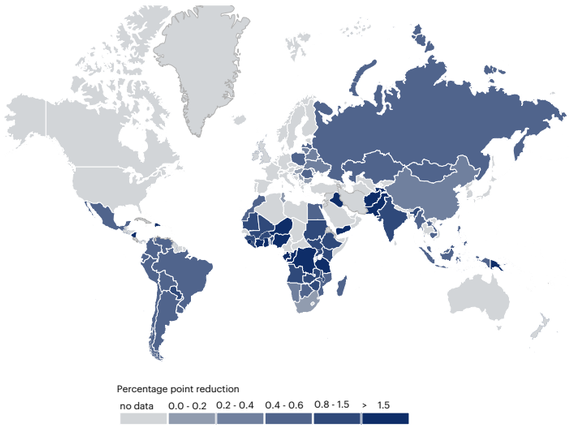
75 - IEA, *Electricity Grids and secure energy transitions*, 2023.

FIGURE 12

Countrywide average utilization rate losses from disruptions in electricity, water, and transport infrastructure[70]

Source: Van World Bank, 2019



- Siloed responsibilities, poor planning and project mismanagement, outdated codes, and slow approvals can delay or derail transformation efforts. The Navi Mumbai Metro project suffered years of delays and cost overruns, with dysfunctional governance and contract mismanagement cited as major factors for the extended timeline and ballooning expenses.[71]
- Retrofits are capital-intensive and harder to finance, with long timelines and often unclear value capture. The San Francisco-Oakland Bay Bridge rehabilitation was a decade-long, partial replacement project that significantly improved earthquake resilience through extensive structural modifications, all while maintaining traffic flow. Ultimately, the project cost USD 6.5bn—far exceeding the initial USD 250m estimate—and overcame major technical, financial, and regulatory challenges.[72]

NEW INFRASTRUCTURE: NAVIGATING THE CHALLENGE, SEIZING THE OPPORTUNITIES

Demand for infrastructure is expected to rise as approximately **50% of the urban environment needed by 2050 is not yet built:** urban land is estimated to grow to between 1.1m and 3.6m km² by 2100, representing roughly 1.8 to 5.9 times the global total urban area occupied in the year 2000 (0.6m km²).[73]

This scale of expansion presents cities with a double-edged reality: immense pressure on resources and ecosystems, but also an unparalleled opportunity to **rethink how infrastructure is conceived, financed, and delivered.** Cities in emerging markets have the potential to attract USD 29.4tn cumulatively by 2030 in investments for climate-resilient urban infrastructure.[74] Yet, traditional approaches are capital-intensive, and often fail to anticipate the stresses of demographic growth and rapid technological shifts. Left unchecked, new urban expansion could exacerbate congestion and vulnerability to shocks such as floods, heatwaves, or supply chain disruptions.

FOCUS 2

The aging of electricity grids: safety and reliability risks

Electricity grids around the world are aging, with many infrastructure assets in advanced economies having been in operation for over 20 years, and in some cases more than 50 years. This aging is due to factors such as the long lifespan of expensive equipment like transformers and transmission lines, but also because maintenance can be delayed or insufficient. As equipment ages, it becomes more vulnerable to failures, which can cause power outages and safety hazards.

Older grid assets, such as transformers and circuit breakers, can suffer from wear and tear due to weather, mechanical stress, and overloading beyond their designed capacity. This leads to a higher risk of faults, short circuits, or fires, as well as reduced reliability of protective devices. Moreover, maintaining these aging assets is more costly and complex, especially as spare parts become scarce and specialized skills are needed.

While digital components in grids have shorter lifespans, they are updated more frequently, allowing for better monitoring and preventive maintenance. Newer technologies help assess the health of equipment in real time, supporting more efficient management of aging assets. Nevertheless, the challenge remains to modernize aging infrastructure to ensure reliability, as well as the integration of new energy sources.[75]

Infrastructure stakeholders moving forward to overcome 'the tragedy of the horizon'

A SHARED AMBITION: FUTURE-PROOF EXISTING INFRASTRUCTURE AND INFRASTRUCTURE TO COME

In response to the urgent call for action, a wide range of infrastructure stakeholders—from policymakers and industry leaders to operators, citizens, urban planners, and investors—have mobilized to apply and strengthen best practices, and ultimately transform and future-proof existing infrastructure. A series of initiatives are emerging to redesign cities around resilience and sustainability, positioning governance as a critical lever:

International frameworks: the UN New Urban Agenda, the OECD Urban Policy Reviews, and the World Bank's City Resilience Program have established global standards and mobilize development finance for sustainable urban infrastructure.

Grassroots and civil society: organizations like the Slum Dwellers International represent a global network of community-based organizations in over 30 countries, advocating for inclusive infrastructure that serves informal settlements.

City-led networks: Eurocities (Focus 3), Alliance for a Sustainable Future (formed by the United States Conference of Mayors and the Center for Climate and Energy Solutions); C40 Cities (nearly 100 megacities), and ICLEI—Local Governments for Sustainability (2500+ local governments) facilitate peer-to-peer learning and coordinate municipal action.

Regional programs: the EU has established a comprehensive toolkit including InvestEU that mobilizes private capital for sustainable infrastructure; the Cohesion Fund and European Regional Development Fund support transport, environment, and integrated urban projects; and the Connecting Europe Facility finances key energy, digital, and transport networks.
The European Investment Bank complements these instruments as the EU's main lender for urban mobility, energy efficiency, water, and social infrastructure. In parallel, the EU Mission on 100 Climate-Neutral and Smart Cities by 2030 addresses an estimated EUR 650bn in investment needs for pioneering cities, while Horizon Europe funds innovation and the LIFE Programme drives climate and environmental action.
By combining these mechanisms, the EU aims not only to reduce the investment gap but also to accelerate the transformation of European cities into greener, more connected, and more resilient places to live.[76]

National programs: India's Smart Cities Mission (100 cities)[77], and the US Infrastructure Investment and Jobs Act (USD 1.2tn)[78] represent major government commitments to urban transformation.
In the UK, 'Investment Zones' have been implemented in areas (Liverpool, Manchester, etc.) where central and local government will work with business and local partners to create the conditions for investment and innovation (not only for infrastructure) including tax reliefs, planning mechanisms and innovation, skills and business support.[79]

MAYORS: THE DRIVING FORCE BEHIND CHANGE

As cities prepare for the demographic, economic, and environmental challenges of 2050, mayors emerge as the most influential actors shaping their future. Unlike national leaders, mayors operate at the scale where policy directly meets people's daily lives. Their proximity to communities makes them uniquely positioned to translate global ambitions—such as climate targets and sustainable growth—into tangible local solutions.

INVESTING TO 'BUILD FORWARD BETTER': SHORT-TERM ROI AND LONG-TERM IMPACT

Whether it is in funding new projects to improve transport links, mobility, connectivity and supply chain logistics, or in updating aging systems to address similar needs, significant long-term planning and **massive investiment are required to help cities evolve to meet the needs of the future.**

According to the World Bank, capital investment needs to achieve resilient and low-carbon cities represent (i) 0.8-2.5% of GDP for upper-middle-income countries (UMICs); (ii) 0.9-2.6% of GDP in lower-middle-income countries (LMICs); and (iii) 2.5-8.4% of GDP for low-and-middle-income countries (LICs).[83] In other words, the amounts required are considerably higher in absolute terms in the rich world than in the low and middle income countries, but considerably higher in relative terms in low and middle income countries.

A study by Hallegatte et al. shows that in low- and middle-income countries, strengthening infrastructure would add USD 11bn to 65bn per year to investment needs in power, transport, and water and sanitation, which represents 3% of baseline infrastructure investment needs. However, across 3,000 scenarios, strengthening infrastructure consistently delivers strong returns: the benefit-cost ratio exceeds one in 96% of cases, two in 77% of them. The lifetime net present value surpasses USD 2tn in 75% of scenarios and USD 4.2tn in half.[84]

76 - Calipel C. et al., *The State of Europe's Climate Investment*, Institute for climate economics, 2025; Andersson M. et al., Green investment needs in the EU and their funding, 2025; Bouabdallah O. et al., *Mind the gap: Europe's strategic investment needs and how to support them*, 2024; D'Amato A. et al., *Investment needs and gaps for the sustainability transition in Europe: Rethinking the European Green Deal as an EU industrial strategy*, 2024; Abnett K., Jessop S., *EU backs EUR 650bn plan to help cities reach net zero by 2030*, 2024.

77 - UN Habitat, *Smart Cities Mission, India: Localizing Sustainable Development Goals*, 2023.

78 - US Department of the Treasury, *Infrastructure Investment in the United States*, 2023. 79 -

79 - UK Government, *Guidance: Investment Zones in England*, 2024.

80 - Eurocities, *Site.*

81 - European Commission, *The Urban Agenda for the EU.*

82 - European Commission, *Urban Agenda for the EU: Pact of Amsterdam*, 2016.84 -

83 - World Bank, *Banking on Cities: Investing in Resilient and Low-Carbon Urbanization*, June 2025.

84 - Hallegatte S. et al., *Strengthening new infrastructure assets: A cost-benefit analysis*, World Bank Group, 2019.

FOCUS 3

Eurocities: the urban agenda for the EU

Eurocities is the leading network of major European cities, established in 1986 by the mayors of Barcelona, Birmingham, Frankfurt, Lyon, Milan, and Rotterdam with the objective of strengthening cooperation between cities and amplifying their collective voice in European decision-making. Since then, the network has grown to encompass more than 200 large cities across 38 countries, together representing over 150m residents.[80]

The association functions both as a political platform and as a professional community for city administrations. It enables local leaders and experts to exchange knowledge and design innovative solutions to shared urban challenges. Eurocities also serves as a recognized advocacy actor at the European level, ensuring that the perspectives of cities are reflected in EU legislation and strategic initiatives such as the European Green Deal, the Digital Decade, and the Urban Agenda for the EU.

The Urban Agenda is a multi-level working method launched in May 2016 to foster cooperation among EU institutions, national governments, city authorities, and stakeholders in urban development. The Urban Agenda promotes integrated urban policy-making across three key pillars: Better Regulation (make EU legislation more urban-friendly and easier to implement), Better Funding (improve cities' access to EU financial instruments and cohesion funds), and Better Knowledge (share data, case studies, and good practices across cities).[81]

The Urban Agenda core objectives were defined in the Pact of Amsterdam[82]:

- Harnessing the full potential of urban areas to contribute to EU and national objectives, respecting subsidiarity and proportionality,
- Achieving integrated and coordinated policy-making, advancing territorial cohesion and reducing socio-economic urban-regional disparities,
- Involving urban authorities in policymaking and implementation processes, ensuring policies are urban-responsive and effectively executed,
- Clarifying scope—the Agenda does not create new laws or funding channels, nor does it transfer competences to the EU.

EXPERT POSITION 3

Elisa Ferreira—Shaping the future of urban infrastructure in Europe

"European cities face unprecedented investment needs of EUR 750-800bn per year by 2030, with an annual shortfall exceeding EUR 300bn. Freeing major cities of their excessive agglomeration costs often requires joint management of public infrastructure from hospitals to transport networks or social support. In very centralized countries, coordinated investment in alternative and complementary urban centers (to the macro metropolitan areas) may be essential to alleviate the pressure on the first. It is expected that, also in reducing agglomeration costs, major cities become a beacon and inspiration in technologies such as AI in traffic management, new building techniques and materials, urban energy saving and clean production, simplified licensing, international networking and sharing of good practices, social inclusion innovative techniques, etc."

Elisa Ferreira,
former EU Commissioner for Cohesion and Reforms

FOCUS 4

Paddington Village: a hub for health, life sciences, and innovation[85]

Paddington Village is a GBP 1bn, 30-acre development located in Liverpool's Knowledge Quarter. This ambitious project aims to establish a world-leading innovation district focused on health, life sciences, technology, and education. Developed through strong collaboration between universities, local government, and the private sector, Paddington Village is designed to foster a thriving ecosystem of research, enterprise, and sustainable urban living.

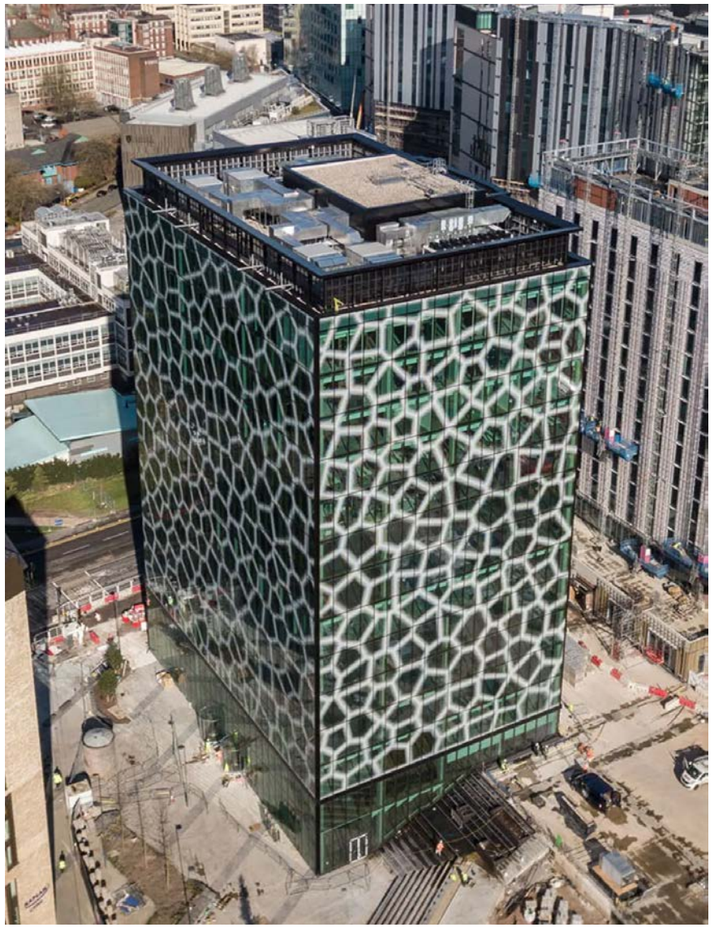
At the heart of Paddington Village stands The Spine, a 14-storey, 160,000 ft² Grade-A office building. Completed in 2021, The Spine is one of the first buildings in the UK to achieve WELL Platinum certification, recognizing it as one of the healthiest infrastructure for mental and physical well-being. The building also boasts BREEAM Excellent rating, highlighting its commitment to sustainability and energy efficiency.

Paddington Village is being developed in three phases. The first phase, Paddington Central, has already seen the completion of The Spine and other key developments. Ongoing and future phases, including Paddington South and Paddington North, will introduce additional office spaces, residential units, public amenities, and green spaces.

FIGURE 13

The Spine Building

Source: Liverpool Health Partners, 2021



EXPERT POSITION 4

Joanne Anderson—The need for urban leaders to commit to the long term

"Liverpool shows how cities can navigate the tragedy of the horizon by leveraging collaborative, cross-sector partnerships to pivot from short-term crisis management toward long-term, resilient economic transformation. By investing in health and life sciences infrastructure, Liverpool is laying the foundation for a sustainable and adaptive urban future.
The Spine case underscores the imperative for urban leaders to embed forward-looking strategies that align scientific innovation and community well-being beyond the constraints of electoral cycles.
Investment Zones are also compelling examples, with Liverpool being one of them. These zones are situated in areas that already have strong local assets but also hold significant untapped potential. They bring together a mix of interventions—such as tax incentives, streamlined planning processes, and support for innovation, skills, and business development—to unlock opportunities for enterprise.
By tackling barriers to private sector growth, they aim to generate more high-quality jobs and deliver lasting benefits for communities nationwide"

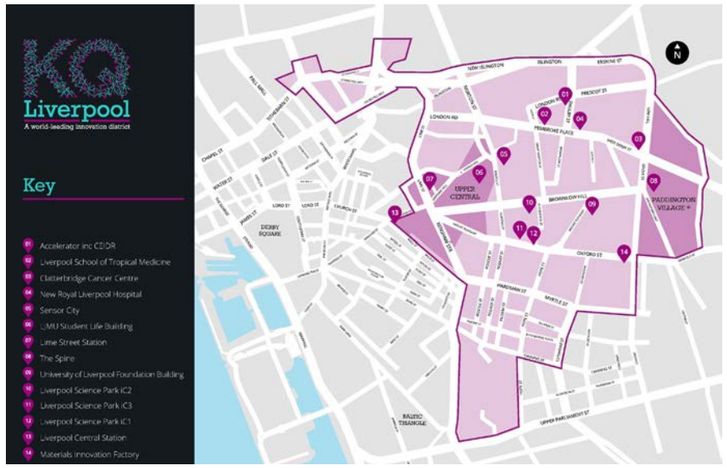
Joanne Anderson, former Mayor of Liverpool

85 - Knowledge Quarter Liverpool, *Discover Paddington Village*, 2020; Invest Liverpool, *Paddington Village*; Liverpool City Council, *Work begins at Liverpool's Paddington South scheme*, 2024.

FIGURE 14

The Knowledge Quarter, part of Liverpool City Region's Investment Zone[86]

Source: Knowledge Quarter Liverpool



THE IDEAL, THE NECESSARY, AND THE FEASIBLE: THE 'TRAGEDY OF THE HORIZON' OF INFRASTRUCTURE

The most complex difficulty for cities lies in the "**tragedy of the horizon**"—a concept popularized by Mark Carney, the current Prime Minister of Canada, when he was Governor of the Bank of England[87]—which is especially pronounced in urban planning and development where the urgent pressures of electoral terms and budgetary periods might clash with the multi-decade horizons necessary to create resilient, sustainable, and livable cities.

While **infrastructure assets demand long-term vision and stewardship**, decision-makers are often constrained by short-term political and financial cycles. The resulting disconnect can foster systemic underinvestment and mismanagement across critical urban systems—ranging from infrastructure and housing to mobility and environmental resilience—ultimately jeopardizing the long-term prosperity of urban populations.

Even with strong commitments to building sustainable systems, policy-makers, private actors, and civil society also face a complex web of constraints that define what can actually be delivered:

Physical and technical constraints: existing utility networks, geological conditions, available space in dense urban areas, compatibility with legacy systems, and current engineering capabilities.

Financial constraints, which require cities to target investments strategically rather than funding every worthy project.

Regulatory and operational constraints: building codes and environmental regulations evolved around older technologies, combined with the imperative to maintain service continuity while upgrading systems that millions depend on daily.

Political and institutional constraints: fragmented responsibilities across agencies, lengthy procurement processes, and the challenge of building coalitions for transformative projects.

In this context, infrastructure stakeholders must navigate these systemic dilemmas as effectively as possible, and **engage in a path for the 'long-run' while managing the tension between 'the ideal, the necessary, and the feasible'.** They must be fully aware of the misaligned incentives and trade-offs that stem real-world constraints, while staying focused on delivering long-term public value.

EXPERT POSITION 5

Jérôme Stubler—Addressing the investment gap in renewable energy

"Investment in renewable energy production within cities remains constrained, largely due to limited available space and the complexity of decision-making at the building scale. Despite these barriers, cities have made substantial progress in renewable energy adoption, through the electrification of heating, mainly in the UK and in the north of Europe, and of transportation systems. In particular, the rapid expansion of electric vehicle (EV) charging infrastructure has been a defining achievement: in just a few years, many major cities have already reached roughly half the capacity required to support widespread EV adoption. Yet, this progress also reveals a critical gap. Investment in EV infrastructure cannot be concentrated solely in large urban centers. Without parallel efforts in smaller cities and towns, disparities will emerge between well-served metropolitan residents and those in less-resourced communities. Such uneven development risks deepening social and economic divides, where wealthier urban populations enjoy the benefits of cleaner, more affordable mobility, while others remain locked into dependence on fossil-fuel vehicles"

Jérôme Stubler, CEO of Equans

86 - Knowledge Quarter Liverpool, *KQ Map*.

87 - Bank of England, *Breaking the tragedy of the horizon - climate change and financial stability* – speech by Mark Carney, 2015.

A SCENARIO-BASED APPROACH TO OUTLINE PATHWAYS TOWARD A NETWORK OF FUTURE-PROOFED URBAN INFRASTRUCTURE

Key takeaways

→ For the future of cities and infrastructure, two critical uncertainties emerge at the confluence of megatrends (section #1) that are medium-high in certainty, high in potential impact, and low in preparedness: the resource-management strategy and the governance model

→ Based on this finding, 4 scenarios map whether cities progress into sustainable, resilient systems or descend into fragmentation and fragility: (1) the hyper-connected and centralized smart metropolis; (2) the resilient, regenerative, community-led city; (3) the resource-strained, fragmented urban landscape; (4) the controlled, efficiency-driven survival city

→ Future urban development will not follow a single blueprint: it will emerge as a complex, hybrid process, blending elements from multiple governance models and resource strategies while adapting to local contexts, evolving challenges, and emerging opportunities

→ Future-proofing infrastructure starts with ensuring adequate maintenance of existing assets and adopting a lifecycle approach, which considers every phase of an asset's life to ensure long-term performance, resilience, and value

→ High-impact and "on-the-shelf" solutions exist and must be implemented systematically in major projects. For instance, circular economy (e.g urban mining) provide near-term levers for building sustainable urban infrastructure—cities can act as "circular cradles" developing circular solutions

Preparing the future of urban infrastructure: a scenario planning approach

Four macro-scenarios for urban infrastructure

TWO 'X FACTORS' AT THE CONFLUENCE OF POWERFUL MEGATRENDS

As outlined in Section #1, the future of cities and infrastructure is not predetermined but is being actively shaped by a constellation of megatrends that combine medium-to-high certainty, high potential impact, and low levels of preparedness. These include demographic change, climate stress, resource constraints, shifting societal expectations, and widening social inequalities—all of which interact in complex and often unpredictable ways. Rather than unfolding along a single linear trajectory, urban futures are being continuously negotiated through policy choices, investment decisions, cultural dynamics, and collective action.

At the intersection of these megatrends, two critical uncertainties emerge as particularly decisive for shaping urban trajectories:

The resource management strategy, which ranges from abundance and high efficiency—driven by proactive measures such as circular economy practices, renewable energy adoption, and advanced resource optimization—to scarcity and strain, marked by linear consumption patterns, dependence on finite resources, and worsening environmental degradation;

The governance model, which spans from centralized governance structures —hierarchical, technology-intensive, and often driven by private-sector actors—to decentralized arrangements that emphasize community leadership, participatory decision-making, and local autonomy, with various hybrid forms occupying the middle ground.

FOUR 'POSSIBLE' FUTURES

Together, these twin dimensions—resource management and governance design—form a framework defining whether cities evolve into inclusive, resilient, and sustainable systems, or confront fragmentation, inequity, and systemic vulnerability. Thus, while the framework simplifies the complexity into two key uncertainties, it holistically accounts for multiple interrelated factors critical to envisioning plausible urban futures.

These uncertainties create a scenario **matrix from which four divergent yet plausible urban futures** can be explored:

HYPER-CONNECTED AND CENTRALIZED SMART METROPOLIS

The hyper-connected and centralized smart metropolis (proactive resource management + centralized governance): in this scenario, urban infrastructure is driven by seamless integration of digital technologies and top-down governance, with a strong focus on maximizing efficiency and economic growth.

Smart grids provide reliable, clean energy; autonomous electric public transport dominates; and 5G/6G networks ensure seamless connectivity.

Centralized governance ensures coordinated planning and rapid decision-making to operate and optimize traffic, energy, and telecom networks. This future sees extensive use of IoT, AI, and digital twins for optimized urban services;

NB: a smart city is a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and businesses.[88] *In other words, it is a city in which a suite of sensors (typically hundreds or thousands) is deployed to collect electronic data from and about people and infrastructure so as to improve efficiency and quality of life*

EXPERT POSITION 6

Carine Staropoli— Ensuring public governance of the smart city

"The hyper-connected and centralized smart metropolis relies on digital technologies such as Internet of Things (IoT), AI, and real-time data systems to optimize all aspects of urban life. Many digital innovations enhance everyday convenience and respond to individual consumption choices. However, when these technologies are deployed in essential infrastructures and services—such as transport, energy, water, healthcare, or digital platforms—they shape access to resources that are fundamental to the common good. Yet, these innovations are largely driven by private actors, digital pure players or traditional public-service operators, whose goals may not align with the public interest.

This makes public-private relations critical: ensuring that digital systems serve the common good requires strong governance to manage diverging priorities and safeguard collective objectives. This requires moving beyond traditional top-down governance and adopting new tools and practices that reflect the complexity of digital urban systems, where big data enables real-time monitoring, cross-sectoral analysis, and evidence-based decision-making. Public authorities can seize the opportunity to build a data-driven approach to regulation and public management, one that not only seeks to optimize economic performance, but also actively promotes inclusion, sustainability, and social equity.

Achieving this shift requires public authorities to develop strong technical and analytical capacities, ensure transparency in decision-making, and make strategic use of data to identify, measure, and assess the wider impacts of digital technologies on urban life. A central challenge lies in reducing information asymmetries in public-private relationships, by embedding data-driven performance mechanisms into contracts and regulatory frameworks that align private action with general interest.

Ultimately, the success of this model depends on using data not for its own sake, but as a means to guide decisions, track outcomes, and align innovation with the common good —bridging efficiency, equity, and environmental sustainability within a coherent and accountable governance framework"

Carine Staropoli, Professor of Economics at University of Rouen Normandie, and co-head of the "Urban New Deal" Chair at Paris School of Economics

88 - European Commission, *Smart Cities.*

Resilient, regenerative, community-led city

The resilient, regenerative, community-led city (*proactive resource management + decentralized governance*): cities become self-reliant, community-centered, and environmentally sustainable, driven by circular economies and localized governance.

Renewable energy microgrids, urban agriculture, water harvesting, and waste-to-resource initiatives form the backbone of urban infrastructure, reducing dependence on global supply chains. Transport includes community-operated EV fleets, bike-sharing, and pedestrian-first urban design.

This scenario prioritizes local self-sufficiency, resource regeneration, and deeply participatory governance models, where technology serves community needs rather than dictating them.

EXPERT POSITION 7

Antoine Picon – The promise of regenerative urbanism

“The resilient, regenerative, community-led city has emerged as a desirable future for cities. The conditions that need to be met to make this future possible are well known: favor local technological solutions as well as short production and consumption circuits and set up governance procedures that give a large place to citizen initiative. To this list should be added the new importance given to natural elements. To be resilient and regenerative, the city must rely as much as possible on its inherent biodiversity and operate within the framework of a bioregion. The scenario is well known but is not all that easy to achieve.

In terms of infrastructure alone, it calls for a profound paradigm shift, which primarily concerns the need to blur the boundary between the natural and the artificial. In many cases, nature becomes synonymous with infrastructure. Think of urban forests designed to combat the effects of global warming, or wetlands that can protect coastlines more effectively than concrete dikes. It also concerns the approach to technological efficiency. Instead of seeking pure performance based on minimal resource use, we should follow the example of natural systems and prioritize redundancy and robustness, which alone can enable urban infrastructure to cope with the unpredictable events associated with climate change. This latest development requires us to rethink many key performance indicators.

A word now on the socio-political uncertainty associated with this transition, which, while desirable, nonetheless raises a number of issues. Since at least the 19th century, the major technical networks that enabled the rapid development of cities have been synonymous with functional, social, and political integration. They helped to establish solidarity between users, neighborhoods, and cities as a whole. They were part of the processes of circulation and minimal redistribution provided by urban organizations. With the development of short supply chains, local infrastructure, and inward-looking eco-neighborhoods, there is a high risk that these mechanisms will become strained. In this context, the necessary reconquest of the local must be accompanied by reflection on what needs to be preserved on a larger scale, from infrastructure to governance”

Antoine Picon, Professor of History of Architecture and Technology at Harvard University

Resource-strained, fragmented urban landscape

The resource-strained, fragmented urban landscape (*reactive resource management + decentralized governance*): this cautionary scenario emerges from a failure to adequately address climate impacts, escalating resource scarcity, and widening social inequalities. Governance is fragmented and reactive, limiting coordination and adaptive capacity, resulting in uneven infrastructure and social fragmentation with a patchwork of vulnerable communities.

EXPERT POSITION 8

Oriana Romano— The risk of staying trapped in a linear economy

“Today's cities represent almost two-thirds of global energy demand, produce up to 50% of solid waste and are responsible for 80% of greenhouse gas emissions. In the future, demographic, climate and economic changes will put heavy pressure on natural resources, while new infrastructure, services and housing will be needed. Avoiding this scenario requires anticipatory, inclusive, and place-based governance based on a systems approach that cuts across sectoral policies and strong coordination across levels of government. Cities can move from linear to circular economies, in which services (e.g. from water to waste and energy) are provided while preventing waste generation, making efficient use of natural resources as primary materials, optimizing their reuse and allowing synergies across sectors; economic activities are planned and executed in a way to close, slow and narrow loops across value chains and infrastructure is designed and built to avoid linear lock-in, which uses resources intensively and inefficiently”

Oriana Romano Head of Unit, Water Governance, Blue Economy and Circular Economy at OECD

Controlled, efficiency-driven survival cities

The controlled, efficiency-driven survival city (*reactive resource management + centralized governance*): in this scenario, cities face ongoing resource pressures but respond through strong centralized coordination that enables efficient resource allocation, emergency preparedness, and rapid innovation.

Top-down and technology-driven governance enforces strict controls and rationing to manage scarce resources amid ongoing crises: transport is rationed with digital permits, telco access prioritized for key sectors, and energy supplied under stringent quotas.

EXPERT POSITION 9

Adam Abdin— Efficiency & resilience: a difficult tradeoff

"The 'controlled, efficiency-driven survival city' highlights a plausible trajectory under mounting climate stress, resource scarcity, and systemic shocks. Strong centralized governance and technology-enabled rationing can indeed sustain urban function under crisis—but they risk concentrating vulnerabilities. Centralized systems can optimize allocation, yet when poorly designed, they create brittle single points of failure and may erode public trust if perceived as coercive or opaque.

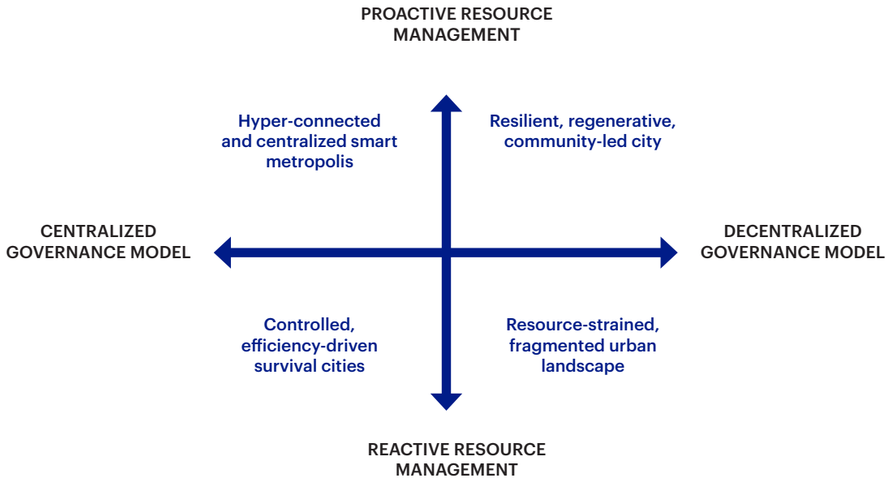
A key challenge is that efficiency and resilience are not the same. Systems optimized for maximum utilization often operate with little or no slack, leaving them brittle when faced with shocks such as extreme weather, cyberattacks, or supply chain disruptions. From a resilience-engineering perspective, survival cities must preserve a degree of redundancy, diversify critical supply chains, and maintain contingency plans to avoid catastrophic failure. Equally important is the social dimension: if rationing is perceived as opaque or unfair, public trust can collapse rapidly, undermining the stability such measures are meant to protect. From a systems perspective, turning centralized control into adaptive governance means designing infrastructure and policies that fail safely, recover quickly, and adapt as conditions evolve. Transparent rationing rules, continuous monitoring, and routine stress-tests of infrastructure and governance processes can reveal hidden vulnerabilities and strengthen legitimacy. This approach transforms survival cities from reactive crisis managers into adaptive, learning systems capable of managing scarcity without sacrificing trust or long-term viability'"

Adam Abdin,
Assistant Professor of Operations Research and Decision Analytics at CentraleSupélec

FIGURE 15

Infrastructure in cities: a scenario-based approach

Source: Altermind and experts, 2025



CONSIDERING A HYBRID SCENARIO: A SYNTHESIS OF TECH-DRIVEN AND COMMUNITY-CENTERED APPROACHES

While each of the four scenarios presents distinct pathways shaped by different combinations of resource management strategies and governance models, **future urban development will inevitably be complex and hybrid**—shaped by overlapping models rather than a single blueprint. Instead, the cities of tomorrow will likely blend elements from multiple scenarios, adapting pragmatically to local contexts, evolving challenges, and emerging opportunities.

In practice, this means a city might combine centralized, technology-driven governance in areas that benefit from efficiency or standardization—such as energy grids and transport networks—while simultaneously adopting decentralized, community-led approaches for sectors requiring local knowledge, social engagement, or resilience-building (e.g. neighborhood planning, local food systems, or participatory budgeting). Similarly, resource strategies may vary within the same city: some districts might operate under circular models, while others remain dependent on linear, externally supplied resources, reflecting infrastructural constraints or social and policy choices.

Scenario planning: the need for a city-specific approach

ANTICIPATING THE POSSIBLE PATHS FOR BETTER PREPARATION

Scenario planning is not just about framing the future with a macro-lens approach. Indeed, it is increasingly recognized as an operational tool for cities seeking to build resilience and proactively shape sustainable, inclusive futures in the face of uncertainty. By systematically exploring multiple plausible futures rather than relying on a single forecast, **scenario planning allows urban policymakers to anticipate** a wide range of challenges—including climate change, technological disruption, demographic shifts, and economic fluctuations—and to develop strategies that are robust across different possible outcomes.

CUSTOMIZING THE APPROACH

Although the scenario planning exercise is key, cities are not homogenous entities (see section #1), and a **one-size-fits-all approach to scenario planning risks overlooking local contexts and opportunities.** Urban systems differ dramatically in terms of population density, economic composition, governance structures, infrastructure capacity, and socio-cultural dynamics. Applying identical scenario frameworks to both would underrepresent the unique vulnerabilities and adaptive capacities inherent to each location.

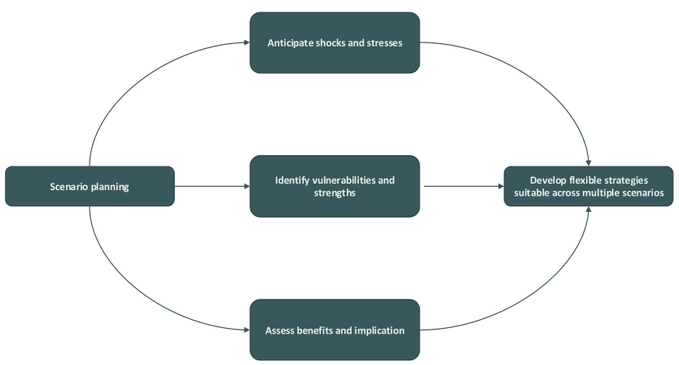
Empirical evidence supports the need for city-specific tailoring. Research by the Urban Climate Change Research Network shows that climate adaptation strategies are most effective when grounded in local risk assessments and stakeholder engagement processes. Cities that have adopted generic scenario models often struggle to translate strategic visions into actionable policies.[89] Conversely, tailored approaches, such as Rotterdam's climate-resilient urban planning initiatives, incorporate neighborhood-level interventions, with the goal of reducting flood risk and improving social resilience.[90]

Melbourne's long-term planning framework provides a compelling illustration of this approach in practice. Plan Melbourne 2017–2050 serves as its strategic blueprint, guiding land use, infrastructure, and transport development across six metropolitan regions.[91] Rather than treating this vision as static, the strategy is supported by periodic implementation plans and monitoring processes that enable adjustment in response to emerging trends. Complementing this strategic framework, Infrastructure Victoria's Choosing Victoria's Future extended the analysis through scenario planning, modelling five alternative patterns of urban growth to test how different choices would affect economic, social, and environmental outcomes (Focus 5).[92]

FIGURE 16

Scenario planning process and outcomes

Source: Altermind 2025



89 - Urban Climate Change Research Network, *Second Assessment Report on Climate Change and Cities*, 2018.

90 - Government of Rotterdam, *Resilient Rotterdam Strategy 2022-2027*, 2022.

91 - Planning Victoria, *Plan Melbourne 2017-2050*, 2017.

92, 93 & 94 - Infrastructure Victoria, *Choosing Victoria's future*, 2023.

FOCUS 5

Scenario planning illustration: Choosing Victoria's Future[93]

To test how different development patterns could shape the state's future, Infrastructure Victoria modelled five urban development scenarios out to 2056. For Melbourne, which has been consistently ranked among the world's most liveable cities over the past 15 years, this scenario planning exercise enabled infrastructure stakeholders to examine key prerequisites for ensuring the city and state continue to thrive under different conditions

The analysis evaluated 15 social, economic, and environmental impacts across five scenarios to assess how each could affect quality of life, the economy, and the environment. While no scenario is without drawbacks and each involves trade-offs, clear differences emerge between growth concentrated in established urban areas and more dispersed development patterns beyond Melbourne's current suburbs or into regional centers. The scenarios modelled were :

- **Dispersed city: strong growth of detached housing on Melbourne's urban fringe, with continued urban sprawl and higher car dependence,**
- **Consolidated city: growth focused in Melbourne's inner and middle suburbs, with many more medium-density homes such as townhouses and low-rise apartments; Compact city: expansion concentrated in Melbourne's inner areas, with a large increase in high-density housing,**
- **Network of cities: rapid growth in Victoria's major regional centers (Geelong, Ballarat, Bendigo), absorbing a significant share of new housing;**
- **Distributed state: population growth spread across smaller regional towns and rural areas, with many more homes located statewide,**
- **Transport infrastructure represent the largest cost component in supporting urban development, due to both significant capital investment and ongoing operational expenses,**
- **New social infrastructure, including schools and community facilities, are more expensive to provide in higher-density, established areas. This is largely driven by the scarcity of surplus land, which raises land acquisition costs for new facilities. Approaches such as repurposing public land, upgrading and recycling existing facilities, and integrating shared-use infrastructure present opportunities to manage and reduce these costs effectively.**

The work conducted also considers how infrastructure delivery will change to achieve broader social and environmental outcomes, especially to achieve net zero carbon emission by 2045. Key findings include:

- **Transport infrastructure represent the largest cost component in supporting urban development, due to both significant capital investment and ongoing operational expenses,**
- **New social infrastructure, including schools and community facilities, are more expensive to provide in higher-density, established areas. This is largely driven by the scarcity of surplus land, which raises land acquisition costs for new facilities. Approaches such as repurposing public land, upgrading and recycling existing facilities, and integrating shared-use infrastructure present opportunities to manage and reduce these costs effectively.**

FIGURE 17

Overall assessment of economic, social and environmental impacts by scenario[94]

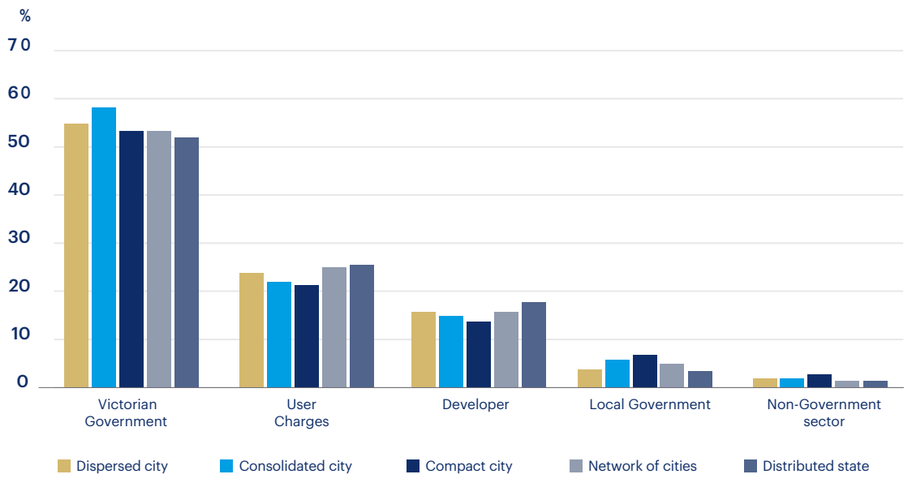
Note: blue shading indicates a more positive outcome and red indicates a more negative outcome, relative to all other scenarios. Gray shading means a neutral outcome.

Source: Infrastructure Victoria, 2023

FIGURE 18

Distribution of infrastructure costs by stakeholder that bears the cost[95]

Source: Infrastructure Victoria, 2023



Driving forward large-scale infrastructure projects

IMPROVING EXISTING INFRASTRUCTURE PROJECTS: INSIGHTS FROM INFRAVISION'S CONTEST

"The City as Network: Reimagining Urban Infrastructure" International student competition

In 2025, InfraVision launched its inaugural competition, "The City as Network: Reimagining Urban Infrastructure". Designed for students and recent graduates from all disciplines, the competition invited fresh perspectives on the future of cities and infrastructure. The call for projects resulted in 96 submissions with applicants from over 40 countries, reflecting a truly global interest in shaping urban futures.

Participants were tasked with rethinking a large-scale urban infrastructure project by proposing concrete strategies for design, planning, stakeholder engagement, technology integration, and decarbonization. The aim was to transform interconnected urban systems – transport, energy, telecommunications, waste, and water management – into resilient and human-centered networks.

From the submissions received, three standout projects were selected for their visionary thinking and practical feasibility. Together, they illustrate the diverse ways cities can be reimagined as dynamic, interconnected networks of people, places, and infrastructure.

The jury

Chaired by Sadie Morgan founding director of dRMM Architects and a champion of design excellence while serving on the UK's National Infrastructure Commission, and including leaders from architecture, and urban planning, politics, sustainable investment, and innovation – evaluated the submissions for creativity, feasibility, and potential impact:

SADIE MORGAN
Chair of the jury
Co-founder of drMM

DOMINIQUE ALBA
An architect and a urban planner, formerly in charge of architecture, public space and urban renewal in the office of the Mayor of Paris, and current CEO of Ateliers Jean Nouvel

DARIO NARDELLA
Former Mayor of Florence, Member of the European Parliament since 2024, and professor of Cultural Heritage Law at the University of Florence

FANNY BOURDAIS DE CHARBONNIÈRE
Investment Director, Sustainable Investments & Infrastructure at CalPERS

PAULO MOURA
Deputy Director of Innovation and Partnerships at Université Côte d'Azur/ IMREDD, who fosters collaboration between academia and industry to address urban challenges

1st place, winning entry

Mohalla Van: a post-masterplan urban design framework for Bhopal

Summary

The project looks to reimagine the investments of the 'Smart City' infrastructure and housing development project in Bhopal, Madhya Pradesh, India, through phased implementation of strategic amenity interventions coupled with future-proofing socio-ecological infrastructure. It aspires to present a novel, contextually appropriate urban design mode demonstrating how tactical interventions, community collaboration and alignment with national initiatives can drive regenerative development, ultimately offering a replicable vision of urban change which reflects Indian aspirations, climate repair needs and harmonious ecological coexistence.

Project members:

Beth Kippin (University of Bath), Jamie Ferguson (University of Bath), Marco Lin (University of Bath), Siena Cornish (University of Bath), Ben Hanger (University of Bath), Joel Boyd (University of Bath)

Jury Comment

"Ambitious, thoughtful, and a delight to read, this proposal won us over for many reasons: a clear theory of change; a strong anchor in a five-minute living framework; and excellent analysis across two scales: the citywide structure and a constellation of small interventions. It successfully delves into the full complexity of rejuvenating a city, skillfully assembling proven ideas and showing how to make them politically viable, while communicating with rare clarity and freshness. Richly crafted representations make the vision tangible and joyful. The result is a rare balance of depth and clarity with an actionable pathway."

Mohalla Van - executive summary.

Bhopal [MP, India] is a precarious city; whilst thriving in its old heart, at the fortieth anniversary of the Union Carbide disaster, an ecocide which claimed over 10,000 lives, there are still severe scarcities in healthy ecology, sanitation and resident wellbeing. Moreover, in 30 years time Bhopal is predicted to have doubled in population, rising from 3 to 6 million residents; as such their is a clear need for urban transformation. However, perhaps owing to the UCIL tragedy, Bhopal is a city resistant to imposition, with existing masterplan propositions under the *Smart City* program having been outright rejected by the population. The following project Mohalla Van (meaning a community forest) seeks to re-imagine the *Smart City* program, stepping away from inappropriate 'western' neo-colonial masterplanning toward a more distinctly *Indian*, and indeed *Bhopali* urbanism.

The project addresses one demonstrative district within the city, weaving together Bhopal's rich social, ecological, and economic fabric, and envisions a resilient, regenerative, and inclusive future for its growing population. Through phased implementation, careful consultation, demonstration and co-authorship, the project delivers future-proofed critical sanitation, water and electrical infrastructure whilst restoring ecological balance and cultural vibrancy. It integrates new homes for 40,000 people, essential amenities for 84,000, as well as 130,000 m² of public green space, including revitalised rivers and tributaries as seasonal social hubs. A focus on upskilling and informal economies strengthens local livelihoods.

This proposal redefines urban planning through a new contextually appropriate design mode - domino urbanism - setting a benchmark for regenerative living in Northern India. It demonstrates how tactical, influential interventions, community collaboration, and alignment with national initiatives can drive regenerative development. As a replicable model for Bhopal and beyond, Mohalla Van offers a vision of urban change that reflects Indian aspirations, addresses the need for climate repair, and supports a harmonious coexistence of humans and more-than-humans alike.

This project has been presented in a way which is playful, contextual and challenging to Eurocentric aesthetic norms in urban planning, with representational techniques rooted in the place itself.

Grounded objectives.

1. A five minute living framework.

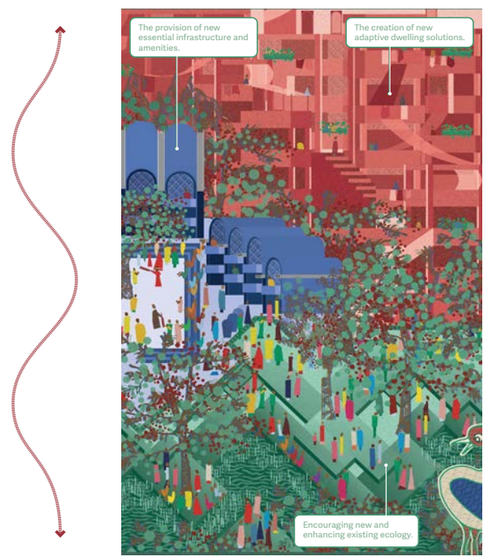
On site analysis and ethnography of the old town in Bhopal indicated the effective radius of five minutes for essential amenities such as education, food and healthcare. This is tied into a communal way of living which encourages cultural resilience and mutual support. This project proposes interventions from micro scale (e.g. low-carbon retrofit details) to macro scale (city-wide infrastructure strategies) which may support this framework.

2. Densification.

In order to cater for the huge population rises while also enabling such access to amenities, densification of the current urban sprawl was identified as crucial. Framing this around community interventions was deemed pivotal to instigating safe, healthy neighborhoods. This strategy was developed following discussions with local architecture and planning students in Bhopal.

3. Revival and stewardship of productive ecosystems.

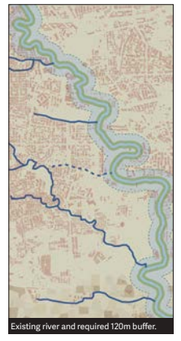
Bhopal's waterways are highly polluted, not least from chemicals leftover following the 1984 gas disaster. Concurrently, developments remove ecological space from the city. The proposal is for the reintegration of ecology within the city's social fabric, empowering local residents through knowledge-sharing opportunities.



Toward ecological balance.

Reviving the Kaliyasot river.

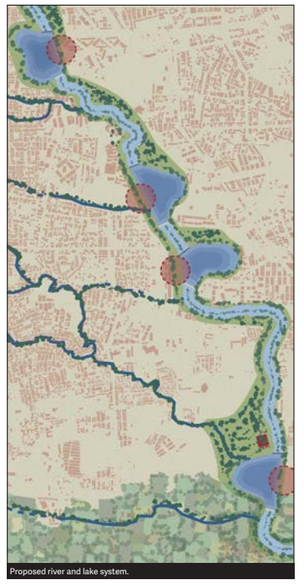
Research by SPA-B also indicates an urgent need for an updated flooding buffer. Our proposal expedites the formation of oxbow lakes to create a tiered system of lakes and dams, ecological protected zones and socioeconomic nodes, to reinvigorate the cultural identity of lakes in Bhopal while reducing the necessary flooding buffer. This would enable the legislated flooding buffer along the river to be amended from the current arbitrary 33m Indian standard taken from the US to a more resilient but variable river edge buffer, which can still avoid the huge impact on existing dwellings of SPA-B's calculated 120m requirement.


Existing river and required 120m buffer.


Establishing an ecological buffer along the river.


Co-locating economic nodes at interfaces between the river and the urban fabric.


A series of cascading lakes improves resilience against monsoons.


Proposed river and lake system.

2nd PLACE

Doire Masterplan

Summary

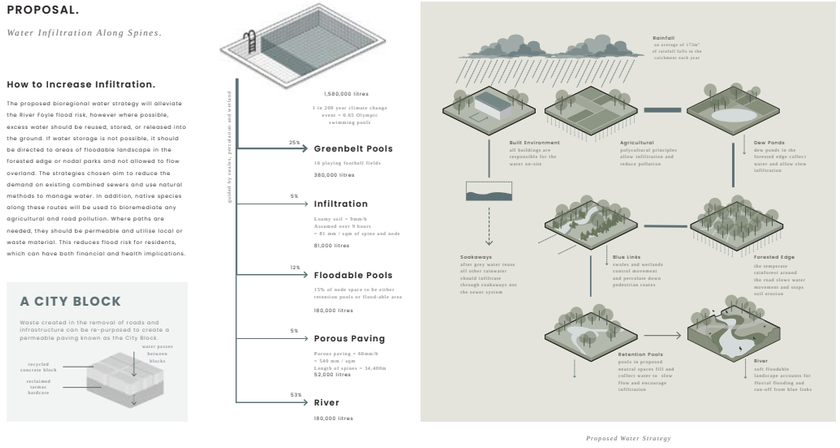
The project explores the regeneration of the city of Derry / Londonderry in Northern Ireland. It is a visionary reimagining of the city that aims to tackle the divided nature of the city's landscape, ecology, and cultural beliefs through proposed infrastructure spines and nodes.

Project members:

Amy Thompson (University of Bath), Alice Kimpton (University of Bath), Caitlin Boeshart-Thomas (University of Bath), Caitlin Meier (University of Bath), Sophie Davies (University of Bath)

Jury Comment

"We were impressed by the project's courage in grappling with the legacy of war, asking how a city can be rebuilt not only physically but socially. Starting from the reality of deep divisions, it poses a vital question of how communities live together, and turns that political ambition into tangible spatial strategies. The careful attention to community needs and everyday encounters reflects a thoughtful and humane approach. It is an inspiring vision that treats infrastructure as common ground supporting reconciliation."



3rd PLACE

The Germinating City

Summary

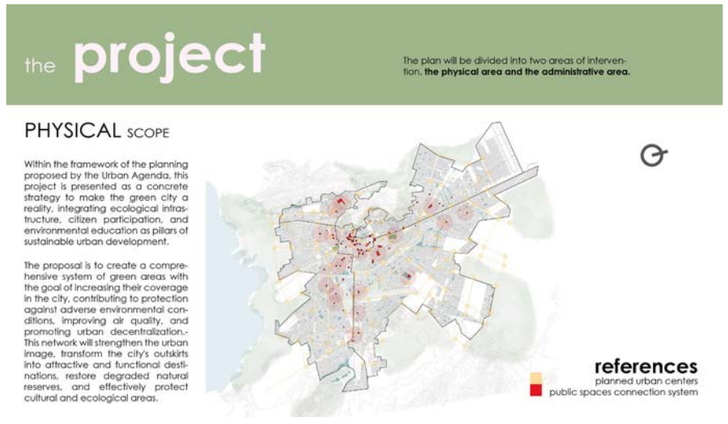
The Germinating City emerges as an educational and urban response to the environmental crisis in Bolivia. Oruro is a city marked by a cold, dry climate, only 0.17 m² of green space per inhabitant, and fragmented urban growth that leaves peripheral districts without access to environmental and social services. This project reimagines infrastructure as a green educational network, where schools become active hubs of regeneration. Planting trees is the starting point, but the core of the project is the transformation of the city through education. High school students plant and steward trees throughout their schooling, while primary students germinate their own, creating continuity between generations. The strategy unfolds over 30 years. As the system grows, schools gradually change the way they think and act, adopting practices such as water recycling, composting, greenhouses, and solar roofs, thereby becoming green hubs that also have an impact on the city and its infrastructure. The goal is not just to plant trees, but to cultivate awareness, foster belonging, and establish an educational model that transforms the city at its roots.

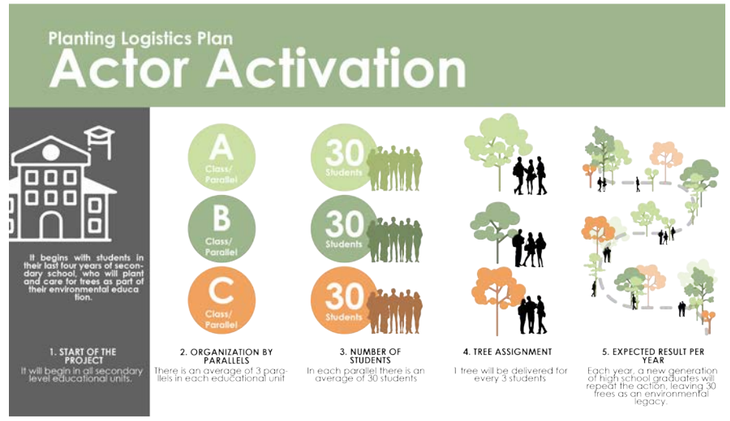
Project members:

Aldrin Luis Villarroel Uño (Universidad Técnica de Oruro), Itati Maritza Quisbert Martinez (Universidad Técnica de Oruro)

Jury Comment

"We were inspired by the project's clear call to action: do, not just talk. Where many proposals focused on systems and plans, this one puts the onus on mobilizing people, turning urban planning into everyday stewardship. The simple idea that each student plants a tree is emblematic, a modest act that scales quickly. This 'let's do it' spirit has a refreshing, even wonderfully naive quality in the best sense, using participation to foster a stronger sense of shared ownership of the city."





Maintaining existing infrastructure and taking up new large-scale projects: thinking long-term, acting on short-term levers

DRIVING URBAN GROWTH: INFRASTRUCTURE AS A LEVER FOR COMPETITIVENESS AND RESILIENCE

A city's capacity to attract and implement large-scale infrastructure projects is increasingly a defining factor in its long-term competitiveness and resilience. For instance, the World Bank's report on urban competitiveness highlights that cities with robust infrastructure systems tend to attract more foreign direct investment (Figure 20), experience higher productivity growth, and offer better quality of life to their residents.[96]

Major projects are on the horizon, both within individual cities and across intercity networks. Brisbane's economy surpassed AUD 200bn in 2024, a 16% increase since 2020, largely driven by over AUD 100bn in infrastructure projects.[98]

These initiatives require a dual focus, with long-term planning to shape resilient urban systems, alongside actionable levers that generate early wins and build momentum:

Energy, managing energy security and energetic transition—Expanding renewable energy production and modernizing grids are currently a top priority for local governments. In June 2025, 284 cities worldwide had net-zero targets.[99] Innovative initiatives include solar and wind microgrids in urban districts, similar to the Solarsiedlung am Schlierberg project in Freiburg, Germany,[100] which aim to enable the energy self-sufficiency of individual neighborhoods.

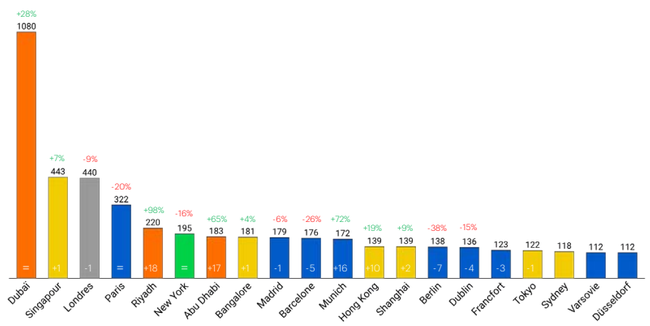
Telecommunications, the ripple effects of connectivity—The wired and wireless backbone of digital economies and societies has become as indispensable to cities as electricity, gas, and water. Investment requirements remain considerable: achieving universal Internet connectivity by 2030 is projected to cost USD 2.6tn to 2.8tn—which represents an opportunity for investors.[101]

A connected, data-driven urban environment not only strengthens public services but also provides the foundational infrastructure to improve health outcomes, expand access to education, and drive economic prosperity. Evidence shows that a 10-percentage-point increase in broadband penetration can raise GDP growth by 1.2.[102]

FIGURE 22

Top 20 most attractive metropolitan areas in 2023 (project number, variation with 2022) for IDE[97]

Source: Paris Île-de-France Capitale Économique



96 - World Bank, *Competitive cities for jobs and growth: What, Who, and How*, 2015.

97 - Paris Île-de-France Capitale Économique, *Global Cities Investment monitor 2024., Observatoire des investissements internationaux dans les principales métropoles mondiales*, 2024.

98 - Brisbane Economic Development Agency, *State of the City Report*, 2025.

99 - UN, *Seizing the moment of opportunity: Supercharging the new energy era of renewables, efficiency, and electrification*, 2025.

100 - Wüstenhagen, R., & Lahlou, S., Rolf Disch's *"Solarsiedlung am Schlierberg": A solar housing estate in Freiburg – from architectural vision to entrepreneurial reality*, in System Innovation for Sustainability, Greenleaf Publishing Ltd., 2009.

101 - ITU, *Connecting humanity action blueprint: Advancing sustainable, affordable and innovative solutions*, 2025.

102 - Brookings Institution, *The benefits and costs of broadband expansion*, 2021.

FOCUS 6

Seoul: a city-leader in digital infrastructure

South Korea is widely recognized as a global leader in digital infrastructure, a status built on sustained public investment, private competition, and technological ambition. In 2024, South Korea boasted the world's second highest fiber broadband penetration rate at 96.6%.[103] South Korea's digital leadership is not new: in the late 2010s, South Korea was the first country to roll out 5G nationwide, showcasing it globally at the 2018 Pyeongchang Olympics through live VR streaming and connected devices.[104]

Seoul, the capital city and the country's digital hub, ranks among the world's top "super champion" smart cities.[105] Its dense fiber and 5G networks enable ultra-fast connectivity, supporting smart transport, healthcare, education, and public Wi-Fi across thousands of location, boosting innovation and productivity. By combining infrastructure scale with leadership in global digital standards, South Korea positions Seoul as both a testing ground and a showcase for the economic dividends of connectivity.[106]

Transportation, ensuring adequate infrastructure and intermodal systems. The drive to shift to sustainable transport systems, and to ensure cities have the capacity to meet demand results in a massive opportunity to invest. Transitioning to electric and efficient urban passenger transport requires an investment of USD 8.6tn, which is projected to generate USD 320bn in annual returns by 2030 and to exceed USD 1tn per year by 2050.[107] However, electrification alone will not solve congestion: it must be paired with a shift to mass transit. Investing USD 4tn in buses, trains, and railways could generate USD 1tn in annual benefits by 2030 and cut emissions by 0.73 GtCO2-e by 2050.[108]

Cities can combine mass transit expansion with electrified and shared-mobility fleets, charging infrastructure, and intermodal connections linking transit, cycling, walking, and ride-sharing. Shared mobility could reach USD 1tn in consumer spending by 2030, with USD 90bn from micromobility and USD 400bn from robotaxis and robot-shuttles.[109]

Waste and water management, the priority of low income cities: a World Bank report estimates that in 2011 low- and middle-income countries generated 1.9m tons of waste per day in 2011, a number projected to have reached 4.2m in 2025.[110] Much of it is disposed of in low-technology dumpsites, contributing to environmental degradation and public health risks[111]: on average, in low-income cities, 49% of waste is not disposed of at formal sites.[112] There are major potential gains from investments in water infrastructure: every USD 1 invested in water supply and sanitation yields USD 2 to 5 in economic returns, depending on region.[113]

While certain nations in the Global South benefit from plentiful water resources, others, particularly in North Africa and the Middle East, face growing pressure to manage water more efficiently. According to the World Bank, water scarcity in these regions could reduce the region's GDP by as much as 6% to 14% by 2050.[114] Addressing these challenges will require an estimated USD 500bn over ten years, or 1.2% of the region GDP per year.[115] Investors are mobilizing to meet this need: The Arab Fund has provided USD 8.1bn to finance 149 water projects, developing more than 3,800 km of wastewater networks that treat 6m cubic meters daily.[116] The World Bank supports projects such as Morocco's rural water supply initiative, which has connected over 1.1m people to clean water.[117]

103 - FTTH Council Europe, *FTTH/B Global Rankings 2025*, 2025.

104 - OECD, *Digital Economy Papers*, 2020

105 - IMD, *Smart City Index 2024*, 2024.

106 - Carnegie Endowment for International Peace, *Korea's Path to Digital Leadership: How Seoul Can Lead on Standards and Standardization*, 2024.

107 - Lazer L.; Khandelwal, N.; Wellman J., *Why is sustainable urban transport a great investment*, World Bank Blogs, 2020.

108 - Lazer L.; Khandelwal, N.; Wellman J., *Why is sustainable urban transport a great investment*, World Bank Blogs, 2020.

109 - McKinsey & Company, *Shared mobility: Sustainable cities, shared destinies*, 2023.

110 & 111 - World Bank, *What a Waste: A Global Review of Solid Waste Management*, 2012.

112 - Wilson et al., *Integrated Sustainable Waste Management in Developing Countries*, Waste and Resource Management, 2013.

113 - WHO, *Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage*, 2012.

114 - WB, *The Economics of Water Scarcity in the Middle East and North Africa. Institutional Solutions*, 2023.

115 - Policy Center for the New South, *The Water-Energy Nexus: The Path to Solving the Water Crisis in the Middle East and North Africa*, 2025.

116 & 117- World Bank Blogs, *In MENA, make every drop of water count*, 2025.

IMPLEMENTING AND STRENGTHENING BEST PRACTICES IN INFRASTRUCTURE MAINTENANCE: ADOPTING A LIFECYCLE APPROACH

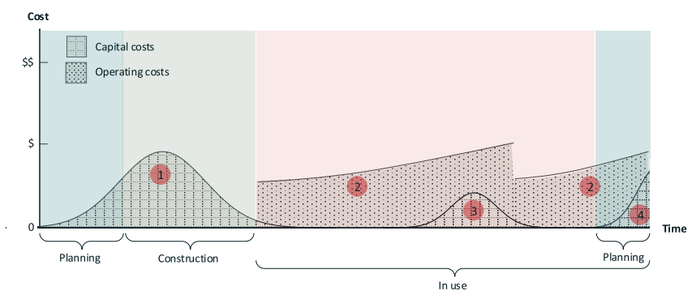
The first step to future-proofing infrastructure is optimizing the use of existing assets. Before embarking on large-scale transformation or expansion, acting sustainably means ensuring that existing systems are maintained to the highest standard. Robust maintenance reduces waste, extends asset lifespans, and delivers greater value from past investments, laying a stronger foundation for future development.

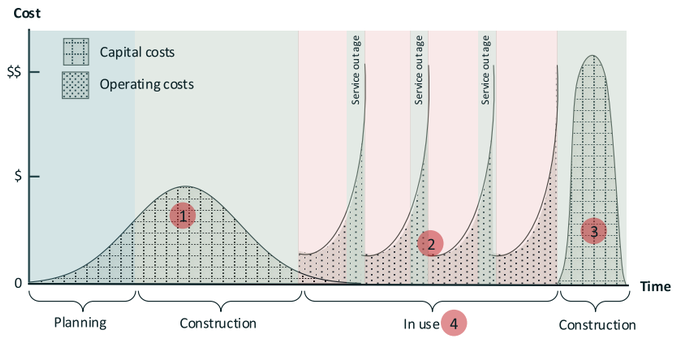
A key best practice in this regard is the **lifecycle approach.** It involves considering every phase of a project's life, from initial planning and design, through construction and operation, to maintenance and eventual decommissioning or renewal. Rather than emphasizing only upfront costs or short-term gains, this approach evaluates cost, impact, and performance over the full lifespan of infrastructure, ensuring that investments deliver resilience and long-term value from design through operation.

FIGURE 23

Lifecycle management extends assets' useful lives and avoids reactive maintenance, reduces operating and capital costs in the long-term[118]

Source: San Francisco Municipal Transportation Agency, 2022





118 - San Francisco Municipal Transportation Agency, *Infrastructure lifecycle management: Balancing capital and operating resources to achieve state of good repair*, 2022.

FOCUS 7

Cape Town Water Strategy: a model of crisis-driven innovation

Cape Town's Water Strategy, approved in 2019, was developed in response to the severe drought crisis that struck the city from 2015 to 2018 that nearly led to "Day Zero", when the city's taps would run dry. Thanks to the efforts of the city and its residents, water demand was cut by half in three years. The strategy focuses on five commitments[119]:

- **Ensuring safe access to water and sanitation for all residents,**
- **Promoting wise water use through pricing, regulation, public engagement, and efficient network management,**
- **Diversifying water sources using surface water, groundwater, desalination, and water reuse to secure supply by 2030,**
- **Collaborating regionally to share risks and benefits of water resource management.**

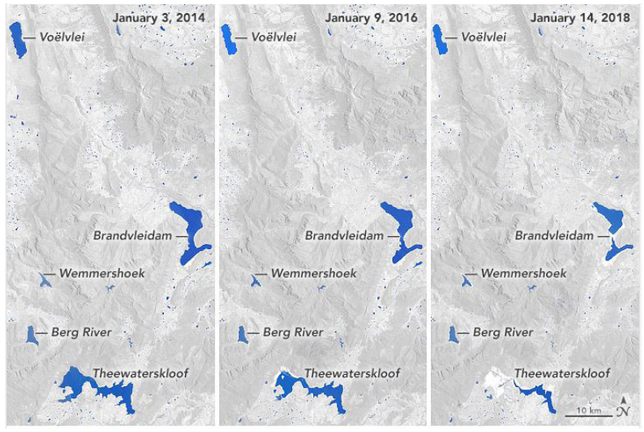
Transitioning toward a water-sensitive city by 2040 with integrated urban water management for resilience and sustainability.

FIGURE 24

The depletion of Cape Town's main reservoirs in the three years preceding the 2018 Water Crisis[120]

This trio of images shows how the three successive dry years took a toll on Cape Town's water system. Voëlvlei, the second largest reservoir, has dropped to 18% of capacity. Some of the smaller reservoirs like the Berg River and Wemmershoek are still relatively full, but they store only a small fraction of the city's water. One of the largest reservoirs in the area – Brandvlei – does not supply water to Cape Town; its water is used by farmers for irrigation.

Source: NASA



119 - City of Cape Town, *Our Shared Water Future: Cape Town's Water Strategy*, 2019.

120 - NASA, *Cape Town's Water is Running Out*, 2018.

Within this framework, strengthening maintenance practices is essential. Key strategies that make possible to manage infrastructure more proactively and effectively include[121]:

Tracking condition and performance: systematic monitoring provides real-time insights into asset health, helping detect early warning signs and ensuring that maintenance interventions are both timely and cost-effective.

Using digital technologies to enhance maintenance: tools such as IoT-enabled sensors make inspections more precise and improve safety, while allowing operators to allocate resources more efficiently.

Leveraging predictive maintenance: advanced analytics and machine learning allow managers to forecast potential breakdowns and extend the useful life of assets while reducing costly service disruptions.

FOCUS 8

Getting it right from day one: the UK's Infrastructure and Projects Authority cost and risk estimation[123]

The UK's IPA has set a gold standard with its 'Cost Estimating Guidance', which organizes best practices around three pillars: Principles, People, and Performance. It emphasizes that cost estimates are dynamic, evolving across project stages rather than fixed numbers, and should always be presented as a range reflective of inherent uncertainty-narrowing as the project matures.
The IPA underscores the importance of early investment—typically 3% to 5% of total project cost—during project initiation to improve estimate accuracy and outcomes.

To support decision-making, IPA sets out an 8-step estimating process:

establishing the brief and engaging the team, through data gathering, selecting methodology, and calculating uncertainty, to reporting, assurance, sign-off, and use in governance decisions. It explicitly requires selecting cost-estimating methods suited to data maturity—such as top-down parametric early on, transitioning to detailed bottom-up as project definition improves—and documenting justifications for method choice. IPA also mandates rigorous uncertainty and risk quantification, using breakdown structures and managed risk registers, to frame confidence levels around anticipated final cost.

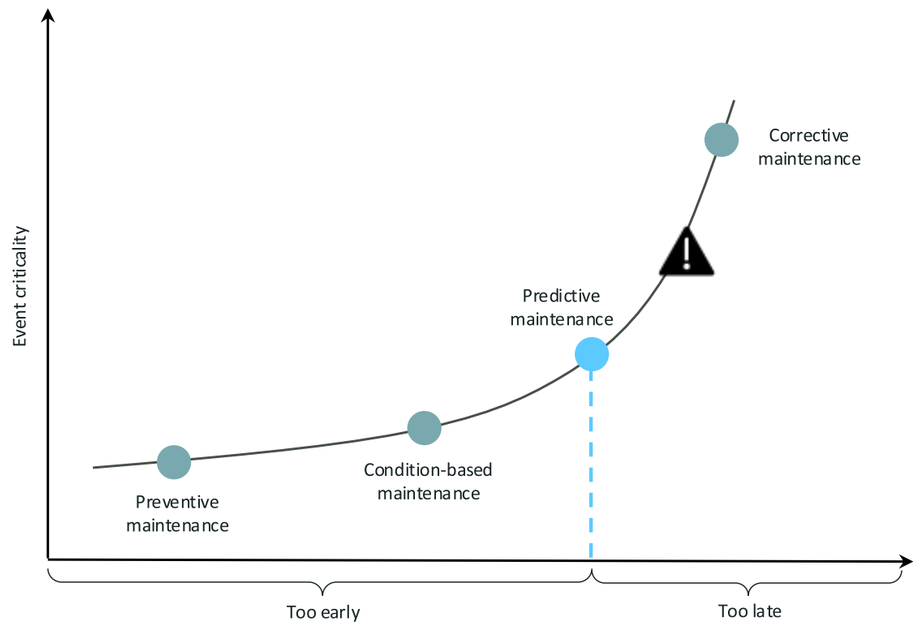
121 & 122 - OECD, *Building resilience: new strategies for strengthening infrastructure resilience and maintenance*, 2021.

123 - Infrastructure and Projects Authority, *Cost estimating guidance: a best practice approach for infrastructure projects and programmes*, 2021.

FIGURE 25

Maintenance policies[122]

Source: OECD



FAST-TRACKING HIGH-IMPACT & READY-TO-IMPLEMENT SOLUTIONS

Engaging in large scale projects does not prevent from moving quickly on practical interventions that can deliver immediate value while setting the stage for long-term transformation. Cities cannot wait for slow, incremental change—what's needed are bold yet feasible measures that improve resilience, sustainability, and quality of life at scale.

Taken together, these strategies (which include maximizing land usage, retrofitting potentially stranded assets such as car parks, deploying renewable energy whenever possible) form a holistic pathway: leveraging the assets cities already have, unlocking underused potential, and deploying interventions that create immediate impact while driving long-term prosperity.

Moving to circular economies is **among the most effective levers to rapidly deliver more resilient, and sustainable cities**. As epicenters of innovation, infrastructure, investment and culture, **urban hubs are where circularity can get scaled up:** cities can be seen as circular cradles in which circular solutions are developed, and as circular catalysts since city authorities can effectively drive the transition.

The potential gains are substantial. A circular economy model could raise Europe's GDP by 7%, generate annual benefits of EUR 1.8tr and save EUR 600bn each year by 2030.[124] It could also cut CO_2 emissions by nearly half by 2030 and over 80% by 2050, while reducing primary material use by up to 53%.[125] In the building sector, deep renovation of the existing stock, along with new buildings that are ultra low-consumption, could slash energy demand for space heating by as much as 80% by 2050.[126]

Among under-exploited circular lever, **urban mining stands out as a major opportunity:** this process consists of recovering valuable raw materials—such as metals, minerals, and rare earth elements—from discarded products, buildings, and infrastructure in cities, instead of extracting them from natural mines. It treats cities as "above-ground mines", focusing on e-waste, construction debris, end-of-life vehicles, and other urban waste streams, generating not only environmental benefits but also **financial gains through cost savings and potential tax incentives.** A number of cities have already positioned themselves at the forefront of urban mining, including in South Holland where it can potentially lead to a reduction of 229 kton CO_2 (Focus 10). Moreover, **cross-infrastructure cooperation** can further amplify both economic and operational efficiency.

EXPERT POSITION 10

Charles-Antoine Blanc—The future of urban waste management

"The future of urban waste management lies in embracing intelligent and circular systems to address the challenges of growing urban populations, complex waste streams, and increasing environmental pressures. As cities face rising waste volumes and stricter regulations, particularly in the EU, scalable and efficient infrastructure is essential to meet recycling targets and reduce landfill use and carbon emissions. Public demand for greener cities and greater transparency in waste handling further underscores the need for modernized collection and sorting systems. Investments in advanced sorting facilities and data-driven technologies are paving the way for a transformative approach to waste management, ensuring cities can extract value from mixed waste while aligning with sustainability goals and citizen expectations"

Charles-Antoine Blanc,
Group CFO at Paprec

124 - Bourguignon D., *Closing the Loop: New Circular Economy Package*, European Parliamentary Research Service, 2016.

125 - Ellen MacArthur Foundation, *Towards a Circular Economy: Business Rationale for an Accelerated Transition*, 2015

126 - European Parliament, *Boosting building renovation: what potential and value for Europe?*, 2016. .

FOCUS 9

Urban mining, trash is cash: the case of South Holland[127]

In South Holland, urban mining can potentially lead to a reduction of 229 kton CO_2.

- Since most material is released from the demolition and renovation of utility buildings, the greatest CO_2 savings (64%) can also be achieved here through reuse,
- 36% of the CO_2 savings are related to the demolition and renovation of residential buildings.

The largest contribution to CO_2 savings comes from steel, concrete, and brick. Other product-market combinations can also lead to CO_2 reduction through reuse —for example, installations, aluminum, and ceiling tiles. Although reuse (and thus CO_2 savings) is possible for all these products, not all of them are equally promising to tackle in closing the loop through urban mining.

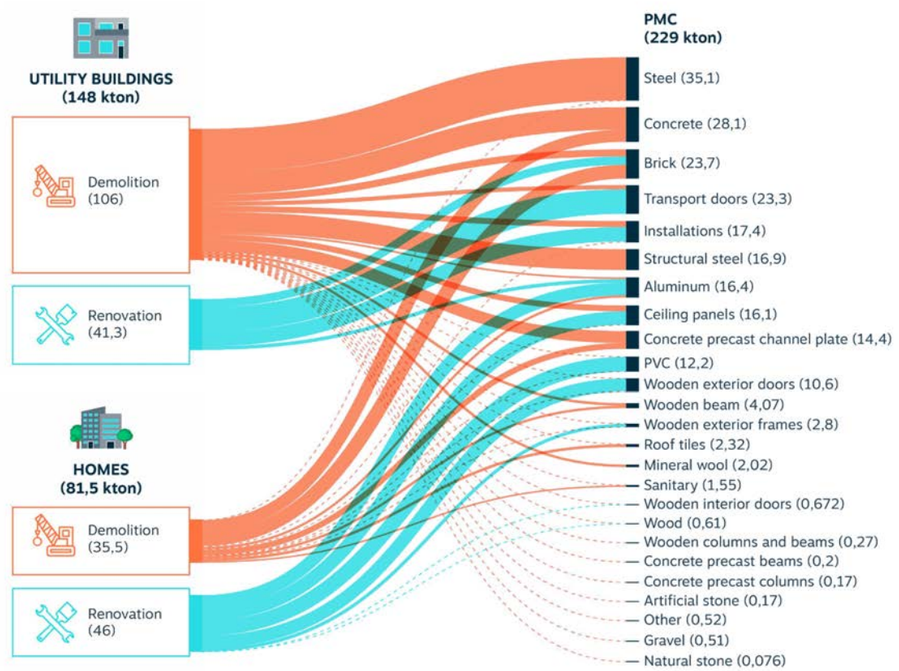
For some material flows, it is important for the scaling up of urban mining that storage in the region is possible. In South Holland and the adjacent provinces, there are a few construction hubs where building materials can be stored. At present, with the current construction hub locations, 6% of the potential CO_2 savings can be achieved within a 10 km driving distance. With a driving distance of 30 km, 47% of the impact can be realized, and with a driving distance of 50 km, 93% of the potential CO_2 savings can be achieved.

127 - Urban Mining Scan, Province of South Holland, 2024.

FIGURE 26

Potential savings of CO_2 impact through reuse per project and material

Source: Province of South Holland, 2024



CASE STUDY 2

Borealis: harnessing renewable energy for digital infrastructure

B

Borealis Data Center designs and operates sustainable colocation facilities in Iceland and Finland. Powered entirely by renewable energy and naturally cooled by the Nordic climate, its data centers provide efficient, low-carbon solutions for AI, HPC, and enterprise customers.

Borealis Data Center operates several facilities in Reykjavík, Blönduós, and Fitjar in Iceland.[128] They are designed to maximize energy efficiency by leveraging the country's naturally cold climate and abundant renewable hydro- and geothermal power. The company manages all supporting infrastructure to ensure optimal cooling and secure operations for high-performance computing and AI workloads. Clients colocate their equipment in these purpose-built data centers,[129] benefiting from 100% renewable energy and a lower-carbon digital environment.

"Borealis leverages renewable energy sources to tackle the challenges of urban data center operations. By locating facilities in regions with abundant hydro and geothermal power, we reduce reliance on electricity grids located in population-dense areas, mitigating stress on urban energy systems while supporting a lower-carbon footprint. Instead of transporting power over long distances—which can result in transmission losses—we prioritize data transmission, strategically locating centers where clean energy is locally available. This approach not only enhances operational efficiency but also stimulates regional high-tech employment, contributing positively to local economies"

Bergþóra Halldórsdóttir, Chief of Staff at Borealis Data Center and Board Member at The Federation of Icelandic Industries

128 - Borealis Data Center, *Sites*.

129 - Borealis Data Center, *Colocation Services*.

ACCELERATING THE PACE TO BUILD ‘ADAPTIVE CITIES’: A SUSTAINABLE AND PRAGMATIC AMBITION FOR URBAN INFRASTRUCTURE

Key takeaways

→ The concept of adaptive cities represents a credible synthesis of the four scenarios outlined in section #2. Planning for hybrid futures encourages a pragmatic approach to urban development—one that neither idealizes a single model nor passively reacts to emerging crises, but instead orchestrates the coexistence of multiple scenarios and strategies

→ Adaptive cities match this versatility as future-ready infrastructure and systems that are flexible and resilient, they combine both digital tools with modular, multi-functional physical systems to adapt rapidly, maintain performance, and integrate innovations effectively

→ Moving faster toward adaptive cities, breaking down sectoral silos will help maximize urban systems efficiency: for instance, sector coupling increases operational efficiency and sustainability, and unlocks financial value for stakeholders. Ensuring interoperability across systems and jurisdictions also enables reduced redundancy, improved coordination, and supports integrated services

→ Cities should also shift from single-purpose infrastructure to multifunctional projects, such as merging utility corridors with green spaces and integrating transport hubs with mixed-use development, to maximize land usage and increase overall interconnectedness

→ Regulatory sandboxes (testing innovations under relaxed rules), smart procurement mechanisms (performance-based specifications, pre-commercial procurement) and a new generation of public-private alliances are critical tools to drive sustainable infrastructure innovation

Toward adaptive cities: designing smart, resilient and nature-based urban infrastructure and services

Recognizing and planning for hybrid futures encourages a **pragmatic approach to urban development**—one that neither idealizes a single model nor passively reacts to emerging crises, but instead deliberately orchestrates the coexistence of multiple scenarios and strategies. The concept of adaptive cities represents a credible synthesis of the four scenarios outlined in section #2. Rather than aligning exclusively with any single pathway, adaptive cities embody a pragmatic ambition: to selectively combine the strengths of each model while mitigating their respective vulnerabilities.

From the hyper-connected metropolis, adaptive cities inherit the efficiency and optimization enabled by advanced technologies; from the resilient, community-led city, they draw lessons in local agency, circular practices, and social cohesion; from the resource-strained, fragmented landscape, they recognize the urgency of preparedness and the need to address inequality and vulnerability; and from the controlled, survival-oriented city, they incorporate the capacity for centralized coordination, resource stewardship, and systemic resilience under stress.

Integrating resilience to advance toward the next generation of smart cities

SMART CITIES ARE DEAD: LONG-LIVE ADAPTIVE CITIES!

The idea of the smart city has long been portrayed as the future of urban living, yet it remains only a necessary first step. Proposed applications range from self-driving cars to smart lighting but while sensors and data are essential, they are merely the raw materials—much like cement, water, sand, and gravel are for concrete—not the ultimate solution. The smart city model may have suited stable, predictable conditions, but today’s world of constant disruption demands more.

In this context, moving beyond the concept of smart cities, **‘adaptive’ cities are shaped by future-ready infrastructure**, built on the principle that urban systems must **remain flexible and resilient** to withstand rapid changes—be they driven by climate impacts, technological advances, or demographic shifts. By design, adaptive cities embed built-in agility that spans both their digital infrastructure and physical operations:

On the digital side, flexibility can be enabled through tools and approaches such as cloud computing, AI, machine learning, digital twins, software-defined networks, smart contracts, and platform-based business models,

On the physical side, adaptability can be achieved through modular and multi-functional design, advanced construction techniques, robotics and drones, as well as methods that enable rapid integration, interoperability, and dynamic provisioning.

FOCUS 10

Singapore’s best-in-class smart city strategy: the constraints on replicating it

Singapore has established itself as a global reference point for ‘smart’ initiatives through its Smart Nation program, launched in 2014 by Prime Minister Lee Hsien Loong,[130] which has successfully embedded connectivity into daily life for both businesses and citizens, driving the adoption of a broad spectrum of smart technologies across both the public and private sectors.[131]

This nationwide strategy not only familiarized the population with emerging technologies but also facilitated rapid adoption of innovative solutions, such as the Safe Distance @ Parks portal during the Covid-19 crisis.[132] The city also has a digital national identity system, a Smart Nation Sensor Platform,[133] and Virtual Singapore—a 3D digital model of the city that can run simulations and support future planning—to name just a few hi-tech innovations.[134]

Yet, the mere transfer of technology does not guarantee effective outcomes in other cities, as local conditions significantly shape the trajectory of smart city projects. This reality is illustrated by the ASEAN Smart Cities Network (ASCN), founded by Singapore in 2018, which encompasses 26 cities with diverse levels of digital maturity.[135] For example, Jakarta focuses on software- and app-based solutions to address pressing issues such as traffic congestion and pollution.[136]

Beyond ASEAN, the data-driven city model also encounters structural and cultural limitations. For instance, extensive data collection strategies that are central to smart services in Asia cannot be directly transposed to Europe, where different ethical and cultural frameworks prevail. Ultimately, while Singapore offers a powerful demonstration of what a smart city can achieve, every urban context presents unique challenges, requiring tailored strategies rather than a one-size-fits-all approach to urban digital transformation.

130 - Prime Minister’s Office Singapore, *PM Lee Hsien Loong at the Smart Nation Launch*, 2014.

131 - Center for Digital Society, Singapore : *From Smart City to Smart Nation*, 2020; Sipahi, E.B., and Saayi Z., *The World’s First ‘Smart Nation’ Vision: The Case of Singapore*, Smart Cities and Regional Development (SCRD) Journal, 8 (1), 2024.

132 - Govtech Singapore, Safe Distance @Parks: *How AI replaced eye power for crowd counting*, 2021.

133 -Govtech Singapore, *5 National Projects For 1 Smart Nation*, 2018.

134 -OPSI, *Virtual Singapore – Singapore’s virtual twin*, 2015.

135 & 136 - Ministry of Foreign Affairs Singapore, *Centre for Liveable Cities Singapore, ASEAN Smart Cities Network*, 2018.

EXPERT POSITION 11

Timothy J. Dixon—The concept of ‘adaptive city’

“Over the last 25 years the concept of a smart city, or one driven by technological innovation, has been a constant theme across the world. But on its own, critics have argued, smart technology cannot save the planet and may have negative impacts on security and privacy. Although technology could be a beneficial means to a sustainable endpoint, it’s equally important to think about the long-term planning of our cities and urban infrastructure (waste, water, energy and transport) and how to make our urban areas more resilient to current and future shocks. This includes not only the obvious impacts of climate change (an example of a ‘wicked problem’—uncertain, liable to impact different stakeholders in different ways and very difficult to resolve), but also the increasing impact of urbanization, and socio-economic and geo-political impacts. The notion of an ‘adaptive city’ goes beyond the idea of a ‘smart city’ by focusing on the ability to dynamically adjust to real-time needs and challenges. There are two important aspects to adaptive cities. Firstly, adaptation can either be incremental, or it can be wider and systemic and transformative within a city. Secondly adaptation is a counterpoint to ‘resilience’, another important concept. Adaptation focuses on the process of adjusting to existing or expected climate shocks and other kinds of impact and their effects, while resilience is the capacity to cope with and recover from shocks and impacts”

Timothy J. Dixon,
Emeritus Professor at the University of Reading and Visiting Fellow at Kellogg College, University of Oxford

EXPERT POSITION 12

Andrew Karvonen – Possible paths ahead for autonomous vehicles

"The rise of autonomous vehicles (AVs) has the potential to become the most significant technological shift since the advent of the automobile over a century ago. While predictions about their widespread adoption vary—ranging from within the next two decades to as far as sixty years—the transition period will likely be marked by uncertainty, regulatory experimentation, and coexistence between conventional and autonomous vehicles. Advocates emphasize the potential benefits of AVs: improved safety, reduced traffic congestion, lower emissions, more affordable mobility services, and expanded access for groups traditionally excluded from driving, such as children, seniors, and individuals with disabilities. However, the extent of these benefits will depend heavily on how the technology is implemented.

Two broad pathways are conceivable. A private, auto-centric model could encourage urban sprawl by enabling longer commutes in personally owned AVs, reinforcing car dependence and weakening the role of public transit. In contrast, a public, human-centric model would prioritize shared AVs, integration with mass transit, and support for active mobility, fostering denser, more sustainable urban development. This divergence highlights a critical question: what social problems should AVs solve? Whether addressing road safety, reducing urban sprawl, or improving mobility equity, the deployment of AVs must align with broader societal goals.

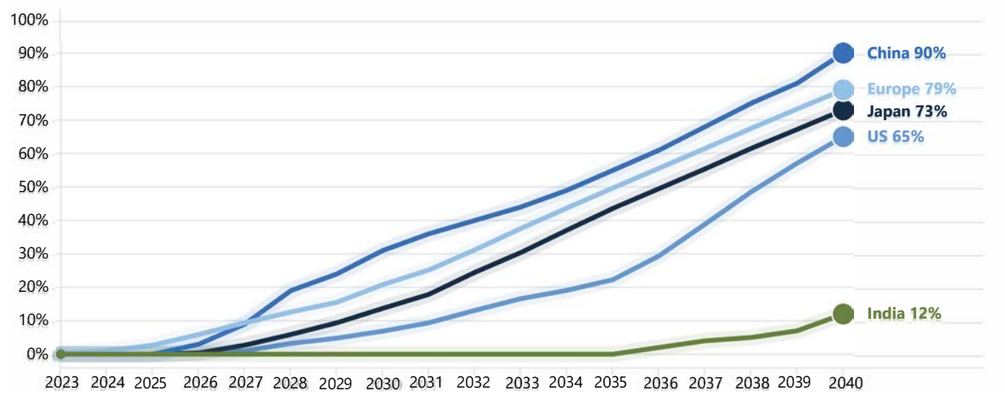
For urban planners, this presents an opportunity to rethink the public realm—repurposing parking space, narrowing driving lanes, expanding pedestrian and cycling infrastructure, and creating calmer, safer streets. The central challenge lies in maximizing the societal benefits of AVs while minimizing their potential drawbacks. The introduction of automobiles a century ago offers a cautionary lesson about failing to anticipate long-term impacts. To avoid repeating past mistakes, policymakers and planners must act proactively, shaping regulations that guide AVs toward collective well-being rather than private profit. As urban thinker Michael Batty observes, we are entering an 'inventive and disruptive century'. This moment represents not merely a technological revolution but also an opportunity to design more sustainable, equitable, and livable cities for the future"

Andrew Karvonen, Professor of Urban Design and Planning at Lund University in Sweden

FIGURE 27

Autonomous vehicles penetration by 2040

Source: Goldman Sachs, 2024



CASE STUDY 3

Telefónica: leveraging IoT for smarter urban management

Telefónica is a leading global telecommunications provider headquartered in Spain, with a strong presence in digital innovation and smart city solutions. Through its platforms, the company connects infrastructures, services, and citizens to help cities become more efficient, sustainable, and livable.

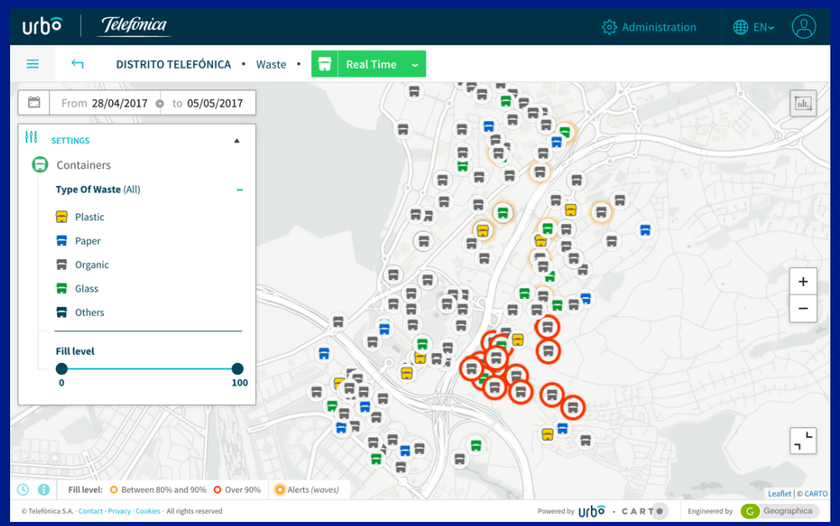
Telefónica is actively engaged in the development of smart cities—urban environments that leverage digital technologies to enhance citizens' quality of life and improve city management. Through its connected platforms and solutions, housed within the Telefónica Tech unit, the company links infrastructures, public services, and residents to make cities more efficient, sustainable, and innovative.[137]

Telefónica launched Urbo, a FIWARE-compliant (an open European framework enabling interoperable digital applications) dashboard developed with CARTO (a platform for geospatial data visualization and analysis) to process real-time data from thousands of IoT sensors, providing role-based access for civic administrators while also offering a public portal where residents can track traffic, air quality, and energy consumption.[138] The private portal consolidates sensor data to monitor mobility patterns, optimize waste collection routes with machine learning, and align decisions with city KPIs. By analyzing historical garbage collection patterns, pickups in low-yield areas have been reduced, while they have been increased in high-volume ones, cutting fuel and labor costs by 7%. While street lighting represented nearly 30% of electricity use, officials introduced adaptive dimming and schedule adjustments across 70% of the network, saving EUR 1.2m annually.[139]

FIGURE 28

Visual representation of Urbo tool[140]

Source: Telefonica



137, 138, 139 & 140 - Carto, *Driving value for Smart Cities with IoT and location intelligence solutions*, 2017.

ADAPTIVE INFRASTRUCTURE: MIXING RESILIENCE AND INTELLIGENCE

Adaptive infrastructure are the physical and digital backbone of adaptive cities. They consist of systems capable of dynamically adjusting their operations and configurations in response to changing conditions, demands, or external stimuli.[141]

Four main principles stand out when talking about adaptive infrastructure:

Flexibility: allows urban systems to respond effectively to changing environmental, social, and economic conditions, whether it be surges in population, shifts in mobility patterns, or climate-related stresses.

Modularity: ensures that components of infrastructure—such as transportation networks, energy grids, and water systems—can be upgraded, expanded, or reconfigured without disrupting the entire system.

Intelligence: often embedded through sensors, data analytics, and connected digital platforms driven by AI, enables real-time monitoring, predictive maintenance, and informed decision-making, making cities more resilient, efficient, and responsive to the needs of their inhabitants.

Integration: ensures that these diverse systems operate cohesively, connecting physical and digital infrastructure, coordinating services, and linking governance, technology, and communities.

Together, **these qualities transform infrastructure from a static support system into a dynamic**, evolving framework that actively shapes urban life and fosters sustainable growth.

TABLE 1

Adaptive infrastructure: cases in action

Source: Altermind

PRINCIPLE	DESCRIPTION	ENERGY GRID	TRANSPORTATION	WATER MANAGEMENT	WASTE MANAGEMENT	DIGITAL
Modular	Build in scalable modules, which allows for easier reconfiguration and expansion without having to rebuild the entire structure	Decentralized microgrids for localized energy supply	Modular road sections for easy reconfiguration or repair	Modular treatment plants for scalable capacity	Modular waste sorting facilities	Modular wireless communication towers
Responsive / flexible	Adjust to disruptions like natural disasters or cyberattacks while maintaining critical functions	Smart meters with dynamic pricing to manage demand	Smart traffic systems that adjust timing based on flow	Real-time leak detection and pressure adjustment	Dynamic waste collection schedules	Dynamic network management systems
Smart	Use sensors, data analytics, and even artificial intelligence to make informed, automated decisions and optimize performance	AI for demand prediction and load balancing	AI to optimize traffic flow and reduce congestion	Smart meters to monitor water quality and contamination	Automated waste sorting systems	Smart utility poles equipped with communication technology that monitor environmental conditions
Integrated	Break down traditional institutional and sectoral silos to devise cohesive and comprehensive solutions that consider social, economic, and environmental factors together	Integration of renewables, distributed generation, and EVs	Street networks with loops to provide redundancy and multiple transfer options	Green infrastructure with multiple uses like stormwater management and recreation	Integrated waste management systems that combine recycling, composting, and waste-to-energy processes	Unified communication networks that integrate various data sources (traffic cameras, weather sensors, public transport systems)

141 - Climate sustainability Directory, *Adaptative Infrastructure Systems*, 2025.

142 - Wong T. et al., *Valuing the benefits of naturebased solutions: A manual for integrated urban flood management in China*, World Bank, 2021.

Leveraging nature-based solutions: strategies for the future rooted in the architecture of cities

HARNESSING NATURAL SYSTEMS FOR URBAN RESILIENCE

Adaptive cities are not defined solely by technological optimization or resource management, but also by their **capacity to draw on the inherent architecture of natural systems** to strengthen resilience. Harnessing ecosystem services—climate regulation, risk reduction, biodiversity support, and improved quality of life—nature-based strategies embody a pragmatic and sustainable approach that combines environmental efficiency, social well-being, and flexibility in the face of uncertainty.

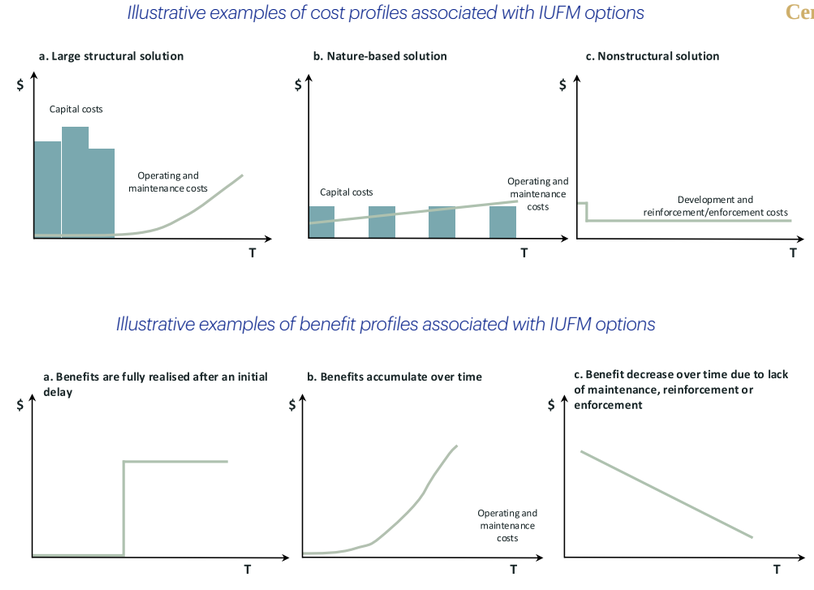
They demonstrate that urban adaptiveness is built not only through technological or institutional innovation, but also through the active reintegration of natural systems into the very fabric of urban infrastructure to tackle the most pressing urban challenges.

Flood risk reduction and stormwater management. Green roofs, wetlands, and permeable pavements absorb and slow runoff, reducing urban flooding and alleviating pressure on drainage systems. Additionally, nature-based solutions help retain moisture during droughts, ensuring a more stable water supply. In coastal cities, integrated prevention systems like the MOSE project in Venice provide further protection against flooding while enhancing resilience to climate change impacts.

FIGURE 29

Nature-based solutions outperform traditional approaches in the long-term[142]

Source: World Bank, 2021



EXPERT POSITION 13

Adam Abdin— AI's potential to enhance urban resilience

"AI-driven predictive analytics is critical for urban infrastructure resilience, enabling early detection of potential failures in interdependent systems like transportation and energy. By analyzing hidden signals in real-time data, such as traffic or grid performance, AI models can anticipate rare events like blackouts, which human operators may miss. For example, a COVID-19 response model can use AI to optimize mobile hospital placement, maximizing societal benefit during crises. This capability supports proactive planning, ensuring urban systems adapt to evolving demands and risks through data-driven strategies"

Adam Abdin, Associate Professor of Operations Research and Decision Analytics at CentraleSupélec

Biodiversity support. Nature-based solutions create and protect habitats in urban areas, supporting wildlife and enhancing urban biodiversity.

Carbon sequestration and climate mitigation. Urban green spaces, trees, and ecosystems involved in nature-based solutions sequester carbon, helping to offset a significant portion of urban emissions and to contribute to climate mitigation goals.

Air and water quality improvement. Natural elements integrated into urban infrastructure filter air pollutants, reduce urban heat island effects, and improve water quality through natural drainage and wetlands restoration.

Urban temperature regulation. Vegetation in cities, such as trees and green roofs, can cool urban temperatures. The cooling capacity of trees alone is estimated to represent 1.1 to 2.9°C for over 600 cities in Europe,[143] mitigating heat waves and improving public health.

The net result is that nature-based approaches can avert billions in climate-related losses to infrastructure assets. For example, Copenhagen is preparing for an upsurge in torrential rain over the coming decades: giant infrastructure is being built above and below ground to make the city more resilient to heavy downpours. This climate-resilient district planning is part of the city's Climate Adapation Plan, which is expected to save EUR 3bn over 100 years.[144] To increase the water capacity of its system, the city has notably launched the construction of several tunnels under the city, including a 1.3 km long tunnel due to open in 2026 that will link Copenhagen's inland lakes to the far end of the harbor.[145]

Beyond water management and biodiversity, **nature-based solutions—**which often already exist at scale—also play a decisive role in **climate transition** and **urban adaptation**. Urban forestry programs, for instance, have been shown to significantly mitigate heat stress: increasing tree coverage to 30% in European cities could reduce average summer temperatures and prevent thousands of heat-related deaths each year.[146] Green roofs further contribute by improving air quality, capturing air pollutants, while also lowering energy demand through enhanced building insulation and reduced cooling needs.[147] For additional, concrete illustrations of how nature-based solutions can advance smarter urbanism, see the winning entries in the "The City as Network. Reimagining Urban Infrastructure" competition (in section #2).

143 - Baker K. et al., *Nature-based solutions in urban areas (Primer 6)*, UNEP Finance Initiative, 2023.

144 - UNDDR, *Copenhagen joins UNISDR campaign after '1,000-year' flood*, 2012.

145 - HOFOR, *Kalvebod Brygge Skybrudstunnel.*

146 - European Commission, Directorate-General for Environment, *Increasing tree coverage to 30% in European cities could reduce deaths linked to urban heat island effect*, 2023.

147 - Cai, L., Feng, X.P., Yu, J.Y., Xiang, Q.C. and Chen, R., *Reduction in Carbon Dioxide Emission and Energy Savings Obtained by Using a Green Roof*, Aerosol and Air Quality Research, 19: 11, 2019.

FIGURE 30

Pumping station of a cloudburst tunnel under construction near Copenhagen harbor

Source: Euronews, 2024

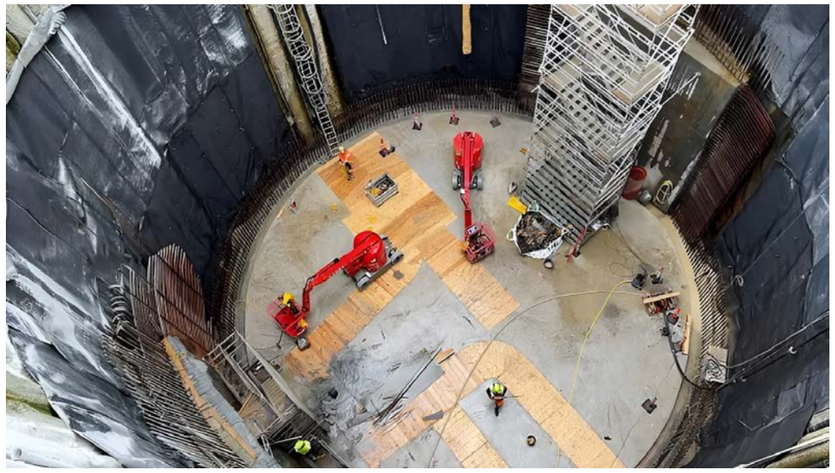


FIGURE 31

A concept drawing of green space in Copenhagen that can retain and filter stormwater

Source: Euronews, 2024

THE SCALING OF 'SPONGE CITIES': A CASE IN POINT

Sponge cities provide a **quintessential illustration of nature-based solutions,** representing an urban development concept that integrates natural water cycles into city design. The concept was initially developed by Kongjian Yu (Peking University's College of Architecture) in response to China's rapid urbanization and increasing vulnerability to floods and water scarcity.

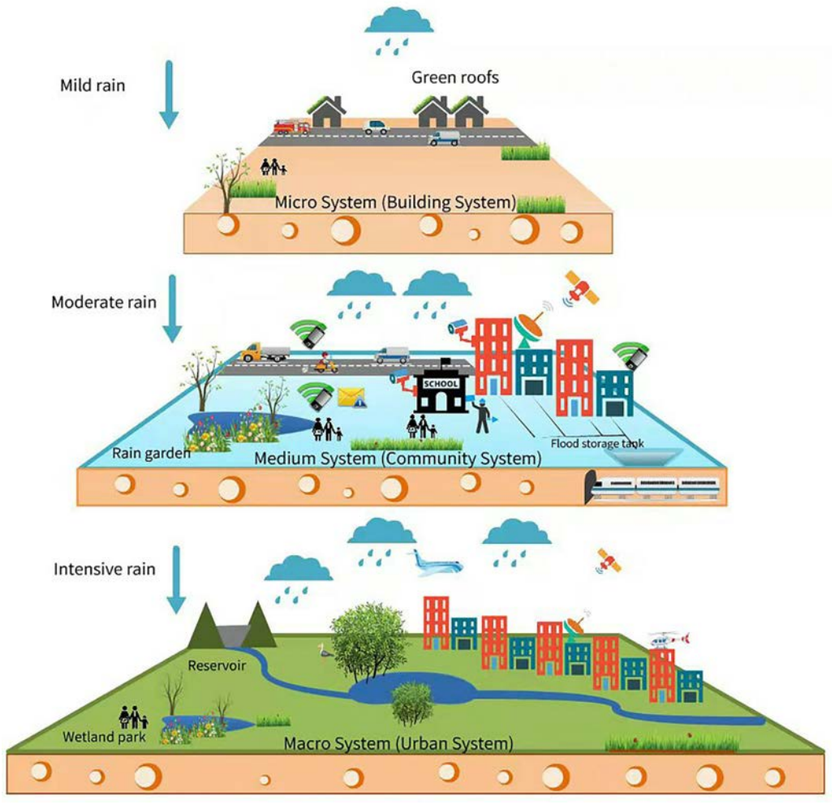
Instead of relying solely on traditional gray infrastructure (concrete drains, pipes, and channels), sponge cities integrate green infrastructure and nature-based solutions, such as: permeable pavements that let water seep into the ground, green roofs and rooftop gardens, rain gardens and wetlands, restored rivers and ponds, urban vegetation and tree canopies, etc.

For instance, Wuhan, historically known as the "city of a hundred lakes", is a pioneer of China's sponge city programme.[148] During its pilot phase (2015-2017), the city implemented 389 sponge projects over 38 km², including urban gardens, constructed water bodies, roads, residential and public buildings.[149] In Wuhan Garden Expo Park, the gardens are estimated to absorb up to 70% of rain that falls there.[150] Other consequences have included a reduction in runoff-borne pollution of around 70%, the creation of new jobs, the improvement of drinking water quality, and the avoidance of significant economic damages.[151] In a true stress test during the unusually intense 2020 rainy season, some areas received up to 472.3 mm of daily rainfall, yet no serious flooding or waterlogging occurred, and the impact on traffic and residents was markedly reduced compared to 2016.[152] The sponge infrastructure saved an estimated CNY 4bn (approx. EUR 509m) over traditional gray infrastructure costs.[153]

FIGURE 32

Visual representation of a sponge city[154]

Source: The conversation, 2023



148 - NetworkNature, *Wuhan Sponge City Programme: achieving harmony among people,* water and city, 2021.

149 & 150 - Oates L. et al., *Building climate resilience and water security in cities: lessons from the sponge city of wuhan, China,* Coalition for urban transitions, 2020.

151 - Oates L. et al., *Building climate resilience and water security in cities: lessons from the sponge city of wuhan, China,* Coalition for urban transitions, 2020; C40Cities, *Cities100: Wuhan - Waterlogging Prevented by Sponge Infrastructure,* 2016.

152 - NetworkNature, *Wuhan Sponge City Programme: achieving harmony among people, water and city,* 2021.

153 - Oates L. et al., *Building climate resilience and water security in cities: lessons from the sponge city of wuhan, China,* Coalition for urban transitions, 2020; NetworkNature, *Wuhan Sponge City Programme: achieving harmony among people, water and city,* 2021.

154 - Qi, Y., Chan, F. K. S., et al., *Exploring the Development of the Sponge City Program (SCP): The Case of Gui'an New District, Southwest China.* Frontiers in Water, 3, 2021.

FOCUS 11

Auckland: a top-ranked sponge city in a changing climate

Sponge cities are urban areas designed to absorb rainwater and prevent flooding through abundant green spaces—such as trees, lakes, and parks—or other well-planned water management features. Cities as diverse as Shanghai, New York and Cardiff are embracing their 'sponginess' through inner-city gardens, improved river drainage and plant-edged sidewalks.

Auckland ranks first globally in sponge city performance, with 35% sponge coverage and 50% green-blue areas. This infrastructure—parks, golf courses, residential gardens, and natural soils—absorbs rainwater and helps mitigate flooding. A low-lying coastal city of 1.4m residents, Auckland receives an average annual rainfall [155] of 1,210 mm, and faces increasing risks from extreme weather episodes, such as heavy rain events and droughts.[156]

The urban fabric is dominated by low-rise residential neighborhoods with sizeable gardens, providing extensive green areas. Large, well-distributed urban parks further boost its green-blue percentage while industrial areas, though less green, are clustered next to parkland, grassed areas, or farmland, enhancing natural retention.

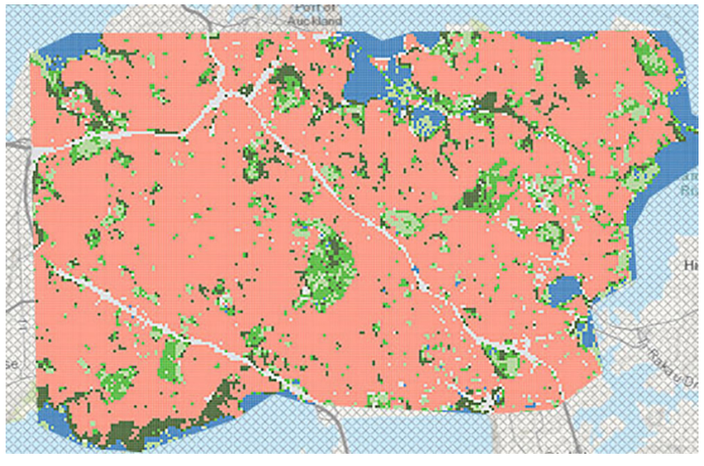
Soils in the central isthmus have relatively high infiltration potential; in some suburbs, stormwater soakage is the primary management method. Auckland Council implements strong policies, including mandatory detention/ retention of stormwater in specific zones, promotion of water sensitive urban design,[157] and a city-wide Network Discharge Consent focused on restoring natural site hydrology.[158]

Taken together, high greenblue coverage, favorable infiltration soils, and integrated water management make the city well prepared for major rainfall events, which is critical as the maximum one-hour total in an average year reaches 20.6 mm.[159]

FIGURE 33

Mapping Auckland's sponginess[160]

This map, created with the Terrain tool, classifies Auckland's land cover: green shows vegetation, blue shows water, and together they act like a sponge to absorb rainfall, while red/orange hard surfaces like roads and buildings prevent water infiltration.



Source: ARUP, 2023

155 - Stats NZ, Rainfall.

156 - Auckland Council, *Annual Report 2021/2022. Volume 4: Climate risk statement,* 2022.

157 - Auckland Council, *Water Sensitive Design for Stormwater,* 2015.

158 - Auckland Council, *Discharging stormwater under our Network Discharge Consent* (NDC).

159 & 160- ARUP, *Global sponge cities snapshot,* 2023

Key levers to accelerate the pace and maximize potential urban upsides

Integrating infrastructure systems: unlocking urban synergies

MAXIMIZING THE POTENTIAL FOR VALUE CREATION OF INFRASTRUCTURE SYSTEMS THROUGH SECTOR INTEGRATION

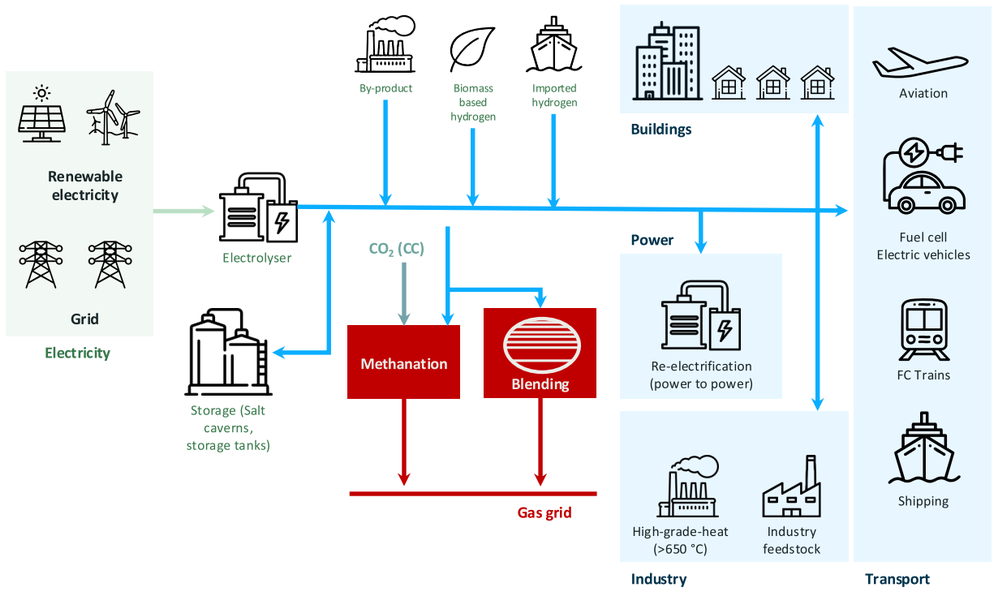
To evolve swiftly and durably toward adaptive cities, integrating transport, energy, water, and digital networks allows cities to operate as cohesive, efficient ecosystems rather than isolated systems. Beyond operational efficiency, such integration is increasingly understood as a driver of **economic value creation.** It enables stakeholders to optimize resource use, reduce infrastructure redundancy, and capture tax and cost efficiencies, while also developing new revenue streams from by-products such as residual heat or curtailed renewable electricity. By doing so, integrated infrastructure becomes more attractive to investors and better positioned to respond to fiscal and regulatory pressures.

In this context, sector coupling has gained traction over the past decade. In principle, sector coupling can be defined as "the process of progressively and increasingly inter-linking the electricity and gas sectors—by optimizing the existing synergies in the generation, transport, and distribution of electricity and gas".[161] While sector coupling indicates the integration of electricity and gas, the interlinking with more sectors (e.g. heating, transport and industrial production) is more often referred to as "sector integration": the electricity system moves from "a system where generation adapts to inflexible demand, to a system where flexible demand adapts to variable generation".[162] Regulatory frameworks reinforce this shift: for example, in France, rules limit both the maximum temperature of discharged water and how much it can heat up rivers, encouraging operators to recover and reuse waste heat instead of releasing it.

FIGURE 34

Coupling of the energy system sectors[163]

Source: Florence School of Regulation, 2020



161 - EUI florence School of Regulation, *Sector Coupling and Energy System Integration*, 2020.

162 -Gea-Bermúdez J. et al., *The role of sector coupling in the green transition: A least-cost energy system development in Northern-central Europe towards 2050*, Applied Energy, 289, 2021.

163 & 164 - EUI Florence School of regulation, *Sector coupling and energy system integration*, 2020.

165 - Ratka S., Boshell F., *The nexus between data centres, efficiency and renewables: a role model for the energy transition*, Energy Post, 2020.

166 - Basmadjian R., *Flexibility-Based Energy and Demand Management in Data Centers: A Case Study for Cloud Computing*, Energies, 12(17), 2019.

167 - Koronen C. et al., *Data centres in future European energy systems – energy efficiency, integration and policy, Energy Efficiency*, 13, 2019.

168 -Ratka S., Boshell F., *The nexus between data centres, efficiency and renewables: a role model for the energy transition*, Energy Post, 2020.

169 -Data Center Dynamics, *Facebook begins data center and district heating expansion in Odense*, Denmark, 2020.

Technological innovation and digitalization are crucial to increasing efficiency and optimizing both electricity and gas infrastructure costs. Within such an integrated framework, these sectors are interconnected to accelerate the deployment of renewable energy sources and improve the financial performance of urban energy systems through synergies and load optimization.

Gas-to-power technologies like CCGTs are long-established, whereas power-to-gas (P2G) is relatively new. P2G converts surplus or curtailed electricity into hydrogen (renewable or low-carbon depending on the power source) for storage or direct use, and can also produce synthetic natural gas via methanation.[164] In other words, surplus electricity generated from wind and solar installations can be converted into hydrogen via electrolysis, subsequently serving as a fuel for transportation or heating. Likewise, residual heat from industrial operations can be recovered for space heating purposes or for electricity generation.

For multi-technical service providers such as Equans, a French multinational company specializing in multi-technical services—electrical engineering, HVAC, etc.—focused on the energy, digital, and industrial transitions, these developments are more than technical advances; **they represent a strategic business opportunity.** By offering integrated multi-energy and cross-infrastructure solutions, such players can diversify revenue streams and differentiate themselves. Sector integration thus delivers not only efficiency and resilience, but also a foundation for **cross-business value creation and long-term competitiveness**.

FOCUS 12

Sector coupling and grid flexibility

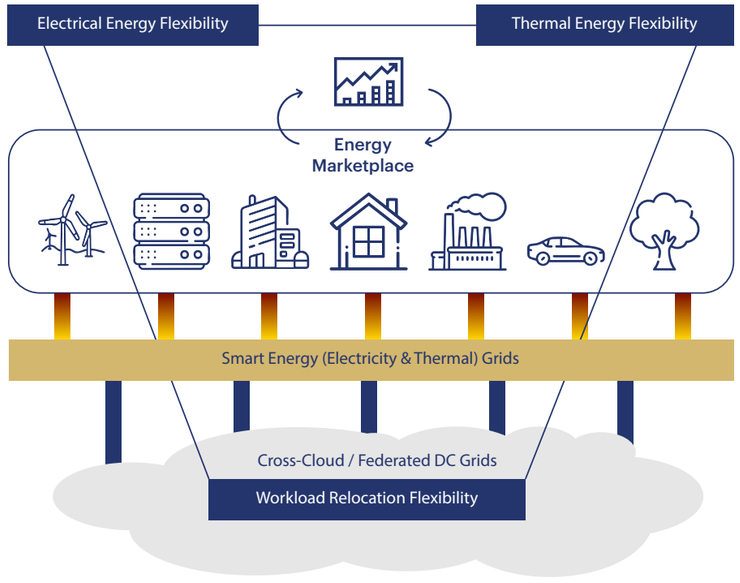
Data centers consist of a dedicated space within a building to house computer systems and associated components, such as telecommunications and storage systems. Given the energy usage and the high degree of automation—due to the integration of technologies such as IoT devices and machine learning algorithms—data centers provide a great opportunity to add to the flexibility of grids through demand-side management.

This flexibility allows grids to integrate higher shares of variable sources of energy, such as solar and wind[165] and favors decarbonation by (i) minimizing the overall energy consumption and (ii) reducing the peak power demand during demand-response periods[166]. This new management approach could also provide more than 10 GW of demand response in the European electricity system in 2030[167].

FIGURE 35

Sector coupling for grid flexibility

Source: Creti A., 2019



Application: using waste heat from data centers

Using renewable electricity for operations and waste heat (a natural product of servers) enable to warm large amounts of water for nearby houses or businesses, data centers indirectly electrify with renewables the heating sector[168]. For instance, Facebook's DC in Odense, Denmark, captures excess heat generated by their servers and recycles it to provide heat to the local community, which is then directed into the local district heating system, operated by district heating company[169].

By fostering resource efficiency and reducing waste, sector coupling builds on systems integration by creating business value through resource-efficient strategies:

Implementing renewable-powered EV charging or waste-to-energy systems can cut costs and emissions, aligning with sustainability regulations.

Engaging municipalities and industries in co-designing coupled systems, like district heating from industrial waste, can ensure solutions meet local needs, maximize efficiency, and unlock business opportunities, increasing property values by sustainable areas.

Tapping into government grants or EU-style funding for clean energy projects with the aim of offsetting initial costs, maximizing returns through reduced operational expenses.

Overall, analysis of EU energy markets has shown that sector coupling could lead to a 60% decrease in emissions from the transport, building, and industry sectors by mid century—a 71% reduction relative to 1990 emission levels.[170]

In this context, infrastructure serves as a platform for sector integration, enabling different industries and systems to connect, reinforce each other, and generate added value beyond their standalone functions:

Functions for economic development: infrastructure can serve as a catalyst for regional and local economic growth by creating new business opportunities, stimulating trade, and enhancing competitiveness. For example, logistics hubs such as the Port of Singapore not only provide maritime services but also host clusters of shipping, warehousing, and financial services that generate significant employment and investment.

Functions for network effect: infrastructure can broaden its functions by integrating with other systems, thereby creating a network effect and increasing value through higher user numbers. The foundation of one technology can be used to embed others, resulting in multifunctional infrastructure corridors while minimizing the impact on the surrounding environment.

Functions for revitalizing space: in Vienna, the redesign of the Josefstädter Straße station illustrates how outdated industrial traffic infrastructure was transformed into social infrastructure by reimagining and enhancing the adjacent public spaces. What was once an obsolete gas station became an open, accessible recreation area that now attracts more visitors.

FIGURE 36

Creating synergies between infrastructure and energy supply assets at the Port of Duisburg: localization and asset synergies

Source: Altermind, World Port Sustainability Program

170 - ICLEI - *Local Governments for Sustainability, Sector coupling for renewable energy integration*, 2024.

FOCUS 13

Building Integrated Photovoltaics (BIPV): integrating solar into the urban fabric

Building Integrated Photovoltaics (BIPV) represents a paradigm shift in how cities generate renewable energy. Unlike traditional solar panels, BIPV systems are seamlessly embedded into the fabric of buildings—roofs, façades, windows, and even urban furniture—transforming passive surfaces into active energy generators. BIPV delivers multiple wins at once: it produces clean power directly where it's needed, replaces conventional cladding or roofing, and enhances thermal comfort by shading or insulating buildings. Façades alone could provide up to 70% of rooftop solar potential in dense cities, unlocking vast new surfaces for generation.[171]

The adoption of BIPV is gaining momentum globally. According to the International Energy Agency (IEA), the current market for BIPV is at around 2 GW, with Europe's share being between 300-500 MW.[172] AN IEA report highlights the growing interest and investment in BIPV technologies, emphasizing the need for standardized testing and certification to facilitate broader adoption.[173]

171 - Yu, Qing, Kechuan Dong, Zhiling Guo, Jiaxing Li, Hongjun Tan, Yanxiu Jin, Jian Yuan, Haoran Zhang, Junwei Liu, Qi Chen, et Jinyue Yan, *Global Estimation of Building-Integrated Facade and Rooftop Photovoltaic Potential by Integrating 3D Building Footprint and Spatio-Temporal Datasets*, arXiv, 2024.

172 & 173 - IEA, *Advancing BIPV Standardization: Addressing Regulatory Gaps and Performance Challenges*, 2024.

CASE STUDY 4

Borealis and Loiste: drawing together a blueprint for sector integration

B

Borealis Data Center builds and operates sustainable data centers powered by renewable energy. Strategically located in Iceland and Finland, its facilities offer natural, year-round cooling, high operational efficiency, and cost predictability via long-term energy contracts. Loiste Lämpö Oy is a Finnish utility company responsible for the transmission, distribution, and sale of district heating in the Kajaani urban area, focusing on renewable energy and sustainable heating solutions. Its ownership is mixed and involves public stakeholders.

In Kajaani, Finland, Borealis Data Center and Loiste Lämpö Oy are collaborating to repurpose waste heat generated by Borealis Data Center's high-performance computing operations.[174] Starting in 2026, the system will capture thermal energy from Borealis's campus and channel it via a heat pump facility into the local district heating network, delivering warmth to homes and businesses in the Kajaani region.

Located near the EuroHPC LUMI supercomputer and built on a repurposed paper mill site, the data center leverages sustainable design, such as environmentally friendly cross-laminated timber, and is powered by Finland's reliably abundant renewable energy, reinforcing its credentials as an ultra-eco-efficient computing facility.

Together, Borealis and Loiste show how data centers can shift from passive consumers to contributors to urban energy systems, offering a replicable model for circular resource use and city-utility collaboration worldwide.

174 - Borealis Data Center, *Borealis and Loiste Sign Agreement to Reuse Data Center Waste Heat in Kajaani*, Finland, 2025.

CASE STUDY 5

Albea and Qair: unlocking solar potential along transport corridors[111]

A

Albea is a French motorway operator committed to embedding sustainability into transport infrastructure, from reducing carbon emissions to promoting renewable energy production. Qair is an independent renewable energy producer active across Europe and beyond, specializing in the development, construction, and operation of wind, solar, hydro, and green hydrogen projects. Together, they are reimagining motorway environments as sites for clean energy generation and territorial value creation.

Albea is partnering with Qair to develop a photovoltaic plant along the A150 motorway in Barentin, France.[175] Covering 6.5 ha, the project will have a capacity of 4.8 MWp and is expected to generate 5,200 MWh per year. It represents an investment of EUR 3.6m and will generate around EUR 25,000 in annual tax revenues for the local community. Commissioning is planned for 2027, This co-location approach points to the potential of scalable solar installations along transport corridors that can integrate with grid services and high-power charging, accelerating the decarbonization of mobility and unlocking the latent value of existing infrastructure by layering complementary functions (energy and transport).

"ALiS and Albea emphasize sustainable development by prioritizing decarbonization measures, including photovoltaic shading and the expansion of EV charging networks. These initiatives are complemented by active biodiversity preservation efforts, such as pond restoration and the protection of native species, which transform highway corridors into ecologically supportive landscapes. By engaging stakeholders from the earliest stages of project planning, these organizations optimize multi-use infrastructure, enhancing operational efficiency and ensuring that transportation networks serve both urban mobility and environmental objectives"
Antoine Tréboz,
CEO of ALiS and Albea

FIGURE 37

Barentin solar project site localization

Source: Qair

175 - Qair, *Barentin photovoltaic power plant project committee*, 2024.

CASE STUDY 6

Indigo and Corsalis: transforming car parks into multi-use mobility and logistics hubs

Indigo is a leading international operator of parking and urban mobility services, with a portfolio of facilities that increasingly serve as multi-functional hubs in dense urban centers. Corsalis is a French real estate company specializing in urban logistics, with expertise in adapting central locations to support sustainable last-mile delivery solutions. Together, they are redefining how parking infrastructure can be repurposed to meet the mobility and logistics needs of modern cities.

Indigo car parks are in city centers and have space that can be used for storage and to improve the flow of traffic. Their locations and layouts are key assets when it comes to developing new urban logistics services.

In partnership with Corsalis, a specialist in urban logistics real estate, Indigo has started converting Parking Foch in Paris into a next-generation urban services hub. The two-year project, started in March 2025, will create a 12,000 m² facility for eco-friendly last-mile deliveries, a tour coach depot, and a 200-bike Cyclopark.[176] Located near the Arc de Triomphe, this hybrid car park renovation aims to reduce city traffic and promote low-carbon mobility by integrating logistics spaces with traditional parking. The facility will support trucks, electric vans, and cargo bikes, improving delivery efficiency in the dense city center.

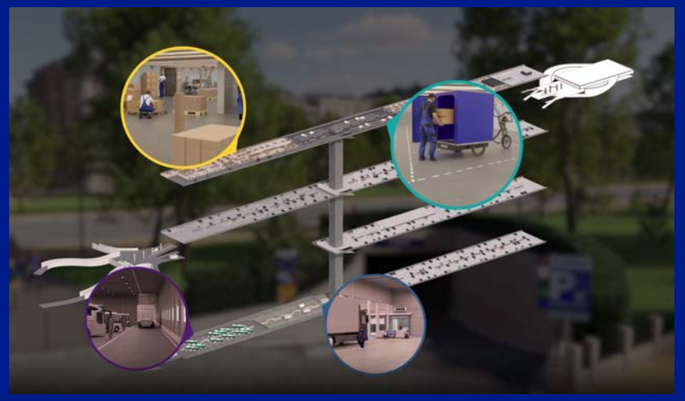
The project is rooted in Indigo's work on the car parks of the future, alongside mobility and architecture experts at the Circular Urban Infrastructures Chair of the École des Ingénieurs de la Ville de Paris (EIVP), which was initiated in 2020.[177] Building on these insights, the Foch project reimagines existing parking assets to ease congestion, and enhance quality of life in Paris, positioning the capital at the forefront of sustainable urban planning.

"This operation stems from a wide-ranging discussion that Indigo has started about the role of parking infrastructure and its vital contribution to optimizing mobility in city centers. We are certain that parking spaces—beyond their primary purpose—have a key role to play in city transformation. The Foch project is an example of this vision in action: we are recasting a parking structure into a multipurpose services hub that addresses the challenges of urban logistics and active mobility, and will ultimately improve quality of life for city-dwellers"
Sébastien Fraisse,
CEO of Indigo

FIGURE 38

Indigo hybrid car parks in association with Corsalis[178]

Source: Indigo, 2025



176, 177 & 178 -Indigo, *Innovation in infrastructure : Indigo starts up a new-generation hybrid car park project in partnership with Corsalis*, 2025.

ENHANCING URBAN SYSTEMS THROUGH INTEROPERABILITY

Besides integration, **interoperability can unlock major gains in efficiency and service quality across infrastructure systems.** By enabling seamless communication between systems and jurisdictions, interoperability has the potential to reduce redundancy and improve system coordination, to enable better decision-making, and to lay the foundation for integrated services.

Expected gains differ by type of infrastructure:

- **Energy systems:** interoperability enables the integration of distributed energy resources and real-time grid balancing. It also facilitates cross-border electricity markets across diverse technologies and operators,
- **Transport and mobility:** standards ensure that different vehicles and networks, from rail to EV charging, can interoperate within and across jurisdictions,
- **Water and wastewater infrastructure:** shared data formats and control protocols allow for system-wide water quality monitoring and flood management across utilities and geographies,
- **Telecommunications and data infrastructure:** interoperability ensures seamless service continuity across networks globally,
- **Urban systems integration (cross-domain):** in adaptive cities, interoperability allows infrastructure systems—transport, energy, buildings, public services—to share data and coordinate actions, enabling efficiency and real-time governance.

Governments have several key levers to encourage interoperability while balancing innovation and competition:

- **Setting regulatory interoperability standards and mandates:** governments can require use of open data formats and common protocols through regulation;
- **Including interoperability criteria in public procurement and funding:** by embedding interoperability requirements in public tenders and investment conditions, governments can drive market demand for compatible and integrable infrastructure solutions,
- **Developing and supporting shared digital infrastructure and data governance frameworks:** creating common platforms and data standards enables seamless data exchange and coordinated management across sectors,
- **Promoting institutional coordination and cross-agency collaboration:** establishing cross-departmental bodies and shared objectives helps break silos and aligns planning and operations for integrated infrastructure governance,
- **Facilitating and funding multi-stakeholder standards development and testing:** supporting inclusive standards bodies and interoperability testbeds accelerates consensus on technical norms while encouraging innovation and participation from diverse market players.

EXPERT POSITION 14

Paulo Moura—Interoperability in the autonomous vehicle project of IMREDD

"The initial step involved establishing a comprehensive test bed through partnerships with a diverse range of territories, including mountain regions, coastal zones, and industrial sites. All participating areas were fully integrated into a unified framework, with interoperability as the guiding principle. This approach moves beyond testing a single technology in isolation; it focuses on connecting systems so they operate seamlessly together. For instance, in the autonomous vehicle project, performance is evaluated not only in terms of the vehicle's operation, but also across multiple connectivity parameters—5G , Wi-Fi, and satellite signals—monitored at every meter along the route. Any weakness in one link can undermine the entire system. The infrastructure of the future must therefore be designed to support this type of integrated, systemic experimentation. Without interoperability, innovation cannot

be scaled effectively"
Paulo Moura,
Deputy Director of Innovation and Partnerships at Université Côte d'Azur/IMREDD

CASE STUDY 7

Axione: enabling mobility with digital infrastructure

Axione is a French digital infrastructure company specializing in the deployment and operation of next-generation broadband and telecom networks. With extensive expertise in both urban and rural contexts, the company supports public authorities and transport operators in enabling high-capacity digital systems that underpin smarter and more sustainable mobility.

In Toulouse, Axione, in partnership with telecom solutions provider Eviden, is equipping the new Metro Line C with a converged communication backbone combining private LTE (4G), Wi-Fi, SD-WAN, and Mission Critical Push-to-Talk (MCPTT). The system integrates with legacy TETRA networks on lines A and B and extends the INPT emergency radio service through distributed antenna systems, ensuring interoperability across operations and public safety.[179] This layered design allows maintenance staff and emergency responders to rely on secure communications in real time.

For the Grand Paris Express, a major expansion project of the Paris transport network, Axione is working with Atos, a digital services and cybersecurity company, and Siemens, a global technology and automation provider, on a EUR 153m project to equip new metro lines 15, 16, and 17 with a multi-service digital network. These include telecom networks, operational data services, security functions such as access control and intrusion detection, intelligent video surveillance, and environmental monitoring. The different systems provide the transport network with reliable services that support efficient operations.[180]

179 - Axione, *Axione repense la connectivité du réseau de transport à Toulouse, avec un projet innovant de couverture 4G et WiFi*, 2025.

180 - Atos, *La Société du Grand Paris choisit Atos, Axione et Siemens pour le réseau multi-services et la surveillance des lignes 15, 16 et 17 du Grand Paris Express*, 2021 ; Siemens, *La Société du Grand Paris choisit Atos, Axione et Siemens pour le réseau multi-services et la surveillance des lignes 15, 16 et 17 du Grand Paris Express*, 2021.

URBAN INNOVATION: THE CASE OF DIGITAL TWINS FOR MORE EFFICIENT SYSTEM AND SERVICES MANAGEMENT

Among key levers for adaptive cities, keeping the existing momentum in favor of industry 4.0 is essential for environmental and social design of infrastructure. Innovative approaches—from smart infrastructure and data-driven governance to sustainable mobility solutions—enable cities to anticipate and respond to emerging needs, rather than reacting to crises after they occur. Urban innovation encourages the use of modular, multi-use infrastructure that can be repurposed as needs change, ensuring that investments remain relevant over time.

Digital twins are perfect illustrations of the potential behind urban innovation, as they clearly redefine how infrastructure are planned, operated, and optimized. These dynamic virtual replicas combine real-time sensor data, historical records, and predictive analytics to mirror physical assets and systems in motion. These models integrate information from sensors, geographic information systems (GIS), building information modelling (BIM), and other data sources to simulate, monitor, and optimize the performance of city infrastructure.

In practice, a digital twin can encompass transportation networks, energy grids, water systems, waste management, and public spaces, enabling decision-makers to assess current conditions, predict future scenarios, and test potential interventions without disrupting real-world operations.

Targeted interventions can then be executed before breakdowns occur, reducing routine maintenance costs, preventing service disruptions, and significantly improving safety—particularly in complex systems such as transportation networks, water infrastructure, and energy grids.

Beyond asset-specific management, digital twins facilitate the alignment of infrastructure projects across sectors. For example, synchronizing upgrades to roads, utilities, and broadband infrastructure supports 'dig once' policies, reduces redundant work, and minimizes disruption. Such coordination enables multi-agency collaboration and delivers higher-quality services to the public at lower cost.

Advanced simulation capabilities allow public-sector users to model the effects of infrastructure decisions on carbon emissions, accessibility, system performance, and climate risk. These scenario analyses help identify projects that deliver the greatest social and economic returns, while stress-testing infrastructure under various future conditions to ensure long-term resilience.

For infrastructure stakeholders under pressure to deliver more with less, digital twins offer a strategic advantage and the economic case is compelling: digital twin technologies may deliver a 20-30% improvement in capital efficiency and operational performance for public sector investments by enabling better capital allocation and reducing delays.[181] Complex city models and digital twins populated with synthetic populations are estimated to improve construction business effectiveness by 10% and boost productivity by over 20%.[182]

At this stage, urban digital twins, even on a local (district) scale, are rare. One example in operation is the city of Helsinki, which offers a 3D map of the city, providing insights into the building's energy saving potential for public and private properties.

181 - McKinsey & Company, *Digital twins: Boosting ROI of government infrastructure investments*, 2025.

182 - World Bank, *Disruptive Technology Opportunities in Infrastructure*, 2023.

FOCUS 14

Helsinki's digital twin: the transformative potential of integrated infrastructure intelligence at scale

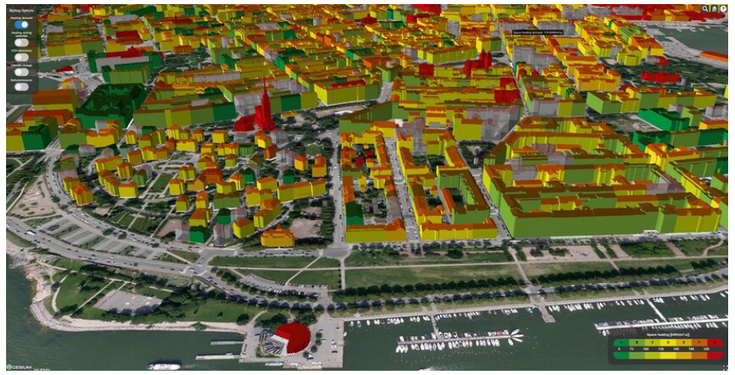
Helsinki has developed a comprehensive 3D city model, known as the Helsinki Digital Twin, which serves as a virtual representation of the city's environment, operations, and evolving circumstances. This model integrates information technology services, open data, and continuously updating information to provide a dynamic and accurate depiction of the urban landscape[183].

The Helsinki Digital Twin enables various applications, including urban planning, infrastructure management, and environmental monitoring[184]. By providing a scalable and adaptable platform, the digital twin facilitates the integration of new technologies and the testing of innovative solutions to address urban challenges effectively. This initiative shows how integrated infrastructure intelligence at scale can transform urban management and enhance sustainability efforts.

FIGURE 39

Helsinky 3D map of the city: energy saving potential[185]

Source: Raes et al.



183 & 184 - City of Helsinki, *Helsinki 3D*.

185 - Raes, L. et al., *Pioneering Practitioners: Key Lessons Learned from Local Digital Twin Implementations*, in: Decide Better, 2025.

186 - Jenik I., Schan D., *How to build a regulatory sandbox: A practical guide for Policymakers*, CGAP, 2020.

EXPERT POSITION 15

Paulo Moura—Urban infrastructure innovation at the Institute of Innovation and Partnerships at IMREDD

"IMREDD is an Innovation and Partnership Institute of University Côte d'Azur (Nice, France). Its mission is to drive collaborative research and technology transfer projects and to offer higher education programs focused on smart cities and territories. The institute's activities are centered around four strategic areas of activity: energy and smart buildings, mobility, risks, and environmental management. When considering urban infrastructure, we need to address it through a comprehensive approach that accounts for the complexity of urban environments. This holistic perspective is central to the Institute proposal but, while it is easy to describe, it is far more challenging to implement. That is why we incorporate another crucial element: innovation. Urban infrastructure innovation it's a new way of thinking about urban planning, energy, mobility, and sustainability in an integrated manner. By innovating our urban infrastructure, we don't just build structures: we build resilience, value, and a sustainable future. Our ambition is therefore to prepare the urban infrastructure as a foundation for accelerating the deployment of innovation—enabling faster transitions from concept to real-world application. IMREDD has launched the Smart City Innovation Center which is a technological platform designed to bring to life, on an industrial scale, various key concepts and technologies aligned with the strategic areas of activity of the Institute. It serves as a hub for experimentation, applied education, and demonstration for the smart city of the future"

Paulo Moura,
Deputy Director of Innovation and Partnerships at Université Côte d'Azur/IMREDD

Regulatory innovation: shaping behavior and scaling what works

SANDBOXES FOR INNOVATION: SAFE ZONES FOR BOLD IDEAS

Regulatory sandboxes are controlled environments where cities can test innovative solutions, technologies, or business models under relaxed regulatory conditions and with direct oversight from relevant authorities. Pilot projects are small-scale, real-world implementations of new ideas or approaches, designed to evaluate their feasibility and impact before wider adoption.

- **Safe testing of innovation:** sandboxes and pilot projects allow cities to experiment with new technologies (e.g., AI, digital infrastructure, green energy solutions) without the risk of immediate regulatory penalties, fostering a culture of responsible experimentation. By observing real-world outcomes, regulators can better understand the implications of new solutions and adapt rules accordingly, leading to more effective, evidence-based regulation;
- **Accelerated innovation cycles:** sandboxes and pilot projects reduce the time and cost needed for innovators to bring new ideas to market by lowering compliance barriers and streamlining approvals. These environments particularly benefit smaller players, who often lack the resources to navigate complex regulatory frameworks, by providing guidance and reducing entry barriers;
- **Scalability:** successful pilots provide a blueprint for scaling up or replicating solutions in other parts of the city or in different cities, promoting wider adoption of best practices.

187 - Ofgem, *Energy Regulation Sandbox*; Ofgem, *Energy Regulation Sandbox: Guidance for Innovators*, 2020

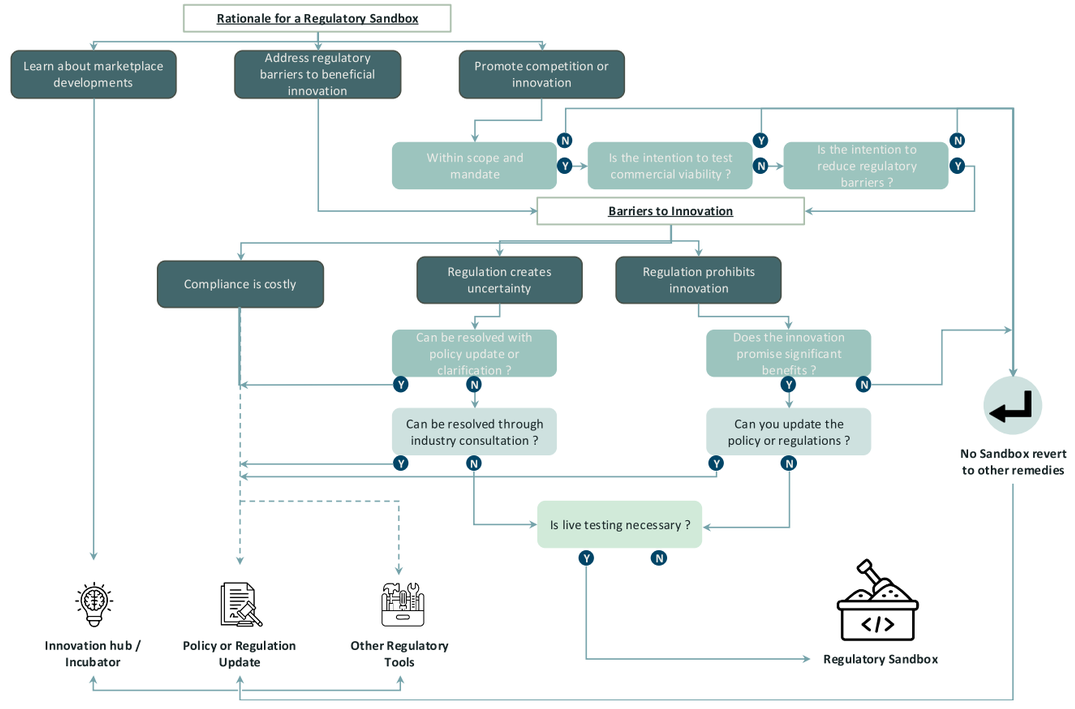
188 & 189-F&S Energy Limited, *Peer to Peer Matching Platform. F&S Energy Sandbox Evaluation Report*, 2022.

190 - Ofgem, *Insights from running the regulatory sandbox*, 2018.

FIGURE 40

Regulatory sandbox decision process[186]

Source: Jenik et al., 2020



FOCUS 15

Ofgem's energy sandbox in the UK

The Office of Gas and Electricity Markets' (Ofgem) Energy Regulation Sandbox in the UK creates a structured pathway for innovators to trial new energy services and business models that would otherwise be blocked by licensing or regulatory requirements. By offering temporary derogations and direct regulatory support, Ofgem allows firms to test concepts in real-world conditions while ensuring consumer protection and system stability[187]. One notable example is F&S Energy's peer-to-peer matching platform, which connected small renewable generators directly with consumers. This pilot was only viable because Ofgem permitted exemptions from supply licensing rules, allowing the project to demonstrate how digital platforms could facilitate local energy trading[188].

The sandbox has generated valuable insights for both innovators and regulators. The F&S Energy pilot, for instance, matched 62 generators and consumers, covering around 5,233 MWh of energy, while highlighting operational challenges such as IT integration and the impact of wholesale price fluctuations[189]. Ofgem's early experience also revealed that many innovators did not fully anticipate regulatory constraints, but the process of close engagement and trial design helped both innovators and the regulator identify the most significant barriers and determine whether they needed the sandbox[190].

Multiple sandbox frameworks enable infrastructure innovation while maintaining appropriate oversight and risk management:

- **Technology-specific sandboxes** that focus on particular innovations like autonomous vehicles, drone delivery systems, or AI-powered infrastructure management platforms,
- **Geographic pilot zones** that allow comprehensive testing of new infrastructure models within defined urban areas or districts with relaxed regulatory requirements,
- **Time-limited experimental permits** that provide temporary authorization for innovative approaches while collecting performance data to inform permanent regulatory decisions,
- **Cross-sector collaboration platforms** that enable testing of integrated solutions spanning multiple infrastructure domains under coordinated regulatory supervision,
- **Outcome-based exemptions** that waive specific compliance requirements in exchange for meeting alternative performance standards that achieve equivalent or superior public benefits.

NEW BUSINESS MODELS: NEXT-GENERATION OF PUBLIC-PRIVATE ALLIANCES

Each city adopts a **mix of business models tailored to its specific challenges and priorities.** London, for example, relies on PPPs for major infrastructure such as transport systems; Amsterdam applies them to urban renewal projects like mixed-use districts; and Berlin leverages them for critical assets such as airports, ensuring both efficient delivery and long-term sustainability.[191]

Regarding adaptive cities, siloed sectoral approaches must be replaced by **integrated, multisectoral strategies built on interconnected networks and pooled services.** Efficiency depends on the ability of diverse stakeholders—each with complementary yet unequal resources—to coordinate and innovate while still competing for value creation. This is a new form of 'coopetition', which not all smart city stakeholders are accustomed to: digital companies have grown within this culture, but this is not necessarily the case for traditional infrastructure operators—they fear unequal value capture, unclear sharing rules, and shifting agreements, leading to underinvestment or increased cost of service delivery.[192]

Public-private relations could therefore be better structured to mobilize smart and climate-proof investments and strenghthen cities' cross-sector integration. In the energy sector, broader partnerships have been developed around smart grids to optimize local energy management: public authorities, together with Enedis, industry players, real estate developers, and energy producers, have piloted demand flexibility services to better balance electricity flows.[193]

As urban infrastructure projects are increasingly complex and long-term, requiring financing and operational models that can adapt to changing circumstances, **there is a growing need for longer-term and more flexible PPP agreements** that incorporate **dynamic negotiation clauses.** Such clauses would allow stakeholders to revisit terms, adjust risk-sharing mechanisms, and incorporate innovations as projects evolve, creating a partnership that is resilient and responsive over time. By allowing for renegotiation under predefined conditions—such as changes in demand, regulatory shifts, or unforeseen environmental factors—investors and public authorities can manage risk more effectively. This, in turn, encourages private investment by providing greater predictability and stability while still allowing for adjustments to safeguard long-term public interest.

EXPERT POSITION 16

Reuven Carlyle – Carbon pricing, a lever for community-directed investment

"Market-based carbon pricing—through subnational emissions trading systems such as Washington's Cap-and-Invest Program (established under the Climate Commitment Act), California's cap-and-trade program, and Quebec's cap-and-trade—aligns financial incentives with environmental goals by capping emissions from major sources and reinvesting proceeds in community benefits, from free youth transit to electric ferry retrofits. What matters most to citizens is how the revenues are used. Channeling funds into high-impact, equitable projects can balance affordability and decarbonization, offering a pragmatic governance model for urban systems and demonstrating policy and market leadership at the state and provincial level"

Reuven Carlyle,
Founder of Earth Finance, former Member of the Washington Senate and of the Washington House of Representatives

191 - Wolniak R. et al., *Business models used in smart cities – theoretical approach with examples of smart cities*, Smart Cities, 7(4), 2024.

192 & 193- Terra Nova, *Smart Cities: Quelles relations public-privé pour rendre la ville plus intelligente?*, 2018.

SMART AND CIRCULAR PROCUREMENT: USING PUBLIC SPENDING TO LEAD THE MARKET

Government procurement represents one of the most powerful tools available to drive sustainable infrastructure innovation. Public procurement accounts for 15-20% of global GDP[194] and sub-national governments are responsible for more than 60% of procurement spending in OECD countries.[195]

Driving innovation in procurement is essential to improving efficiency, boosting competitiveness, and supporting the economic, environmental, and social goals of cities. By directing investment toward smart, low-carbon technologies, public procurement can accelerate the uptake and scaling of sustainable solutions, stimulate demand, and enhance competitiveness through innovation and digitalization.

Multiple **smart procurement mechanisms** enable governments to drive market transformation while securing enhanced infrastructure value:

- **Pre-commercial procurement**, which supports the development and testing of innovative solutions before they reach the commercial market,
- **Performance-based specifications** that define desired outcomes and performance standards while allowing suppliers maximum flexibility in solution design and delivery methods,
- **Market development incentives** including volume commitments, risk-sharing arrangements, and guaranteed purchase agreements that provide suppliers with confidence to invest in innovative solutions.

Success in smart procurement requires **careful balance between innovation incentives and risk management**, with clear performance metrics that enable meaningful evaluation while avoiding overly prescriptive requirements that stifle creativity. Governments must establish robust supplier assessment capabilities that can evaluate technical feasibility, financial viability, and innovation potential rather than relying solely on traditional procurement criteria.

As circular economy will be a key decider in the future of cities, **procurement must also be circular.** Lisbon has begun to embed circular economy principles systematically into municipal operations, particularly in goods procurement and infrastructure with a Procurement Planning Platform to guide more sustainable purchasing decisions.

To support such initiatives, the Ellen MacArthur Foundation has created a circular procurement framework. This tool identifies key procurement steps where municipalities can choose more circular options and form collaborative partnerships.[196] It provides guidance from the early decision-making stage through to implementation and scaling, helping cities advance circular public procurement while encouraging innovation, regulatory adaptation, and a culture of circularity.

FOCUS 16

AI4Cities: a new pre-procurement strategy for AI-driven solutions[197]

AI4Cities is a three-year EU-funded project uniting six European cities and regions—Helsinki, Amsterdam, Copenhagen, Grand Paris, Stavanger, and Tallinn—in the search for AI solutions to help achieve carbon neutrality. The project focuses on addressing urban challenges in mobility and energy, aiming to reduce CO_2 emissions and meet climate targets.

Using a pre-commercial procurement (PCP) model, the cities co-develop innovative solutions with suppliers before they are commercially available, ensuring they meet real-world sustainability needs in energy and mobility. In the first phase, the buyer group defines the functional requirements of the desired innovations. Next, startups, SMEs, larger companies, and other stakeholders are invited to design cutting-edge AI-based solutions, potentially using technologies like big data, 5G, edge computing, and IoT. A total of EUR 4.6m in funding is allocated to support selected suppliers throughout the PCP process.

194 - European Commission, *International public procurement*, 2023.

195 -OECD, *Size of public procurement*, 2021.

196 - Ellen MacArthur Foundation, *Circular public procurement: a framework for cities*, 2022

197 -AI4Cities, *What is AI4Cities about?*

FASTER PROJECTS FROM THE PIPELINE TO THE MARKET

Delays and legal challenges in permitting are a significant barrier to timely and cost-effective urban infrastructure development, with wide-ranging economic and social impacts.

Permitting procedures for infrastructure projects have become increasingly lengthy due to overlapping regulations, administrative bottlenecks, and growing legal and environmental requirements, with delays often stretching to years or even over a decade for complex developments. Despite EU-level reforms aimed at streamlining these processes, little progress has been made[198] and permitting remains a major bottleneck—especially for renewable energy, where 81% of EU wind capacity is currently stalled, facing approval timelines of five to ten years or more.[199]

Countries and municipalities can implement **clear, legal frameworks, and transparent procurement processes** to increase the speed of delivery of infrastructure projects. These reforms serve as valuable models for others seeking to modernize and expedite their infrastructure development processes:

- **Technology-powered stakeholder engagement:** digitalizing stakeholder engagement can significantly speed up permitting by broadening participation and enabling meaningful feedback through tools like social listening, digital twins, and augmented reality. These technologies make project plans clearer, increase community support, and reduce legal risks, streamlining the permitting and approval process.
- **One stop shop:** a "one-stop shop" model consolidates all permitting, approvals, and procurement steps into a single, streamlined process. This reduces bureaucratic hurdles and accelerates project timelines.
- **Standardized procedures:** standardized and transparent procurement processes help expedite project timelines and foster fair competition. Many leading jurisdictions use digital procurement platforms to manage documentation, track progress, and communicate with stakeholders, further expediting processes and increasing transparency.
- **Dedicated PPP Units:** many high-compliance countries have established specialized agencies or units to oversee PPP projects, ensuring expertise and consistency in contracting. PPP units provide training and technical assistance to public officials, helping build institutional knowledge and avoid common pitfalls..

198 - World Economic Forum, How permitting processes are hampering Europe's energy transition, 2024

199 - World Economic Forum, *Innovation and Digitalization in the Permitting Process for Clean Energy*, 2023.

200 - WB, *Doing Business 2020: Comparing Business Regulation in 190 Economies – Economy Profile of Hong Kong SAR, China*; WB, *Dealing with Construction Permits*; World Bank, *Doing Business 2011: Making a Difference for Entrepreneurs* – Economy Profile of Hong Kong SAR, China; Government of Hong Kong SAR Digital Policy Office, *Success Stories – Transformation of Building Plans Submission*; Government of Hong Kong SAR, *Hong Kong Policy Address 2025*, 2025.

FOCUS 17

Streamlining permitting in Hong Kong[200]

Hong Kong faced significant delays in its warehouse construction permitting process. Multiple government departments and utility providers were involved in reviewing and approving applications, resulting in fragmented workflows, duplicated efforts, and slow project delivery. To address these challenges, Hong Kong implemented a reform in December 2008 centered on the One Stop Center (OSC) for Warehouse Construction Permits, operated by the Efficiency Office (now under Digital Policy Office). This approach was designed to streamline and accelerate the permitting process for two-storey warehouses by providing a unified entry point for pre- and post-construction applications and approvals, including plan approvals, commencement consents, excavation permits, water supply audits/certificates, and utility connections.

Centralized Application Portal: applicants submit all documentation and requests (e.g., Form OSC-1) through a single platform, eliminating the need to interact separately with multiple agencies.

Integrated Workflow: the system routes applications to the relevant departments and tracks progress, ensuring transparency and accountability at each stage. It connects six government departments (Buildings for approvals/consents, Lands for planning, Fire Services for safety, Water Supplies for water audits/certificates, Drainage Services for sewerage, and Highways/Police for excavations) and two private utility providers (electricity and telecommunications), ensuring that essential utilities (such as electricity and water) are coordinated with building approval.

Unified Communication: stakeholders receive consolidated updates and requests for additional information, reducing confusion and minimizing back-and-forth communication; joint inspections by all departments can be organized upon request.

The OSC has evolved with digital tools like the Electronic Submission Hub (ESH, launched 2022–2023) for general building plans. Ongoing reforms emphasize streamlined approvals and inter-departmental coordination for infrastructure.

TAILORMADE AND SYSTEMIC GOVERNANCE MODELS AND PROTOCOLS FOR INFRASTRUCTURE STAKEHOLDERS

Key takeaways

→ Strong governance directly correlates with better investment and growth outcomes. At this stage, a 'governance mismatch'—where responsibilities for infrastructure are delegated to subnational governments without sufficient autonomy, capacity, or resources—undermines effective delivery

→ Urban infrastructure assets are not isolated entities but form highly interconnected systems, often described as 'systems of systems', that necessitate integrated planning and management to mitigate cascading failures and unlock synergies

→ Recognizing cities as a Complex Adaptative System (CAS) highlights the need for a new approaach to urban planning and governance - one that is context-sensitive and acknowledges the city's inherently dynamic nature

→ The next era of urban life demands not only new technologies and financing, but new social relationships between all stakeholders

→ National governments must catalyze urban transformation by establishing long-term policies, mobilizing finances, and setting infrastructure standards, while fostering innovation and embedding inclusivity into urban policy frameworks

→ At the city level, strategies should be differentiated according to city typologies, promoting targeted interventions that account for economic strength, urban density, infrastructure uniformity, and environmental externalities, in order to design sustainable urban futures through tailored protocols

→ The financial community carries a special responsibility, as investors are actors who can bridge the global infrastructure gap, enabling the financing needed to transform urban systems

Governing adaptive cities: a systemic vision for networks of infrastructure

Managing interdependent and interconnected infrastructure

ADDRESSING THE 'GOVERNANCE MISMATCH': A PREREQUISITE FOR GOOD INFRASTRUCTURE DELIVERY

Up to now, discussions on infrastructure have largely centered on financing while paying far less attention to the broader dimension of public governance. Yet, investment in public infrastructure can pay for itself and more, but only if it is done correctly: OECD analysis shows that important benefits can be achieved by improving the management of public investment across its entire life cycle. Strong governance quality is closely linked to better growth outcomes, both nationally and sub-nationally.[201]

In 2013, the European Commission already highlighted the **existence of a governance mismatch:** *"Many central governments in developing countries have attributed responsibilities to Local Authorities in country development processes, with a view to allow for the definition of public policies and service delivery on local realities. However, this political recognition has not always been accompanied by an adequate level of autonomy, capacity development and financial resources, leaving their empowerment incomplete".*[202]

According to the World Observatory on Subnational Government Finance and Investment, there are approximately 637,900 sub-national governments in 122 surveyed countries. This figure includes all levels below the national government, such as regions, states, provinces, counties, and municipalities;[203]

The majority of sub-national governments are at the municipal level—cities, towns, and villages with local administrative authority. The World Observatory estimates over 624,000 municipal-level entities worldwide.[204]

201 - OECD, *Getting Infrastructure Right: A Framework For Better Governance*, 2017; OECD, *Investing Together: Working Effectively Across Levels of Government*, 2013.

202 - European Commission, *Empowering Local Authorities in partner countries for enhanced and more effective development outcomes*, 2013.

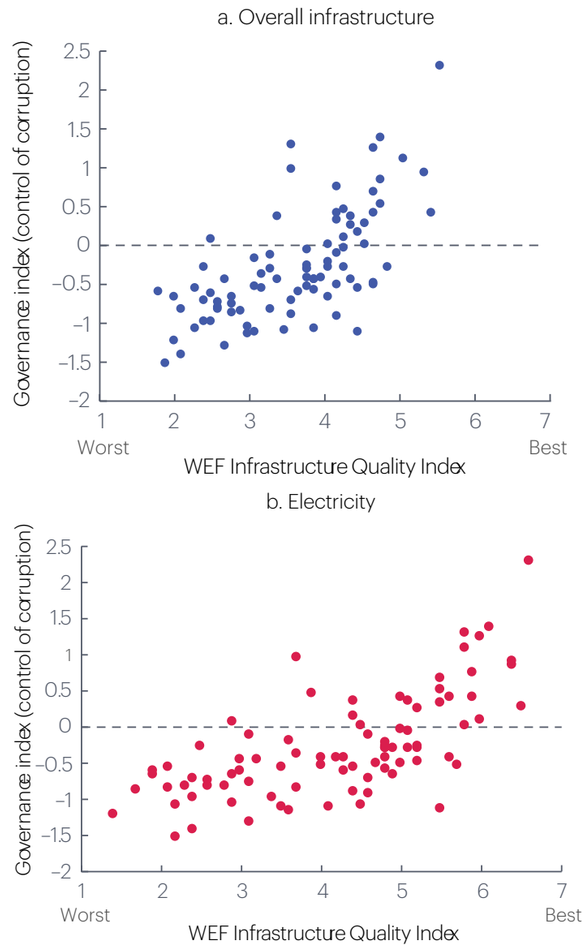
203 & 204 - URBANET, *World Observatory on Subnational Government Finance and Investment.*

205 - Hallegatte S. et al., *Lifelines: The resilient infrastructure opportunity*, World Bank, 2019.

FIGURE 41

Infrastructure quality correlates strongly with governance standards[205]

Source: World Bank, 2019



EXPERT POSITION 17

Timothy J. Dixon – The quadriple helix model of governance

"Adaptive cities must overcome the disconnect between short-term political cycles and long-term environmental challenges through deliberative democracy. This calls for a highly collaborative approach, embedding engagement with multiple stakeholders: the general public, local authorities or municipalities, the private sector, and universities. Together, these actors form the quadruple helix model, which ensures that diverse perspectives are represented in urban planning. Although involving citizens and stakeholders is often resource-intensive and time-consuming, it delivers substantial dividends by enabling more thoughtful, forward-looking city planning where citizens have a real voice. Through mechanisms such as citizen assemblies and mini-publics, this approach fosters co-creation of urban infrastructure that is equitable, resilient, and aligned across all stakeholders, allowing cities to explore multiple possibilities and make informed, inclusive decisions for the future"

Timothy J. Dixon,
Emeritus Professor at the University of Reading and Visiting Fellow at Kellogg College, University of Oxford

INTERVIEW 1

Marché International de Rungis: building food resilience with public stakeholders

A conversation with Stéphane Layani, President of the Marché International de Rungis

InfraVision: ***Like other global cities, Paris faces converging pressures, such as climate change, demographic shifts, urban congestion, and the energy transition. Which of these will most affect the city's food infrastructure in the coming decades, and how? How is Rungis adapting its operations and investments in response?***

Climate change and the ecological transition are the main challenges for the Marché International de Rungis in the coming decades. Their effects are already evident on agricultural production and require the decarbonization of the logistics chain and of procurement. In this context of climate change, increased congestion, and demographic growth, the government has asked us to lead the Agoralim project in Goussainville, the future hub of food provision in the Paris region. This second wholesale market in Île-de-France, complementary to Rungis, will bring residents closer to their food, secure the supply of quality fresh products, and reduce the environmental impact of logistics. By itself, it will avoid nearly 17% of CO_2 emissions related to the transport of food products in Île-de-France.

In parallel, Semmaris, which manages the Rungis Market (which is a Marché d'Intérêt National: a state-designated wholesale market), is investing heavily in its sobriety plan: energy-efficiency renovation of buildings, installation of charging stations for electric vehicles, deployment of photovoltaic panels, and exploration of new clean mobility solutions. In a process of co-creation with companies located on the Market, we also recently launched the 'Marché durable' (Sustainable Market) label, in partnership with AFNOR Certification and the Federation of Wholesale Markets of France, to support the evolution of practices, with the goal of rolling out this label across all wholesale markets in France.

Food operations are intrinsically linked to transport, energy, water, and waste systems, and depend on close collaboration with public authorities. How do you engage these stakeholders?

Ensuring the food supply of Île-de-France, a mission entrusted by the state to Semmaris, depends on constant cooperation with public authorities and local governments. This collaboration is embodied in shared governance, particularly with the state, the Val-de-Marne département, and the City of Paris, as well as in delegated prerogatives such as certain policing powers on the Market. It takes shape through structuring projects such as Agoralim, recognized as being of public interest; the Cité de la Gastronomie, in connection with local authorities; and our partnership with INRAE (the National Research Institute for Agriculture, Food and Environment) in support of sustainable food systems.

A pillar of French food sovereignty, the Rungis Market also maintains daily relations with the Ministry of Agriculture and the Departmental Directorate for the Protection of Populations for sanitary safety. A France Travail agency is also present on the Market: it plays a key role in connecting Rungis businesses with job seekers, fostering local hiring and professional integration. These partnerships reflect ongoing consultation serving major urban, food, and environmental transitions.

Which best practices of the Rungis model are most exportable to other metropolitan regions?

The best practices of the Rungis model rest on efficient, transparent management; close relationships with customers; infrastructure designed according to sustainability criteria; a strong brand synonymous with quality; and high standards of safety, both sanitary and operational. These assets make the Market an exportable model adaptable to the needs of major metropolises. The example of taking over the public service delegation of the Toulouse MIN illustrates this: applying the Rungis model there has strengthened attractiveness, modernized management, and supported competitiveness.

MANAGING URBAN INFRASTRUCTURE AS 'SYSTEMS OF SYSTEMS'

Because infrastructure networks operate as **systems of systems,**[206] they are vulnerable to cascading impacts from cross-sector disruptions. While they are key engines of innovation and growth, modern cities concentrate the maximum level of risks and systemic fragilities. Highly centralized grids (power, water, transit) create single points of failure, and a disruption in one node can cascade across the entire system, as seen in large-scale blackouts or water supply crises: for instance, insufficient backup systems and limited decentralization mean critical services (hospitals, emergency response) may be interrupted during disasters.

Examples of the reality of infrastructure as interconnected systems of systems abound in real life. In July 2001, a freight train derailment in Baltimore, Maryland, triggered a chemical fire that burned for over five days. On the first day, a ruptured water main flooded downtown streets for the same duration. The combined impact of fire and water damaged an electric power cable, cutting access to electricity for 1,200 buildings. Additionally, the accident destroyed a fiber-optic communication cable running through the tunnel, slowing Internet service across the Northeast, while train, bus, and boat services were disrupted.[207]

Embedding redundancy, flexibility, diversity, and continuous learning into urban systems enables cities to thrive, not just survive, in unpredictable environments. Consequently, anti-fragile urban planning must address both acute shocks (black swan events—rare but high-impact disruptions like pandemics, cyber-attacks, wars, or extreme climate incidents) by ensuring such events do not cause systemic collapse and long-term shifts, by adapting to gradual yet profound changes, such as demographic evolution, technological advancements, climate change or economic upheavals.

Managing those interconnexion does not only reduce risks, it also adds value. When infrastructure is planned as a system, not in fragments, cities cut costs, reduce inefficiencies, and unlock co-benefits: in the Gulf Cooperation Council countries, integrating renewable energy into water infrastructure is expected to reduce water withdrawals for power generation by 20% by 2030.[208]

206 & 207 - Merad M. et al., *Integrated perspectives on sustainable infrastructures for cities and military installations*, NATO Science for peace and security series, 2013.

208 - International Renewable Energy Agency, *Renewable Energy in the Water, Energy & Food Nexus*, 2015.

209 - Baker Institute for Public Policy, *The Iberian Peninsula Blackout: Causes, Consequences, and Challenges Ahead*, 2025.

210, 211 & 212 - ENTSO-E, *28 April 2025 Blackout*, 2025.

213 - WEF, *What we can learn about building a resilient energy grid from the Iberian power outage*, 2025.220 -

214 - ORNL, *Climate Change and Infrastructure, Urban Systems, and Vulnerabilities. Technical Report to the U.S. Department of Energy in Support of the U.S. National Climate Assessment*, 2012, as used in: Wilbanks, T.J., *Integrating infrastructures in the United States: experience and prospects, People, Place and Policy*, 11, 1, 2017.

FOCUS 18

A black swan event showing system fragility

On April 28, 2025, a major power outage struck Spain and Portugal, leaving most of the Iberian Peninsula without electricity for hours. The crisis began with technical failures in southern Spain, which quickly cascaded across the entire grid[209].

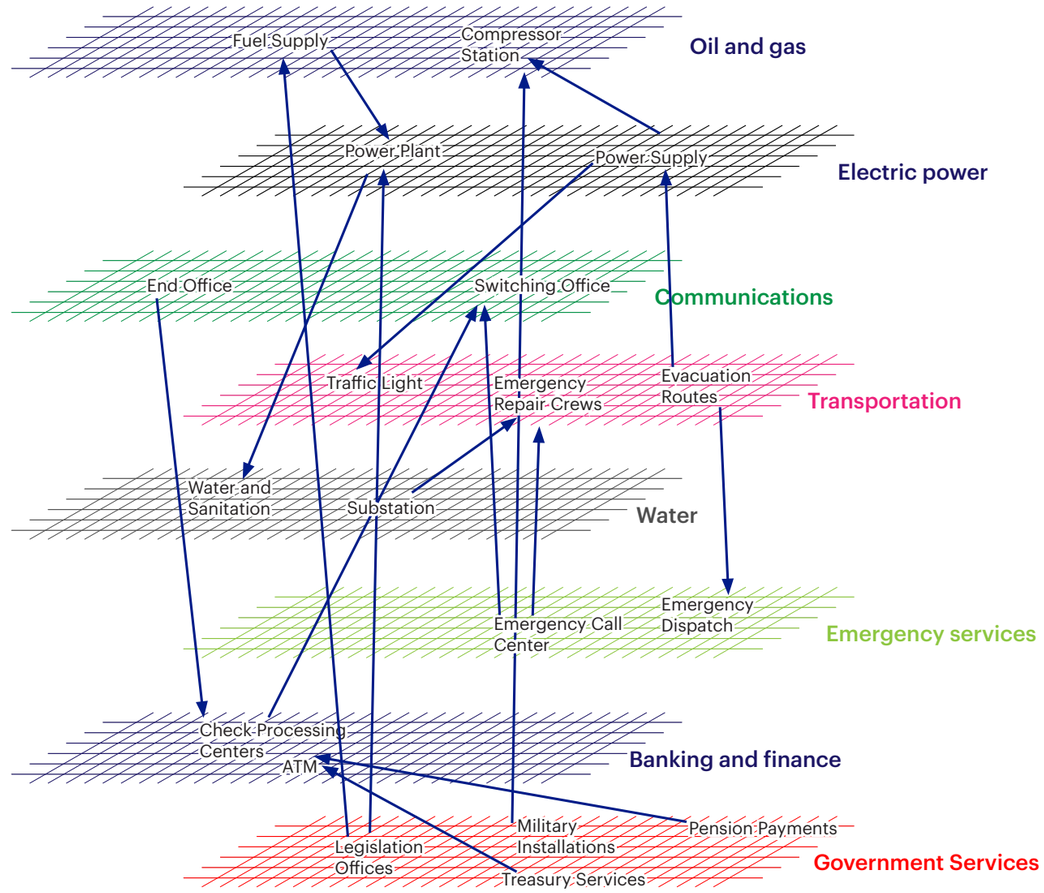
Investigations into the causes of the blackout are still ongoing. Based on available reports, particularly from ENTSO-E (the European Network of Transmission System Operators for Electricity), a few lessons can already be drawn. These remain provisional, pending further analysis, particularly the publication of the final ENTSO-E Expert Panel report[210]:

- **Planning must account for low-probability, high-impact "black swan" scenarios, not only historically observed failure modes. Preliminary analyses indicate that cascading voltage increases, rather than traditional frequency drops, likely triggered the blackout, a mechanism not previously associated with blackouts in the European power system.[211]**
- **Preparedness and interagency coordination, at both national and international levels, are pivotal for reacting successfully to a system crisis. The rapid restoration of power was made possible by the high level of preparedness of the Spanish, Portuguese, Moroccan, and French agencies (Red Eléctrica, REN, ONEE, RTE) and by their long experience of collaboration.[212]**
- **The incident highlighted the need for enhanced system inertia as fossil fuels are replaced by renewable sources that lack the natural "momentum" to keep grids stable. Technologies like pumped hydro storage and synchronous thermal energy are key to meet this need.[213]**

FIGURE 42

The interconnectedness of infrastructure systems[214]

Source: World Bank, ORNL, 2012



CASE STUDY 8

Val d'Europe: a future-oriented partnership between Disney and public partners[215]

Val d'Europe, established in 1987 through an innovative public-private partnership, represents a unique fusion of urban and tourist spaces. Covering nearly 2,100 hectares, it is home to Disneyland Paris—Europe's top tourist destination—and a vibrant city with 53,000 residents and 49,000 jobs, serving as the eastern gateway to Greater Paris.

A proactive policy of joint investment between Disney and public entities, including the state, the Île-de-France Region, the Seine-et-Marne Department, the Val d'Europe Agglomeration, the RATP, and the public developer EPAFrance, has facilitated the development of the city. It provides comprehensive facilities tailored to residents, businesses, and tourists. Key infrastructure assets include France's leading TGV hub, connected to major cities, with Paris-Charles-de-Gaulle Airport just 10 minutes away, two RER stations linking Paris in 30 minutes, bus hubs, and a road network connected to eastern Paris highways. In terms of environment, the area benefits from a deep geothermal network meeting 18% of Disneyland Paris's heating and domestic hot water needs, a wastewater treatment plant saving more than 300,000 m^3 of water annually at Disneyland Paris, and one of Europe's largest photovoltaic plants with a production of 36 GWh per year. Thanks to this achievement, Disneyland Paris aims to reduce greenhouse gas emissions by approximately 890 tons of CO_2 per year in the Val d'Europe territory.

Val d'Europe's development is guided by a long-term strategy aimed at ensuring sustainable and balanced growth, making it an ideal place for residents, businesses, and tourists. This strategic planning ensures the future capacity of infrastructure, including controlled land management for roadway expansion, enhanced electrical capacities, and investments in renewable energy projects. With robust infrastructure, facilities like the Grand Hôpital de l'Est Francilien, and educational institutions, Val d'Europe is attracting more businesses, such as Deloitte University. The city aims to reach 80,000 inhabitants and 80,000 jobs by 2040.

215 - Information courtesy of Disneyland Paris.

EXPERT POSITION 18

Damien Audric – Shaping sustainable, connected, and resilient urban futures

"At Disneyland Paris, we envision the cities of tomorrow as places that are sustainable, connected, and resilient. Val d'Europe embodies this vision: a territory conceived from the beginning with our public and then private partners, to integrate, through structuring and evolving infrastructures, efficient mobility, renewable energy production, and intelligent water management. Our ambition is to create and continue to develop, with these partners, spaces capable of adapting to economic, climatic, and technological challenges, while offering an exceptional quality of life"

Damien Audric,
Head of Sustainability and Land Development at Disneyland Paris

Urban planning: a systemic and decentralized approach for infrastructure

A SYSTEMIC VISION OF URBAN PLANNING TO MANAGE 'RIPPLE EFFECTS'

By recognizing cities as **Complex Adaptive Systems** (CAS), planners and policymakers can better navigate the challenges posed by urban complexity and work toward more resilient and sustainable urban environments. **Urban planning is central to this effort**, guiding the design, organization, and management of land, infrastructure, and resources to foster functional, sustainable, and livable cities

The traditional planning model, or 'Plan A', is rooted in a linear understanding of the world, prioritizing functionality, certainty, and predictability, all of which have proven to be unreliable in the face of urban complexity. To navigate the unpredictable nature of a city, a new approach—a 'Plan B'—is necessary, one that is situational and embraces the city's inherent dynamic reality.

This new paradigm is being enabled by the rise of sophisticated tools and **a shift toward adaptive urban planning.**

Rather than betting on a single forecast, adaptive urban planning accepts uncertainty as a constant and plans for multiple plausible scenarios. It builds in the capacity to respond over time, reducing the risk of locking into the wrong strategy too early and ensuring infrastructure stays aligned with evolving conditions. Two frameworks operationalize adaptive planning in infrastructure contexts, each offering structured approaches to managing uncertainty and preserving flexibility over time[216]:

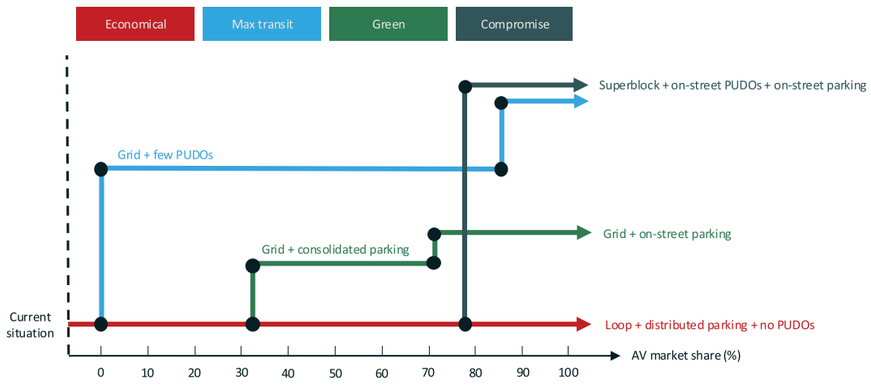
Dynamic Adaptive Policy Pathways (DAPP): DAPP maps out decision pathways over time and identifies 'adaptation tipping points': moments when existing strategies no longer perform. It helps planners anticipate change and pre-select alternative courses of action, allowing infrastructure systems to adjust without losing sight of long-term goals;

Real Options Analysis (ROA): ROA brings financial options thinking to infrastructure. By valuing flexibility, such as deferring, expanding, or modifying investments later, ROA supports staged, informed decision-making under uncertainty. It helps cities avoid premature commitments while keeping options open as new information emerges.

In this perspective, urban design is not simply about controlling space, but about facilitating the processes through which cities thrive. By acknowledging cities as organic, adaptive systems (see section #1), Berthaud advocates for **planning approaches that are flexible, responsive, and attentive to the human experience**, ensuring that urban environments remain vibrant, inclusive, and resilient over time. Systemic and adaptive urban planning must treat cities as interconnected systems rather than collections of isolated parts[217].

FIGURE 44

Adaptive plans represented in a pathways map[218]



In the x-axis the "AV Market Share" is used as the indicator to trigger interventions over time (nodes in the map). Three single-objective plans are shown: The "Economical" pathway minimizes investments, the "Max Transit" pathway maximizes public transport use and the green pathway minimizes carbon emissions. Additionally, a "Compromise" pathway is shown, as an alternative that can balance the three objectives altogether.

Source: Adey B. et al., 2023

216 - Rangwala T., *Literature review: Adaptive planning practices*, Water, 16(12), 2024.

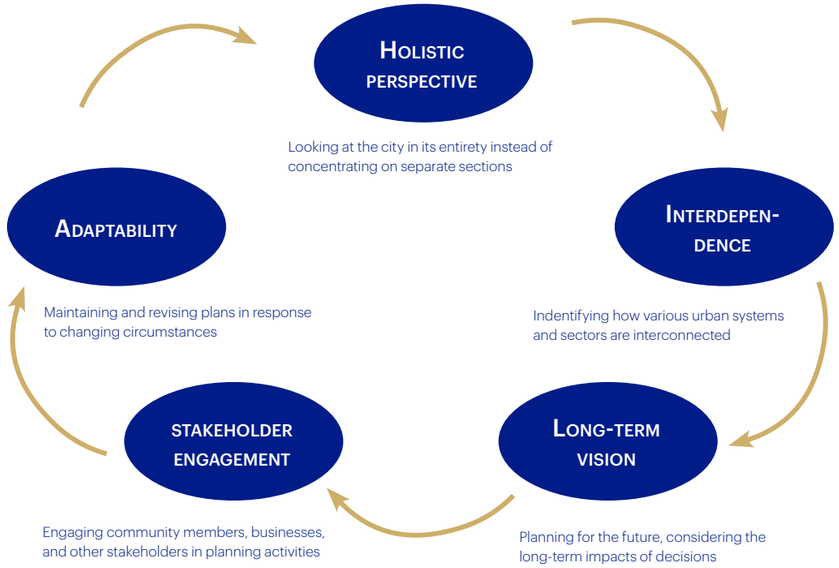
217 - Prism sustainability directory, *Systemic Urban Planning*, 2025.

218 - Adey B. et al., *Adaptive urban planning for an uncertain future: Infrastructure interventions for the technological shift in transportation*, NSL, Newslatter 60, 2023.

FIGURE 45

A systemic and adaptive urban planning approach for infrastructure[219]

Source: Systemic Urban Planning, 2025; Altermind, 2025



219 - Prism sustainability directory, *Systemic Urban Planning*, 2025.

EXPERT POSITION 19

Cecilia Wong—'Networked governance' to foster resilience in urban systems

"Urban governance today must grapple with increasingly complex, cross-jurisdictional challenges—ranging from flooding and air pollution to housing shortages and mobility pressures—that no single municipality can solve alone. These issues cut across administrative boundaries, demanding networked collaboration between cities, regions, and multiple layers of government. Such cooperation enables coordinated action that strengthen both resilience and equity across urban systems. Examples like Manchester's inter-authority meetings show how informal collaborations can serve as laboratories for innovative governance. By bringing together different municipalities to align spatial planning, these networks unlock synergies that individual jurisdictions could not achieve in isolation. They also create flexible governance structures that can adapt more readily economic, environmental and demographic change. A networked approach to urban governance also fosters fairness and inclusivity. When cities work together to manage shared resources and vulnerabilities, they reduce the risk of uneven development, where some communities benefit while others are left behind. By embedding collaboration into governance systems, urban regions can move toward and equitable, capable of withstanding shocks and promoting long-term sustainability"

Cecilia Wong,
Professor of Spatial Planning, Planning, Property and Environmental Management at the University of Manchester

DECENTRALIZATION AND RISK MANAGEMENT: LOCAL GRIDS AS A BACKUP

Integrating risk reduction and decentralization (i.e. the distribution of decision-making authority from a central agency to local communities) into urban planning is key to manage hazards such as climate change, natural disasters, and socioeconomic shocks, which are expected to rise over the next decades. Rather than reacting to crises, risk-informed planning seeks to identify vulnerabilities and avoid risky development.

Decentralized infrastructure is increasingly recognized as a vital strategy for urban resilience, acting as a safeguard against external shocks such as natural disasters, cyberattacks, or grid failures. Urban planners should strive to:

Develop multiple, decentralized energy, water, and transport systems (e.g., microgrids, local water recycling, multimodal mobility) to prevent single points of failure,

Ensure critical services (hospitals, emergency response, data centers) have independent power and communication backups, allowing for continued operation during crises.

Local energy grids or microgrids can operate independently during outages or disasters,[220] ensuring that critical facilities—such as hospitals continue to receive power even if the main grid fails. Decentralized grids are particularly valuable in cities prone to extreme weather as they can quickly isolate and protect vital infrastructure.

These systems can balance variable renewable output locally, smoothing fluctuations and supporting a higher share of clean energy in the urban mix. Cities can incrementally expand decentralized grids as demand grows or new technologies emerge, reducing financial risks and allowing for flexible planning.

220 - World Bank, *Sustainable Infrastructure Series, Lifelines: The Resilient Infrastructure Opportunity*, 2019.

TABLE 2

Decentralization: a challenging ambition

Source: Altermind

CHALLENGE AREA	FRAGMENTATION SUBTOPIC	IMPACT OF FRAGMENTATION/DECENTRALIZATION
Digitizing	Fragmented Data Systems	Incompatible digital platforms and data standards across municipalities, making integration and data sharing difficult.
	Limited Capacity and Investment	Smaller authorities lack resources and bargaining power to invest in advanced digital infrastructure, leading to uneven adoption.
	Coordination Barriers	Absence of unified digital strategies results in duplicated efforts and siloed operations.
Greening	Inconsistent Standards and Policies	Patchwork of environmental regulations and building codes hinders implementation of green infrastructure at scale.
	Disconnected Green Assets	Fragmented governance leads to isolated green spaces, limiting ecosystem restoration and climate adaptation.
	Resource and Knowledge Gaps	Smaller municipalities often lack expertise and funding for green projects, slowing progress.
Building at Scale	Permitting and Approval Delays	Multiple permitting processes across jurisdictions cause delays and uncertainty for infrastructure projects.
	Lack of Economies of Scale	Fragmented procurement prevents pooling resources, resulting in higher costs and less efficient deployment.
	Inconsistent Project Prioritization	Without regional coordination, investments may be misaligned, leading to inefficiency and service gaps.

EXPERT POSITION 20

Yves Lederer – Managing green energy infrastructure in a smart and adaptive way: where the real revolution lies

"District heating holds enormous potential for the energy transition. In France, it currently supplies only about 5% of heating needs, despite capacity having tripled over the past 20 years. This illustrates how much untapped potential remains to expand renewable and recovered heat sources—whether from biomass, industrial waste heat, or geothermal—through district networks. Yet scaling these systems is not only about expanding production; it is about transforming them into digital, flexible, and adaptive infrastructure, capable of balancing seasonal and daily variations through smart storage. This is where the real revolution lies: in the intelligent management of green energy, ensuring that supply and demand are coordinated seamlessly across urban systems. Crucially, district heating also demonstrates how public policy can unlock private capital. Every euro of public subsidy leverages four to five euros of private investment, multiplying impact and accelerating deployment. By combining innovation in technology with catalytic financing, district heating becomes a cornerstone of scalable urban decarbonization"

Yves Lederer, President, Coriance

CASE STUDY 9

Equans: powering urban regeneration with geothermal energy

Equans is a global leader in energy, digital, and industrial services, supporting cities and developers in accelerating the transition to low-carbon infrastructure. Through expertise in heating, cooling, and smart energy systems, the company delivers integrated solutions that combine technical innovation with environmental performance.

In Brussels, Equans, in partnership with Colas, has delivered a fully operational 3,500 m-long urban heat network providing heating and cooling powered by geothermal energy to the new USquare district, replacing the former Fritz Toussaint police barracks.[221] The project comprises low-temperature networks powered exclusively by geothermal energy and medium-temperature networks fed by gas-condensing boilers and cogeneration units.
The system serves 600 student residences, university facilities, an auditorium, and a hall, integrating renewable energy to meet the district's heating and cooling needs. A closed-loop geothermal system with 131 water boreholes 115 m deep transfers thermal energy to the heat network, combined with heat pumps and intelligent regulation systems to optimize efficiency.
The geothermal system also enables passive cooling, extracting excess heat from buildings, reducing operational costs and CO_2 carbon emissions.

The installation uses pre-insulated synthetic "Calpex" pipes for medium-temperature distribution, ensuring long-term durability and energy performance in an urban environment.

Equans teams coordinated closely with Colas to manage trenching and pipe installation.[222] The network is now fully operational,[223] connecting substations at each building and providing sustainable heating, domestic hot water, and cooling across 56,000 m² of refurbished urban space,[224] supporting the city's transition to low-carbon, energy-efficient infrastructure.

Building on this success, Equans is expanding integrated thermal solutions through HEATEO, a dedicated offer that combines heat recovery, thermal storage, and low carbon heat production to unlock the full potential of local energy resources.[225] The company is also scaling up its geothermal capabilities, notably through the Aquifer Thermal Energy Storage (ATES) solution, a technology that stores and recovers thermal energy in subsurface aquifers by extracting and reinjecting groundwater, enabling seasonal heating and cooling of buildings. ATES has demonstrated energy savings exceeding 60% and has already been successfully implemented in around 3,000 installations across the Netherlands.[226]

In many countries, geothermal power's potential is only slowly being recognized. Equans is well positioned to accelerate deployment thanks to its capacity to design, finance, deliver, and operate heat-and-cool networks, and its breadth of solutions adaptable to different needs. In France, geothermal energy only supplies ~1% of heat.[227] The government aims to quadruple output by 2035,[228] but permitting hurdles and low awareness persist.

221 & 222 - Equans, *Usquare: geothermal energy and heat networks for an urban and ecological district*, 2025.

223 - Ecobuild Brussels, *Commissioning of the largest heat network in Brussels: Revolutionary Heat Network for Brussels*, 2025.

224 - Equans, *Usquare: geothermal energy and heat networks for an urban and ecological district*, 2025.

225- Equans, *Unlock the full potential of thermal energy. HEATEO.*

226 - Equans, *Geothermal Energy: Unlocking the Earth's Hidden Heat to Build a Sustainable Future.*

227 - Ministère de l'Economie, des Finances, et de la Souveraineté industrielle et numérique, *Géothermie : sept mesures pour accélérer le développement d'une énergie renouvelable et locale*, 2025.

228 - Ministère de l'Economie, des Finances, et de la Souveraineté industrielle et numérique, Géothermie : sept mesures pour accélérer le développement d'une énergie renouvelable et locale, 2025; Ministère de la Transition Energétique, Géothermie : un plan d'action pour accélérer son développement, 2023.

A compass for 2050: targeted protocols for infrastructure stakeholders

Not a one-size-fits all solution

UNDERSTANDING EACH CITY DYNAMICS TO PREDICT LAND USE

From a urban planner's perspective, the monocentric model, as outlined in *Duranton and Puga's Urban Land Use*[229] and Glaeser's *The Economic Approach to Cities,*[230] provides a powerful lens for anticipating how changes in accessibility will reshape land values, population distribution, and economic activity. By predicting where demand for housing, commercial space, and infrastructure will intensify or decline, **the model helps guide strategic decisions on where to allocate capital, design transport networks, and zone for future growth.** Understanding these spatial dynamics is essential for maximizing returns on infrastructure investments while ensuring that urban expansion remains efficient, sustainable, and responsive to shifting mobility patterns.

First developed in the 1960s by William Alonso[231] and further refined by Edwin Mills[232] and Richard Muth,[233] the model remains a cornerstone of urban economics and a benchmark for analysing more complex, polycentric urban structures. A prominent application of the monocentric city model lies in assessing the impacts of transportation infrastructure investments on urban form and spatial development. In this model, **households and firms make location choices by trading off commuting costs against land rents:** proximity to the CBD reduces travel time but commands higher rents, while peripheral areas offer cheaper land at the expense of longer commutes. The introduction of high-speed commuter rail can flatten the land rent gradient, expanding the city's footprint as suburban and exurban areas become more accessible. Conversely, policies such as congestion charging steepen the gradient by increasing the effective cost of commuting, leading to denser development near the CBD.

The model also offers insights into contemporary shifts such as hybrid and remote work patterns, which reduce the frequency and cost of commuting. Early evidence from global cities suggests that this change weakens the traditional pull of the CBD, prompting the adaptive reuse of centrally located office space into residential or mixed-use developments.

The standard monocentric city framework has also been extended to incorporate radial highway infrastructure to analyze land use and commuting patterns. The model demonstrates that the construction of highways facilitates urban expansion along these corridors, leading to a decentralization of population and economic activity. Conversely, areas lacking highway access experience relative decline as the urban periphery shifts toward more connected zones: research suggests that highway development may have been a significant factor in the depopulation of city centers in the US between 1950 and 1990.[234]

EXPERT POSITION 21

Dario Nardella— Reinforcing the role of cities in multi-level governance

"As former President of Eurocities and mayor of Florence for 10 years, I have seen cities pioneer solutions for social inclusion, climate change, and urban regeneration. Yet, they lack legislative power, often controlled by states. For instance, urban security is a state competence in many European countries, limiting mayors' authority. To address the democratic crisis in Europe, the US, and beyond, we need a bottom-up approach integrating local and central decision-making while involving citizens. With 70% of mayoral actions tied to EU legislation, city-to-city cooperation and stronger networks are vital. These networks often outperform traditional national cooperation. Cities are flexible and fast-acting, making city diplomacy key to sharing values, projects, and innovation globally. New models of local and global collaboration are essential to strengthen urban leadership and multi-level governance for EU integration and beyond"

Dario Nardella, Member of the European Parliament, former Mayor of Florence

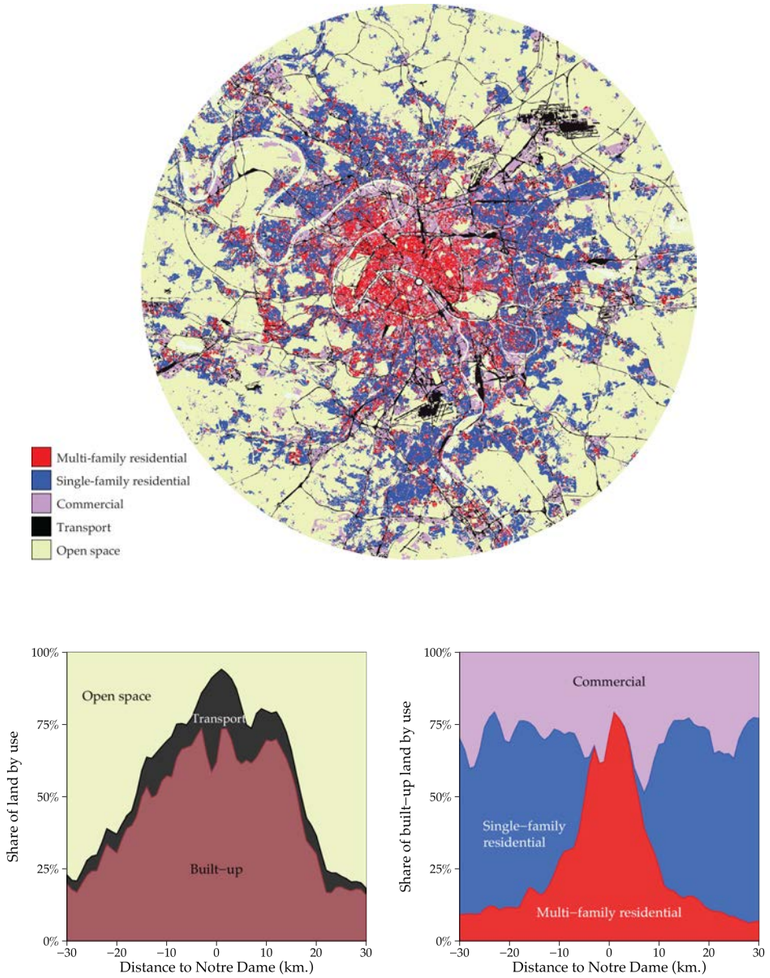
FOCUS 19

Paris: a monocentric city shaped by history and transit[235]

Paris displays a spatial structure consistent with the monocentric city model, with land prices and population densities decreasing outward from the central business district around Notre Dame. Commercial activity and dense multi-family housing dominate the core, giving way to lower-density housing and open space with distance, a pattern reinforced by strong metro and rail accessibility. However, historic preservation rules in the center restrict redevelopment and building heights, sustaining exceptionally high land prices and flattening the decline in values compared to theoretical predictions.

FIGURE 46

Distribution of land across various uses in Paris[236]



The map shows how land is used across Paris, within a 30 km radius of Notre Dame. The top map divides the area into five land-use types, while the two bottom graphs summarize these uses by distance from the center—North on the right, South on the left.

Source: Duranton G., Puga D., 2014

229 - Duranton G., Puga D., *Urban Land Use, Handbook of Regional and Urban Economics*, 5, 2014.

230 - Glaeser E., *The Economic approach to cities*, Harvard Institute of Economic Research Discussion Paper No. 2149, 2008.

231 - Alonso W., *Location and Land use: Toward a General Theory of Land Rent*, Harvard University Press, 1964.

232 - Mills E., *An Aggregative Model of Resource Allocation in a Metropolitan Area*, The American Economic Review, 57(2), 1967. 240 -

233 - Muth R. F., *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. Chicago and London: The University of Chicago Press, 1969.

234, 235 & 236 - Duranton G., Puga D., *Urban Land Use*, International Trade and Regional Economics, 5, 2014.

A SUSTAINABLE 'URBAN CONTRACT' FOR INFRASTRUCTURE

For adaptive cities, one of the most pressing challenges will be **ensuring that inclusion remains central**. Technological innovation and environmental sustainability alone are not enough; social equity must be integrated at the heart of urban planning. Achieving this requires embedding inclusive governance mechanisms that allow diverse communities to shape decisions related to smart technologies, infrastructure development, and environmental initiatives. Policies should support equity audits, participatory design processes, and community-driven budgeting, ensuring that the benefits of adaptation are distributed fairly across all segments of society.

The prerequisite will be to align all city stakeholders around projects that are **funded, fair, low-carbon, and resilient** (the 'just transition'). The next era of urban life demands not only new technologies and financing, but new social relationships—between governments and residents, between private actors and the public, between present generations and those yet to come.

A few principles can be used as reference for more adaptive and inclusive cities:

Shared stewardship: infrastructure must be recognized not as a commodity delivered to passive end-users, but as a collective asset whose value depends upon the sustained commitment and mutual responsibility of all stakeholders.

Inclusive stakeholder engagement: communities are not merely recipients of decisions; they are active partners in shaping design and delivery. Technical expertise is indispensable, yet true legitimacy arises from meaningful collaboration;

Equity as a foundational principle: the success of infrastructure is measured not by aggregate outcomes but by the fair distribution of benefits. No community should disproportionately bear costs while others disproportionately enjoy rewards;

Transparency and accountability in decision-making: data, processes, and impacts must be disclosed openly, ensuring that decision-making is subject to scrutiny and that public trust in institutions and policymakers is reinforced.

Intergenerational reciprocity: to overcome the 'tragedy of horizons', today's investments must safeguard tomorrow's prospects. Future generations are entitled to infrastructure that are livable, sustainable, and just.

For a fuller treatment of how infrastructure can be engaged in a 'just transition', a helpful reference should be InfraVision's report 'Infrastructure and Inclusion', published in 2024, which offers an in-depth roadmap.[237]

EXPERT POSITION 22

Virginijus Sinkevičius – Don't forget about social inclusion

"Although European cities are at the forefront of the twin transition—the digital and the green—this transformation must not come at the expense of social inclusion. As urban populations expand and available space becomes increasingly constrained, the pressing challenge is to manage that space both efficiently and equitably. Achieving this balance requires modern digital infrastructure that can unlock the full potential of connected systems, from mobility to energy, while ensuring accessibility for all.
At the same time, investment in traditional physical infrastructure remains essential to guarantee that cities are functional, navigable, and welcoming.
The goal is not to prioritize one over the other, but to integrate both in a way that enhances everyday urban life. Ultimately, what matters is adopting an approach that is not only effective but also resource-efficient—particularly as the investment gap continues to widen and public resources remain scarce.
By aligning digital innovation, sustainable development, and social equity, European cities can ensure that the twin transition delivers benefits that are shared broadly across society"

Virginijus Sinkevičius,
MEP and former European Commissioner for Environment, Oceans and Fisheries

FOCUS 20

Spatial planning for multifunctional green infrastructure: the case of Detroit[237]

Using the case of Detroit, a study conducted by Meerow and Newell in 2016 showed that although green infrastructure is promoted for its multifunctionality, projects are typically sited based on a particular benefit, such as stormwater abatement, rather than a suite of socio-economic and environmental benefits. This stems in part from the lack of stakeholder-informed, city-scale approaches to systematically identify ecosystem service tradeoffs, synergies, and 'hotspots' associated with green infrastructure and its siting. To address this gap, Meerow and Newell introduced the Green Infrastructure Spatial Planning (GISP) model, a GIS-based multi-criteria approach that integrates six benefits: 1) stormwater management; 2) social vulnerability; 3) green space; 4) air quality; 5) urban heat island amelioration; and 6) landscape connectivity. Stakeholders then weight priorities to identify hotspots where green infrastructure benefits are needed most.

Applying the GISP model to Detroit shows that certain parts of the city have a stronger need for green infrastructure than others, and these priority areas vary depending on the ecosystem service considered. For instance, locations most suitable for stormwater management are generally not the same as those best positioned to improve landscape connectivity. Some benefits—such as stormwater control, urban heat island reduction, and air quality improvement—overlap more closely, but realizing these synergies still requires a deliberate planning approach to balance trade-offs.

The results of the GISP model suggest that current green infrastructure projects in Detroit are not being strategically planned to maximize multiple ecosystem service benefits. Even when Detroit stakeholders' priorities are used to weight and combine criteria, the results are still significantly negatively correlated with current green infrastructure sites. For example, although local stakeholders identified reducing social vulnerability as a key goal of green infrastructure (second only to stormwater management), few projects have been implemented in the neighborhoods where residents are most vulnerable.

FIGURE 47

Current green infrastructure project locations and prioritized sites[238]

Source: Meerow S., Newell J., 2016

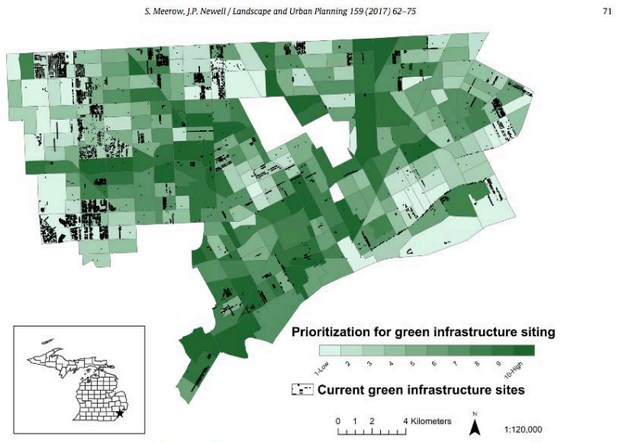


Fig. 8. Overlay of current green infrastructure project locations and GISP model combined criteria scores using stakeholder pairwise comparison weights. (Please see the web version of this article for a color version of this figure.)

FOCUS 21

Urban data governance: ensuring ethical stewardship

Digitalization and data-driven technologies are central to the smart city promise of more efficient urban services. Yet the very systems that enable optimization, such as sensors or AI, raise governance dilemmas. Without clear oversight, they can lead to intrusive surveillance, misuse of personal information, or algorithmic bias, with potentially damaging effects on public trust and social legitimacy. Managing smart city data is therefore not only a technical issue but a question of good governance: ensuring transparency and ethical use of data.

To meet this challenge, cities are beginning to institutionalize human-centric governance models through a variety of approaches, as outlined by the OECD in its Smart City Data Governance report.[240] Value-anchored frameworks set the ethical direction: this is the case of Bilbao's Data Manifesto, which articulates principles for fair and transparent data use. Comprehensive strategies aim to embed data governance across the municipal system, as does Vienna's Data Excellence Strategy. Specialist bodies provide oversight, such as London's Data for London Advisory Board, which advises the mayor on responsible data management and the development of the city's new data platform, and Seattle's Privacy and Cybersecurity Committee, which monitors municipal data practices. Finally, leadership mechanisms strengthen accountability: cities such as Barcelona, Paris, and Reykjavík have appointed Chief Data Officers to provide strategic oversight.

237 -InfraVision, *Infrastructure & Inclusion*, 2024.

238 & 239 - Meerow S., Newell J., *Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit*, Landscape and urban planning, 159, 2017.

240 - OECD, *Smart City Data Governance: Challenges and the Way Forward*, 2023.

Suggested playbooks for infrastructure stakeholders

A CITY PLAYBOOK FOR FOCUSED ACTION BY 2050

A differentiated approach acknowledges that while all cities share the common goal of becoming resilient and low-carbon, the pathways to achieve this goal must be tailored to local contexts, capacities, and constraints. Only through such differentiated strategies can public officials and associated stakeholders, such as civil society and industry leaders, ensure that no city is left behind in the transition to a sustainable urban future, notably by:

- **Starting where cities are:** build on existing capacities rather than imposing universal solutions,
- **Prioritizing high-impact, low-cost interventions:** especially for resource-constrained cities/states,
- **Enabling progressive scaling:** allow cities to advance through development stages,
- **Fostering cooperation:** both horizontal (peer-to-peer) and vertical (international support),
- **Maintaining long-term vision:** while adapting to immediate constraints and opportunities.

It is crucial to establish a taxonomy of cities to develop targeted protocols. Ensuring a sustainable future of cities requires distinct strategies shaped by each city's economic context, institutional capacity, and specific risks. Yet, devising a finite number of blueprints ensures replicability and scaleability of high impact solutions based on four different criteria.

Economic strength: economic strength categorizes cities based on their income level—low-income, middle-income, or high-income—which shapes the scope of their financial resources, availability of credit, and ability to attract both public and private investment. Low-income cities often face severe budgetary constraints, limited fiscal autonomy, and restricted access to external finance, hindering their capacity for large-scale urban improvement or adaptation measures;

Urban density: this key criterion determines the progress to make to achieve strategic urban density. Urban density describes the concentration of people, buildings, and infrastructure within a given area. Low-density cities typically spread populations and services across larger land areas, resulting in extensive urban sprawl, car dependency, and greater infrastructure and service provision challenges. High-density cities, in contrast, cluster populations and activities more compactly—enabling efficient public transport, reduced per capita resource use, and the potential for more vibrant public spaces.
The choice and management of density directly shape a city's ability to transition toward strategic urban density: increasing density may unlock economic and environmental efficiencies, but also risks congestion or loss of green space if not managed well, while overly low density can create long-term barriers to resilience and climate adaptation. As such, urban density is a critical lever for advancing efficiency, accessibility, and sustainability in city development;

Infrastructure homogeneity: refers to the uniformity of a city's built environment, such as consistent building heights and land uses across large areas.[241] Cities can exhibit homogenous or heterogenous built environments (see section #1).
This criterion is important for resilience because homogenous areas may lack the functional diversity, redundancy, and "mix of uses" that support social and infrastructural adaptability. Urban homogeneity also shapes the potential for greening: uniform, single-use zones may present barriers to multifunctional green infrastructure or mixed-use public spaces, whereas heterogeneity may support a broader range of adaptation and mitigation solutions;

Human and environmental externalities: environmental externalities frame a city's typology by highlighting the predominant environmental threats it faces, such as flooding, heat, drought, air pollution, solid waste, and wastewater management.

EXPERT POSITION 23

Carine Staropoli – The Urban New Deal Chair: providing decision-making support tools for city stakeholders

"The Urban New Deal Chair, created in 2021 at the Paris School of Economics, is funded by key partners—ENEDIS, the Caisse des Dépôts Research Institute, PTV Group, and SNCF Réseau—who are key actors supporting cities and territories in their Net Zero transition. The Chair provides a platform for PSE scholars to collaborate with other researchers and engage with economic actors, fostering exchanges between academia and practice.
Its ambition is to analyze the transformation of essential urban services such as energy, mobility, housing, and water, with a strong focus on the role of the digital transition, toward more sustainable, inclusive, and efficient models. Research projects, grounded in applied economics and using methods from spatial econometrics and cost-benefit analysis to behavioral experiments and simulations, cover topics such as the deployment of renewable energies, energy efficiency in buildings, energy demand modeling, and sustainable mobility policies. By combining academic rigor, industry expertise, and decision-support tools, the Chair contributes to both scientific debates and practical policy design for the urban transition"

Carine Staropoli
Professor of Economics at University of Rouen Normandie, and co-head of the "Urban New Deal" Chair at Paris School of Economics

These risks set the agenda for climate action—informing which mitigation priorities (such as emissions reduction, air and water quality improvement, or waste minimization) and which adaptation strategies (including flood defenses, urban greening, or advanced waste and water treatment infrastructure) should take precedence.
Cities exposed to frequent extreme weather, chronic pollution, or mounting waste and sanitation challenges must tailor investments in nature-based solutions and resilient infrastructure to address their specific vulnerabilities, making environmental externalities a central criterion.

No single city fits only one category. Most will require an integrated approach across these action areas. However, focusing first on each city's main blockers—specific to their economic, spatial, and environmental context—will deliver the biggest gains toward greening and resilience by 2050.

241 - Satellite mapping of urban built-up heights reveals extreme infrastructure inequality in global cities by Zhou Y. et al., published in the Proceedings of the National Academy of Sciences (PNAS) in 2022. The figure displays cities grouped into six typologies based on 2D urban density and 3D built-up height, using global satellite data. The authors show the 3D view of representative cities for six types of urban forms, categorized by continent and impervious surface area (ISA).

TABLE 2

A matrix for focused action, for public officials and associated stakeholders (civil society, industry leaders, etc.)

KEY CATEGORIES	CITY TAXONOMY	KEY GOALS
Economic strength	Low Income Cities (LICs)	**Strengthen local institutions.** Build municipal capacity and governance structures to plan and deliver resilience projects. **Unlock basic finance.** Leverage international climate and development grants; pursue microfinance or blended finance mechanisms to overcome limited user contributions.
	Middle Income Cities (MICs)	**Close funding gaps.** Strengthen creditworthiness and leverage PPPs for infrastructure investments. **Prioritize multi-benefit projects:** Invest in solutions (e.g., green corridors, integrated water/waste systems) that deliver both climate adaptation and broader urban improvements.
	High Income Cities (HICs)	**Streamline permitting and regulations.** Fast-track green and resilient infrastructure approval processes. **Overcome NIMBYism.** Use robust stakeholder engagement and incentives to build support for density, infrastructure upgrades, and greening.
Urban density	High 2D / Low 3D	**Promote mixed-use, walkable neighborhood**s. Reduce car dependency via planning reforms. **Invest in mass transit.** Expand affordable and efficient public transport networks.
	High 2D / High 3D	**Retrofit existing buildings.** Prioritize energy efficiency, cooling upgrades, and climate-proofing. **Encourage acceptable densification.** Involve communities in designing dense, green, livable spaces to reduce resistance.
Infrastructure homogeneity	Heterogeneous	**Pilot and demonstrate solutions.** Use demonstration projects to refine "what works" in complex, mixed urban contexts. **Build partnerships for scale.** Create multi-stakeholder coalitions to achieve economies of scale and lower costs.
	Homogeneous	**Foster flexibility for future redesign.** Diversify infrastructure options to avoid being locked into "single-path" development (e.g., mono-functional highways or utilities). **Regulate adaptation planning.** Mandate future-proofing reviews for major investments and developments.
Human and environmental externalities	Heat	**Expand urban greening.** Plant trees, green roofs, and parks to reduce heat islands. **Upgrade cooling infrastructure.** Mandate passive cooling designs. **Improve surface albedo.** Promote high-reflectance surfaces for roofs and pavements.
	Wildfires	**Strengthen zoning and land-use controls.** Prohibit or tightly control new development in fire-prone areas. **Create defensible spaces.** Enforce buffer zones and firebreaks; educate property owners.
	Solid waste	**Embed waste-to energy (WTE) systems.** Process municipal solid waste and other waste streams to generate usable energy, such as electricity, heat, or fuel. **Strengthen enforcement.** Improve regulatory oversight and public education to reduce illegal dumping.
	Wastewater	**Upgrade treatment and collection.** Target investment in modern, decentralized systems for underserved and informal zones. **Monitor and enforce standards.** Expand coverage, boost monitoring, and set clear treatment requirements.
	Floods	**Expand and upgrade drainage.** Invest in green and gray drainage solutions. **Mandate risk mapping and land use controls.** Integrate updated risk maps into planning decisions and zoning enforcement.
	Droughts	**Strengthen water management.** Invest in leak reduction, water-saving incentives, and resilient sources. **Promote demand reduction.** Facilitate low-flow standards, pricing incentives, and public outreach for less water use.
	Air pollution	**Decarbonize transport and industry.** Shift to clean energy, electrify transport, and improve public transit. **Tighten air quality regulations.** Set stricter standards and enhance monitoring, particularly around major emission sources.

FOCUS 22

Las Vegas: leveraging smart urban planning for inclusion and better decision-making[242]

In 2023, the City of Las Vegas entered into a partnership with NTT DATA to deploy a private 5G network, aimed at addressing two critical challenges: expanding broadband access in underserved communities and enhancing municipal decision-making through real-time data analytics. NTT DATA Smart Solutions turn real-time data into actionable insight, enabling officials to make smarter decisions.

The ultimate goal was to craft a safer, more connected and intelligently planned urban landscape by harnessing the power of IoT devices, secure networks and edge analytics.

The implementation of NTT DATA's Smart Solutions has been justified by clear, measurable outcomes and cost efficiencies. Notable achievements include:

Expanded digital inclusion with reliable, low-latency connectivity to more than 1,000 students and families in low-income neighborhoods, significantly improving internet access,

Enhanced road safety and cost savings of over 90% in wrong-way driving incidents, generating annual savings exceeding USD 1m through avoided accidents and reduced enforcement costs,

Better data-driven urban management with deployment of smart park and traffic management systems provide actionable insights, supporting more effective city planning, resource allocation, and infrastructure development,

As a result of the City's innovative efforts around smart parks, it was awarded the 2024 IDC Smart Cities North America Award for Data Driven Policing. It should be noted, however, that the deployment of IoT devices and real-time data analytics in Las Vegas raises significant concerns regarding privacy and data security.

FOCUS 23

Paris: the first 15-min city

According to Carlos Moreno in, the idea of a 15-min city is to "design or redesign cities so that in a maximum of 15 minutes, on foot or by bicycle, city dwellers can enjoy most of what constitutes urban life: access to their jobs, their homes, food, health, education, culture, and recreation"[243]. The 15-minute city concept has gained traction in recent years, with numerous cities around the world embarking on pilot projects and policy changes to transform their urban landscapes.

The city of Paris has been at the forefront of implementing the 15-minute city concept, leveraging its unique urban fabric and cultural heritage to redefine the spatial organization. Mayor Anne Hidalgo proposed a "big bang of proximity"[244], which would involve major decentralization and the creation of new services tailored to each borough. The move was part of a larger attempt to improve air pollution and livability, spanning a wide range of public investments across transportation, sustainability and new programs to strengthen neighborhood-level governance.

Although Paris has shown notable agility in using the COVID-19 pandemic as a catalyst to advance its urban agenda, questions persist regarding the relevance and effectiveness of certain strategies, especially in diverse urban settings with different scales and socio-economic conditions[245].

242 - NTT Data, *The City of Las Vegas shapes the future of urban living.*

243 & 244 - Bertaud, A., *The Last Utopia: The 15-Minute City*, Urban Reform Institute, 2022.

245 - Christoforaki K., *Towards a sustainable urban future: the 15-minute city approach in Paris*, France, SDCT Journal, 2024.

A COUNTRY PLAYBOOK FOR FOCUSED ACTION BY 2050

By 2050, the shape of urban infrastructure will not only be determined by city planning and trade-offs, but also by societies' strategies in the face of climate change, demographic shifts, and technological disruption. Cities often face structural barriers—fragmented authority or limited fiscal capacity—that cannot be overcome by local action alone. National governments play a pivotal role in setting the enabling conditions for urban transformation, from policy and finance to standards and knowledge-sharing.

In addition, **overall financing needs will be considerable** (section #1), and **national governments worldwide will play a major role in meeting them**. The roadmap below outlines five priority areas where differentiated national strategies can support cities across income levels—high, middle, and low—while addressing persistent gaps between city ambition and systemic capacity.

By providing clear national frameworks, mobilizing finance, setting infrastructure standards, fostering innovation, and embedding inclusion, governments can ensure that urban transitions are coordinated, equitable, and, ultimately, successful.

TABLE 4

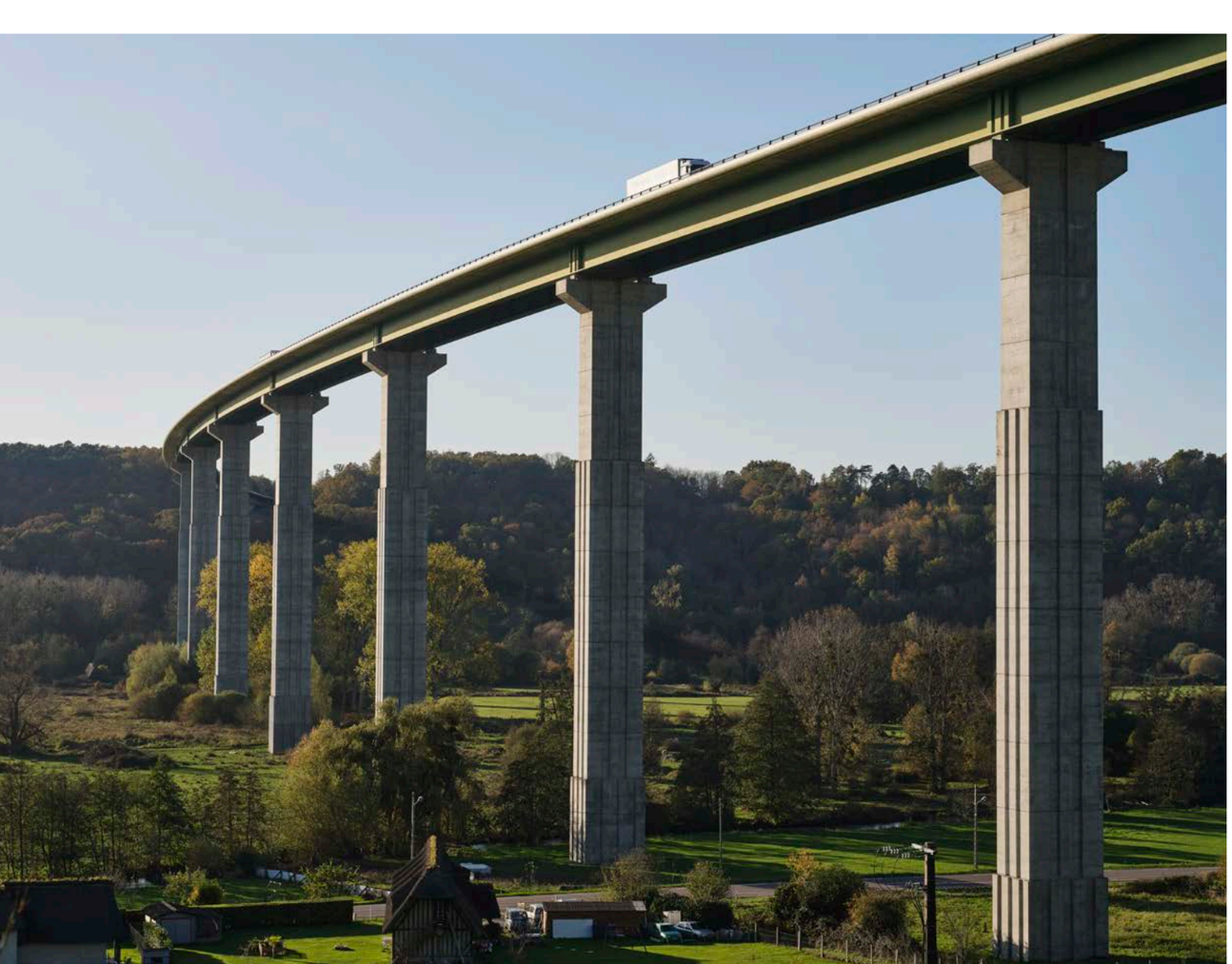
Roadmap for national governments

PRIORITY	HIGH-INCOME COUNTRIES (HICS)	MIDDLE-INCOME COUNTRIES (MICS)	LOW-INCOME COUNTRIES (LICS)	CITY/REGIONAL GAP ADDRESSED
1. Strategic long-term urban policy and coordination	Set binding national targets and frameworks for resilient and green urban development Ensure city plans align with net zero and SDG targets	Institutionalize integrated, cross-sector urban plans with national climate and resilience objectives	Build foundational legal and institutional frameworks for city planning Link city plans to national goals	Cities may have fragmented or short-term plans without national integration and backing
2. Mobilize and target urban finance	Provide fiscal incentives, guarantee city borrowing for retrofits, and deliver resilience funds	Enable PPPs, support municipal bond markets, direct funding to high-impact city projects	Secure international climate/development finance and direct to city priorities (grants, blended finance)	Cities cannot raise sufficient funds alone National pooling unlocks scale and risk sharing
3. National infrastructure standards and mandates	Mandate minimum green performance (buildings, mobility, waste), scale retrofitting, and require nature-based solutions nationally	Set baseline standards for waste, water, and clean energy Enforce resilience in all city projects	Establish essential service standards (waste, water, risk reduction) and basic green infrastructure targets	Cities lack authority/resources for universal resilient infrastructure and innovation
4. Innovation and knowledge sharing at scale	Fund research, pilots, and scale-up of advanced tech (smart city, circularity) Enable city learning platforms	Support demonstration projects, city peer-learning, and adapt global best practice to local context	Pilot low-cost scalable solutions Sponsor city learning networks for local adaptation and knowledge transfer	Cities struggle to access R&D, tech transfer, or to scale up successful models beyond pilots
5. Embed equity and inclusion in national urban policy	Mandate inclusive urban investments (retrofits, public transit) prioritizing underserved areas Support engagement and anti-NIMBY action	Require participatory planning Target infrastructure investments to vulnerable regions/populations	Ensure resource allocation to informal settlements and marginalized populations Involve community/NGOs	City action alone risks exclusion or underinvestment in the most

AN INVESTOR PLAYBOOK TO BRIDGE QUANTITATIVELY AND QUALITATIVELY THE INVESTMENT GAP

Investors carry a particular responsibility as actors uniquely positioned to bridge the global infrastructure gap and provide the financing needed to transform urban systems. Their strategic choices are critical not only to ensure projects are bankable but also to align them with long-term urban development goals. This responsibility is shared with public authorities and other stakeholders, highlighting the need for collaboration to ensure that infrastructure is high-quality, and sustainable.

To outline a path for investors, InfraVision has conducted a series of interviews with key public and private stakeholders to gather insights and outline best practices that could be scaled.



INTERVIEW 1

Banque des Territoires: partnering with local authorities for the public interest

A conversation with Antoine Saintoyant, Director of the Banque des Territoires, Deputy CEO of the Caisse des dépôts et consignations

InfraVision: ***What are the Banque des Territoires' priorities for infrastructure investment?***

Banque des Territoires was created in 2018 to bring under one umbrella Caisse des dépôts' activities supporting the development of local territories in France. As such, infrastructure is at the heart of our activity and represents around 85% of our operations across transport, energy, digital, and water infrastructure, as well as real estate and affordable housing. We address the needs of local authorities and of the social and affordable housing sector through three main instruments: lending (which should reach over EUR 30bn this year), investment (EUR 1.5bn in gross flows), and engineering support (EUR 250m annually).

We focus on three strategic areas: first, helping achieve a 'Just transition' with massive investments and financing in the green transition, while maintaining our strong commitment to support social housing and urban policy, for instance by supporting the growth of proximity retail to revitalize city centers. Specific priorities include the renovation of 10,000 public buildings by 2028 to achieve higher energy-efficiency, financing the construction and rehabilitation of water-supply networks, and cleaner and affordable energy through heating and cooling networks, via Banque des Territoires' financing but also through our 50/50 investment partnership with Vauban in leading provider Coriance. Second, climate change adaptation, helping territories adapt infrastructure : for example, supporting mountain regions dealing with reduced snowfall, by dismantling old ski lifts and developing new leisure infrastructure. Third, digital sovereignty with major data center investments planned, to meet the needed capacities for sovereign cloud and AI.

As a public investor, how does the Banque des Territoires position itself in the investment ecosystem?

We are a 100% public investor with close ties to the State, local authorities, and mixed-economy companies. This proximity gives us a comprehensive overview of both national needs and of what is needed by local decision-makers. In any project, our key differentiator is that we strive to balance financial performance with the public interest. We calibrate return expectations to the level of social benefit: we accept lower returns when the positive impact (on the environment, socially, etc.) is significant, while otherwise operating at market standards. We also adapt our role to market conditions. When major players are reluctant to invest, we step in to address market failures and target specifically investment needs that are not covered—or not yet sufficiently covered—by the private sector, until they reach maturity. For example, Banque des Territoires financed the 2013-2022 wave of fiber rollout, and France is now well covered. One area we are focusing on today is electric vehicle charging networks, to accelerate the transition to sustainable mobility. In elderly care, for instance, following the post-COVID sector crisis, we supported the maintenance and expansion of essential services by participating in the recapitalization of a leading operator, Emeis (ex-Orpea), helping preserve and improve care capacity.

INTERVIEW 2

Harmonie Mutuelle: health-centered urban development

A conversation with Catherine Touvrey, CEO of Harmonie Mutuelle, Lionel Fournier, Director of Impact and Sustainable Health at Harmonie Mutuelle, and Patrice Tillet, Director General of Groupe Arcade-VYV

InfraVision: ***Housing is a major challenge for cities worldwide across all levels of economic development. In France, 2.8 million households are waiting for social housing.[246] How does Harmonie Mutuelle, through its activities and investments, provide a distinctive approach to urban development?***

Harmonie Mutuelle is a fouding Member of Group VYV. VYV is a major investor, with EUR 27bn in assets and EUR 11bn in revenue, operating across health insurance and support services, from early childhood to end-of-life care. Through our subsidiary Arcade VYV, we are actively involved in housing, particularly social housing, where we are the fourth-largest group in France, generating around EUR 1bn in revenue. What sets us apart is our integrated approach: we are constructors, owners, and managers, not merely buyers from developers. This enables us to ensure high quality and adapt housing to specific needs. For example, we manage 10,000 military housing units, which we rehabilitated and will oversee for 35 years.

For us, housing is not just a product: it is designed to promote health. We see ourselves as co-producers of well-being. For instance, we take into account the health of vulnerable tenants during renovations; and we extend our impact assessment further than any other housing provider. Through this approach, we ensure that our investments in urban housing genuinely contribute to healthier, more sustainable communities.

How do you integrate your health expertise with environmental and social considerations in urban development?

Health challenges today require interventions that go beyond education or individual responsibility. To truly promote well-being, we focus on sustained, long-term actions that address the determinants of health. We see strong synergies between health, environmental, and social factors: lifestyles that are good for health (such as nutrition, mobility, and social engagement) often benefit the environment as well. For example, in Rouen, we have developed shared gardens and common spaces that serve as 'life infrastructure,' promoting healthy living, nutrition, and social connections. This integrated approach, which we call within Harmonie Mutuelle our 'health-ecology-social' triptych, underpins our contribution to France's health transformation .

A particular focus for us is combating sedentariness and promoting physical activity, which has significant implications for urban planning and design. Across all our projects, this philosophy drives our investment in what we term 'eco-health,' ensuring that our urban development efforts create lasting benefits for both people and the planet.

246 - L'Union sociale pour l'habitat, *Dossier - Les Hlm fiers de loger la France telle qu'elle est*, 2025.

INTERVIEW 3

The Global Infrastructure Investor Association: learning the art of communicating with policymakers and citizens

A conversation with Jon Phillips, CEO of the Global Infrastructure Investor Association

InfraVision: ***Communication with the public and policymakers is crucial for infrastructure development. What role does the Global Infrastructure Investor Association play in facilitating these conversations?***

ur role is multifaceted. We advocate for the sector by stimulating better dialogue between investors and policymakers, so each side understands the other's needs, creating opportunities for engagement when governments want to connect with the infrastructure investment community. We challenge policymakers to think harder about their decisions. Every government faces domestic challenges about infrastructure costs, including affordability constraints exacerbated by COVID, energy security and defense priorities, climate adaptation and resilience, and the never ending challenge of renewing infrastructure. We challenge whether their stated goal of becoming attractive to capital is matched by actual policy decisions. We also convene our members to prompt meaningful conversations within the sector, helping them better understand challenges while building community and relationships.

What advice do you have for infrastructure investors seeking to improve the dialogue they have with policymakers and their engagement with the broader public?

Investors must get better at articulating the benefits they bring to society, not just to their own stakeholders. Traditionally, they have focused on communicating benefits to investors: the people who put money into their funds. They believe managing stakeholder relationships is the responsibility of their assets, but they have missed the societal perspective entirely. This has left a vacuum that opponents of private infrastructure investment have filled with negative narratives.

At the GIIA, we help shift the narrative from one focused solely on returns to one emphasizing shared societal value. For instance, we communicate how millions of British savers have stakes in British infrastructure. More than 11m pension savers have invested in UK infrastructure through over 150 pension funds, representing GBP 87.5bn in ownership stakes across power, renewable energy, water, telecommunications, transportation, and social infrastructure. By highlighting these connections, we demonstrate that infrastructure investment isn't just institutional capital: it's ordinary workers' pension savings invested in the infrastructure serving their communities.

INTERVIEW 4

The European Investment Fund: setting social standards for urban infrastructure investment

A conversation with Gabriele Todesca, Head of Infrastructure Investments at the European Investment Fund

InfraVision: ***What are the European Investment Fund's priorities for urban infrastructure investment?***

We distinguish between core and ancillary urban infrastructure. Our primary investment focus is on social urban infrastructure, particularly affordable, energy-efficient, and sustainable housing. For example, in Pantin, in the Greater Paris area, we are investing in development through decontamination of existing sites, to avoid urban sprawl by reconditioning already-built land. Beyond housing, we are active in urban transport (trams, electric buses), digital infrastructure (data centers, connection infrastructure typically at city edges), and energy distribution networks serving urban areas. These sectors are interconnected and essential for sustainable urban development.

As a public investor, how does the EIF position itself in the investment ecosystem?

We occupy a unique position: we invest in funds and take commercial views like private investors, but our public nature allows us to set additional standards and criteria. Our primary motivation is helping cities become greener, more sustainable, and more affordable. We are supported by an in-house team of engineers and economists, who help us to establish concrete criteria for concepts like 'affordability'. For instance, by defining standards for student housing that the broader financial community can adopt. This supports private investors' ESG strategies and helps align policy objectives with financial objectives.

The key challenge is avoiding superficial compliance. Just as greenwashing exists in environmental sectors, investors might pretend to do good while only focusing on profits. Our role is creating measurable standards and working with investors to implement them effectively. We do not replace the private market but complement it. When we invest in funds, we require private investors to participate alongside us, ensuring projects maintain commercial discipline while achieving public policy goals. The need for social standards exists across Europe: the infrastructure gap exists not just between developed and emerging markets, but within developed markets themselves; between European countries and even between cities in the same country.

From your perspective, how can governments foster a policy environment that encourages financial institutions to support affordable infrastructure?

EU governments have tried many different approaches, with various degrees of success. In general, I think that market-based approaches have the best chance of success. The most effective solutions are those that put in place clear and reliable incentives for market players. If necessary, this may include targeted subsidies—what is important, however, is that competition and market forces are allowed to play freely within the defined framework.

Perspectives for InfraVision

Urban infrastructure holds a structuring power that will decisively shape whether cities can withstand converging pressures, capitalize on opportunities for transformation, and secure prosperity and resilience for their inhabitants. Recognizing this, the report advocates for a paradigm shift toward adaptive cities—urban systems that embrace integrated infrastructures, nature-based solutions, regulatory innovation, and systemic governance models.

These elements must operate in concert to navigate the evolving landscape of climate change, demographic shifts, and the emergence of new infrastructure patterns.

The key findings of the report therefore open a number of forward-looking questions and areas for further exploration:

- Global interdependence: How will shifting trade realignments, and resource dependencies affect the ability of cities to plan for resilience?
- Infrastructure, geopolitics, and sovereignty: how will shifting global alliances and supply chain vulnerabilities reshape infrastructure priorities?
- Economic transformation: What models of growth and productivity can reconcile decarbonization with job creation and long-term prosperity?
- Social cohesion: How can cities maintain trust, inclusion, and democratic vitality under conditions of polarization, migration, and inequality?
- Technological disruption: What ethical and societal frameworks are needed to govern the rapid deployment of AI, automation, and digital infrastructure in urban life?
- Cultural transformation: What narratives, values, and forms of collective imagination are necessary to mobilize societies toward adaptive and regenerative futures?
- Long-term investment and decision-making: How can cities design policies, financing strategies, and governance structures that balance immediate needs with long-term resilience and adaptability?

Taken together, these questions point to the urgent need for strategic experimentation and integrated approaches that can prepare cities not only to survive future disruptions, but to emerge more equitable and resilient.

After launching in 2024, the InfraVision has charted a path of expansion in 2025, with plans to further scale its operations between 2026 and 2027. InfraVision aims to be a critical platform in a time of rapid political and economic change, as elections approach in major countries and regulatory uncertainty looms over infrastructure sectors. InfraVision will strive to connect a diverse range of stakeholders, including operators, investors, local authorities, and international entities such as the European Commission, the European Parliament, and the OECD. By facilitating collaboration among industry leaders, researchers, policymakers, and investors, InfraVision will promote the exchange of best practices and innovative solutions.

APPENDIX 1

BIOGRAPHIES OF EXPERTS

ADAM ABDIN

Adam Abdin is an Associate Professor of Operations Research and Decision Analytics at CentraleSupélec, University of Paris-Saclay, specializing in the risk and resilience of complex systems. He holds a PhD in Engineering of Complex Systems and a multidisciplinary background in industrial engineering and network economics. He is also Chief Strategy Officer and co-founder of ArcSpace, a startup focused on space technologies. His research applies operations research and AI to improve decision-making in engineering systems, with projects spanning power system planning, pandemic response, space systems and critical infrastructure management.

DOMINIQUE ALBA

Dominique Alba is an architect and a urban planner who has been the CEO of Ateliers Jean Nouvel since 2022. She began her career in 1982 at the Jean Nouvel agency, then worked on sustainable development projects in Africa and Latin America. From 1986 to 2000, she partnered with Philippe Roux on building rehabilitation and urban planning in France, Europe, and Africa. She served from March 2001 to May 2003 as the official in charge of architecture, public space, and urban renewal in the office of the Mayor of Paris under Bertrand Delanoë. From 2003, she became General Director of the Pavillon de l'Arsenal, Paris' center for architecture and urbanism. Between 2008 and 2012, she was deputy director and then from 2012 to 2022 director general of the Atelier Parisien d'Urbanisme, overseeing urban planning for Paris and the Greater Paris area. Dominique Alba is an architect DPLG who studied at the École Nationale Supérieure des Beaux-Arts de Paris.

DAMIEN AUDRIC

Damien Audric is the Head of Sustainability and Land Development at Disneyland Paris. He has been with Disneyland Paris since 2016, serving as Director of Land Development until 2022. Damien Audric previously worked at Grand Paris Aménagement. He holds an engineering degree from the École Nationale des Travaux Publics de l'État and an architecture degree from the École Nationale d'Architecture Paris-Malaquais with an INSEAD certification in Sustainability Leadership.

JOYCE ABOU MOUSSA

Joyce Abou Moussa has been Head of Organizational Performance in Groupe ADP's Transformation Division since May 2025, after serving as Deputy Director of Innovation and Business Development for more than two years. In her new role, she steers operational transformation and performance strategies at one of the world's leading airport groups. Previously, she led business development, innovation, and sustainability initiatives—including the group's Advanced Air Mobility pilot program—leveraging her background in strategy, urban planning, and mobility innovation. Joyce has a background in smart cities management, urban planning, and architecture, with degrees from the American University of Beirut and École des Ponts ParisTech. She is currently pursuing her Executive MBA at INSEAD.

JOANNE ANDERSON

Joanne Anderson was the Mayor of Liverpool from 2021 to 2023. During her tenure as Mayor, Joanne prioritized climate action, making sure that every decision advanced the city's net-zero target and benefited residents by adhering to her triple-lock framework centered on people, planet, and equality. Leveraging her national influence in the field of social investment, Joanne has collaborated with regional and national partners to launch a social investment pathfinder in Liverpool, aiming to secure GBP 50m in place-based social investment. Joanne is also an Adjunct Professor and Board Member at Liverpool John Moores University Business School, where she chairs the Strategic Advisory Board, linking her academic expertise with her commitment to inclusive economic growth. Joanne has also worked as a civil servant as the community engagement policy lead within the Crown Prosecution Service.

CHARLES-ANTOINE BLANC

Charles-Antoine Blanc is the Group CFO of Paprec Group, a leading French company specializing in recycling and environmental services. Since 2013, he has been responsible for finance, mergers and acquisitions, investor relations, controlling, and tax functions. Charles-Antoine Blanc plays a key role in financing Paprec's growth, including several major green bond issuances and strategic corporate acquisitions. He graduated from SKEMA Business School and holds an Executive MBA from HEC Paris, as well as a French CPA qualification. He began his career at Ernst & Young's corporate finance division.

FANNY BOURDAIS DE CHARBONNIÈRE

Fanny Bourdais de Charbonnière has been the Investment Director for Sustainable Investments at CalPERS since October 2024. She joined CalPERS in June 2015 as an Investment Manager for Real Assets and Infrastructure. She has a background in investment banking, having worked as Vice President for Infrastructure at BNP Paribas in New York from 2006 to 2015. Fanny graduated from HEC Paris and has extensive experience in project finance, capital markets and financial analysis.

REUVEN CARLYLE

Reuven Carlyle is an American entrepreneur, climate strategist, and former politician from Washington state in the United States. Carlyle served as a Democratic Washington State legislator, first in the House of Representatives (2009-2016), then in the Senate (2016-2023) where he chaired the Environment, Energy & Technology Committee. He was a key architect of some of America's most comprehensive climate policies, including carbon pricing legislation, clean fuel standards, and 100% clean electricity goals. After leaving office in 2023, Carlyle founded Earth Finance, a global climate strategy and investment firm.

BIOGRAPHIES OF EXPERTS

TIMOTHY J. DIXON

Timothy J. Dixon is a British academic specializing in sustainable built environments. He is Professor Emeritus of Sustainable Futures in the Built Environment at the University of Reading, a Research Associate at the Global Centre for Healthcare and Urbanisation, and a Visiting Fellow at Kellogg College, both at the University of Oxford. Tim J. Dixon's research focuses on sustainable built environments, particularly city-scale issues and urban futures related to climate change, social sustainability, and urban regeneration. He is active in sustainable built environment research and has worked closely with local governments and organizations in shaping climate adaptation and mitigation strategies. He has been involved in major projects like the Reading 2050 vision for a smart and sustainable city and co-chaired the Reading Climate Change Partnership (2019-23).

ELISA FERREIRA

Elisa Ferreira isis an economist with extensive experience in Portuguese and European politics. In her home country, she served as Minister of the Environment from 1995 to 1999 and as Minister for Planning from 1999 to 2002. She became a Member of the European Parliament (MEP) as an independent for the Socialist Party in 2004, a mandate she held until 2016. Elisa Ferreira returned to Portugal in 2016 to serve as a member of the Board of Bank of Portugal, and as vice-governor after 2017. In 2019, she became European Commissioner for Cohesion and Reforms, a post she held until 2024. During her tenure as EU Commissioner, Ferreira championed the EU's cohesion policy, emphasizing sustainable urban development. Elisa Ferreira holds a degree in Economics from the University of Porto and a Master and PhD from the University of Reading. She is a professor at the Faculty of Economics of the University of Porto, and, since June 2025, a Honorary Professor at the University of Manchester.

LIONEL FOURNIER

Lionel Fournier has been the Director of Impact and Sustainable Health at Harmonie Mutuelle since September 2024, leading the expanded department focused on environmental and health-related factors. He has been part of Harmonie Mutuelle's executive committee since 2015 and previously served as Director of Health & Ecologies. He also held the role of Director of Sustainable Development at Groupe VYV. With a background in law and an executive master from Sciences Po Paris, Lionel has over 20 years of experience in mutual insurance and sustainability, driving initiatives to improve health by addressing environmental and social determinants.

SÉBASTIEN FRAISSE

Sébastien Fraisse is the CEO and President of the Executive Board of Indigo Group, a global leader in parking, individual mobility, and urban services. He has been CEO since 2022 and became President of the Executive Board in April 2023. Fraisse is a graduate of École Polytechnique and École Nationale des Ponts et Chaussées. He began his career at the French Ministry of Equipment, in charge of road projects, then in the motorway sector, holding executive positions at Autoroutes du Sud de la France between 2007 and 2012 before joining Indigo in 2012 as Deputy Managing Director for France.

BERGÞÓRA HALLDÓRSDÓTTIR

Bergþóra Halldórsdóttir has served as Chief of Staff at Borealis Data Center since May 2023, overseeing strategic operations and organizational initiatives. Since March 2024, she has also been a board member of the Federation of Icelandic Industries (Samtök iðnaðarins). Previously, Bergþóra was Managing Director of Icelandic Trademark Holding, and served as Senior Advisor to the Federation of Icelandic Industries. Her extensive experience includes roles in trade, European affairs, and legal advisory, notably as a Deputy Prosecutor in Iceland. Bergþóra holds a BA in Law and an ML in International Law from the University of Reykjavik.

ANDREW KARVONEN

Andrew Karvonen Andrew Karvonen is a Professor of Urban Design and Planning at Lund University, in Sweden. With a PhD in Community and Regional Planning from the University of Texas at Austin, Karvonen has held positions at leading institutions, including the University of Manchester and KTH Royal Institute of Technology. His research focuses on sustainable cities and the interactions among technology, people, and the environment.

STÉPHANE LAYANI

Stéphane Layani has been President of the Marché International de Rungis since 2012. He started his career as a competition commissioner at the Ministry of Economy and Finance. He later served as Secretary General of the Comité économique du médicament, was an expert detached to the European Commission, an adviser to ministers, and an inspector at the Inspection générale des finances (2005-2006). Stéphane Layani is an alumnus of the École Nationale d'Administration (ENA) and of Sciences Po Paris, and holds a DEA in public law from the University of Paris I Panthéon-Sorbonne.

YVES LEDERER

Yves Lederer has been President of Coriance since 2003. Founded in 1998, Coriance is a leading French company specializing in district heating networks powered by renewable energy sources such as geothermal, biomass, and waste incineration. Under his leadership, Coriance has grown to employ over 500 people and invests approximately EUR 200m annually to expand sustainable heating infrastructure. Yves Lederer is a graduate of SKEMA Business School.

FERNANDO LOZANO RUIZ

Fernando Lozano Ruiz has been the CEO of Metro de Málaga since 2010 where he leads the strategic development, operation, and sustainability initiatives of Málaga's light rail network. He joined Metro de Málaga in 2007 as Technical Director. Prior to this role, Lozano worked at FCC (Fomento de Construcciones y Contratas), a major Spanish infrastructure and environmental services company, where he gained experience in infrastructure project management and transport systems. He graduated as a Civil Engineer (Ingeniero de Caminos, Canales y Puertos) from Universidad Politécnica de Madrid in 1993.

SADIE MORGAN

Sadie Morgan is a co-founding director of dRMM, a Stirling Prize-winning architecture studio known for innovative and socially useful design. With over two decades of experience, she has played a leading role in advising major infrastructure projects and serving as a commissioner for the UK's National Infrastructure Commission, now NISTA. She was a Mayor's Design Advocate for Greater London and is a professor at the universities of Westminster and Cambridge. Sadie Morgan has been recognized with numerous awards for her contribution to architecture and design advocacy, including fellowships of the RIBA, RIIA and ICE, with honorary doctorates from both the London South Bank University and the University of the Built Environment. In 2019 she founded the Quality of Life Foundation, focusing on wellbeing in the built environment, and in 2020 was awarded an OBE by the queen for services to design in the built environment.

PAULO MOURA

Paulo Moura is Deputy Director of Innovation and Public-Private Partnerships at Université Côte d'Azur's IMREDD, where he leads initiatives in mobility, resilience, data governance, and local economic development through designing and delivering collaborative urban innovation projects. He chairs the "Chaire Territoires & Navettes Autonomes" on autonomous mobility, co-founded the Atelier Experimental d'Urbanisme and The Security Design Lab, and manages JOIN GROUP with a focus on real estate and impact investments. With over two decades of experience in strategic consulting, technology transfer, and innovation—including roles at JP Morgan and Abril—he has a strong record of building partnerships and delivering large-scale projects for smart city and regional development in Europe and Brazil. Paulo holds a PhD in Economics from Université Côte d'Azur/CNRS-GREDEG, an MSc in Engineering for Smart Cities, and MBAs in strategic planning and finance from leading Brazilian institutions.

DARIO NARDELLA

Dario Nardella is an Italian politician currently serving as a Member of the European Parliament for the Democratic Party, elected in 2024 from the Central Italy constituency. He was Mayor of Florence from 2014 to 2024 and the first Metropolitan Mayor of Florence from 2015 to 2024, following earlier roles as vice-mayor of Florence and as a deputy in the Italian Parliament. Nardella holds a law degree and a Ph.D. in public law from the University of Florence, where he has also served as a professor of cultural heritage law.

JON PHILLIPS

Jon Phillips is the Chief Executive Officer (CEO) of the Global Infrastructure Investor Association (GIIA), appointed in June 2023. He joined GIIA in 2016 initially as Corporate Affairs Director and Deputy CEO, leading communications strategy, public affairs, and membership growth. Before GIIA, Jon was Communications Director at the UK Nuclear Decommissioning Authority from 2005 to 2016, overseeing communications for an annual nuclear clean-up program. Prior to that, he spent over a decade at BAA Heathrow managing communications for major projects including the Terminal 5 development. Jon holds a Bachelor's degree in Government Studies and an MBA, with extensive experience in corporate communications, public affairs, and stakeholder engagement in both public and private sectors.

ANTOINE PICON

Antoine Picon ithe G. Ware Travelstead Professor of the History of Architecture and Technology at the Harvard Graduate School of Design, where he also chairs the PhD program in Architecture, Landscape Architecture, and Urban Planning. His work explores the intersections of architectural and urban space with technology and society. Picon has published extensively on the impact of digital culture on architecture and urban planning. He has received numerous honors, including the Georges Sarton Medal. He is a member of the Académie d'Architecture, of the Académie des Technologies, and a Chevalier des Arts et Lettres. He holds degrees from École Polytechnique, École Nationale des Ponts et Chaussées, and a PhD in history from the École des Hautes Études en Sciences Sociales.

ORIANA ROMANO

Oriana Romano is Head of Unit for Water Governance, Blue and Circular Economy at the OECD's Centre for Entrepreneurship, SMEs, Regions and Cities. In her role, she supports governments in designing policies that promote water resilience and access to services, sustainable blue economies and accelerate the transition to a circular economy, helping them address environmental, social, and economic challenges in an integrated way. Prior to joining the OECD in 2013, she was a lecturer in Environmental Economics at London Metropolitan University and at the L'Orientale University in Naples. She holds a Ph.D. in Institution, Economics and Law of Public Services. Oriana Romano also teaches the transition to a carbon-neutral and circular economy at Sciences Po Paris..

ANTOINE SAINTOYANT

Antoine Saintoyant has served as Deputy CEO of the Caisse des dépôts et consignations and Director of the Banque des Territoires since June 2025. He graduated from Sciences Po and the École Nationale d'Administration (ENA) in 2003 and began his career at the French Ministry of Economy and Finance in the Treasury Department. From 2007 to 2009, he was appointed financial services advisor at the Permanent Representation of France to the EU in Brussels. He later held senior roles at the Directorate General of the Treasury and was Director of Investments at the French State Holdings Agency from 2012 to 2015. Between 2017 and 2020, he served as economic and industrial advisor in the office of Prime Minister Édouard Philippe. He joined the Caisse des dépôts et consig-

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nations as Director of Strategic Investments in 2020.

VIRGINIJUS SINKEVIČIUS

Virginijus Sinkevičius is a Lithuanian politician currently serving as a Member of the European Parliament, elected in 2024. From 2019 to 2024 he was European Commissioner for Environment, Oceans and Fisheries, and earlier served as Lithuania's Minister of Economy and Innovation as well as a member of the Seimas, where he chaired the Economic Affairs Committee. He holds a Bachelor's degree in Economic and Social Studies from Aberystwyth University and a Master's degree in European Studies from Maastricht University.

CARINE STAROPOLI

Carine Staropoli is a Professor of Economics at the University of Rouen Normandie and an Associate Professor at the Paris School of Economics. Her research work focuses on the economics of regulation and the economics of contracts. She is the co-Head of the Urban New Deal Chair at PSE, a research initiative dedicated to the economic analysis of cities' transition toward zero carbon, resilience, and inclusion. Carine Staropoli has recent publications in national and international peer-reviewed journals such as the European Journal of Law and Economics, Journal of Economics and Management Strategy and Energy Economics. She also contributes her expertise to companies and public institutions, including France Stratégie and the French Energy Regulatory Commission (CRE).

JÉRÔME STUBLER

Jérôme Stubler iCEO of Equans, part of Bouygues Group. A graduate of École Polytechnique and École Nationale Supérieure d'Arts et Métiers, he began his career at Freyssinet, overseeing major infrastructure projects such as the Pont de Normandie. He became Technical Director of Freyssinet in 1996. He developed its nuclear business, creating the Nuvia subsidiary. He became Managing Director of Freyssinet and Terre Armée, and Chairman of Nuvia in 2009. In 2012, he became CEO of Soletanche Freyssinet and Chairman of Soletanche Bachy. He later served as CEO of Vinci Construction. In 2021, Jérôme Stubler joined ENGIE as Deputy CEO and became CEO of Equans.

PATRICE TILLET

Patrice Tillet has been the Director General of Groupe Arcade-VYV since June 2024. He holds a DEA in labor law and began his career at the Mayor of Lyon's office before moving into the housing sector in 1995. He has held various leadership roles including Director General of Alliade Habitat (2007-2018) and Deputy Director General of Action Logement Immobilier. His work focuses on territorial governance, linking housing and health, and responding to socio-economic challenges in affordable housing.

CATHERINE TOUVREY

Catherine Touvrey is Chief Executive Officer of Harmonie Mutuelle, a position she has held since June 2016. She is also Director of Insurance and Financial Protection for Groupe VYV, France's largest mutualist insurance group, since September 2017.A graduate of NEOMA Business School (ESC Reims), Catherine began her career in the health sector before joining the Macif Group in 1994. Over two decades there, she held a wide range of leadership roles, including Deputy Managing Director overseeing property and casualty, health and provident, and retirement savings and finance, as well as serving as CEO and Chairman of the Management Board of personal insurance subsidiaries.

GABRIELE TODESCA

Gabriele Todesca has been Head of Infrastructure Investments at the European Investment Fund since January 2024. He has over 20 years of experience in private markets, having held various roles within the EIF since 2006, mainly in investment and business development. His background includes experiences in investment banking and direct private equity, and degrees in Law from the University of Trento and the London School of Economics.

ANTOINE TRÉBOZ

Antoine Tréboz has served as the CEO of ALiS (Autoroute de Liaison Seine Sarthe), the concessionaire managing the A28 motorway between Rouen and Alençon, since 2018. In April 2024, he also became CEO of ALBEA, which manages the Rouen to Yvetot motorway. Prior to these roles, Antoine Tréboz held several management positions at VINCI Autoroutes, including Operational Infrastructure Director and Department Head. His earlier career includes engineering and project management positions at Egis. Antoine Tréboz graduated from INSA Lyon (Institut National des Sciences Appliquées de Lyon) with a degree in civil engineering.

CECILIA WONG

Cecilia Wong iis a Professor of Spatial Planning and Co-Director of Policy@Manchester at the University of Manchester. She is also Director of the Spatial Policy and Analysis Lab. Cecilia is a chartered town planner with prior practical experience at Liverpool City Council and Cleveland County Council before entering academia. Her research focuses on strategic planning, spatial policy monitoring, urban and regional development, and housing and infrastructure planning, primarily in the UK, China and other contexts. She actively bridges academic research and policy-making, contributing to applied research projects addressing sustainable urban development and regional inequalities. Cecilia is a Fellow of the UK Academy of Social Sciences and the Royal Town Planning Institute, chair of the UK REF 2021 sub-panel for Architecture, Built Environment and Planning, and serves on several expert advisory panels addressing spatial planning and infrastructure. Her recent work includes projects on tackling root causes upstream of unhealthy urban development and promoting eco-urbanization in metropolitan Chinese regions.

APPENDIX 2

GLOSSARY

AI	Artificial Intelligence
AVs	**Autonomous vehicles**
BCE	Before the Christian Era; Before the Common Era
BIPV	**Building Integrated Photovoltaics**
CBD	Central Business District
ESG	**Environmental, Social and Corporate Governance**
EU	European Union
EV	**Electric Vehicles**
GBP	Great British Pound
GDP	**Gross Domestic Product**
GIS	Geographic Information System
GISP	**Green Infrastructure Spatial Planning**
IDE	Integrated development environment
IEA	**International Energy Agency**
IMREDD	Institut Méditerranéen du Risque, de l'Environnement et du Développement Durable (Université Côte d'Azur)
INPT	**Infrastructure Nationale Partagée des Télécommunications**
IPA	Infrastructure and Projects Authority
IPCC	Intergovernmental Panel on Climate Change
IUFM	**Integrated urban flood management**
LTE	**Long Term Evolution**
MCPTT	Mission Critical Push-To-Talk
OECD	**Organisation for Economic Co-operation and Development**
PPP	Public-Private Partnership
ROI	**Return on investment**
SD-WAN	Software-Defined Wide Area Network
TETRA	**Terrestrial Trunked Radio**
UK	**United Kingdom**
UN	United Nations
UNESCO	**United Nations Educational, Scientific and Cultural Organization**
US	United States
USD	**United States Dollar**

APPENDIX 3

MAIN BIBLIOGRAPHIC REFERENCES

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APPENDIX 4

LIST OF FIGURES, EXPERT POSITIONS, FOCUS, CASE STUDIES AND TABLES

FIGURES

LIST OF FIGURES, EXPERT POSITIONS, FOCUS, CASE STUDIES AND TABLES

EXPERT POSITIONS

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