WORLD ECONOMIC FORUM

Implementing a Life-Cycle Approach to Infrastructure: A Policy Roadmap for Cities

MODEL POLICY

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Images: Getty Images

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Introduction

A whole-of-life-cycle approach to infrastructure, from planning to decommissioning, requires robust models from the outset.

> Decisions made during planning, design and construction influence the functionality of citie for many generations.

Purpose and scope of the policy roadmap

Infrastructure is a significant generator of economic and social value, but it is also expensive to design, build, operate and maintain. Projects can take many years to plan and once delivered, assets are intended to endure for decades, if not longer. Decisions made during planning, design and construction influence the functionality of cities for many generations.

Over the next 40 years, the global building stock is projected to double,[1] adding 241 billion square metres (an entire New York City) each month. United Nations Secretary-General Antonio Guterres has estimated that three-quarters of the infrastructure that will exist in 2050 has yet to be built.[2] Given these projections, exploring new approaches to planning and development that will deliver more sustainable, well-maintained and affordable infrastructure will be critical: we cannot build as usual, but need to advance innovative and holistic approaches to achieve better outcomes in the long term.

This roadmap offers an overview of the life-cycle approach to infrastructure, with concrete examples, insights and tools for implementing the approach from inception to decommissioning, and from city policy to contract structure.

Task force on Building Tomorrow's Urban Infrastructure

This work has emerged from a particular inflection point: At the tail end of the pandemic, governments worldwide advanced ambitious economic stimulus packages to jumpstart their economies and reinvest in failing infrastructure. More than $10 trillion in funding was committed to global recovery packages, which included significant commitments to infrastructure investment.[3] Cities moved to identify priority projects, increase their capacity, and make the most of once-in-a-generation opportunities. They found that even with unprecedented funding, the challenges for infrastructure planning, delivery and funding persisted.

The World Economic Forum convened leaders from 12 cities, subject-matter experts from civil society and national governments, and executives from the private sector to form a task force. Under the name Building Tomorrow's Urban Infrastructure, the task force's goal was to work together to identify how infrastructure delivery at the city scale could be improved. The task force focused on how an end-to-end, or life-cycle, approach to infrastructure could change the way we plan, build and manage our most ambitious projects. How can we develop better models to engineer life-cycle goals from the outset? How can we embed maintenance and operations planning at the project's inception, and weave these costs into capital planning?

The purpose of this policy roadmap, therefore, is to set out how city leaders working on planning and building infrastructure projects can adopt a whole-of-life-cycle approach – from planning to management to repurposing.

Through the policy roadmap, city administrations could be better equipped to:

- Establish governance arrangements that drive collaboration, innovation and better apportionment of risk between public and private partners.
- Address the historic imbalance between capex (capital expenditure) and opex (operating expenditure) approaches so that public money and organizational capacity that are often siloed into commissioning and buildout will be better integrated into operations and asset resilience.
- Create better infrastructure programmes, better functioning and competitive economies, and resilient communities in cities.
- Through all of the above, establish a strong and logical framework in which whole-of-life-cycle approaches evolve and grow.

Who is the policy roadmap for?

This policy roadmap is aimed at two main audiences: senior political, policy and operational decision-makers (mayors, city managers and executive directors) who are concerned with driving long-term value from infrastructure projects; and directors of service who are more involved in planning, funding and structuring deals, and implementing infrastructure projects.

> **"60% of infrastructure assets currently have a net zero target, but only one third have one that is science-based or aligned to a net zero target-setting framework."**
>
> Global Infrastructure Hub Monitor 2023[4]

We hope it also serves as a pointer to best practices for the industries and professional advisors who help finance, plan, build and maintain infrastructure projects.

Definition of infrastructure

For the purposes of the roadmap, we define infrastructure as follows:

"Urban infrastructure refers to the physical networks and structures that provide essential services to residents and businesses of a given metro region. These systems form the foundation of urban life, enabling activities like transportation, communication and resource distribution. Key areas of urban infrastructure include: mobility networks, utilities, public-use spaces, and facilitating buildings and structures."

Principles for driving action

The principles around which this policy is organized are as follows.

- Strengthen public accountability for all partners to drive better contract performance, minimize conflicts of interest, and decouple infrastructure planning and delivery from the variability of the political cycle.
- Use infrastructure to deliver demonstrably better outcomes around the strategic challenges of today – namely sustainability and net-zero emissions, climate resilience, social equity and inclusive communities.
- Encourage geography-based approaches for regions and cities most heavily impacted by climate change.
- Build trust between the public and private sectors in order to deliver more holistic project approaches and better strategy, planning, funding, and operations and maintenance.
- Promote continual improvement and innovation in public authorities' monitoring and management of infrastructure assets, including the use of data and digital technologies across the whole-of-life-cycle value chain.
- Encourage strong community engagement at appropriate points of the life-cycle (e.g. planning, design and discussions about repurposing/ reuse) so that infrastructure meets community needs and drives well-being.

How to use the roadmap

This document is structured around five key stages of the infrastructure life cycle.

- Strategic planning, funding and partnering
- Design and procurement
- Commissioning and delivery
- Operations and maintenance
- Repurposing and end-of-life decommissioning

In its final section, the roadmap addresses life-cycle management at the city scale.

The policy roadmap is broad, covering a lot of territory and drawing on many sources. Currently, there is no one unified public policy laying out how cities can implement a life-cycle approach to infrastructure. We use case studies to illustrate how elements of the roadmap are being implemented and to describe approaches being taken in global cities. For readers in search of more detail, links to reference material and more detailed resources can be found throughout and are appended.

Related policies in the Group of 20 (G20) Global Smart Cities Alliance suite of model policies (e.g. Whole Life Carbon Assessment Mandates)[5] and reports from the World Economic Forum (e.g. Nature Positive: Guidelines for the Transition in Cities)[6] may also prove valuable.

FIGURE 1 | **Whole-of-life-cycle approach to infrastructure management**

Five stages and key concepts

Planning, funding and partnering

- Aligns to strategic, financial and social-spatial plans
- Evidence-based and community-centric
- Uses stand-alone vehicles
- (Debt and equity) financed and funded
- Yeilds non-economic outcomes
- Requires early-stage market engagement
- Focuses on cost estimates and risk profiling
- Supported by policies to drive demand/occupancy

Design and procurement

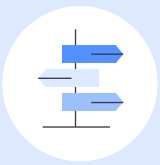
- Based on innovation that persists across life cycle
- Yeilds outcomes in energy, carbon reduction and climate resilience
- Designs-in circularity (and to do so, considers end-of-life uses)
- Aligns to a wide range of sustainability standards
- Yeilds social outcomes (quality of “place” and inclusive growth)

Commissioning and delivery

- Comprises a range of models influenced by project size, aims and operating context
- In traditional models, different degrees of responsibility and risk shared between public sector and contractor
- PPPs offer opportunity for innovation, risk-sharing, and strongest consideration of costs over the full life cycle

Operations and maintenance

- Uses asset management plans as active tools
- Uses asset data to monitor and predict usage, performance and resilience
- Review of contextual risk (economic, environmental and social)
- Based on analysis of asset risk (condition, criticality and type)
- Uses service-level data to ensure reliability, quality and sustainability



Repurposing and end-of-life

- Advanced cases comprise whole-system circular economy strategies
- Guidelines for decommissioning can cover vertical, horizontal and utility infrastructure
- Looks increasingly to examples of entirely new uses (e.g. of airports)
- Requires significant supply chain collaboration

Each stage benefits from:

1. Clear, evidence-based and data-enabled strategy.
2. Strong governance frameworks to amplify collaborative political and managerial cultures.
3. Enhanced staff capabilities across key activities – investment and capital markets; infrastructure expertise; procurement; and data and digital technology for monitoring and management of outcomes, contracts and assets.

1 Strategic planning, funding and partnering

The life-cycle approach plans for operations, maintenance and the end of life during the project's initial phases, and makes sure that the project is aligned with the community's core values.

Strategy, planning and community engagement

Infrastructure projects should be aligned with the vision and strategic goals of the city. Integration with core principles and policies, as laid out in the city's strategic plan and supporting social, economic and spatial planning strategies, and supported by corporate asset management policy, financial and capital plans, will foster internal collaboration around the widest possible set of strategic outcomes.

State governments such as Victoria in Australia, and city governments such as Copenhagen in Denmark, have a long history of using urban planning strategy as a template to achieve their broader sustainability goals. The Danish capital has enacted strict regulations to ensure that new architecture is sustainable and that energy-efficiency improvements are carried out for existing building stock. It has adopted a citizen-centric approach to urban development that is aligned with the core vision for the city.

BOX 1 **Putting core values at the heart of long-term infrastructure strategy: Victoria, Australia**

Infrastructure Victoria, the state's advisory body, has produced a 30-year strategy, galvanizing public authorities around a vision for housing, energy, transport and social infrastructure. It has made more than 90 recommendations for infrastructure projects, policies and reforms. The plan is based on four key values:

1. Confronting long-term challenges: In an uncertain and unpredictable world, long-term strategy must be adaptable and resilient.
2. Managing urban change: Anticipating population change, and better integrating Victoria's land-use and infrastructure planning, so as to guide housing and commercial construction to the most appropriate locations and provide the right infrastructure at the right time.
3. Harnessing infrastructure for productivity and growth: Improving the productivity and effectiveness of existing infrastructure, and assessing and selecting future "hard" infrastructure – as well as social and environmental infrastructure – to support growing communities and reduce disadvantage.
4. Developing the Victoria region: Enabling Victoria's diverse communities to adapt to economic change and address socio-economic disadvantage for some of the state's most vulnerable communities (e.g. through connectivity).

The plan is revisited regularly to accommodate a changing world, and the overall strategy is updated every three to five years. Extensive, inclusive community engagement is also emphasized. A wide range of supporting data, policy analysis and technical documentation (e.g. feasibility assessments for larger infrastructure projects) is also made available.

Source: Infrastructure Victoria[7]

The planning and management of infrastructure assets are generally subject to oversight – the recommendation here is that planning align closely with the core values of the municipality, and that reporting include progress in developing the infrastructure pipeline and in implementing the asset management plan, as well as identifying any barriers to successful implementation and designing a strategy to address them.

Stakeholders such as civil society, community groups, local businesses, residents and renters can also contribute significantly to long-term asset planning. It will be helpful for government entities and asset developers to create strong and flexible mechanisms for constructive dialogue, negotiation and resolution to help stakeholders reach consensus and navigate diverging interests.

Approaches that can be used include town hall meetings, workshops and quantitative surveys. Front-end loading (FEL) is a project management approach where the project owner advances the planning, development, construction and operational phases of a project during its early stages. This approach helps clarify objectives and ultimately, if done with care, improves the design and procurement process by helping to produce more realistic design alternatives, performance requirements and cost estimates. It also helps forecast and factor in operational and life-cycle needs, including defining environmental costs (e.g. embodied carbon). This approach can reap significant benefits in project planning and design, can foster more balanced investment decisions, and can help ensure the long-term success of the asset.

BOX 2

Best practice in cost and risk estimation: Infrastructure and Projects Authority, United Kingdom (UK)

The UK government's Infrastructure and Projects Authority has produced cost estimating guidance to encourage best practice in the costing and estimation of risk in infrastructure projects and programmes. It contains a set of principles to help navigate around common pitfalls at the earliest project stages. Key among these principles are:

1. Clear ownership: There is well-defined ownership and accountability for the estimate.
2. Front-end loading: Investment is made to develop the project early on for better outcomes and more accurate estimates at every stage.
3. Risk-adjustment: Estimates are risk-adjusted, presented clearly and consistently, showing a range of possible outcomes.
4. Evidence-based: Estimates are transparent, robust and data-based.
5. Reviewed and assured: Project teams use review and assurance to improve the quality of their estimate.

Source: Infrastructure Projects Authority[8]

> Stakeholders such as civil society, community groups, local businesses, residents and renters can also contribute significantly to long-term asset planning.

Funding and financing

How to pay for large infrastructure projects is a significant challenge, revolving around two related elements: funding and financing. Funding covers all sources of investment and income required to pay for a project in its entirety (e.g. taxation, grants, and user fees such as ridership, toll and congestion charges).

Financing comes in two forms – debt and equity – and covers the "cash" needed upfront including borrowing to be repaid from the project's funding. City authorities can seek debt financing to pay for upfront costs by borrowing on the capital markets or issuing bonds, or equity financing for which the costs of financing a project are covered by the private sector. This latter option is often accompanied by the setting up of a specific entity to own and manage infrastructure assets.

Individual projects often require multiple parties to structure financial support or to attract commercial investment. Lenders and investors require a feasible or "bankable" business case for a well-defined project, featuring early and well-evidenced cost estimates, and clearly articulated revenue streams and profitability assessments over the longer term.

City authorities can work with infrastructure operators to ensure that their pipeline projects are attractive to both short- and long-term investors, including institutional investors such as pension funds. Where investors have broader goals for long-term value such as social or environmental gains, these projects can offer an opportunity to deliver non-cyclical yields over the long term, while simultaneously achieving outcomes that go beyond monetary returns and can be tracked over the long term, such as social impact or affordability.

As sustainability and social value – including requirements for carbon capture and emissions reduction, climate resilience and social outcomes – become more and more central to infrastructure delivery and performance, it is important that city authorities incorporate expert opinion at the outset and adopt costing methodologies that allow for consideration and revision of these factors in the building and operating phases.

> When life-cycle approaches are adopted, it is critical to measure and track outcomes – from better cost estimates to improved outcomes across other life-cycle stages.

Partnering and market engagement

Early-stage partner engagement, through for example a request for information (RFI), is an effective means of catalysing innovation and encouraging a diversity of responses to subsequent formal procurement exercises. Public authorities can use the RFI as a way to consider the value of new or innovative approaches at the beginning of the procurement process. This type of market shaping, in which authorities outline the issues to tackle and consider proposed solutions rather than prescribing them, can solicit more innovative proposals and can greatly improve the chances of delivery of wider social and environmental outcomes across operational life.

The criteria for selecting partners should operate around the broad principle that good private-sector collaboration encourages action and alliances beyond traditional commissioning arrangements (e.g. engineering, procurement and construction contracts). Good partners will balance economic motivation with a detailed understanding of global trends in infrastructure and an ability to navigate political relationships, engage with local communities and accommodate local requirements, and, potentially, drive innovation in infrastructure delivery and operation.

Of course, partnering is a two-way street. Not meeting the market's own requirements discourages responses to requests for proposals (RFPs). Public authorities should engage in early collaborative discussions based on well-considered cost estimates and risk profiling, in which upside and downside risks are balanced and fairly apportioned. City authorities should work to be more transparent about how projects are structured. When life-cycle approaches are adopted, it is critical to measure and track outcomes – from better cost estimates to improved outcomes across other life-cycle stages.

For public-private partnerships, investors tend to look for projects that are backed by evidence that the asset will provide economic benefits, such as an improved tax base that will help fund the investment in the long term. One example of this would be public or "key worker" housing, supported by a wider range of social and economic policies that strengthen the municipal authority's guarantee of future occupancy rates.[9] This type of approach can unlock more capital, given the greater certainty of a bigger tax base in future, though in rural and low-income areas access to capital and a low-density tax base can present difficulties.

Attention should also be paid at the RFP development stage to managing "optionality", so that risks for alternative technical concepts (e.g. the inclusion of on and off ramps to serve communities) are controlled. This ensures that utility and financial viability are not in tension with one another, and that the responsibility for assets (e.g. public parks) for which income streams cannot be identified is correctly apportioned.

BOX 3 **The Development Authority Model: The London Legacy Development Corporation (LLDC), UK**

LLDC was formed to use the significant opportunity of the London 2012 Olympic Games and the creation of the Queen Elizabeth Olympic Park to ensure that the physical legacy of the games would benefit Londoners for years to come, and to create an inclusive community, thriving business zone and leisure destination as part of the development of the Olympic Park.

An appointed board comprising industry leaders with skills across community engagement, public service delivery, and business, marketing and finance, oversees the delivery of the LLDC's business plan and strategy.

LLDC has been responsible for the long-term planning, development, management and maintenance of the Olympic Park and its impact on the surrounding area.

As a "mayoral development corporation," it is accountable to Londoners through the Mayor of London, and is required to work with a wide range of stakeholder organizations, including municipal authorities, and local and national sporting, cultural, business and regeneration agencies. As with many independent redevelopment vehicles, LLDC will not retain its planning and development powers in perpetuity. Its remit will change as the project reaches completion, and it will pass its planning oversight function to surrounding boroughs in 2024.

Source: Queen Elizabeth Olympic Park[10]

For large infrastructure projects that take on a specific focus (e.g. geography or community-based regeneration; remediation of large tracts of land; or transformation of assets after major sporting events), cities should also consider creating stand-alone vehicles, to offer the following advantages:

- Specialization and expertise: These vehicles can attract talent in obvious areas such as infrastructure development but also in disciplines such as infrastructure financing and sustainability.

- Long-term vision: These bodies can take a long-term view of development and infrastructure needs, independent of the shorter political cycle. This leads to more strategic planning and sustainable community outcomes.

- Flexible and timely decision-making: Freed from some of the constraints of larger government bodies, these organizations can respond more flexibly to changing market circumstances and demands.

- Public-private collaboration: Because of the above, such focused projects are viewed more favourably by private-sector partners and are better able to leverage expertise.

2 Design and procurement

The procurement process is a powerful tool for city leaders to build internal capacity while identifying social value and life-cycle goals.

Project leadership can guide materials procurement processes to prioritize sustainability standards, such as LEED, BREEAM, Envision and Buy Clean.

The design and procurement phase of an infrastructure project can be an opportunity to inject significant ambition and innovation. Given their assets, commissioning authority and procurement power, city authorities have the scope to influence outcomes in:

- Energy consumption
- Climate resilience and adaptation
- Quality of urban settings (e.g. architecture and culture)
- Circularity (at building and district level)
- Embodied carbon footprint and future impacts of replacement
- Social outcomes (e.g. delivering inclusive growth)

At this stage, project leadership can guide materials procurement processes to prioritize sustainability standards, such as LEED, BREEAM, Envision and Buy Clean.[11] Procurement may also support the use of bio-based, low-carbon alternatives, and recycled materials, or may prioritize local supply chains (e.g. Buy America).[12]

Design and procurement can be key to the life-cycle approach: procurement and performance standards help ensure not only the long-term sustainability of the asset, but its anticipated lifespan. For the recent Samuel De Champlain Bridge project in Montreal, Canada, for instance, the design life of the materials was set at 150 years, with performance standards accommodating up to 60 million vehicle crossings on the bridge per year. This helped ensure that materials used to construct the bridge would be appropriate for its use and lifespan, and reduced the risk of unforeseen capital outlays over the course of its life.[13]

Tenders may also include performance requirements to meet standards such as those set out in Singapore's "Building & Construction Authority Green Mark Scheme".[14] The Green Mark awards a green standard to buildings that use sustainable materials, but which also meet performance requirements for water and energy consumption during the building's operation. It incentivizes developers and government agencies to consider the long-term environmental impact of projects at the outset of project planning.

The development stage of an RFP allows for the consideration of the whole life-cycle approach and to identify possible positive and negative externalities (e.g. quantifying and reducing embodied carbon within infrastructure design and estimating the carbon footprint across the full asset life cycle). Such externalities can carry long-tail risks that outweigh benefits, which emphasizes the importance of engagement and market shaping exercises with investors to assess feasibility.

Given the novelty and complexity of emerging disciplines like circular construction, city commissioning authorities may wish to seek out opportunities for research and capacity building with industry and knowledge institutions to better identify these emerging opportunities and risks.

BOX 4 **Including social outcomes in procurement: U.S. Bank Stadium, Minneapolis, United States**

The state of Minnesota has set ambitious goals for the inclusion of more women, minorities, veterans and lower-income residents in large infrastructure developments to ensure equitable access to procurement opportunities in state-funded contracting and construction.[15]

The Minnesota Sports Facilities Authority, which owns and operates the U.S. Bank Stadium, implemented several initiatives aimed at promoting inclusion throughout its design, construction and operation. The authority set these out in an equity plan.

Using the plan's procurement framework and with support from specialized employment assistance organizations, the stadium development sought to provide employment and equal access to labour market opportunities and establish goals for contract awards to minority groups.

In compliance with Minnesota statutes, the authority applied inclusivity targets to integrate women and minorities in the workforce and involve businesses owned by women and minorities in the design and construction of the stadium. Contractors, subcontractors and vendors had to comply with data requests, which were then monitored by the authority, the City of Minneapolis and other government agencies.

The project exceeded its targets, achieving greater integration of women and members of minority groups, as well as veterans and low-income residents.

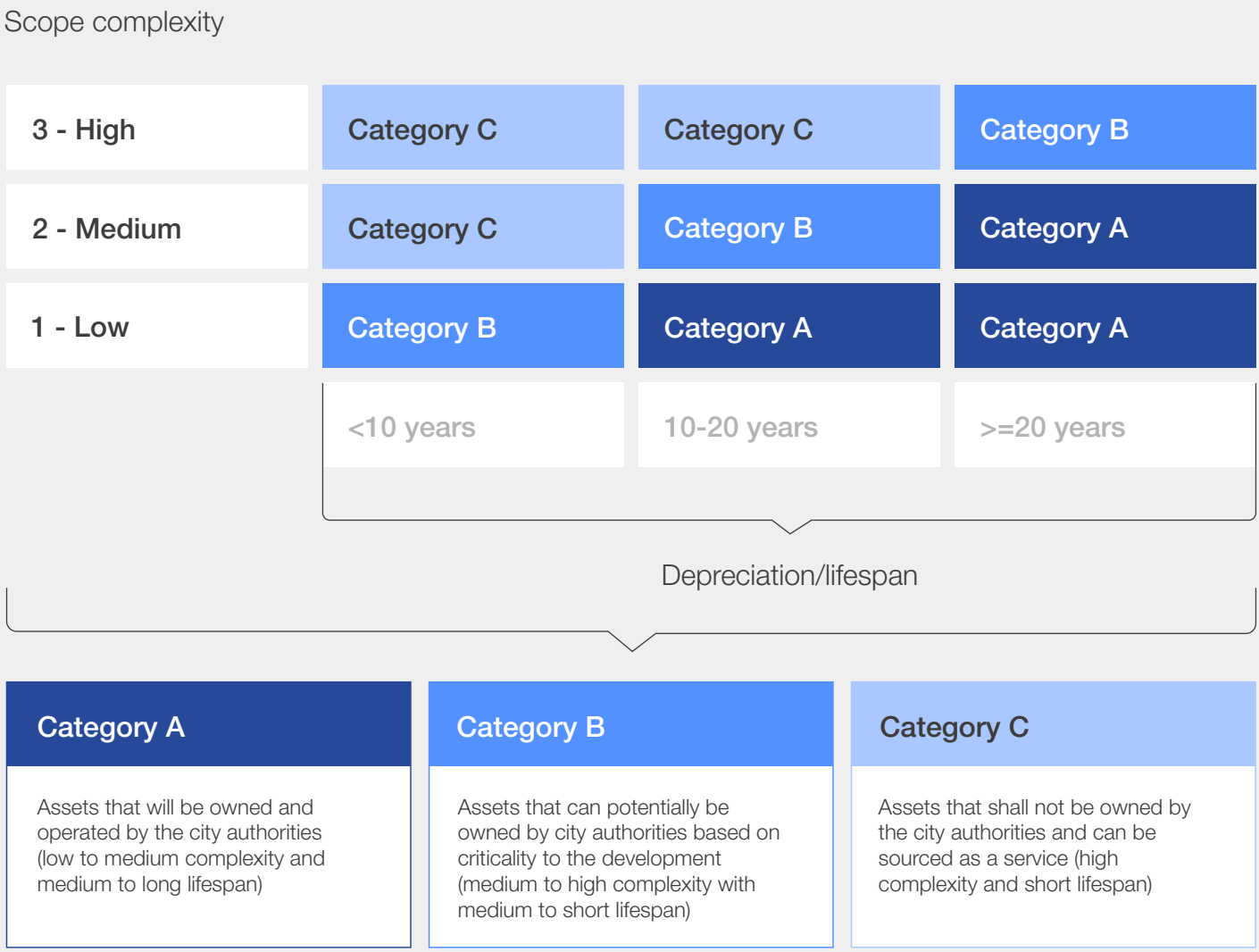
Source: Global Infrastructure Hub[16]

3 Commissioning and delivery

There are numerous models for infrastructure delivery, each solving for different goals and risk factors.

City authorities have a range of commissioning and delivery models to consider, the final choice of which depends on project vision, size, aims and wider context. Public entities should encourage potential developers and partners to also consider delivery methods and provide them with their view of short- and long-term benefits of adopting new approaches. City authorities can explicitly and intentionally encourage approaches that have a greater focus on the total life cycle, and within this, a total cost of ownership (TCO). Investors consider several factors – related to supply and demand, the nature of assets (criticality, lifespan and operational complexity) and market response.

FIGURE 2 **Example approach to categorizing infrastructure and consequent delivery models**



Source: Parsons Corporation, 2024.

FIGURE 3 | **Project factors and their influence on market scaling**

Streamlined market scaling	Factors	Enhanced market scaling
Small	Scale of project	Large
Few	Similar examples in local market	Many
Low	Degree of complexity and innovation	High
High	Certainty of market interest, capacity and competitiveness	Low
Unlikely	Need to form partnership or consortium	Certain
High	Public authority knowledge and experience	Low

Source: Parsons Corporation, 2024.

Who owns and operates infrastructure assets – now and in the future – can influence how their lifespan is calculated and the overall project complexity. Mixed ownership or infrastructure-as-a- service models generally have greater complexity, and require more highly skilled personnel and technical expertise for project delivery. Project directors can evaluate their projects according to the categories described in Figure 2, to anticipate the investment and technical skillsets that will be required to deliver the final product.

City authorities may also wish to evaluate the current capacity in the market to avoid single-source supplier or non-competitive bid scenarios. The authorities must effectively understand if and how they can scale the market, based on a combination of potential factors, which will streamline or enhance market scaling.

Factoring in funding and financing considerations will enable an optimized choice from a possible range of delivery models.

TABLE 1 | **Choice of delivery models**

Model (lower to higher complexity)	Main characteristics	Distinguishing features	Description of roles (of industry and investor)
Engineering, construction and procurement (ECP)	A contractor is responsible for the entire project, from design to construction. Contractor manages supply chains and construction.	Ready-to-operate infrastructure is handed to the commissioning body. Responsibility for time-bound delivery and main risk lies with the EPC contractor.	Industry: Well-known process, eliminates long-term risk. Investor: Less upfront risk, but does not provide assurances for long-term performance.
Two-stage early contractor involvement (ECI)	A contractor is appointed at an initial stage of the project based on an outlined scope of work.	The contractor undertakes pre-construction services, with the intention that the parties will ultimately enter into a lump-sum contract, or a cost-reimbursable contract with a target price, following a period of negotiation.	Industry: Emerging process, reduces procurement time. Investor: Balanced cash-out, main risk is limited getaway options in case of non-performance.
Design, build and operate (DBO)	In an integrated approach, the private sector entity hands over responsibility at the end of a specified operating period.	The entity undertaking the project manages design, construction and operational risk, and assumes accountability throughout the project life cycle.	Industry: More risk and responsibility, but more flexibility at all stages due to prolonged ownership of asset.
Design, build, own and operate (DBOO)	The contractor owns the infrastructure and operates it.	The entity undertaking the project manages design, construction, upgrades and operational risk, and assumes accountability throughout the project life cycle.	Industry: Emerging process for short lifespan assets. Investor: Balanced cash-out. Main risk is having no control over the technology deployed.
Build, operate and transfer (BOT)	The private sector entity hands over responsibility for the asset at the end of an agreed (shorter) operating period to the contracting entity. The private sector recovers its investment and makes profit through revenue streams.	Risk and revenue sharing can help attract private investment and ensure viability. Performance incentives and penalties encourage efficient operation and maintenance.	Industry: Similar to BDO, but has a shorter term of responsibility, which could affect long-term durability. Investor: Has multiple joint-investment options for shared cost, which can lead to better overall product.
Public-private partnership (PPP); DBFOT – Design, build, finance, operate and transfer	Shared risk, based on competencies across building, maintenance and operations; transfer of responsibilities in operation to the private sector; model may include performance-based payments that are linked to KPIs; financing models may include private equity.	Knowledge transfer; introduction of future innovation; strongest consideration of operating costs and sustainability.	Industry: Ideal for long-term relationships where there is a desire to work with the client/owner and have future opportunities beyond the current project. Investor: Considerable resources dedicated from both sides for viability of long-term success. Can also transcend shifts in personnel and involve more stakeholders.

4 Operation and maintenance

Including O&M in initial project funding and financing, as well as in the design and construction phases can ensure optimal asset management.

Cities can improve outcomes by actively using asset management plans to oversee the operation and maintenance (O&M) of assets under their ownership or control. These plans can be developed for all assets that cross the capitalization threshold set by the city and would obviously vary based on the relevant accounting standards and organizational policies. There is also the option of including assets that fall below the threshold, but which – based on professional judgment – are critical to city operations and service delivery.

The life-cycle approach moves the development of these plans to the beginning stages of the project development cycle: operation and maintenance plans are built into initial project funding and financing, and are considered through the design and construction phases to help ensure that the asset is maintained well. Even so, asset management plans need to be re-examined and updated regularly to ensure the ongoing health of infrastructure assets.

BOX 5

Operation and maintenance strategies: The City of Calgary's Corporate Asset Management Plan, Canada

The City of Calgary produces a publicly available Corporate Asset Management Plan – a long-term plan created to promote and improve the practice of asset management, and ensure that the city is meeting service levels and mitigating risk across its CAD 100 billion of infrastructure assets.

The document features a snapshot of the overall trend of asset conditions and sets out an infrastructure gap of CAD 7.2 billion (the difference between investment needed to meet desired service levels and mitigate risk and the resources available to address those needs).

An analysis of asset risk (condition and criticality) by infrastructure type (e.g. affordable housing, roads, bridges and tunnels, and water infrastructure) sets out priorities for business case development and investment by tax- and self-funded categories.

The plan also features wider contextual risks, such as climate-related impacts for the short, medium and long term (e.g. acute and disruptive impacts such as flooding and more gradual effects of shifting temperature patterns). Investment strategy recommendations (e.g. seeking alternative forms of funding opportunities) are also put forward.

Source: City of Calgary[17]

Asset management plans should be revisited and updated at least every five years, with special consideration given to:

- Projected versus actual asset utilization.
- Projected versus actual "wear and tear" on the asset (and any influence due to changes in conditions such as climate and population).
- Upgrades, retrofits and digitalization.
- Additional or updated policies and regulations that may require new operations and maintenance plans.

Systemic processes that will enhance asset management and planning can include:

- Collection, accuracy and use of asset data to monitor and predict usage, performance and resilience.
- Use of criticality models to evaluate the importance of infrastructure assets to wider infrastructure, city services and systems.
- Integration of whole-of-life-cycle approaches and financial strategy to ensure return on investment, cost-effectiveness of operations, meeting of budgetary targets, as well as to inform the broader capital investments programme.
- Service levels and performance to ensure reliability, quality (including user needs), sustainability and resilience.
- Adoption of standards and protocols for condition assessment.
- Use of risk models or systematic approaches to pinpoint and analyze the severity of risk events such as the impact of physical climate risk on capital and operating costs, and transition risks (such as market, policy and legal, reputation and technology risks).
- Innovation (e.g. the use of artificial intelligence for predictive maintenance).

BOX 6 **Physical, financial and transition risks**

By 2050, the physical risks posed by climate change could reduce the value of infrastructure assets by up to 27%.[18] Most infrastructure assets that have been assessed by GRESB (formerly the Global Real Estate Sustainability Benchmark) have a systematic process for identifying physical risks (88% of reporting assets) and for assessing their material financial impact (78%). They also have a systematic process for identifying transition risks (84% of reporting assets) and their material financial impact (77%).[19]

Overall, policy and legal risks were the most commonly identified transition risks, together with market risks. Among the assets with a process for identifying transition risks, 85% identified a policy and legal risk. This risk most commonly relates to enhanced obligations for emissions reporting, as well as mandates and regulations on existing products and services.

Source: Global Infrastructure Hub Monitor 2023[20]

5

Repurposing and end-of-life decommissioning

For cities to reduce construction waste, a circular marketplace needs to be developed.

Nearly 600 million tons of construction and demolition (C&D) debris were generated in the US in 2018 (latest data); 90% of this was from demolition; less than 10% from construction. Just over 455 million tons of C&D debris were directed to next use and just under 145 million tons were sent to landfill. Aggregate was the main "next use" for the materials in the C&D debris, meaning that only a small share was truly recycled and reused, necessitating production of new material for new projects.[21]

The need to reduce construction waste and advance more sustainable approaches is clear – but considering reuse and end-of-life at the project's inception is also useful for planning purposes both within and beyond the scope of an infrastructure project. How and when is an asset going to need to be decommissioned or rebuilt is an important factor in capital planning, while a decommissioned asset may be able to provide useful resources to surrounding communities. For instance, an abandoned train track can be converted into a recreational corridor, and a pier can be used as a green market.

Strategies for the circular economy and sustainable infrastructure

Some city authorities have established circular economy strategies. Amsterdam has set out the ambitious target to halve the use of primary raw materials by 2030 and reduce CO_2 emissions, on the path to becoming entirely "circular" by 2050. Such strategies are heavily dependent on cooperation (e.g. with the construction industry supply chain and from city residents themselves), and thus require significant political leadership, with the city authority taking responsibility for changes of use for public spaces and buildings, and adaptation of wider urban infrastructure.

BOX 7 | **Circular infrastructure: Amsterdam's circular strategy (2020-25), Netherlands**

Long known as a thriving, equitable city that proactively embraces progressive policies, Amsterdam has produced a "circular strategy" focusing on three main areas – food and organic waste, consumer goods and the built environment.

For the latter, the city council's significant role in spatial planning and granting of permissions for construction and demolition allows it to propose more extensive policy interventions than for the other two areas. To encourage new circular developments, the strategy states that the city is considering the expansion of or changes to financial instruments such as land prices, fees and levies.

The full array of policy instruments used by Amsterdam for the built environment are organized under three main headings:

Regulatory and legislative instruments 	**Regulations**	Strategy and objectives Spatial planning Environmental assesment and permits Monitoring and enforcement
	Legislation	Prohibitory provisions Performance standards Technical standards Labels Other legislation
Economic instruments 	**Fiscal frameworks**	Positive financial incentives
	Direct financial support	Subsidies Circular procurement and infrastructure Debt financing
	Economic frameworks	Tradable permits Strong producer responcibility Public-private partnership
Soft instruments 	**Knowledge, advice and information**	Research activities Educational programmes Information campaigns Capacity building
	Collaboration platforms and infrastructure	Data and information exchange platforms Matchmaking platforms Participation platforms Living labs
	Governance	Institutional design Public-private partnerships Voluntary agreements Lobbying

Source: City of Amsterdam[22]

The City of London, through the Greater London Authority's London Plan Guidance, asks for "circular economy statements" with planning applications. These are intended to demonstrate how a development (including public realm and supporting infrastructure) will treat building materials as resources rather than waste and incorporate circular economy measures into all aspects of the design, construction and operation process. This will help to ensure that applicants seeking planning permission consider strategies to facilitate the transition towards a circular built environment and are able to report against quantifiable targets that facilitate monitoring of waste and recycling.

> Data is emerging as a useful tool to overcome information gaps in the current and future availability of demolition materials, and to encourage their reuse.

Policies for decommissioning and repurposing

To maximize reuse and circularity, city authorities should consider adopting guidelines for how infrastructure is decommissioned and repurposed. City authorities such as those of Hamburg, Germany, have advanced guidelines to ensure that repurposing is prioritized, and that disposal of materials is carried out in the most sustainable way possible.

Guidelines can cover the following:

- Vertical infrastructure (e.g. buildings and bridges built with a specific purpose, sometimes serving as landmarks in urban settings).
- Horizontal infrastructure (e.g. ground-level assets including roads, railways, airports and ports, essential for the movement of people, goods and services).
- Utility assets (e.g. water, electricity, gas, water and telecommunications infrastructure, critical to daily life, business and industry; often found underground or within buildings).

For both new and existing assets, city authorities should consider including the following in decommissioning plans:

- Criteria to identify material for reuse, recycling and responsible disposal.
- Guidelines to ensure compliance with regulatory and environmental standards.
- The parties responsible and reasonable timelines.
- Environmental impacts to assess the viability of restoration of the site and the wider area.

For both new and existing assets, the following should be considered in repurposing plans:

- Criteria that qualify "magnetic spaces" (i.e. those that attract community gatherings).
- Potential alternative uses (planned or unplanned at construction) for the infrastructure and occupied space.
- Potential impacts of not repurposing the infrastructure and leaving it abandoned or in disrepair.

Reimagining entirely new uses

A growing number of cities and private-sector partners are using economic planning and investment approaches to deliver long-term community impact (e.g. the Berlin Tegelhof Airport in Germany is being transformed into the "innovation campus" of the Berlin TXL research and urban technology park, and the Greek capital Athens' abandoned "ghost airport" is evolving into a new urban cluster, the Ellinikon). Working around solid design principles that encourage inclusion, sustainability, resilience and distinctiveness can help de-risk and increase the chances of long-term positive impacts.

Data

Data is emerging as a useful tool to overcome information gaps in the current and future availability of demolition materials, and to encourage their reuse. Amsterdam is developing the "Amsterdam Circular Monitor" to understand the flow of materials through the Amsterdam economy and their environmental impact. Helsinki is embarking on a data collection and publishing effort, so that operators planning new infrastructure can take into account the materials available for reuse and repurposing.

BOX 8

Data to support reuse of materials in the Vattuniemi district demolition, Helsinki, Finland

The city of Helsinki has developed an innovative approach to the decommissioning of 16 dilapidated office properties in Vattuniemi district, an area that has evolved over the last century from an industrial district to a residential one. Under Helsinki's broader pursuit of circular economy strategies, the aim is to re-use as much of the demolition material as possible – preferably as it is – in future construction.

To promote behaviours in the supply chain that follow the circular economy model, information about materials gathered through demolition surveys has been compiled, analysed and harmonized on a shared digital platform. This information can be taken into account when planning new construction or passed on to operators in the building products industry.

The large size of condemned properties equates to large amounts of potential reusable materials (estimates run to 170,000 tons of concrete, or 3,400 lorries full). The usefulness of efforts to manage, analyse and share data with different operators will be evaluated.

Source: Testbed Helsinki[23]

5 Gearing up a city administration for optimized whole-of-life-cycle infrastructure management

New innovations such as digital twin technology are enabling life-cycle management across city departments.

The size, budget and prescribed powers of city administrations will vary and have a bearing on what is possible in local contexts. That said, there are clear pointers about how positive political and managerial cultures, professional skill sets and use of data and digital technologies can support whole-of-life-cycle approaches to infrastructure planning and management.

Collaborative frameworks

Collaborative governance frameworks are shown to lead to proactive planning across city government departments and the identification of shared future infrastructure priorities. Ambitions are ideally set out in a city plan or strategy that is the result of expert consultation, community engagement and political agreement.

These city-level priorities can then be integrated into individual departments' programmes of works, while vehicles (e.g. a city infrastructure board) are set up to connect departments at various levels and drive coordination.

"Win-win" models for jointly funded projects that are aligned with city-level objectives can be incentivized and supported through pooled budgets, and with a centralized approach to programme and project delivery that focuses on how collaboration drives outcomes over the longer term.[24]

BOX 9

City of Vancouver's collaborative approach to infrastructure

Vancouver has spent many years developing a governance model that increases collaboration around infrastructure, encourages joint funding of projects, and spurs future engagements across the board. The steps Vancouver has outlined for collaborative governance are as follows:

1. Establish and integrate city-level priorities into all departmental plans and programmes using a "layered" system, referencing an overall city-wide vision.
2. Connect departments at multiple levels, specifically at the director level, ensuring consistency, collaboration and coordination throughout.
3. Explore and implement collaborative delivery models that align with citywide targets and objectives and may lead to stronger performance in the long term.
4. Create a centralized approach for programme and project delivery, focused on outcomes and on ensuring that collaboration yields desired outcomes in the long term.
5. Instil a culture that can adjust, evolve and input feedback from all stakeholders to decrease chances of failure.

This process is anchored in the overall citywide vision and land-use strategy, the Vancouver Plan.

Source: World Economic Forum[25]

> Procurement requires an ability to design and commission outcomes deep into the operations and end-of-life phases of infrastructure, rather than just for the completion of the built asset.

Organizational capabilities

In some cities, a deputy mayor or "tsar" for infrastructure provides prominent leadership. The key function of this entity is twofold: first, to streamline and expedite inter-agency coordination; and second, to work with voluntary boards representing infrastructure builders, investors, utility providers, other tiers and relevant agencies of government, whose main role is to coordinate around the future development and financing of infrastructure. Decisions on infrastructure investment and management may be taken by an internal, formal board that has senior political and managerial representation from within the city authority.

City authority core staffing arrangements have tended to be stronger in the domains of policy, project management, procurement and commissioning of physical and social projects. As the infrastructure sector evolves, new roles and capabilities will emerge. Across the whole-of-life-cycle approach, experience in the following domains could prove valuable:

- Cost estimation and business case validation.
- Knowledge of capital markets (e.g. developing investment proposals; to include advanced approaches to risk assessment and a range of valuation methodologies such as discounted income methodologies).
- Working with investors and infrastructure providers on long-term strategic asset management.
- Management of partner roles across the range of commissioning and delivery models.
- Data and digital tools to capitalize on the digitalization of assets and to consider how to monitor and report on KPIs based on environmental and social outcomes, which should increasingly feature in whole-of-life-cycle contracting arrangements (see below).
- Cyber security to account for the increasing presence of digital technologies in infrastructure and the risk this poses to security and privacy.

Specific areas of existing domain expertise should reorient around key concepts of whole-of-life infrastructure management. Increasingly, procurement requires an ability to design and commission outcomes deep into the operations and end-of-life phases of infrastructure, rather than just for the completion of the built asset.

BOX 10

Data innovation for better infrastructure planning and maintenance, London, UK

The London Infrastructure Mapping Application (IMA) is a digital mapping tool that displays growth and development data, future infrastructure investment data (over a time frame of six months to 30 years for more speculative and larger infrastructure development), and other contextual information relating to growth.

The IMA can be used as a collaboration tool so that street projects can be coordinated and dug once only. Complex underpinning data models mean it can also be used to visualize and summarize the scale, scope and status of infrastructure and construction projects in the planning and construction phases in a specified area. This allows a range of public authorities to build understanding and identify possible future sites for infrastructure development, which in turn drives investor confidence.

Two forms of the IMA are available – a public version of the site containing less sensitive data; and a private version containing more sensitive data that can be accessed by local authorities and infrastructure and transport providers under a non-disclosure agreement.

Source: City of London[26]

Enhancing the evidence base for infrastructure prioritization

City authorities have access to a range of established statistical sources from which to gain insight into their spatial, economic, employment and demographic growth. Cities are also increasingly able to access data on projected housing growth and transport ridership. Incorporating novel forms of data may augment the quality of decision-making about infrastructure (e.g. telecom data to measure footfall, financial data to measure economic performance and digital media data to understand community sentiment).

Digitalization of assets and the growing influence of data platforms allows for the presentation of existing infrastructure and pipeline projects across whole jurisdictions. This can include information on the funding and planning status of planned infrastructure developments, as well as performance data for existing infrastructure. Such initiatives involve complex stakeholder engagement and need to be underpinned by solid data governance, but they offer the opportunity to identify overlaps or gaps in future plans and to determine opportunities to deliver infrastructure jointly and at pace.

As digital and computational twin technologies become more commonplace and able to operate at a city-systems level – that is, incorporating transport, housing, utilities, etc. – and also cover cross-cutting themes such as resilience and carbon reduction in real time, city authorities will have faster and better tools available to integrate the operational and strategic insights generated into budgeting, community engagement and decision-making.

Political support – Executive orders

Political support, and reducing the impacts of political cycles, is a critical element in infrastructure delivery. **Appendix 1** of this policy roadmap is an executive order for advancing a life-cycle approach to infrastructure; it is a template for mayors and city leaders to adapt and adopt. It is principles-based and asks that commissioning authorities consider the life-cycle approach to infrastructure. This template can be used and further developed to help inform and advance the life-cycle approach, and to improve infrastructure funding, planning and delivery.

Conclusion

Infrastructure is a powerful engine for economic growth: its multiplier effect on local economies is 1.5 times the initial investment within two to five years – much higher than other forms of public spending.[27] Infrastructure is also critical for delivering high-quality built and natural environments, healthier communities and social equity. But it is also expensive to build, complex to deliver, and requires ongoing planning and investment in its operation and maintenance to be successful in the long term.

New approaches to planning and delivery will be critical to closing the infrastructure investment gap, and to the future prosperity of communities.

The life-cycle approach is one tool that cities can use to deliver more effective, durable, well-maintained and sustainable infrastructure.

This policy roadmap is a practical framework for city leaders and for infrastructure practitioners. Hopefully, they will continue to evolve and advance this approach to improve infrastructure delivery and operations; build trust between the public and private sectors; and raise the quality of life for populations around the world by ensuring that the infrastructure that supports their lives is of the highest quality from its planning and design through to the end of life.

Appendices

A1 Executive order template

Urban Infrastructure Life Cycle – City Executive Order Template

City of [City Name]

Executive Order No. [Year]-[Order Number]

An Executive Order Establishing a Life-Cycle Infrastructure Approach

WHEREAS, our city faces the critical challenge of maintaining and improving infrastructure to support the needs of residents and ensure their future wellbeing and prosperity.

WHEREAS, traditional infrastructure development models often focus on initial construction costs, neglecting the long-term needs of infrastructure assets, including ongoing maintenance and eventual repurposing.

WHEREAS, the complexity of infrastructure projects, involving multiple stakeholders and lengthy development timescales, can hinder efficient delivery and create long-term budgetary challenges.

WHEREAS, a comprehensive life-cycle approach to infrastructure management, considering the entire lifespan of an asset from inception to decommissioning, has the potential to improve efficiency, cost-effectiveness, and long-term utility and sustainability.

NOW, THEREFORE, I, [Mayor Name], Mayor of the City of [City Name], by the authority vested in me by the City Charter, do hereby order as follows:

Section 1. Establishment of life-cycle approach to infrastructure

There is hereby established a Life-Cycle Approach to Infrastructure. In order to better enact best practices in an end-to-end, or life-cycle approach to infrastructure planning, delivery, maintenance and decommissioning, I hereby establish a task force to advance this approach across agencies, departments and authorities.

Section 2. Composition of the task force

The task force shall be composed of the following members:

- A representative from the City Department of Public Works (Chair).
- A representative from the City Department of Finance.
- A representative from the City Planning Department.
- A representative from the City Engineering Department.
- A representative from the City Sustainability Office.
- Three (3) representatives from the private sector with expertise in infrastructure development, financing and life-cycle management.
- Two (2) representatives from community organizations.

The Mayor may appoint additional members to the task force as deemed necessary.

Section 3. Duties and responsibilities of the task force

The task force shall:

- Conduct a comprehensive review of existing infrastructure development and management practices in the City of [City Name].
- Research and analyze the benefits and challenges of implementing a life-cycle approach to infrastructure management.
- Identify potential models for life-cycle infrastructure management that could be adapted for use in the City.
- Develop recommendations for improving infrastructure delivery across all phases, from planning and design to construction, operation, maintenance and end-of-life re-purposing.
- Develop strategies for integrating long-term maintenance and operational costs into capital planning.
- Recommend potential financing mechanisms to support a life-cycle approach to infrastructure management.
- Engage with stakeholders, including City departments, residents and the private sector, to solicit input and feedback.

– Submit its findings and recommendations for implementing a life-cycle approach to infrastructure management in the City of [City Name] to the Mayor and [City Council] for review and adoption.

Section 4. Reporting and Recommendations

The task force shall submit its findings and recommendations to the Mayor no later than [Date - Six Months from the date of enactment]. The findings shall be made available to the public on the City website.

Section 5. Severability

If any provision of this Executive Order is held to be invalid or unenforceable, such provision shall be struck and the remaining provisions shall remain in full force and effect.

Section 6. Effective Date

This Executive Order shall take effect immediately.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the Seal of the City of [City Name] to be affixed this [Date] day of [Month], [Year].

[Mayor Name]

Mayor

[City Seal]

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