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Dubai Municipality

The Proactive Municipality

Shaping the Future Through Foresight-Driven Signals

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Foreword

Serving People and Brining the Future Forward

We operate today in a complex and fast-changing global landscape. As leaders, our primary mandate is to safeguard quality of life for our people amidst this uncertainty, while proactively building a resilient and prosperous future. This requires a shift from reactive management to proactive design.

At Dubai Municipality, guided by the vision of our wise leadership, foresight is not a separate function; it is embedded in our operational DNA. It is the institutional practice of systematically scanning for emerging signals, understanding their potential impacts, and translating these insights into tangible projects and scalable policies. It is how we ensure that our long-term vision, to make Dubai the best city for living in the world, is reflected in the daily experience of every resident.

This report, "The Proactive Municipality: Shaping the future through Foresight-Driven Signals" is the direct outcome of this practice. It is not an academic exercise but a practical playbook for leaders. It moves beyond cataloguing the "best practices" of today to explore the "next practices" of tomorrow, the non-obvious, high-impact solutions that will define the next era of municipal work.

By sharing these insights, we are not just showcasing Dubai's journey; we are contributing to a new global conversation on urban leadership. It is an invitation to our partners worldwide to join us in practicing the future, building cities that are not just smart and sustainable, but also profoundly human-centric and ready for whatever comes next.

H.E. Eng. Marwan Ahmed Bin Ghalita

Director General, Dubai Municipality

Executive Summary

Cities are getting busier and hotter, and residents judge us by what they feel each day. The municipalities' future foresight journey starts from that reality and turns signals into visible improvements that can be trusted, then locks those improvements into rules and contracts so they become the new normal. The aim is simple and practical: more citizen-friendly streets, faster and fairer decisions, steadier services, and a level of trust that grows as proof is shown in public.

The aim is to sense what is changing in daily operations, read global signals through a local lens, try small pilots in the open, and show the before and after for anyone to see and contribute to the result. When the proof is clear, rules, contracts or codes can be changed, so the win could be scaled accordingly through systematized approaches, and the cycle could be repeated in the other districts. **Proof first, policy next, scale by default.**

The focus lands where outcomes are made. Urban planning sets the defaults people feel on every block when heat, flood, access, and evidence are part of baseline approvals and when model supported summaries make choices explainable. Sustainable city systems keeps the city running under stress when power, water, mobility, and waste are treated as one connected service and when financing follows reliability, reuse, and measured performance rather than inputs. Health and wellness become the city's everyday lifestyle or norm when prevention is run like a utility and exposure to heat and air triggers simple, timely actions that protect the public before emergencies escalate

What this adds up to is a city that learns in public and moves with purpose. Residents see cooler blocks, faster fixes, and clearer choices, and they see why those choices were made. Departments share one picture of reality, so the small wins stack into reliable patterns that outlast any single program. Investors back projects that prove they work, because delivery is steady and visible. Trust grows not from slogans but from a rhythm of things getting easier, safer, and fairer week by week. The flagship sites become shorthand for what good looks like and set expectations for the rest of the network. As approvals and contracts reflect these lessons, the default shifts toward resilience, reuse, and clear accountability. The result is a calmer, more predictable city where people feel the benefits first and understand the path that got them there.

The World is Getting Hotter and Busier

1

The world we're in and the moves we make

Cities are where the future lands first. Heat arrives on sidewalks, growth shows up at bus stops, and trust is measured in how quickly services work when people need them. This report starts from that simple reality: residents don't feel strategies or visions, they feel commutes, bills, comfort, and safety. If those improve, the story writes itself.

Here we set the baseline and the pivot. First, a clear read of where municipalities stand today: what is working, what is stretched, and what is quietly breaking under load. Then, the signals worth heeding now: shifts in urbanization, city systems, health, technology, finance, and demand that turn small choices into outsized outcomes. Finally, the moves that matter practical steps that look beyond the obvious, travel well across departments, and can be made visible in weeks, not years.

Think of this as the bridge from context to action: what the world looks like, why it is changing, and the few decisions that convert understanding into progress people can feel.

Two short stories about tomorrow

A city that chose to act

The municipality makes a clear choice to treat future foresight as a strategic priority, streamlining and aligning cross-functional operational. It assigns a protected budget for horizon scanning, data collection across domain areas, and controlled experimentation, sets up simple mechanisms to gather inputs from multiple services, and equips teams with tools to synthesize and analyse those inputs so they inform decisions. On a set cadence it selects a short list of pilots that fit its mandate and budget, runs them on real sites, and accepts upfront costs for learning, knowing some solutions will matter more tomorrow than today. Evidence from these tests, kept to plain measures and clear findings, is used to adjust policy, update procedures and contracts, and build for residents' needs now and in the future.

This is a governance decision with practical follow through: budget is allocated, roles are clear, pilots move to implementation on documented criteria, and learning is treated as part of delivery.

A city that chose to drift

Here the municipality prioritizes recurring daily operations over future-facing work. Teams are capable but time-constrained; they manage floods, backlogs, and urgent repairs, and push long-term initiatives down the queue. With tight budgets, slow procurement, and strict audits, leaders are understandably cautious about investing in data programmes, R&D, AI tools, digital twins, or city systems concepts when closing the year is hard enough. It is a strategic choice, not a failure of intent: future foresight is acknowledged in principle, but in practice it is deprioritized, so data collection is patchy, synthesis is limited, and pilots rarely start.

The trade-off is predictable: immediate problems are handled, yet longer-term needs remain under-addressed because evidence and implementation pathways never get the time or resources to form.

What today feels like

People experience cities not in statistics, but in moments. A delayed bus. A shaded bench. The hum of air conditioning in a sweltering summer. The quiet of a clean park on a weekday morning. These fragments of daily life form the emotional and physical reality of urban living far more than dashboards or master plans ever can.

Across the globe, city rankings and livability indexes try to capture these feelings. They measure things like air quality, housing affordability, commute times, and access to green space. But behind the numbers are lives in motion and often, a quiet disconnect between what the data says and how people feel.

Commute times differ dramatically. While some cities average below 30 minutes one-way, it is more common for larger ones to exceed 40 minutes (e.g. Venice) and reach as far as 77 minutes (e.g. Istanbul) [1] [2]

In one city, the train runs on time, but walking to the station feels unsafe. In another, new parks are built, but no one stays long. These are not flaws in the city systems; they are signs of something deeper. People are not just asking for more services. They are asking for comfort, dignity, and belonging.

What matters most is often what is easiest to overlook:

- Shade and a place to sit within a short walk
- Drinking water and clean, open public toilets
- Crossings timed for slower walkers, with audible cues
- Step-free curb ramps and smooth, even pavement
- Lighting that makes streets feel safe at night
- Shelter and real-time info at bus stops

These are the small details that shape how people navigate, adapt, and thrive in a city. And they're often the earliest signs of how well a city is preparing for change.

A recent scan of global cities shows a growing gap between technical delivery and public trust. The municipal networks may be smart, but does it feel kind? Services may be reliable, but are they shared fairly? These questions don't come from reports. They come from people.

"What today feels like often determines what tomorrow becomes."

Figure 1 The little things that make a city livable

That is why we begin here - not with strategy, but with sensation. With the rhythms of daily life. Because when you know where people linger, hesitate, or avoid, you begin to see not just what is, but what could be.

This is not a method. It is a way of paying attention. A way of reading the present with enough care to glimpse the future taking shape.

Seeing what others miss

Some signals make headlines. Others start as quiet discomforts or unexpected workarounds. The art of reading the future lies in learning to notice what doesn't shout - and asking better questions about what already surrounds us.

Cities are full of surface noise: announcements, dashboards, agendas. But beneath them are deeper rhythms like patterns in behaviour, changes in tone, contradictions between what is said and what is done.

So, what does it take to really notice change as it begins?

What we pay attention to

Instead of beginning with technology or policy, we start with tensions - the spaces where expectation and reality diverge:

- Places that are avoided despite investment.
- Services that are technically available but barely used.
- Promises made in planning documents that don't show up on the ground.

Public green space accounts for only 3% of total city area on average across 38 European countries, despite total green space averaging 42% [3]

These are more than mismatches. They are early warnings or openings, moments that signal a deeper story unfolding.

How we read them

This is not about collecting more data. It is about reading across moments, places, and systems. Three practices help:

1. **Repetition** – If something small happens once, it may be noise. If it recurs, it may be a pattern.
2. **Contrast** – Looking at places with similar city systems but different use. What is driving the difference?
3. **Absence** – What is missing that everyone assumes is present? Who is not showing up, and why?

What This Tells Us: Sometimes the strongest signal is a silence.

Signal examples in real life

Surface Observation	Deeper Signal
Bike lanes underused in winter	Comfort, not just city systems, drives use.
Self-service kiosks unused at clinics	People seek reassurance, not just efficiency.
Empty parks in new developments	Liveability is not just about green space size.

Why it matters

Seeing these early signals reshapes where attention goes next and what cities choose to test, tweak, or build. This is how strategy becomes real: not by waiting for trends to mature, but by spotting possibilities in discomfort and opportunities in gaps.

This way of seeing is not a toolset – it is a habit. A rhythm. One that turns passive observation into active design for what comes next.

From Fragments to Foresight

2

A single data point rarely tells a story. But when patterns emerge across sectors, timelines, or geographies fragments start to form a picture. And from that picture, strategic foresight takes shape.

Cities do not move all at once. Most transformation begins with small shifts. A subtle change in foot traffic. A new kind of homegrown innovation. A local pilot project gaining unexpected traction. What matters is not the individual moment, but what it might point to when seen in context.

How fragments evolve

1. **Notice the friction.** Something is not working like it used to, or is being used in a new, unintended way.
2. **Observe the workaround.** People adapt skipping steps, adding tools, using spaces differently.
3. **Look across domains.** Is the same shift happening in health, mobility, or public safety?
4. **Track velocity.** Is it spreading, accelerating, shifting to other places or actors?
5. **Reframe the meaning.** What once looked like a glitch now becomes a clue.

The Deeper Story:
One person's workaround is another city's next big idea.

Cross-sector pattern example

Case Illustration
Real Case: Vienna's Everyday Gaps Spark Change

In Vienna, city surveys since the 1990s revealed something planners hadn't considered: **women moved through the city differently.** Their daily trips were shorter, more frequent, and often involved caring for children or elderly relatives. But the streets, parks, and public transport weren't designed with this in mind [4].

So, the city started small - **more lights on walking paths, wider sidewalks for strollers, better access to toilets.** But these everyday fixes sparked bigger shifts. Vienna went on to build **housing designed with families and caregivers in mind,** and redesigned **public spaces to feel safer and more inclusive for all ages** [5].


Vienna 2010


Vienna Now

A mobility friction point revealed deeper gaps in how cities were designed and sparked systemic innovation across planning, housing, and social policy.

Today, Vienna is considered a global leader in inclusive design [6]. And it all started with what seemed like a minor observation: women taking longer, less direct walks.

Thinking in systems, not silos

Too often, signals are tracked within their original domains. But real change almost always moves sideways:

- A transportation solution sparks mental health benefits.
- A housing design shifts energy patterns.
- A tech tool shapes social behaviours.

"Foresight happens when ideas cross borders, between sectors, between people, between timeframes."

That is why this is not about horizon scanning in isolation. It is about weaving. Reading early signs not just as trends, but as threads - threads that, when pulled, might just reveal the shape of what is coming next.

What others are trying

Not all change begins with a big strategy. Sometimes, it starts with a bold experiment, a curious pilot, or a community idea that works better than expected. Across the world, cities are testing ways to solve old problems with fresh tools – and what's emerging is not just new urban fabric, but new trust.

While some places are focused on mobility and climate, others are asking: **What if loneliness is a design flaw? What if play is a public service? What if belonging is municipal networks too?**

Vienna's transformation from a small insight about women's mobility to a full shift in inclusive planning is just one example. It's not unique. **Cities everywhere are uncovering new futures through unexpected entry points. Let's look at what these questions look like in action.**

Snapshot: what bold cities are exploring

Helsinki: Loneliness as a Public Issue

The city of Helsinki began treating loneliness not as a social issue, but a systemic urban challenge. Officials ran workshops where elderly residents mapped their daily journeys – revealing where isolation, unsafe paths, or lack of resting spots broke their connection to the city [7]. This led to rethinking benches, lighting, and street events as not just amenities, but **antidotes to social disconnection.**

Insight: Urban warmth is not just social – it is spatial.

Dubai:
Turning Waste into Grid Power

Warsan's Waste-to-Energy Centre converts 5,666 tonnes of waste per day into about 200 MW for roughly 135,000 homes, diverting up to 45% of Dubai's waste from landfill and **now operating at full scale with power to the DEWA grid** [8].

Insight: Treating waste as fuel turns a disposal cost into dependable baseload power for a cleaner grid.

Singapore:
Green City Systems as Public Health

Singapore's "Park Connector Network" links green spaces, water canals, and neighbourhoods into a 300+ km loop of shaded, bikeable, and walkable paths. But it's more than green transit – it's preventive health [9]. Programmes like the Health District in Queenstown now build seamless green corridors as preventive-health infrastructure.

Insight: Nature is not just nice – it's measurable.

What makes these experiments stick?

Cities experiment all the time. But some pilots disappear while others shape the mainstream. What makes the difference?

Factor	When It's Missing	When It's Present
Public Imagination	People don't believe the change is for them	Residents feel invited and empowered
Visible Co-Benefits	Benefits seem niche or narrow	Solutions improve multiple systems (health + mobility + equity)
Low Entry Points	Only experts or officials engage	Communities can test, tweak, and co-own

"Good pilots work technically. Great pilots work emotionally too."

From experiment to everyday

What is clear from the global frontlines is this: when cities test ideas in public view, with public voice, they learn faster and lead better.

These experiments are not just about city systems – they are about belief. They show what happens when small ideas get just enough room to prove something bigger. And they remind us: sometimes, the future doesn't need more tech. It needs more trust.

Urban Planning

3

Cities are changing faster than the plans that shape them. Population growth, climate volatility, and rising expectations for public services are redefining what "good planning" looks like. Effective foresight effort starts with a clear picture of where cities stand today and the global currents that will shape tomorrow.

> "The future of countries, the future of human beings and the future of life is directly linked to the future of cities."
>
> **HH Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum**

The headline facts are stark but useful. By 2050, nearly 68% of the world's population will live in cities [10]. Urban areas already account for around 70% of global greenhouse-gas emissions [11]. Meanwhile, the city systems investment gap keeps widening.

These pressures coincide with rapid market shifts: OECD projects the global smart-city market to rise from about USD 512B in 2022 to over USD 1T by 2027 [12], while urban digital twins are scaling from early pilots to 500+ deployments by 2025 [13].

What this means for planners: the baseline is moving. Tools once considered experimental like geospatial analytics, 3D modelling, digital twins, AI-assisted design - are becoming standard. They've quietly shifted from cutting edge to baseline. At the same time, the scope has broadened: beyond land use and transport to resilience, inclusivity, health, and environmental outcomes. Many governance systems weren't built for this breadth or speed, which is why foresight matters now more than ever.

Key Takeaway: Cities are now measured not only by growth, but by their ability to balance liveability, equity, and sustainability under uncertainty.

In principle: the current context demands two moves at once. First, maintain the reliability of today's services. Second, build the capacity to sense, interpret, and act on weak, emerging, and converging signals that indicate where the next planning advantages will come from.

Trends and drivers of change

What's moving the baseline

Which shifts are structural, and which are noise? How to distil a shared baseline for decisions, prioritize limited resources, and link day-to-day choices to long-term outcomes? Where to experiment and where to set standards now? Reading trends becomes a by-default capability fundamental for municipalities' daily work.

Taken together, tracking the multiple shifts show that the planning baseline has moved. **Data and AI are moving from pilots to standard tools**, while expectations around liveability and risk management are becoming integral to design choices. The practical takeaway: decide where to embed standards now, where to run controlled pilots next, and where enabling policies will unblock adoption.

Trend #1 - Data-driven city making

- When geospatial analytics meets live mobility data and twins, blind spots shrink, and trade-offs come into focus.
- AI-assisted planning (generative design, scenario evaluation) accelerates option testing and sensitivity checks.

Trend #2 - Climate resilience becomes a design constraint

- Heat, flooding, water stress and coastal risks are shifting zoning, building codes, materials, and open-space ratios.
- Nature-based solutions (blue-green corridors, sponge districts) move from pilots to standards.

Trend #3 - Housing affordability & mixed-use resurgence

- Conversions (office-to-residential), gentle density, and mixed-use neighbourhood clusters are guiding new local plans.
- Inclusionary policies and community land trusts gain traction in fast-growing cities.

Trend #4 – Designing for wellbeing

- Heat-safe streets, active mobility networks, and access to green/blue spaces enter the planning brief.
- Dementia-friendly and age-inclusive design principles appear in neighbourhood

Trend #5 – Smart Resource Loops

- District energy, water reuse, low-carbon materials, and construction circularity reshape codes and procurement.
- Embedded carbon accounting begins to influence planning approvals.

Drivers of change

What does this mean from a strategic perspective? Every external change may convert into state-led decisions and initiatives, from governance and pricing systems to technology adoption and engagement platforms.

Political (Rules are moving faster than plans)	**Economic** (money follows proof)
• City-regional models are emerging to coordinate housing, transport, utilities across borders. • Evidence-backed permitting and outcome-based zoning are shortening approvals without lowering standards. • Sandboxes let cities trial new materials, mobility modes, and data-sharing under controlled risk.	• Persistent funding gaps push blended finance: PPPs, bonds, land-value capture, user fees. • Hybrid work is rewriting demand: more conversions and mixed-use retrofits; different logistics footprints. • Insurers and investors price heat and water risk into viability; procurement shifts to lifecycle cost.

Social (expectations reset space)	**Technological** (from pilots to policy tools)
• Health and wellbeing outcomes become explicit planning targets alongside jobs and housing. • Ageing & care needs shift design toward step-free access, shaded routes, and proximity to primary care. • Affordability pressure pushes conversions, co-living, and mixed tenure in well-served districts.	• Urban twins and multi-domain stress-test land use, mobility, energy, heat, and flood choices. • AI supports massing options, impact scoring, and code checks—with human oversight and audit trails. • Interoperable data platforms (open standards, shared IDs) chip away at agency silos.

Environment (climate reads as design input)	**Legal** (the rulebook opens new paths)
• Extreme heat makes shading, albedo, canopy, and blue-green systems core controls, not add-ons. • Water stress drives non-potable reuse districts and resilient landscaping. • Flood and storm risks trigger multi-layer protections and updated floodplains.	• Data governance clarifies how mobility/health/utility data inform planning decisions. • Performance-based specs and code pathways create room for circular, low-carbon solutions. • Clearer accountability for cross-agency outcomes; new roles embed continuous learning.

Exploring the future landscape

Progressing along a single path is rarely the case. Multiple futures can unfold in parallel, and planning must recognise uncertainty while still enabling decisive choices.

From signals to meaningful patterns

Cities are already showing where change is heading underground spaces opening new capacity, data-rich twins shaping approvals, nature-inspired buildings cutting cooling loads, and shifting demographics redefining access and care. The point is not to "predict" one path but to read these visible shifts together and ask what they imply for streets, buildings, services and finance. Look for where momentum is building, where trade-offs appear (heat vs. mobility, density vs. comfort), and where a small policy change could unlock outsized impact.

Power & rules

Cities are moving beyond single-layer land use toward multi-layer rights: surface above, regulated subsurface below, and decisions backed by simulation rather than static reports. Approvals begin to cite model outputs as evidence, shifting how certainty is established.

Watch for: the first formal requirements to submit digital-twin scenarios with major permits.

Money & markets

Financing is chasing measurable outcomes: retrofit bonds tied to cooling, curb pricing that manages demand, and circular construction credits that value materials flows. Funds move at a different pace when congestion, heat and waste are priced explicitly.

Watch for: lifecycle-cost tenders that reward performance, not just lowest capex.

People & place

Engagement is simplifying and deepening at once—residents test options in "what-if" portals while accessibility and heat comfort show up as baseline requirements. Everyday usability becomes as important as floor area or traffic counts.

Watch for: inclusion and comfort metrics baked into local plan approvals.

Systems & tech

Operations are going model-first: district simulation models, live mobility data, and automated inspections are shifting from pilots to the city's operating system, with humans providing oversight and governance.

Watch for: control rooms that run scenarios before changing streets, signals or service levels.

Climate & resources

Heat, water and materials cycles are turning into design inputs, not add-ons—shading, canopy and blue-green corridors sit alongside circular construction norms as standard controls. Projects are expected to deliver ecological, infrastructural and social value together.

Watch for: mandatory heat-mitigation and reuse clauses in development conditions.

Planning is shifting to model-first decisions and performance-based finance, with climate, comfort, and inclusion as core design inputs, stimulating locking in standards, piloting emerging areas, and clear policies to scale what works

Timing emerging technologies

Right now, the centre of gravity is shifting to model-first operations and adaptive design.

Next, expect formal rules to catch up: approvals that routinely require simulation evidence, underground rights mapped as zoning overlays, and performance pathways in codes that reward passive outcomes.

Later, the frontier moves to autonomous maintenance and self-tuning districts city systems that senses stress, reallocates capacity, and repairs before failure, with governance focused on assurance and public trust.

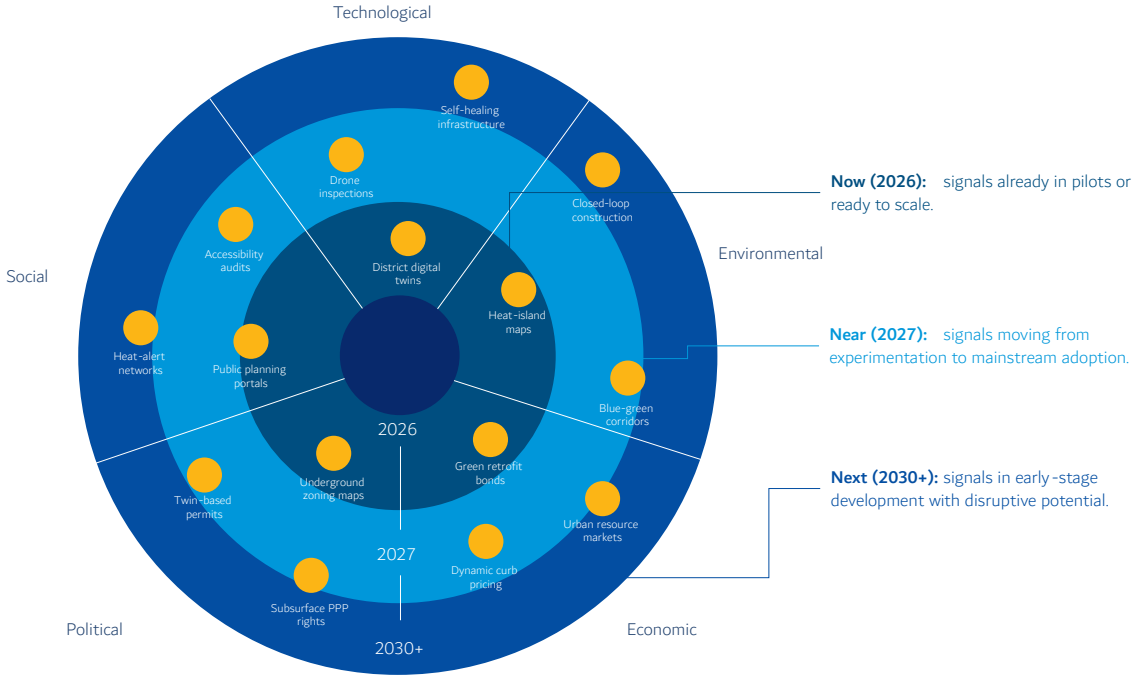


Figure 2 Planning Horizons of Urban Planning

The point of the radar is simple: act on what is already moving, pilot what is gathering momentum, and keep deliberate watch on the few bets that could rewrite the playbook.

Three clusters stand out as actionable, high-impact opportunities, when mapping signals against time horizons:

1. Codified Underground Zoning & Subsurface Hubs

What it is: A digital governance leap that enables evidence based planning and participatory transparency.

Why it matters: Faster, auditable approvals; live operations; clearer public trust.

2. Civic-Grade Digital Twins in Approvals & Operations

What it is: Governance and planning innovation linking density, climate resilience, and PPP finance.

Why it matters: Frees surface capacity, cools corridors, and unlocks investable sites.

3. Passive Bio-Mimicry Systems at Building-Code Scale

What it is: A design and construction shift embedding nature inspired performance into codes.

Why it matters: Boosts resilience, cuts cooling energy, and lowers lifetime costs.

The three together deliver outsized impact fast and can scale: a regulatory shift, a digital leap, and a design/code pathway, forming a balanced portfolio to have a visible “now”, credible to investors, and ready to move from pilots to system-wide change.

Hot topics: Signals Shaping the Next Urban Planning

Hot Topic I - Codified Underground Zoning & Subsurface Hubs

Around the world, cities are beginning to recognize the **subsurface as a strategic planning layer** [14]. With limited surface land and growing demand, subsurface options are moving into mainstream planning. This is more than isolated tunnelling or metro stations: it is the systematic codification of underground use into zoning, planning, and investment frameworks. In practice, that means mapped subsurface corridors and hubs, clear rights-of-use and design standards, and PPP/concession pathways embedded in the code so projects can be approved, funded, and operated like any other part of the city.

Key Observations:

- Underground zoning overlays: Cities like Nanjing [15] and Helsinki [16] are publishing official maps that designate underground corridors, hubs, and land use categories, treating the subsurface as a regulated part of the urban plan.
- Multi-use hubs: Not only transport: cities are planning underground logistics servicing, retail corridors, cooled pedestrian networks, and cultural facilities:
  - Logistics servicing: Helsinki's city-centre service tunnel removes supply traffic from surface streets and serves shops, hotels, and parking below grade [17].
  - Retail corridors: Montréal's RESO (33+ km) and Toronto's PATH (30+ km) form extensive underground shopping/pedestrian networks [18].
  - Cooled pedestrian networks: Singapore's Underground Pedestrian Links/Network (UPL/UPN) connect developments to MRT stations with barrier-free, air-conditioned links [19].
  - Cultural facilities: Helsinki's Amos Rex Museum places large exhibition galleries underground beneath Lasipalatsi Square [20].
- Heat and resilience factor: With urban heat intensifying, underground space is increasingly seen as a climate adaptation tool, enabling shaded mobility routes and thermal buffers [21].
- Governance innovation: Rights-of-use, subsurface land values, and PPP concession models are emerging as new tools in city planning [22] [14].

Municipalities Impact

Codified underground urbanism creates structural change across governance, planning, and finance. For municipalities, the impacts extend beyond spatial relief into sustainability, resilience, and long-term fiscal health.

Dimension	Impact Area	Practical Outcomes
People	Safety & Accessibility	Climate-controlled underground routes improve mobility for vulnerable groups, ensure year-round accessibility, and create inclusive urban spaces.
	Liveability & Health	Reduced surface congestion and shaded pedestrian corridors improve comfort and protect citizens from extreme heat exposure.
Planet	Climate Resilience	Subsurface development reduces the urban heat-island effect, provides thermal buffers, and enables integration of green cooling city systems.
	Operational Efficiency	Shared corridors for utilities and mobility lower environmental impact by reducing redundant construction and land use.
Prosperity	Density Management	Frees surface land for parks, housing, and commercial space, supporting growth without outward sprawl.
	Revenue Innovation	PPP concessions monetize underground logistics, retail, and mobility hubs, creating new municipal revenue streams.

Codified underground zoning is a targeted governance tool, not a slogan. Consider it where surface networks are saturated, heat exposure is material, and demand clusters around transit so a credible business case exists. It can shift freight and flows off the surface, free land for public use, improve thermal comfort, and create investable sites; but risks include high capex and lifecycle costs, evacuation and safety complexity, utility conflicts, and weak public acceptance if access and security aren't clear. Proceed only with defined rights-of-use and valuation rules, enforceable life-safety and maintenance standards, and bankable PPP terms.

Case Illustration
Helsinki, FI - Underground Master Plan

Land scarcity and climate goals pushed Helsinki to organize the subsurface as a planned, investable layer rather than project-by-project tunnel.

What Was Done: A statutory Underground Master Plan was integrated into the city's master plan. It maps subsurface volumes, assigns functions (transport, logistics, utilities, commercial, civic) and depth bands, and sets interface rules with surface parcels [22].

Governance & Legal: The underground plan carries legal force equal to surface zoning, defining rights-of-use, access easements, performance controls, and concession terms. A coordinated approval pathway reduces risk and speeds delivery [23].

Outcomes: Surface space preserved for parks and people-first streets; coordinated utilities and mobility; thermal comfort improved in connected corridors; higher investor confidence and a clearer PPP pipeline.

Hot topic II - Civic-Grade Digital Twins In Approvals & Operations

Cities are entering a new phase where digital twins are no longer experimental showcases but **decision-support systems at the heart of urban governance.** Instead of relying on static models or fragmented data, municipalities are integrating dynamic digital environments that can simulate policy choices, test city systems options, and communicate impacts in real time. This transition reflects a growing need for cities to manage complexity, ensure transparency, and deliver faster, evidence-based approvals [24].

Key Observations:

- Integration into approvals: Municipal authorities are beginning to require twin-based simulations in building and transport permits, ensuring projects demonstrate traffic, energy, and environmental compliance before approval [25].
- Operational governance: Twins are evolving from design tools into continuous monitoring platforms, enabling real-time management of congestion, emissions, and resource use [26].
- Public transparency: By opening interactive dashboards, cities invite citizens to explore "what-if" scenarios, strengthening participatory governance and trust in municipal decisions [27].
- Cross-system connectivity: Advanced cities are linking sensor networks, BIM databases, and policy rules into unified platforms, breaking down silos and creating a single source of truth for urban operations [24].

Cities are entering a new phase where digital twins are no longer experimental showcases but decision-support systems at the heart of urban governance

Municipalities Impact

The adoption of civic-grade digital twins marks a structural transformation in how municipalities govern growth, city systems, and services. Rather than relying on fragmented datasets or static master plans, digital twins provide a continuously updated model of the city that allows real-time monitoring, scenario testing, and participatory decision-making.

Dimension	Impact Area	Practical Outcomes
People	Safety & Accessibility	Interactive dashboards and portals allow residents to test "what-if" scenarios, improving transparency and civic trust.
	Service Accessibility	Real-time monitoring of mobility, utilities, and public services ensures faster response times and inclusive service delivery.
Planet	Environmental Monitoring	Continuous simulation of air quality, emissions, and energy loads supports evidence-based sustainability measures.
	Climate Adaptation	Predictive models stress-test city systems against extreme weather, supporting proactive resilience planning.
Prosperity	Planning Efficiency	Model-based approvals shorten permitting cycles by embedding compliance checks into the digital twin.
	Investment Confidence	A unified city model reduces project risk, attracts private capital, and enables more reliable city systems concessions.

Civic-grade digital twins are a governance tool for when permits and operations stall on siloed data or disputed impacts. Used well, they shorten evidence-based approvals, clarify trade-offs, and steady operations; used poorly, they add cost, opacity, and skills gaps. Proceed only with interoperable data/model standards, auditable assumptions, a narrow year-one use case, and funded teams - start with a district pilot tied to a specific decision, publish results, then scale by policy.

Case Illustration
Dubai, AE — The Dubai Live Integrated Digital Twin Ecosystem

Dubai is moving beyond isolated pilots to build a fully integrated, city-wide digital twin ecosystem, positioning Dubai Municipality as the central nervous system for urban management and future planning [28].

What Was Done: At GITEX Global 2025, Dubai Municipality showcased Dubai Live, its integrated command hub. This platform is not just a 3D model; it is a real-time, operational digital twin that provides live oversight of the entire urban lifecycle, from construction licensing and monitoring to strategic planning via its Urban Planning Observatory. It fuses data from buildings, infrastructure, and even vehicle and marine movements into a single, unified operating picture [28].

Governance & Legal: The ecosystem is a model of collaboration. Dubai Live serves as the operational heart, connecting various initiatives like the DANA project for smart building analysis and a new partnership with the Dubai Land Department [29]. This ensures that insights from the digital twin are not confined to a single department but are used to inform real estate policy, regulatory oversight, and strategic investment decisions across the city.

Outcomes: The result is a shift from reactive to predictive governance. By leveraging AI and advanced analytics on this integrated data, Dubai Municipality can support rapid emergency response, optimize service delivery, and, most importantly, test and simulate the impact of future urban plans before a single brick is laid. This demonstrates a clear, evidence-led path from a smart city concept to a daily operational reality.

Hot topic III - Passive Bio-Mimicry Systems at Building-Code Scale

Cities are more and more recognizing **biomimicry as a practical regulatory pathway** rather than an architectural curiosity. As of 2022, about 80 countries had national building-energy codes in place, expanding the space for performance-based, passive solutions [30]. With escalating cooling loads, rising energy prices, and the need for climate resilience, municipalities are turning to natural systems for solutions that can be codified into building regulations. This is not simply about one-off green buildings; it is about systematically embedding **nature-inspired performance standards** into codes and approvals [31]. Dubai's Green Building Regulations became compulsory for all buildings in 2014 and are now implemented via Al Sa'fat performance pathways [32].

Key Observations:

- Bio-inspired design: Facades and ventilation systems are modelled on termite mounds, desert plants, and animal thermoregulation, reducing dependence on mechanical cooling [33].
- Regulatory adoption: Cities are introducing performance-based building codes where developers can meet thermal comfort requirements through passive, nature-based methods [34].
- Material breakthroughs: Innovations such as porous wall systems, phase-change materials, and adaptive shading inspired by natural morphologies are entering mainstream construction supply chains [35].
- Resilience factor: Biomimicry improves comfort and safety during grid failures or extreme heat events, ensuring habitability when mechanical systems are compromised [36].

Impact for Municipalities

Rather than treating bio-inspired design as niche innovation, integrating passive biomimicry within the regulatory framework ensures benefits at scale. For municipalities, the impacts go beyond architecture, as they touch on public health, climate adaptation, and long-term affordability.

Dimension	Impact Area	Practical Outcomes
People	Health & Comfort	Passive cooling strategies ensure stable indoor temperatures, reducing heat stress and improving wellbeing without dependence on mechanical systems.
	Safety & Inclusivity	Bio-mimicry pathways deliver resilient conditions during power outages, protecting vulnerable populations and ensuring continuous habitability.
Planet	Climate Resilience	Reduced reliance on mechanical cooling lowers peak energy demand and emissions, while buildings adapt naturally to extreme weather conditions.
	Resource Efficiency	Bio-inspired materials and designs optimize airflow and thermal balance, cutting energy intensity and reducing reliance on resource-heavy HVAC city systems.
Prosperity	Affordability & Savings	Lower operational costs from passive design ease household energy burdens and reduce long-term municipal subsidies for energy resilience.
	Market Competitiveness	Regulations encouraging biomimicry attract developers and innovators seeking to align with global sustainability standards, enhancing Dubai's position as a hub for advanced building technologies.

Done well, it yields healthier interiors, lower peak demand, and long-run affordability; done poorly, it adds compliance complexity without performance. Proceed only with clear performance paths (comfort hours, cooling EUI), verified simulations plus post-occupancy Measurement And Verification (M&V), and supply-chain readiness for materials and maintenance. The safe choice is to start with a limited code pathway for two typologies, require third-party verification, publish results, then expand by rule once benefits are proven.

Case Illustration
Freiburg, DE — livMatS Biomimetic Shell

A city-permitted research pavilion on the University of Freiburg campus that passed formal structural checks via the state materials-testing authority (MPA) shows how novel façades can move through real approval pathways, not just lab demos [37].

What Was Done: The building integrates a weather-responsive "Solar Gate": hydromorphic, bio-based 4D-printed elements that open/close autonomously like pinecones in response to humidity/temperature, modulating solar gains and heat with no external energy. The system has operated reliably for over a year on the façade/skylight of the completed building [38].

Governance & Legal: Approved by the City of Freiburg as a permanent 200 m² pavilion at FIT, the project followed German building control procedures, including MPA structural checks. It reports to recognized assessment norms and offers a reference for municipalities evaluating adaptive bio-based façades [39].

Outcomes: Verified field performance of a passive, energy-autonomous shading façade; peer-reviewed evidence of durability and repeatability; a scalable template for code-eligible, bio-inspired envelope systems that cut cooling loads and improve comfort [38].

What leaders need to decide

The signals we have surfaced point to three big moves with real city-making consequences. This shifts the mentality from "spotting" to "doing": brief scenario snapshots to test ideas, a few uncertainties to watch, and the trade-offs that matter in practice. The aim is simply to give leaders enough clarity to choose where to set standards now, where to run targeted pilots next, and where to keep a watching brief as things evolve.

Future pathways are shaped by critical uncertainties that influence how fast and effectively new practices can scale.

- **High impact** - decisive factor that can accelerate or block success.
- **Medium impact** - important influence but not a deal-breaker.
- **High uncertainty** - outcome is difficult to predict, requires close monitoring.
- **Medium uncertainty** - trajectory is clearer but still evolving.

Uncertainties	Degree of Potential Impact	Degree of Uncertainty
PPP appetite for underground hubs	High	Medium
Data-sharing across agencies	High	High
Market readiness for bio-mimicry materials	Medium	Medium
Regulatory acceptance of simulation evidence	High	Medium
Public acceptance of underground and passive systems	Medium	Low

Success will hinge less on tech (which already works) and more on people and institutions: investor appetite, regulator buy-in, and citizen trust. Keep an eye on these uncertainties, adjust policy as you learn, and you turn risks into room to innovate.

Leaders need a **single view** of what to do first, what to scale next, and **who owns it**, with a **sequenced delivery plan** split into clear time horizons so momentum is not lost in abstract strategy.

Sustainable Infrastructure

4

Infrastructure is the quiet backbone of every modern city - the hidden network that keeps energy flowing, water clean, sewerage managed and mobility effortless. Yet this backbone is under strain. Global demand for city systems is rising faster than investment and innovation can keep pace. By 2030, the world will need nearly $6.9 trillion in annual city systems spending to stay aligned with global sustainability goals [40].

As cities swell, heatwaves, flooding, and water scarcity now test both old and new networks, turning resilience from an optional feature into a survival trait [41]. Technology is opening a way forward. AI, IoT, and predictive analytics can extend the life of assets and make operations adaptive in real time. But the leap from pilot to practice remains uneven, slowed by cost, regulation, and habit [42]. Where cities do make the leap, the results are tangible: in Dubai, the Warsan Waste-to-Energy Centre processes 5,666 tonnes of municipal waste a day (about 1.9 million tonnes a year) into roughly 200 MW for the grid, enough for around 135,000 homes, while diverting up to 45% of waste from landfill [43].

Above all, city systems is about people. City's pipes and cables mean little if access is unequal or green space unthoughtfully used. As UN-Habitat reminds us, the most sustainable systems are those that serve every community - reliably, fairly, and without leaving anyone behind.

> "Our development model is designed to create the best environment and city systems, ensuring sustainable prosperity for generations to come"
>
> **HH Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum**

By 2030, the world will need nearly $6.9 trillion in annual city systems spending

Numerous initiatives globally illustrate the direction of sustainable city systems development:, such as **Global Infrastructure Facility (GIF)** to provide technical and financial support for sustainable, climate-aligned city systems projects, **Cities Climate Finance Leadership Alliance (CCFLA)** to mobilize blended finance solutions and expertise, as well as **Mission Innovation & Clean Energy Ministerial Initiatives, UNDP's Urban Resilience Programmes, European Investment Bank (EIB) Green Infrastructure Financing** and many more.

For sustainable city systems, the baseline is moving rapidly. Investments, governance, and innovation must converge to deliver systems that are resilient, inclusive, and future-ready. These initiatives show that the global momentum is toward financing, planning, and operating city systems that is **resilient, low-carbon, and socially inclusive**, setting the stage for cities to adopt integrated strategies that address both near-term needs and long-term challenges.

Trends and drivers of change

Cities run on quiet systems like power, water, mobility, data that were built for a steadier world than the one we now inhabit. The baseline for "good city systems" is shifting, it must cut carbon, flex under stress, and serve people fairly. The tools to do this as clean energy, digital operations, circular design are partly here; **the work is to connect them and scale what works.**

What's moving the baseline

The landscape of urban city systems is undergoing significant transformation, driven by a confluence of technological advancements, environmental imperatives, and evolving societal expectations. Understanding these shifts is crucial for cities aiming to build resilient, sustainable, and inclusive city systems.

Trend #1 - Accelerated Decarbonization

- Renewables, low-carbon materials, and retrofits become standard in new urban projects.
- Cutting fossil reliance delivers both emission and resilience gains.

Trend #2 - Smart Systems Integration

- IoT, AI, and twins optimize assets, predict faults, and automate operations.
- Smart grids and predictive maintenance scale from pilots to norm.

Trend #3 - Climate Resilience by Design

- Heat, flood, and water risks reshape codes, materials, and open-space ratios.
- Bioswales, green façades, and shaded corridors move from pilots to policy.

Trend #4 – Equity and Inclusion

- Municipal system planning secures fair access to water, transport, and public space.
- Participatory tools and inclusive standards embed social outcomes.

Trend #5 – Circular Economy Integration

- Modular builds, reuse loops, and material passports boost efficiency and cut waste.
- Lifecycle tracking and green markets lower embodied carbon.

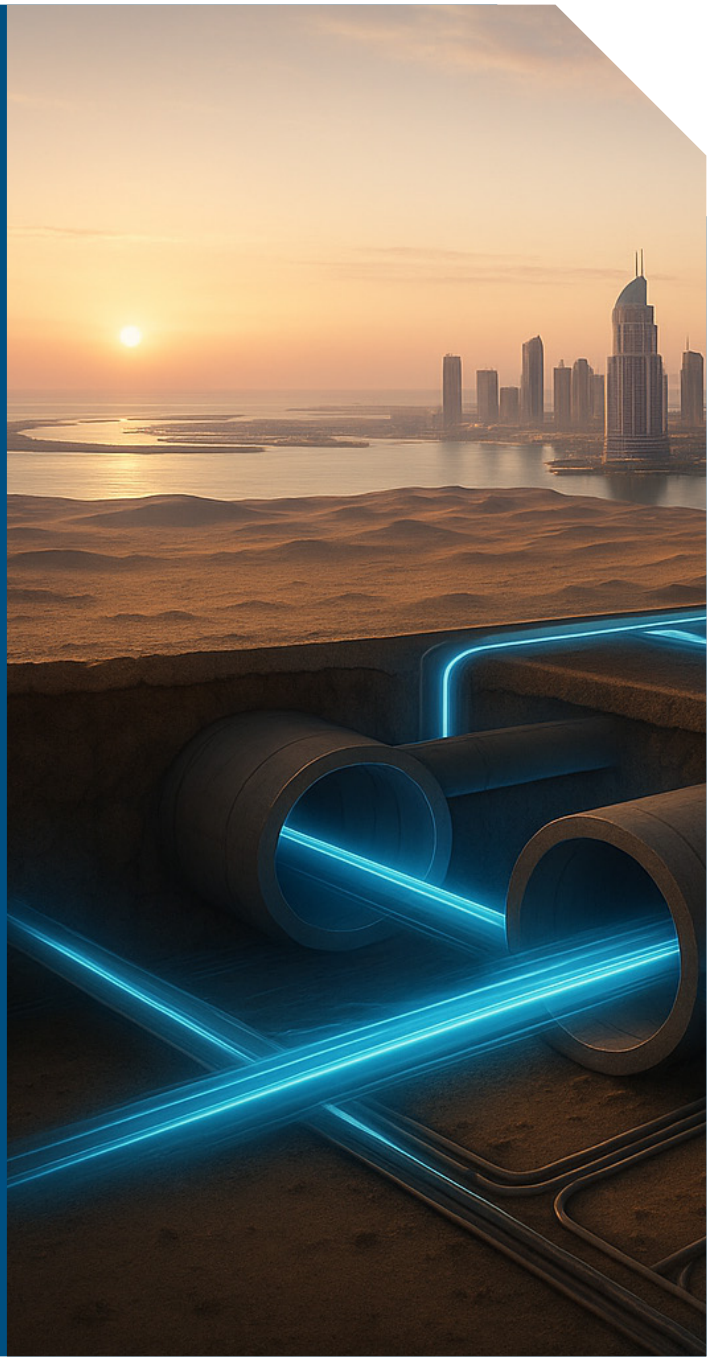
Taken together, these trends indicate that sustainable city systems is moving toward a **more integrated, resilient, and inclusive paradigm.**

Case Illustration
Dubai's Deep Tunnel makes drainage a resilience platform

An extreme cloudburst in April 2024 exposed how quickly a low-lying, fast-growing city can flood [44]. Roads ponded, flights were disrupted, and response crews worked through the night. The event was treated as a design challenge to solve, not an anomaly to endure.

Tasreef, an emirate-wide program of about AED 30 billion, is scaling drainage capacity sevenfold to manage more than 20 million cubic meters on peak days by 2033. The backbone is a kilometres-long deep tunnel 30 to 45 meters underground that carries runoff by gravity away from streets and critical hubs [45]. In 2025, a AED 150 million link connected Dubai South to this system, extending coverage to homes, logistics zones, and the airport city [46].

Results are emerging as the network grows: fewer road closures in served districts, quicker recovery after heavy rain, and steadier municipal services during seasonal peaks. The case shows sustainable infrastructure in practice: anticipate extremes, build once for decades, and knit new districts into shared backbones.



Where the signals point

No single trend operates in isolation. Smart technologies accelerate decarbonization, circular models strengthen resilience, and inclusive planning improves both equity and system reliability. The real task is to align funding, policy, and innovation so that city systems becomes adaptive, not just sustainable.

Early occurrences such as smart grids, regenerative corridors, and new financing models show that solutions are already shifting from pilots to practice. Some advances are scaling quickly, others remain experimental.

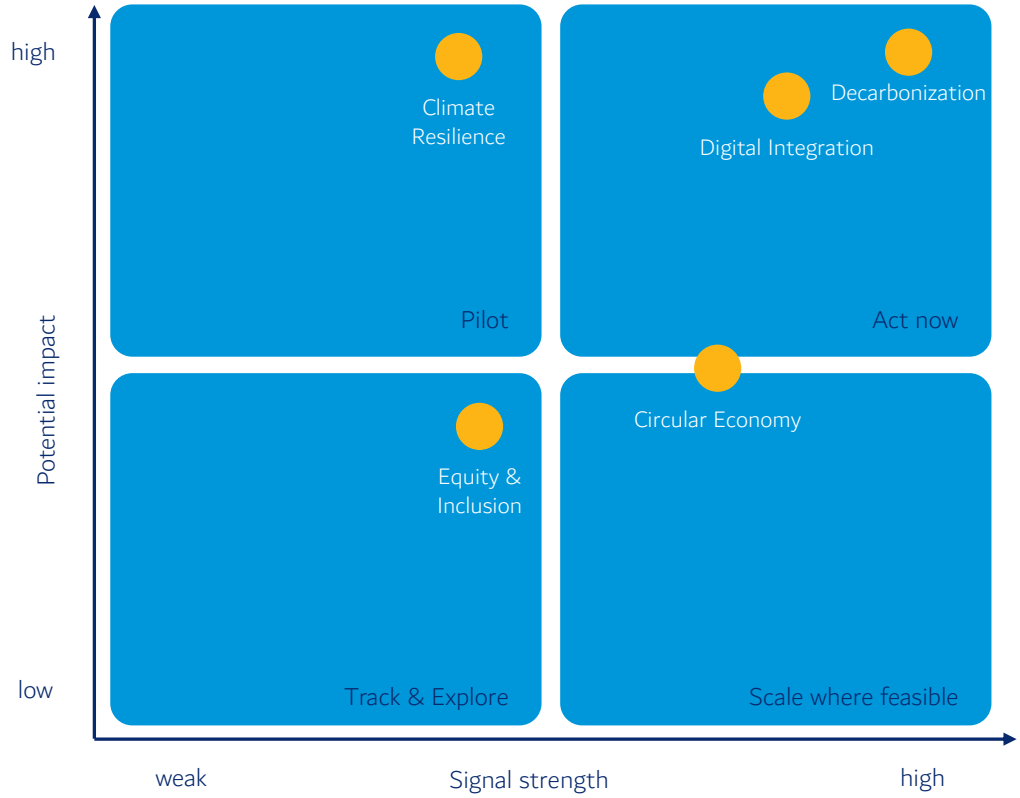


Figure 3 Early Indicators vs. Impact: Sustainable Infrastructure

What We Have Noticed: The direction is clear: decarbonization and digital integration are ready to scale, climate resilience needs targeted pilots, circular systems can expand, and equity remains the quiet enabler of lasting sustainability. Together, they mark the shift from vision to execution.

Exploring the future landscape

Every city carries a map of its future within its streets, pipes, and power lines. Some parts are clearly drawn electric grids that hum with renewable energy, streets that double as cooling corridors while others are still faint sketches waiting for the right mix of technology and willpower to bring them into focus. **What makes this moment different is not the arrival of new tools, but how quickly they are beginning to work together.**

How trends reinforce each other

Cities do not change one lever at a time; they "click" into place when the pieces reinforce each other. Think of the future landscape as a set of interlocking gears: turn one, and the others start to move. What follows connects the gears, so the story flows from clean energy to data, to resilience, to fairness and back again.

Intersection	How They Connect
Decarbonization × Digital Integration	Renewables, low-carbon materials, and efficient assets become far more effective when guided by smart meters, digital models, and predictive maintenance.
Climate Resilience × Circular Economy	Blue-green corridors, porous streets, and modular components recover faster when supplied by local reuse networks.
Digital Integration × Equity & Inclusion	Open data and participatory tools reveal hidden service gaps in cooling, water, and mobility systems.
Decarbonization × Equity & Inclusion	Energy-efficient housing and low-emission mobility lower both bills and exposure to heat and pollution.

The future of sustainable city systems will not be driven by any single innovation but by how these forces interact. Digital systems make decarbonization measurable and adaptive; circular flows make resilience faster and more cost-effective; equity ensures the benefits reach everyone. When these dimensions align, city systems evolves from static assets into living systems continuously learning, repairing, and redistributing value.

Timing emerging technologies

Now: Ops are shifting to **model-led, corridor-scale management** (AI x IoT), **tracing materials** where municipalities already control permits, and **pre-balancing cooling loads** with smarter dispatch.

Next: Simulation evidence to be baked into approvals, materials passports standardized in codes, and **quantum-assisted scheduling** piloted where renewables, storage, and cooling intersect.

Later: Districts **self-tune** - corridors reallocate capacity, grids co-optimize heat–power, and material flows clear via automated marketplaces while governance focuses on **assurance, audit trails, and public trust**.

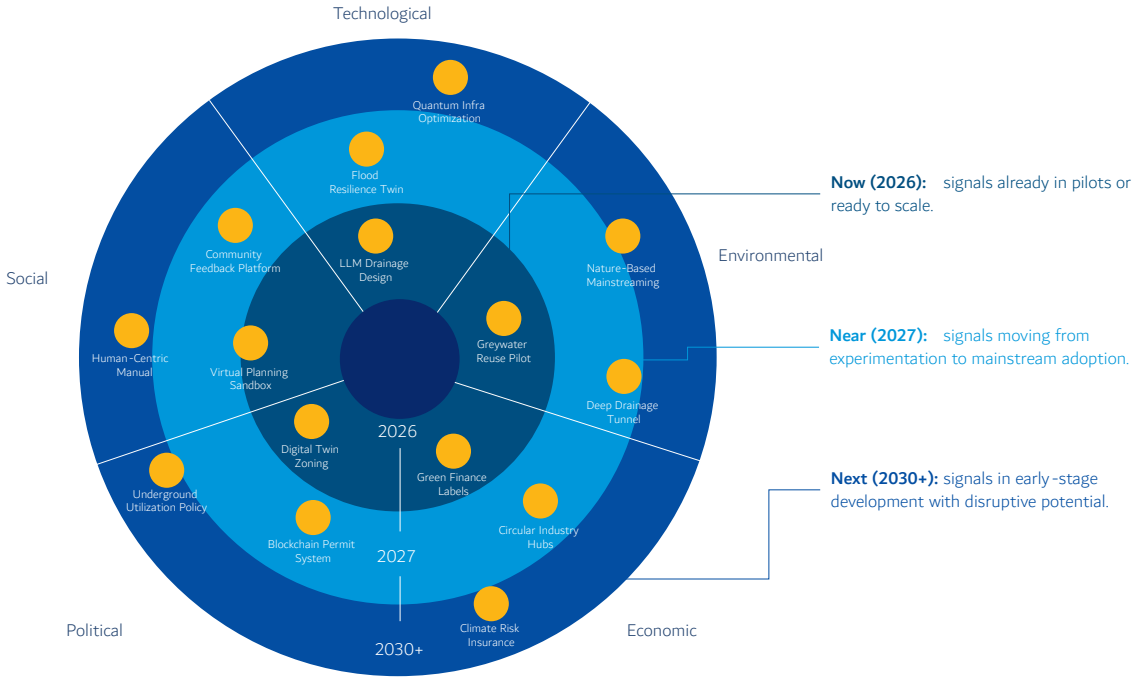


Figure 4 Planning Horizons of Sustainable Infrastructure

Three clusters stand out as actionable, high-impact opportunities:

1. AI-Orchestrated Resilience Corridors

What it is: Smart, multi-utility corridors combining transport, drainage, cooling, and greenery AI-managed to balance flows, detect risks, and coordinate maintenance in real time.

Why it matters: Cuts flood and heat risks; reduces operational and maintenance (O&M) costs; integrates drainage, cooling, and mobility into one adaptive asset class; builds data governance capacity for live municipal operations.

2. Quantum-Enabled Energy-to-Cooling Grid

What it is: An AI–quantum optimization layer that synchronizes renewables, storage, and district cooling to route power and thermal energy with minimal losses and peak demand.

Why it matters: Handles rising AI and cooling energy loads; raises renewable utilization; reduces peak strain; positions leading cities as quantum-testbeds for sustainable utilities.

3. Circular Construction & Materials Passport Network

What it is: A citywide digital passport system linking material data to permits and inspections, enabling reuse, recycling, and verified circular procurement.

Why it matters: Reduces waste and embodied carbon; speeds approvals through automation; builds a local market for certified secondary materials; enforces circular standards transparently.

Hot topics: next-gen sustainable infrasructure

Hot topic I - ai-orchestrated resilience corridors

Cities are beginning to manage their city systems more like a living network than a fixed system. Streets, drainage, sewerage, cooling lines, and greenery are no longer planned in isolation - they are connected through AI-driven platforms that read live conditions, predict stress points, and adjust operations automatically [47]. Where once corridors were lines on a map, they are becoming data-driven arteries pumping information, resources, and resilience through the urban fabric. Decision-making is no longer limited to design time. With live models and sensor feedback, corridors can now self-adjust, prioritize repairs, and optimize performance in the moment. Predictive maintenance programs typically reduce maintenance costs by ~18–25% and unplanned downtime by up to 50% [48].

The hope: city systems that doesn't just withstand change but evolves with it.

Key Observations:

- Real-time coordination: Urban sensors now feed data on flow, temperature, and rainfall into shared platforms that trigger quick responses rerouting runoff, adjusting cooling, or signalling maintenance crews before faults occur [49].
- Predictive upkeep: AI tools are being tested to anticipate city systems wear, allowing maintenance to be planned of failures and saving both cost and disruption [50].
- Blue-green integration: Cities like Singapore and Copenhagen are combining vegetation, permeable surfaces, and smart drainage to cool surfaces and absorb floods while collecting performance data for future designs [51].
- Collaborative data sharing: Municipal utilities are starting to pool information from transport, water, and energy systems on open dashboards, giving planners and engineers a common operating picture [52].
- Performance-based planning: Instead of fixed standards, corridor projects are increasingly measured by results like reduced runoff, lower surface temperatures, faster recovery after storms linking investment directly to verified outcomes [53].

Together, these shifts point to a new operating model for cities—one where city systems is not just built to last, but designed to sense, adapt, and respond in real time.

Impact for Municipalities

AI-Orchestrated Resilience Corridors turn city systems from a collection of pipes, pavements, and cables into an adaptive urban network that can sense stress, predict failure, and rebalance itself in real time. The effects ripple across planning, operations, data governance, and finance making resilience a measurable, service-based outcome rather than a one-time capital project.

Dimension	Impact Area	Practical Outcomes
Urban Systems	Adaptive Corridor Management	AI syncs roads, drains, and cooling; auto-adjusts flows during storms/ heat to cut disruption.
	Blue-Green Integration	Dynamic bioswales and permeable surfaces lower temps and absorb peak runoff.
Operations & Maintenance	Predictive Servicing	Condition-based maintenance reduces OPEX and prevents failures.
	Performance Assurance	Live KPIs (runoff, °C, uptime) verify service levels and compliance.
Data & Governance	Integrated Data Layer	Sensors, BIM, and rules connect via shared APIs for a single operating picture.
	Transparent Decision-Making	Public dashboards + explainable models show why/when actions occur.
Finance & Innovation	Outcome-Based Investment	Funding tied to verified risk reduction (flood, heat, downtime).
	Local Tech Ecosystem	Demand for analytics/sensors fuels SME growth and partnerships.

When drainage, cooling, and mobility networks are guided by real-time intelligence, cities move from reacting to crises toward preventing them, cutting costs, reducing risk, and earning public trust through visible, data-driven results.

If one is exploring AI-Orchestrated Resilience Corridors, it is worth focusing on what matters most: make the corridor sense, decide, and act simply, visibly, and with purpose. Do not overbuild the tech; start with a single stretch that proves coordination works before scaling.

Case Illustration
Singapore – Integrated Smart Corridor Operations

Land scarcity, intense rainfall, and high mobility demand pushed Singapore to manage streets, drainage, and green space as one operational corridor rather than separate projects.

What Was Done: Agencies retrofitted priority corridors with ABC Waters features such as bioswales, rain gardens, permeable surfaces, and canal naturalisation, while island-wide hydrometric sensors and CCTV support flood operations [54]; analytics from the Smart Nation stack can be applied to maintenance and people-flow where deployed [55].

Governance & Legal: A whole-of-government digital layer under the Smart Nation Sensor Platform provides shared data services and visualization so agencies can act on common, live information [56].

Outcomes: Lower peak runoff at precinct scale, cooler microclimates along greened corridors, and higher-quality public spaces that remain usable after heavy rain turning linear rights-of-way into multi-benefit urban assets [55].

Hot Topic II - Quantum-Enabled Energy-to-Cooling Grid

Electricity and cooling are becoming one system. Variable renewables, surging AI data-centre loads, and heat-driven demand mean grids must forecast, coordinate, and dispatch both electrons and cold. The next step adds quantum optimization on top of today's AI forecasting - so power, storage, and district-cooling plants can be scheduled together for the least loss and lowest peaks.

Key Observations:

- AI is already improving forecasts: Utilities are deploying machine-learning models to predict renewable output and balance supply and demand foundational for joint power-and-cooling dispatch [57].
- Thermal & electrical coupling works: District heating/cooling systems show measurable gains when operated with optimization controls and thermal storage evidence that "cold" can be planned like a grid asset [58].
- Quantum is moving from lab to grid interfaces: National labs and vendors have demonstrated quantum classical approaches for grid optimization and even direct interfaces with power-system equipment an on-ramp to real operations [59].
- Field demos are emerging: Recent quantum classical studies with Oak Ridge National Laboratory report advances on power-grid optimization problems, indicating practical steps toward lower losses and better dispatch [60].
- Cooling can flex and recover heat: City systems are increasingly coordinated with controls (AI in Scandinavian district networks) and can absorb or reuse waste heat from data centres, tightening the power thermal loop [61].
- Data-center surge is reshaping load. U.S. data centers could consume 6.7–12% of national electricity by 2028 (up from 4.4% in 2023), highlighting why joint power-and-cooling dispatch matters [62].

Impact for Municipalities

A quantum-enabled energy-to-cooling grid treats electricity and thermal networks as one coordinated system. AI handles forecasting: quantum optimization tackles complex dispatch so renewables, batteries, and district cooling move in sync to shrink losses, shave peaks, and keep comfort steady. The shift touches planning, operations, data, and finance turning reliability and efficiency into measurable, service-based outcomes rather than one-off projects.

Dimension	Impact Area	Practical Outcomes
Urban Systems	Power–Thermal Co-Dispatch	Joint scheduling of renewables, storage, and cooling plants lowers peaks and curtailment.
	Heat Recovery & Reuse	Data-centre and industrial waste heat feeds district loops to offset cooling energy.
Operations & Maintenance	Forecast-Driven Operations	AI forecasts for load, solar/wind, and cooling demand cut reserve margins and ramp stress.
	Condition-Based Assets	Predictive servicing for chillers, pumps, and batteries reduces OPEX and outages.
Data & Governance	Unified Telemetry Layer	Grid, cooling, and weather data share one schema/APIs; operators see a single live view.
	Explainable Optimization	Audit trails for dispatch decisions (constraints, costs, emissions) build trust and compliance.
Finance & Innovation	Outcome-Linked Contracts	Payments tied to verified metrics (losses ↓, renewable utilization ↑, peak kW ↓, comfort hours ↑).
	Local Tech Ecosystem	Time-/temperature-aware tariffs and flexibility payments reward demand shifting and storage.

Coordinating electrons and cold - AI for foresight, quantum for complexity moves cities from managing shortages to optimizing comfort and carbon in real time, with clear metrics that align engineering practice, regulation, and investment.

Quantum Optimization Sandboxes could provide a controlled space to test that future linking renewable generation, battery storage, and district cooling networks under a shared digital layer that optimizes performance in real time.

Case Illustration
USA – IonQ × Oak Ridge National Laboratory

Rising variability from renewables and new peak loads pushed researchers to test quantum methods for generation scheduling a core grid optimization problem.

What Was Done: IonQ and ORNL built a hybrid quantum classical approach to the Unit Commitment problem, using IonQ hardware to explore generator on/off configurations and classical solvers to refine dispatch, demonstrating feasibility on realistic test cases [63].

Governance & Legal: Conducted under U.S. Department of Energy partnerships with national-lab oversight and published case results; the work positions quantum as a complement to existing utility planning and market operations, with transparent benchmarks and hardware roadmaps [60].

Outcomes: Demonstrated improved scheduling quality on benchmark instances and a path to lower losses and better renewable utilization as qubit scale and fidelity increase [64].

Keep it practical. Treat power and cooling as one service with a light shared data layer, a few clear targets, and pre-agreed actions. Prove it in one zone before expanding. Run efficiency like a shared service: few signals, clear triggers, transparent data, and funding tied to verified energy and cooling gains.

Hot Topic III - Circular Construction & Materials Passport Network

Construction has been long shifting from a linear "take–build–waste" cycle to a circular model where materials retain identity and value across their lifespan. Materials passports give every component - from steel beams to facade panels - a verified digital record of origin, composition, and performance. Combined with open data platforms and circular procurement, they turn waste into an asset and traceability into policy. One of the prime example is Amsterdam's strategy that targets 50% less use of primary raw materials by 2030 on the way to a fully circular city by 2050 anchoring demand for passports and reuse markets [65].

Key Observations:

- Regulations advancing: The EU's new Construction Products Regulation will require Digital Product Passports (DPPs) that include sustainability and life-cycle data for materials [66].
- Regional pilots scaling and digital methods maturing: The Amsterdam Metropolitan Area, working with Madaster, is issuing passports for municipal buildings to test circular flows in demolition and reuse. Platforms like Madaster let users generate material passports from BIM or Excel - automatically enriching them with environmental and recovery data [67].
- Standards rising: The ESPR (Eco-design for Sustainable Products Regulation) mandates DPPs across goods, including construction materials, pushing lifecycle data into baseline practice [68].
- Scaling in housing: Dutch pilots are issuing ~1,000 material passports for new homes to give owners component-level insight and circularity scores, signalling market readiness beyond public buildings [69].
- Carbon savings from reuse are large: reusing structural steel (beyond recycling) can cut embodied greenhouse-gas emissions by about 60–83% compared with producing new steel for buildings; conventional steel recycling saves roughly ~75% of embodied energy versus primary production [70].

Impact for Municipalities

A Circular Construction & Materials Passport Network shifts the building sector from one-time projects to continuous material stewardship. Every component gains a digital identity tracking its source, performance, and reuse potential so cities can design for longevity, verify sustainability claims, and recover value at the end of each lifecycle. The impact cuts across planning, operations, governance, and investment making circularity a measurable, data-driven practice rather than an abstract goal.

Dimension	Impact Area	Practical Outcomes
Urban Systems	Circular Building Frameworks	Building components are logged, rated for reuse, and reintegrated into future projects.
	Lifecycle Design Integration	Projects are designed for disassembly, repair, and recycling from the start, reducing embodied carbon.
Operations & Maintenance	Asset Traceability	Digital passports allow easy tracking of components for maintenance, warranty, and performance audits.
	Deconstruction Planning	Material inventories guide safe and profitable recovery during renovation or demolition.
Data & Governance	Standardized Passport Registry	Unified data standards across suppliers and regulators ensure consistent tracking and reporting.
	Transparent Verification	Auditable material records verify sustainability metrics and compliance with green procurement rules.
Finance & Innovation	Circular Procurement Models	Contracts reward reuse and verify recycled content, turning waste reduction into measurable value.
	Market Development	Demand for verified secondary materials stimulates local reuse markets and data-driven innovation.

The passport network turns buildings into long-term material banks, where transparency, reuse, and digital traceability reduce waste, lower emissions, and unlock new value across the urban economy.

The goal is not to digitize everything at once, but to prove that material tracking, reuse, and reporting can work within normal project timelines and show measurable savings.

Case Illustration
Netherlands – Digital Materials Passport Platform

Land, climate, and waste goals pushed Dutch stakeholders to treat buildings as material banks, documenting components for future reuse instead of one-off demolition.

What Was Done: Madaster created a web-based registry where owners, designers, and contractors generate materials passports for buildings via BIM (IFC) uploads or a structured Excel template by capturing composition, quantity, location, and reuse potential. The platform functions like a “cadastre” for materials and is used in municipal pilots (e.g., Amsterdam Metropolitan Area) [67].

Governance & Legal: Operated by Madaster Services with a mission-led Madaster Foundation stewarding circular-economy aims; passports follow standardised data fields and can support compliance and reporting. Public-facing summaries and partnerships align methodology and accelerate adoption [71].

Outcomes: Traceable components across projects, better insight into material, circular, and financial value, and practical reuse workflows supported by a secure, online library [67].

What leaders need to decide

The Sustainable Infrastructure signals point to three big moves with real city-making consequences. Cities face different pressures at different moments - heat, energy strain, material waste, or all at once. How can the signals be brought together in one place?

If	Then
Extreme heatwaves and flash floods are becoming more frequent, stressing roads, cooling, and drainage networks.	**Activate Hot Topic 1** – AI-Orchestrated Resilience Corridors: integrate live data from transport, water, and greenery systems to coordinate shading, runoff control, and maintenance in real time.
Electricity peaks and cooling demand rise sharply due to AI data centres and longer hot seasons.	**Activate Hot Topic 2** – Quantum-Enabled Energy-to-Cooling Grid: deploy AI forecasting and quantum optimization to balance renewable generation, battery storage, and district-cooling loads.
Construction waste and embodied carbon continue to grow despite green-building policies.	**Activate Hot Topic 3** – Circular Construction & Materials Passport Network: introduce digital passports in permits and procurement to trace, reuse, and verify materials across projects.
Multiple stressors overlap — heat, congestion, energy strain, and resource inefficiency.	Combine **1 + 2 + 3** into a single demonstration district: smart corridors powered by efficient grids and built with circular materials, creating a measurable climate-neutral zone.
No major stress yet, but pilot results are strong.	Convert pilots into **City Standards** — update design codes, procurement clauses, and KPIs to embed each practice into routine operations.

The design of such systems is not trivial, yet, if done carefully, significant results can be achieved in the long run.

1. **Value & Impact:** How can we design future city systems to deliver measurable social and environmental returns alongside financial ones?
2. **System Reliability:** What checks ensure AI and optimization models stay transparent, explainable, and open to independent validation?
3. **Scaling Readiness:** How will we decide when pilots' corridors, cooling grids, or passport systems are ready to expand citywide?
4. **Data Collaboration:** Which agencies need shared data frameworks this year to connect mobility, energy, and construction systems?
5. **Investment Alignment:** What funding models reward proven performance risk reduction, peak savings, or waste diversion instead of project size?
6. **Policy Conversion:** What clear criteria will move tested innovations into formal codes, tenders, and procurement templates?
7. **Public Trust:** How can residents see and understand progress in real time, from cooler streets to lower energy peaks to cleaner construction sites?

Health & Wellness

5

Cities are increasingly expected to safeguard not only livelihoods but life itself. New health risks, rising temperatures, and digital acceleration are reshaping what "healthy city" means. Where wellbeing and innovation sit at the heart of national vision, the baseline for municipal leadership is moving fast from reactive health protection toward predictive, tech-enabled resilience.

> "Ensuring our people have everything they need to live fulfilled, comfortable, and happy lives remains the basis of all our future plans."
>
> **HH Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum**

The global context underscores the urgency. The wellness economy now exceeds USD 6.3 trillion and is projected to reach nearly USD 9 trillion by 2028 [72]. Yet population face mounting pressure: health impacts of climate change projects 0.7–1.3% of GDP losses in low- and middle-income countries by 2050 [73], while non-communicable diseases already account for 75 % of global deaths [74]. At the same time, AI-powered HealthTech investment has grown ten-fold since 2019, signalling a market shift from treatment to prediction [75].

Dubai's HS RADAR shows what this shift looks like in practice: a citywide, AI-assisted navigational map that fuses inspections, complaints, permits, and laboratory data to surface risk before it harms people. With live compliance views across 60,000+ establishments and upgraded control interfaces spanning public, occupational, and environmental health, managers can forecast trends and trigger targeted action quickly. Early results are tangible as indoor air and water quality indices improve, non-compliance declines, and monthly report volumes fall by 13%, freeing capacity for prevention.

Planning was once optimized for land use and traffic. Today, it must also optimize for exposure, recovery, and resilience under uncertainty. The question is not only "Where do people live?" but "What do they breathe, how hot does it feel, how safe is the commute, and how quickly can we act when signals flicker red?" How can that shift become intentional rather than accidental?

> **Urban health is no longer a hospital metric it is a systems metric. The cities that lead will balance livability, equity, and sustainability under uncertainty by making prevention an operational capability, not a campaign.**

In principle: Stepping into Trends and Drivers of Change for health and wellness means following the forces that will redefine prevention and safety at city scale.

Trends and drivers of change

The idea of health as a municipal outcome is expanding. Beneath the surface of daily operations, several long-term shifts are converging: a climate that tests endurance, a digital layer that never sleeps, and citizens whose expectations for care are shaped by real-time service in every other part of their lives.

Trend #1 - Health as Civic Hardware

- Prevention expands beyond clinics into urban systems - air, water, cooling, and waste managed as one wellness grid.
- Performance is tracked by exposure, recovery, and safety, not just uptime.

Trend #2 - Heat-safe Microclimate Design

- Rising heat and particulates make comfort features mandatory for health protection.
- Materials, shading, and microclimate design evolve into core resilience controls.

Trend #3 - Urban Health Telemetry

- Wearables, building sensors, and environmental monitors form continuous health feedback loops.
- Anonymized “health telemetry” informs zoning, emergency response, and safety planning.

Trend #4 – Circular Food Systems

- Waste, water, and nutrient reuse support circular urban food systems.
- Controlled-environment farming and digital surplus markets stabilize nutrition at city scale.

Trend #5 – Trust by design

- Public consent depends on fairness, transparency, and explainable automation.
- Secure civic IDs and clear data rights enable large-scale bio-digital health systems.

The transition from healthcare systems to health systems can be described as distributed, data-rich, and embedded in everyday city systems.

Exploring the future landscape

Across the world, quiet experiments are showing what may soon feel ordinary: environmental data feeding health dashboards; AI flagging heat exposure before an emergency call; waste-to-protein loops supporting local food security. These are small signals, but together they sketch a different model of urban wellness distributed, data-driven, and responsive in real time.

The challenge for planners and operators is to connect them into meaningful patterns. Which ones point to genuine transformation, and which remain background noise? Which need policy guardrails, and which can be allowed to evolve through market or community experimentation?

Engines of change in urban health operations

The scattered signals point to one pattern: health is becoming an operational system -measured live, managed across departments, and financed for prevention.

How we translate signals into engines. We reviewed recent policy moves, procurements, pilots, and tech maturity and asked a simple question: where do visible shifts meet levers we can pull? The result is a set of operating drivers that turn weak signals into action. Each entry explains what is changing, why it matters for day-to-day operations and investment, and when momentum is likely to crest from first sightings to expected standardization. Taken together, these drivers point to a single direction: run wellness like a core utility.

Name	Description	Implications	Impact		
Preventive governance mandates	Shift from compliance reporting to live service levels for exposure, heat safety, and IAQ.	Common metrics, faster cross-dept coordination, procurement tied to outcomes.	↗ 2026	→ 2028	↘ 2030
Outcome-based finance	Capital moves toward measurable prevention (green/health bonds, pay-for-success).	Projects compete on verified risk reduction; lifecycle costing replaces lowest-capex bids.	↗ 2026	→ 2029	↘ 2032
Edge AI & dense sensing	Low-cost sensors & on-device AI enable continuous monitoring and micro-actions.	From batch audits to real-time control, need audit trails and human oversight.	↗ 2025	→ 2027	↘ 2030
Bio-data ethics & trust	Clearer rules for combining environmental, biometric, and facility data.	Social license hinges on consent, transparency, and data minimization.	↗ 2026	→ 2028	↘ 2031
Heat & air as design inputs	Rising wet-bulb days and particulates make comfort a safety requirement.	Cooling, shading, filtration, and reflective materials become code pathways.	↗ 2025	→ 2028	↘ 2033
Localized circular nutrition	Controlled-environment age & waste-to-nutrient loops stabilize food quality.	Nutrition becomes an city systems metric; less exposure to import shocks.	↗ 2027	→ 2029	↘ 2034
Workforce risk rebalancing	Ageing workers & outdoor heat exposure reshape duty-of-care.	Shift scheduling, shaded routes, smart PPE; insurers reward verified protections.	↗ 2026	→ 2028	↘ 2031
Supply resilience for wellness tech	Dependence on a few sensor/cloud vendors risks blind spots.	Dual-sourcing and local maintenance capacity become critical.	↗ 2025	→ 2027	↘ 2030

The timeline band at the right shows how each driver evolves over time:

↗ marks the **onset or early impact phase**; when the first pilots, regulations, or funding programs start to appear.

→ indicates the **scaling phase**; when technologies or policies move from pilots to standard practice, usually through procurement, incentives, or public-sector adoption.

↘ signals the **maturity phase**; when standards, codes, or formal governance frameworks are established, making the change part of routine municipal operations.

The near-term move is to standardize what we can measure today, pilot where uncertainty is highest and build the data-trust foundations that let prevention scale across departments.

Timing emerging technologies

Now/near, the centre of gravity is shifting to **bio-digital prevention at city scale:** health twins, exposure sensing, and service triggers that forecast heat, air, and fatigue risks and intervene early (Bio-Digital Health City Systems & Predictive Municipal Care, 2028).

Next, **rules and response knit together**: a synchronized safety grid fuses air, climate, mobility, and workplace sensors into one operating picture so incidents are predicted and departments auto-coordinate with clear accountability (AI-Synchronized Safety & Preventive Response Grid, 2029–2030).

In parallel, **food and resource flows go circular and measured:** AI farms, desalination by-products, and waste-to-nutrient plants are tracked on a live ledger, tightening resilience against heat and import shocks (Climate-Adaptive Food & Bio-Production Loops, 2028–2029).

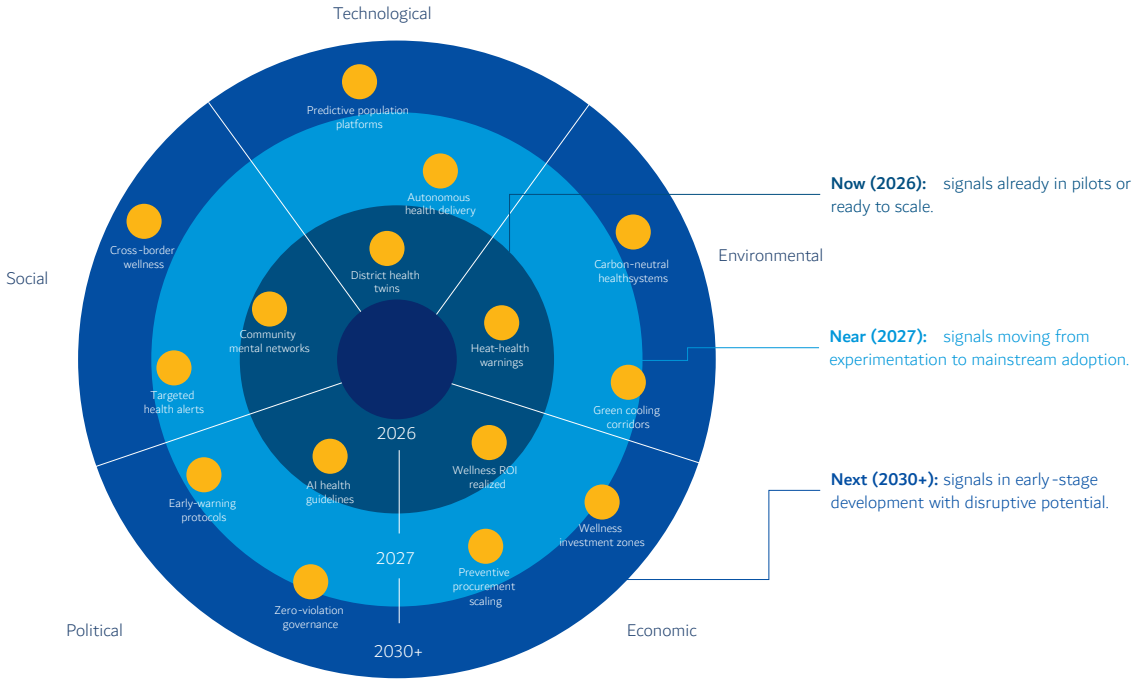


Figure 5 Planning Horizons of Health and Wellness

The practical read of the radar is simple: **operationalize the bio-digital layer, codify the cross-agency grid, and scale circular production** so prevention becomes the default, response becomes predictive, and resource security becomes auditable.

Mapping the signals against time horizons showed that three clusters stood out as actionable, high-impact opportunities:

1. Bio-Digital Health City Systems & Predictive Municipal Care

What it is: A connected layer that fuses environmental sensors, wearables, and municipal analytics to forecast exposure risks (heat, air, fatigue) and trigger early interventions through public services.

Why it matters: Shifts city health from reactive to preventive; reduces incidents, protects vulnerable groups, and builds trust with real-time, auditable care.

2. AI-Synchronized Safety & Preventive Response Grid

What it is: An integrated safety operating picture that unifies air, climate, mobility, and facility/occupational sensors, predicting incidents and auto-coordinating cross-department response.

Why it matters: Ends siloed safety ops; accelerates response time, raises transparency, and continuously lowers a district's "risk temperature."

3. Climate-Adaptive Food & Bio-Production Loops

What it is: A circular ecosystem linking AI-driven urban agriculture, desalination by-products, and organic-waste valorisation into a live "bio-productivity ledger" tracking water, nutrients, and emissions.

Why it matters: Builds heat-resilient resource security; cuts waste, lowers imports, and hardwires transparency into food–water–energy flows.

These three deliver outsized impact fast and have potential to scale: a regulatory shift, a digital leap, and a design/code pathway.

Hot Topics: What's Next in Health & Wellness

Hot Topic I - Bio-digital Health City Systems & Predictive Municipal Care

Municipal wellness is shifting from programs to platforms: shared data layers, sensor-rich operations, and AI that turns environmental and clinical signals into timely action. Thus, three pillars set point of this operating model: population-scale data backbones, predictive municipal analytics, and early-warning integrations. The investment context is also moving in step; the wellness economy is documented at $6.3T in 2023 with a forecast to ~$9T by 2028, creating supplier depth and financing logic for city-grade systems [72].

Key Observations:

- Population health data backbones. National systems such as Singapore's National Electronic Health Record show that shared, secure data layers can coordinate care across agencies a foundation for any municipal-scale wellness platform [76].
- Digital-twin health systems. City platforms are beginning to merge IoT sensors, health surveillance, and AI to model risk and guide response, with early pilots expected around 2026–2028 and wider use in the early 2030s [27].
- Governance and trust gaps. Remaining uncertainties AI reliability, equity, and cost-effectiveness require continuous outcome tracking, ethical oversight, and community engagement as adoption scales.
- Heat-risk signals are rising. WHO reports ~85% increase in heat-related mortality among people >65 between 2000–2004 and 2017–2021, underscoring the need for heat-health early warnings, cool-room networks, and targeted outreach [77].
- Air-quality analytics tie to outcomes. Reductions in ambient pollution have been associated with fewer acute asthma admissions; for example, analyses in Oxford (UK) observed a 42% reduction in adult acute-asthma admissions in 2020 vs the prior 5-year average amid improved air quality [78].
- Telehealth and wearables feed the loop. Post-2020, telemedicine use increased multiple-fold in several jurisdictions, with recent studies showing statistically significant growth in the share of outpatient claims delivered via telehealth; meanwhile, the global wearables market shipped 534.6M units in 2024, expanding the sensor base for preventive analytics [79].

The investment context is also moving in step; the wellness economy is documented at $6.3T in 2023 with a forecast to ~$9T by 2028.

Impact for Municipalities

The effects cut across services, data, governance, and finance turning prevention into a measurable, budget able utility.

Dimension	Impact Area	Practical Outcomes
Population Health	Health Security & Response	Continuous sensing and prediction shorten response times, prevent ER spikes in heat/air events, and push timely alerts to vulnerable groups.
	Wellbeing Equity	Exposure hotspots and service gaps are mapped in real time, so interventions target underserved districts and close fairness gaps.
City Operations	Integrated Response Architecture	A shared dashboard and playbooks synchronize environment, mobility, and safety teams to trigger coordinated early actions.
	Performance-Based Maintenance	Facilities operate to comfort/IAQ SLAs, shifting to condition-based servicing that cuts OPEX and extends asset life.
Data & Governance	Ethical Intelligence	Privacy by design, explainable AI, and auditable logs build citizen trust while meeting regulatory requirements.
	Outcome Accountability	Common KPIs exposure minutes, comfort hours, incident-free days—anchor transparent reporting and budget decisions.
Finance & Innovation	Value-Linked Funding	Bonds, PPPs, and contracts pay for verified reductions in risk, aligning capital with measurable preventive outcomes.
	Local Innovation Ecosystem	Demand for analytics, sensors, and wellness platforms fuels SME growth and research partnerships that scale city solutions.

Bio-digital health city systems is a citywide operating layer that links shared data, predictive analytics, and coordinated response not a standalone system. It pays off through faster prevention and fewer incidents, leaner operations, and higher public trust, but only if built on clear data rights, common standards, explainable automation, and funding tied to verified risk reduction.

Case Illustration
Hong Kong, HK — Heat Stress at Work Warning (HSWW)

Hong Kong introduced a territory-wide heat-stress warning to protect outdoor and non-air-conditioned workers, tying operational guidance to live meteorological conditions [80].

What Was Done: The Labour Department issues Amber / Red / Black warnings based on the Hong Kong Heat Index (HKHI). When active, employers must adjust shifts and rest cycles; public channels show the warning alongside weather info. Guidance materials and tools (risk assessment form, rest-time calculator) support on-the-ground decisions [81].

Governance & Legal: HSWW operates in coordination with the Hong Kong Observatory; rules are codified in official guidance, linking warning levels to employer obligations and safe-work practices [82].

Outcomes: A single, public indicator (HKHI) now aligns workplace actions with live conditions, improving consistency and compliance; public advisories appear in real time across government channels [83].

Keep it simple and operational. Aim for one shared data layer, a few clear service levels, and pre-agreed actions that turn signals into responses then scale only after the basics work in the field.

Hot topic II - AI-synchronized safety & preventive response grid

Municipal safety is moving from siloed monitoring to a single, AI-enabled operating layer that fuses sensor feeds, analytics, and multi-agency action. The model is already visible in official initiatives that run 24/7 operations centres, apply government-grade video analytics across networks, and use high-fidelity digital environments to test responses before changing the real world. Together, these moves point to earlier detection, faster coordinated dispatch, and clearer audit trails for public accountability [84].

Key Observations:

- **Government-grade AI for real-time detection.** GovTech's Video Analytics System is a core platform for public agencies, built to automate analysis of large video streams and surface operational insights at speed reducing manual review and enabling earlier, data-driven action [85].
- **Round-the-clock, multi-agency operations.** Singapore's Smart Nation Operations Centre provides 24/7 support for agencies using the national sensor platform an explicit template for aggregating live city signals and coordinating responses from one hub [84].
- **Scenario-first governance.** The EU's Destination Earth is developing a high-accuracy digital environment to monitor, simulate, and predict hazards and human activity supporting policy design and operational decisions with tested scenario outputs [27].
- **Public-sector rationale for AI.** OECD's work on AI in government frames the objective as improved decisions, responsiveness, and service quality while underscoring the need to manage risks and ensure transparency [24].

An AI-synchronized grid turns fragmented CCTV, environmental, mobility, and facility feeds into one set of rules and playbooks: detect earlier, coordinate faster, and show your work through explainable logs.

Impact for municipalities

AI-synchronized safety grids connect sensors, AI analytics, and inter-agency coordination into one real-time operating system where **every alert becomes an action** and every action is logged and learned from.

Dimension	Impact Area	Practical Outcomes
Public Safety	Early Risk Detection	AI analytics on cameras, mobility, and environment data flag anomalies instantly, reducing detection-to-response time and preventing escalation.
	Community Protection	Predictive alerts reach the public through simple channels, guiding movement and behaviour during heat, crowd, or hazard events.
City Operations	Unified Response Grid	A shared operations platform connects emergency, environment, and transport units for synchronized actions and situational awareness.
	Adaptive Service Management	Dynamic routing and staffing based on live conditions keep public areas safer and services steady with lower resource waste.
Data & Governance	Responsible AI Use	Transparent algorithms, audit trails, and human-in-the-loop oversight ensure fairness, privacy, and public trust in automated decisions.
	Operational Accountability	Incident metrics response time, false alarms, near-misses become common KPIs for evaluation and budget allocation.
Finance & Innovation	Outcome-Driven Investment	Contracts reward verified reductions in incident rates and faster resolution, aligning funding with measurable safety outcomes.
	Local Tech Capacity	Demand for trusted AI models, analytics, and maintenance builds local skills and innovation ecosystems around civic safety.

An AI-synchronized safety grid is not a new control room – it is a governance layer that turns city data into coordinated prevention. Its return comes through quicker interventions, lower risk exposure, and stronger citizen confidence, provided it runs on transparent algorithms, clear accountability, and cross-agency collaboration.

Case Illustration
Seoul, SK - S-DoT + Smart Public Safety

Seoul set out to turn diverse city risks into faster, data-driven response by collecting real-time urban signals (air, heat, noise, crowds) and linking them with smart public-safety tools for rapid action.

What Was Done: The city deployed S-DoT, a municipal IoT network that collects 17 types of data every few minutes from more than a thousand sensors, and uses the feeds for policy and services; in parallel, it stood up Smart Public Safety measures (intelligent cameras, safety lighting, and the "Ansimi" app) to reinforce emergency response in vulnerable areas [86].

Governance & Legal: S-DoT is operated by the Seoul Metropolitan Government as core smart-city city systems; data are integrated with CCTV and agency systems, and the city committed to a city-wide public IoT network to ensure coverage "in every corner of the city." Safety management programs extend the approach to construction and aging buildings using AI/IoT to detect risks early and prompt swift action [87].

Outcomes: Real-time situational awareness across districts; earlier detection of hazards; coordinated response in high-risk zones; and a single municipal capability that supports policy, operations, and citizen-facing safety tools [86].

Treat AI-enabled safety as a coordination fabric, not a technology race: a shared view, clear triggers, human oversight, and honest measurement that makes prevention the city's default response.

Hot topic III - Climate-adaptive food & bio-production loops

Food is shifting to a shorter, circular, climate-ready system: high-productivity controlled-environment agriculture (CEA) close to demand, urban/peri-urban production embedded in planning, and resource loops that recover water and nutrients from city by-products. Public agencies now publish targets, definitions, and financing lanes that make this transition concrete and investable.

Key Observations:

- Urban/peri-urban agriculture is a formal system. Food and Agriculture Organization (FAO) defines UPA as production plus processing, distribution, marketing, and recycling within cities and nearby regions giving municipalities a clear scope to plan and service local food loops [88].
- Controlled-environment agriculture is climate-proofing yields. EU programme notes describe CEA (greenhouses, vertical farms, hydroponics/aquaponics) as controlling light, temperature, humidity and nutrients to deliver reliable output on scarce land [71].
- Water and brine need circular pathways. UNEP highlights that desalination's by-product brine can harm ecosystems unless recovered or repurposed arguing for resource-recovery steps in city water–food planning [89].
- Finance is lining up behind climate-smart food. The World Bank frames climate-smart agriculture as boosting productivity, resilience, and lower emissions and is scaling funding and results metrics to back it [90].
- Targets drive adoption. Singapore's official food strategy ("30 by 30") sets a clear local-production goal, pushing innovation in high-productivity, resource-efficient urban farming [84].

Policy Indicator: These anchors let cities design near-term pilots that shorten supply lines, stabilize output during heat/disruption, and turn wastes into inputs - with definitions, targets, and finance already on the record.

Impact for Municipalities

Climate-adaptive food & bio-production loops reframe food from a linear import chain into a resilient, circular utility linking local production, resource recovery, and data-guided operations.

Dimension	Impact Area	Practical Outcomes
Public Safety	Nutrition Security & Stability	Local, climate-proof production (CEA/UPA) reduces supply shocks and keeps nutrient-dense foods available during heat or disruption.
	Food Safety & Traceability	Sensor-verified growing, processing, and cold-chain data cut spoilage and contamination, with rapid recalls when thresholds are breached.
City Operations	Integrated Food Logistics	Shorter, city-region routes and timed deliveries ease curb pressure, cut waste, and improve last-mile reliability.
	Resource Looping in Assets	Organic waste, wastewater nutrients, and brine by-products are recovered and routed to permitted farms, lowering disposal and input costs.
Data & Governance	Market Visibility & Alerts	Live dashboards track yields, prices, and waste; early-warning signals trigger procurement shifts or community distribution before shortages hit.
	Standards & permitting	Clear rules for indoor farms, rooftop/garage conversions, and nutrient reuse accelerate approvals while safeguarding health and hygiene.
Finance & Innovation	Performance-Linked Funding	Contracts and bonds pay for verified outputs (kg/m² yield, waste diversion %, water-use intensity), aligning capital with resilience metrics.
	Local Agri-Tech Ecosystem	Demand for CEA gear, controls, and safe-reuse services grows local SMEs and research partnerships around urban food.

Treat food resilience as city systems: zone and permit for local production, wire resource-recovery into city services, and finance against measurable outputs so supply stays steady in heat, waste becomes input, and every dollar buys both nutrition and resilience.

Case Illustration
Copenhagen, DK – Amager Bakke Resource Park

Copenhagen turned essential city systems into a model of circularity by merging waste-to-energy, district heating, and public recreation on one site.

What Was Done: The Amager Bakke plant treats over 400,000 tonnes of waste each year, generating about 2.7 MWh heat and 0.8 MWh electricity per tonne for 150,000 homes [91]. This means that even non-recyclable waste is turned into a continuous local energy source, supplying both electricity and district heating across Copenhagen.

Governance & Legal: The plant is owned by Amager Resource Centre (ARC), a consortium of five municipalities: Copenhagen, Frederiksberg, Tårnby, Hvidovre, and Dragør. It supports the city's climate plan targeting carbon neutrality [92].

Outcomes: Every tonne of residual waste helps power and heat thousands of homes while displacing fossil fuel use and supporting the city's circular-energy goals [91].

It is worth keeping the focus on coordination, not complexity. A good starting point could be to link the feeds already in place (CCTV, environment, mobility, facilities) to a few shared alerts and simple playbooks – hence, prove faster, cleaner responses in one place before expanding.

What leaders need to decide

The future of municipal health and wellness will not unfold in a straight line. Cities face overlapping pressures climate stress, aging populations, new technologies, and shifting citizen expectations that can steer them toward very different operating realities.

Each of the multiple scenarios represents a distinct way urban wellness systems might evolve from reactive models focused on crisis response to predictive networks that treat prevention as city systems.

Rather than forecasts, some of the trajectories outlined below could serve as strategic lenses, or short, plausible stories that highlight trade-offs, uncertainties, and practical choices cities may face over the next decade.

Four paths to the future of health & wellness

Scenario 1 – Reactive City Care

Drivers: Fragmented data systems, limited budgets, delayed adoption of AI/IoT.

The Scenario:

Municipalities focus on traditional healthcare and emergency response rather than preventive systems. Air and heat events, among ongoing food, age- and work-related issues, cause recurring strain on hospitals. Wellness is managed through campaigns, not city systems.

Operational Implications:

Reactive mode dominates; municipal budgets face rising health and maintenance costs. Data silos limit cross-agency insight, and trust in automation remains low.

Opportunities:

Strengthen basic sensing city systems, pilot community-level early warning systems, and establish shared health dashboards for key districts.

Scenario 2 – Coordinated Preventive Grid

Drivers: Integrated data governance, early adoption of bio-digital health systems, performance-based funding.

The Scenario:

Cities run health and wellness like a utility. AI-enabled monitoring and predictive alerts guide maintenance, safety, and public communication. Preventive overlays become standard in urban planning.

Operational Implications:

Budgets shift from emergency response to continuous prevention; clear KPIs (comfort hours, incident-free days) anchor funding.

Opportunities:

Scale digital health city systems across districts; invest in cross-agency data-sharing protocols; develop outcome-based funding tied to verified prevention.

Scenario 3 – Adaptive Resilience Economy

Drivers: Climate stress, global supply-chain disruption, food and resource volatility.

The Scenario:

Municipalities integrate wellness with food, water, and climate resilience. Bio-production loops and heat-adaptive zoning guide land use. Food waste, desalination brine, and wastewater become inputs for local nutrition and cooling systems.

Operational Implications:

City operations merge environmental and health data streams; planners coordinate energy, food, and wellbeing systems.

Opportunities:

Establish "climate-health" districts; co-locate water, waste, and food recovery; incentivize urban bio-production SMEs

Scenario 4 – Hyper-Automated Health Ecosystem

Drivers: Rapid AI adoption, mature data ethics, and autonomous city systems.

The Scenario:

Citywide AI grids autonomously detect risks, deploy response units, and maintain optimal comfort. Real-time citizen feedback loops shape operations.

Operational Implications:

Massive efficiency gains but new governance and ethics challenges; data bias and transparency become critical risk areas.

Opportunities:

Develop AI governance charters; create citizen data councils; train staff for algorithmic oversight.

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Path to Action

6

How to turn foresight into delivery? Analytics helps to inform strategic decisions; however, there needs to be more to unlock change and moving ideas off the page onto the street.

Seeing the future – is a given. Reliable services keep the city steady while we listen. Every street, queue, and park offer clues about what is changing: heat rising on a corner, a drain filling after a short storm, a routine that keeps slowing down. These small signals tell stories of what residents feel day to day, showing where a small shift could unlock a better experience.

Following the signals – imagine what's next. From these signals come simple, practical ideas that fit the moment. A single corridor, a digital form, a shaded path, each tried quietly and explained in plain language, measured by what people can sense: cooler air, shorter waits, smoother flow. When change is visible and relatable, it builds confidence and curiosity to try again.

Finally, we grow what works. Some ideas prove their value and become part of how things are done, not through new policies but by becoming habit. A note is added to a guide, a routine adjusts, a small fix becomes the new normal. What does not work teaches its own lesson. Each cycle strengthens how the city learns, turning foresight into everyday practice that people can trust and see.

Figure 6 Turning foresight into everyday practice

How do we see the future?

Before big ideas, cities need clear sight. "See the Future" is about keeping daily services steady while quietly listening to what the city is already telling us. When operations and observation move together, small signals point to practical, near-term moves that people can feel.

Why Singapore as the case. Singapore treats reliability as a listening system. Its buses, drains, signals, and bins feed live telemetry; crews and controllers use that pulse to adjust routes, cleaning, and timing in the moment. The result is calm on the surface and awareness underneath, showing how a city can integrate IoT, service dashboards, and resident feedback without fanfare. It is a clear, transferable example of how to see emerging issues early and act before they become problems.

Keep the city in rhythm

Every city runs on rhythm. Streetlights, waste trucks, permits, and water pumps keep time together, creating a steady pulse that residents rarely notice until it stops. Reliability is the foundation of foresight because a calm, predictable system leaves room to listen. When people trust that their bins will be collected and their roads won't flood, they start to share what else could work better.

Cities that treat daily service as a feedback loop, not just a task list, begin to uncover patterns early. A queue forming every Monday morning tells one story; a sudden spike in water-pump energy use tells another. When operations and observation move together, maintenance crews, data dashboards, and residents all become part of the same conversation.

These are not problems to fix immediately, they are clues about where the city's pulse is uneven.

Cities that listen while they operate start to hear what data alone cannot say. It is the difference between reacting to faults and feeling the rhythm of the place. A street that stays clean or a bus that arrives on time may seem ordinary, yet these quiet consistencies give people confidence in change. Once the city moves in rhythm, it can begin to listen more deeply, to sense what is shifting beneath the surface and prepare for what is next.

Run the engines of foresight

From multiple sources, municipalities may choose to build foundations in which foresight activities can flourish. By sensing, or gathering, the signals from multiple channels, covering: IoT and city service data, Vendor and private sector data, Open data and public repositories, Data science, analytics, and agentic AI/ BI tools, State directions, policies, and strategies, among others, a consolidated evidence base can be built that integrates municipal operations with external insights. Early detection of weak signals could shape city's urban future, city systems, or public health agenda. Moreover, this provides greater visibility on where global trends intersect with local realities, enabling informed decision-making at the next phases of foresight.

Once a strong foundation is in place, foresight moves into its most dynamic phase - the engines that transform signals into tangible ideas and test them in practice through key actions:

- **Futurize:** Turn signals into foresight narratives and scenarios, applying tools from horizon scanning and tech radars to digital twins and simulations, as well as cross-country comparisons to illustrate possible futures.
- **Innovate:** Define and prioritize concepts through innovation frameworks and systems, labs, and a culture that supports open science and creativity.
- **Experiment:** Conduct trials in sandboxes and testbeds. Work with ecosystem collaborators, explore government-driven ventures or external innovation adoption, and apply mechanisms such as digital/innovation tokens to enable experimentation.

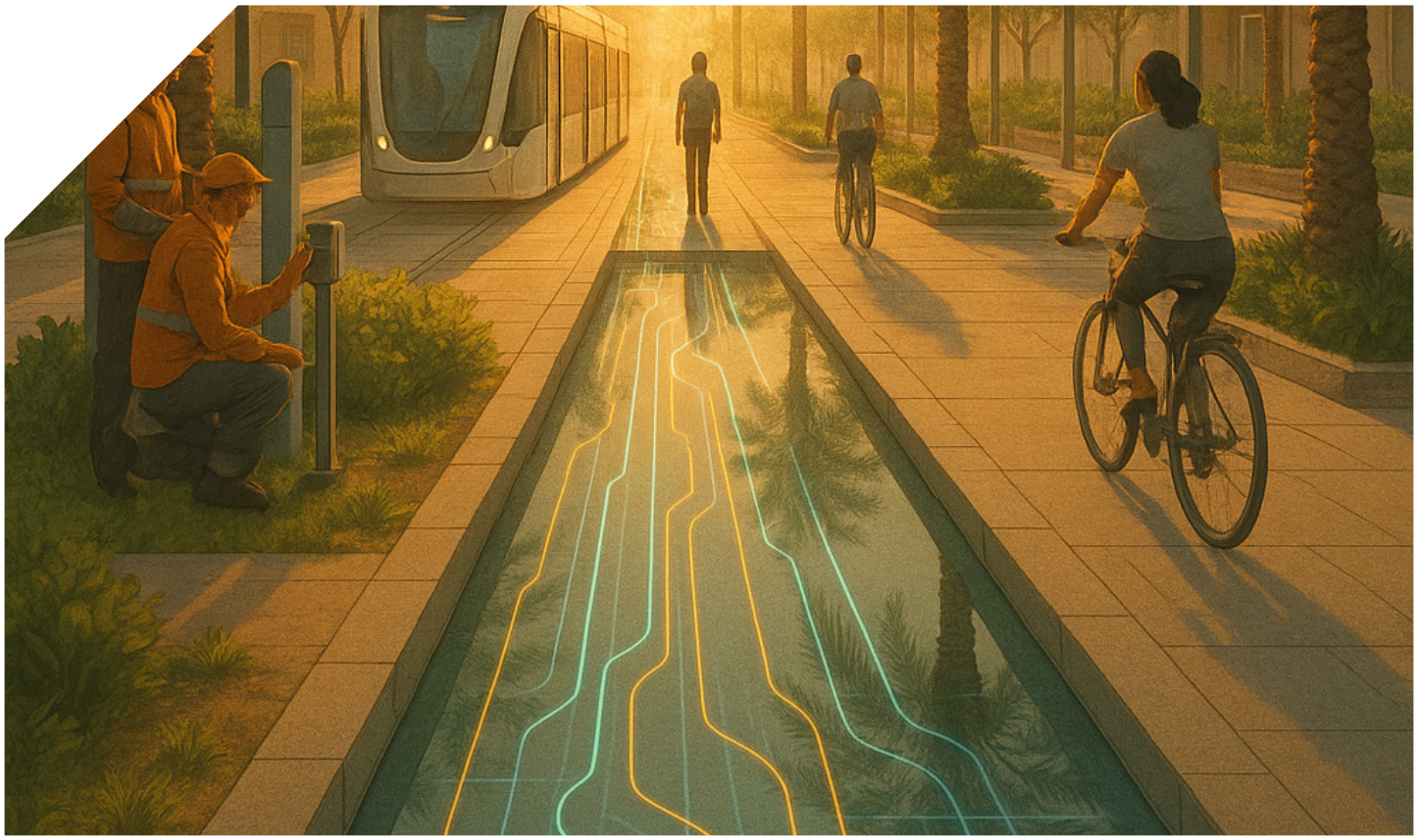
This is how bulks of data transform into a clear portfolio highlighting plausible futures, concepts and evidence from controlled environments, indicating which solutions are scalable and which should be refined or set aside.

Each proven concept goes through further cycles of productizing and integration with key platforms and then scaling based on performance and strategic needs.

Does this fit our city – right now?

Not every good idea is a good idea for us in the near-term strategic horizon. A quick fit check protects focus and trust.

A quick fit check asks whether the proposal delivers public value soon and to clearly defined beneficiaries; is feasible with at least 80% of the required levers already under our control; has a firm mandate with a named owner, budget, and authority; adds something distinctive we cannot easily get elsewhere; strengthens trust by producing evidence residents can see and understand; and is a no-regrets move that remains useful even if the larger vision stalls.



The Future is Not Predicted, It's Practiced

7

Cities become what they repeatedly do. The future is not a distant vision or a fixed plan; it is the accumulation of daily decisions, data, and actions that shape how people live, move, and trust their surroundings.

At its core, this is a shift from intent to iteration. Cities used to forecast and then build. Now they must listen and adapt. The municipal way of operating, sensing, experimenting, and proving turns what once felt speculative into evidence that can be scaled. When the public can see the "before" and "after," trust grows and the distance between citizen and institution narrows.

Predictable services, safe streets, and clean systems are what give a city the credibility to try something new. Reliability frees attention for foresight. A city that keeps time, with its buses, bins, and lights working in an organized "rhythm", earns the right to experiment because residents know that even as things evolve, their everyday life remains steady. This is why the most advanced cities appear calm on the surface; their systems are alive underneath, quietly learning and adjusting.

The most resilient progress begins small: a single corridor that stays cooler, a faster permit that frees human time, a dashboard that shows clear results. When outcomes are made visible and replicable, change moves from individual effort to institutional habit. The rulebook evolves not from argument but from evidence.

Listening is not passive; it is an active stance of openness and attention. It turns maintenance crews into observers, data into dialogue, and feedback into design. When this listening becomes habit, foresight ceases to be a distant exercise; it becomes the everyday operating mode of a confident, adaptive city.

Dubai offers a reliability first, evidence led model for cities worldwide. We will continue to deliver steady services that earn trust, test ideas in the open, measure results, and convert proven wins into codes, contracts, and standards that scale across districts.

The commitment speaks for itself: a city steady today and readier tomorrow, providing a practical blueprint others can adapt.

The city of the future is not built by experts alone but co-authored by those who live in it. Residents, sensors, service crews, and algorithms each hold a fragment of foresight. The task of leadership is to weave those fragments into one picture, a civic intelligence that notices early, acts quickly, and learns publicly.

Table of Acronyms

Acronym	Full Term	Meaning / Use in Context
AI	Artificial Intelligence	Data-driven models for prediction, automation, decision support.
API	Application Programming Interface	Standard way for software to exchange data; connects sensors, BIM, dashboards.
BIM	Building Information Modeling	Data-rich 3D building model used across the asset lifecycle.
CCFLA	Cities Climate Finance Leadership Alliance	Coalition mobilizing finance for city climate projects.
CCTV	Closed-Circuit Television	Fixed video cameras for monitoring public spaces/ facilities.
CEA	Controlled-Environment Agriculture	Indoor/greenhouse farming with controlled climate and inputs.
DPP	Digital Product Passport	Structured product record for materials, repair, reuse, and compliance.
EIB	European Investment Bank	EU public bank financing city systems and green projects.
ER	Emergency Room	Refers to hospital emergency departments; used when discussing reduced emergency visits during heat or air-quality events.
ESPR	Eco-Design For Sustainable Products Regulation	EU rule setting design/sustainability requirements and data.
EUI	Energy Use Intensity	Energy per floor area (kWh/m²/yr); used to benchmark buildings.
FAO	Food And Agriculture Organization	UN agency with standards/definitions for urban and peri-urban agriculture.
GIF	Global Infrastructure Facility	World Bank–hosted platform to prepare/finance complex city systems and PPPs.
GovTech	Government Technology	Public-sector use of digital tech; agencies/vendors delivering civic services.
HKHI	Hong Kong Heat Index	Composite index used for official heat-stress warnings in Hong Kong.
HSWW	Heat Stress At Work Warning	Workplace heat-risk warning/advisory level.
HVAC	Heating, Ventilation, And Air Conditioning	Building comfort/environmental control systems.
IAQ	Indoor Air Quality	Air cleanliness/ventilation metric for wellness and comfort targets.
IAQ	Indoor Air Quality	Same as above; lowercase variant.
IFC	Industry Foundation Classes	Open BIM data schema enabling software interoperability.

Acronym	Full Term	Meaning / Use in Context
IoT	Internet Of Things	Network of connected sensors/devices streaming operational data.
ITS	Intelligent Transport Systems	Tech (sensing/comms/control) to manage traffic and public transport.
KPI	Key Performance Indicator	Quantified metric (e.g., comfort hours, incident-free days) to track outcomes.
kW	Kilowatt	Unit of power; used for peak demand and capacity.
M&V	Measurement And Verification	Validates realized performance vs. predicted after implementation.
MRT	Mass Rapid Transit	Metro/rapid-transit rail system.
O&M	Operations And Maintenance	Day-to-day running and upkeep so assets meet safety/performance targets.
OECD	Organisation For Economic Co-Operation And Development	Intergovernmental body providing policy guidance, stats, and best practices.
OPEX	Operating Expenditure	Day-to-day operational costs; reduced via predictive maintenance/efficiency.
PPP	Public-Private Partnership	Contract where public/private share investment, risk, and rewards.
R&D	Research And Development	Activities to innovate, prototype, and test new solutions.
S-DoT	Seoul Data Of Things	Seoul's municipal IoT sensor network providing multi-parameter telemetry.
SLA	Service Level Agreement	Predefined performance target (e.g., comfort hours, IAQ range) guiding O&M.
SME	Small And Medium-Sized Enterprise	Business size class; typical innovators/partners in pilots.
UN	United Nations	International organization; provides norms, data, and programs.
UNDP	United Nations Development Programme	UN agency supporting development, governance, and resilience projects.
UNEP	United Nations Environment Programme	UN agency for environment/climate policy and guidance.
UPA	Urban/Peri-Urban Agriculture	Food production within/around cities.
UPL	Underground Pedestrian Links	Climate-controlled links connecting buildings and transit.
UPN	Underground Pedestrian Network	Citywide system integrating multiple UPLs.

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About Dubai Municipality

The Dubai Municipality guides Dubai's urban growth with a focus on innovation and sustainability, handling urban planning, waste management, public health, and more. Its visionary efforts have transformed the cityscape and set international urban governance benchmarks, reflecting meticulous planning for a resilient metropolis.


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