European Commission

INTELLIGENT CITIES CHALLENGE

TWIN TRANSITION OF CITIES:

TRACKING LOCAL PROGRESS AND IMPACT THROUGH KPIs

The European Commission's 100 Intelligent Cities Challenge

An initiative by **EISMEA** and **DG GROW**

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LEGAL NOTICE

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ISBN 978-92-9469-581-9 *doi:10.2826/877622* *EA-04-23-659-EN-N*

Prepared by technopolis group ARUP

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1 About the Intelligent Cities Challenge

The Intelligent Cities Challenge (ICC) is a European Commission initiative that brings together a network of 136 European cities and supports them in their transition towards an inclusive, green and digital economy. The ICC is based on an action-oriented and collaborative approach, and the initiative encourages the participating cities to become the leaders of their own transformational growth, by developing locally actions adapted to each city's context and ambitions.

In the first phase of the ICC, cities built their actions around five overarching thematic tracks, central to the ICC: '*Citizen participation and the digitalisation of public services*', '*Green economy and Local Green Deals*', '*Upskilling and reskilling*', '*Supply chains, logistics and the economics of mobility*', and the '*Green and digital transition in tourism*'.

The ICC actions are aligned with the objectives of the EU's new Industrial Strategy and its priorities for the European industry. **Achieving global competitiveness, climate-neutrality and digital leadership**[1] are at the core of ICC cities strategic visions and ambition statements.

The importance of having the necessary skills in particular, for SMEs to adopt advanced technologies and play a key role in the twin transition, is equally an aspect that is covered in the ICC and pursued as a central topic of at least 26 ICC local initiatives. As highlighted in the European Commission Communication on our European Growth Model[2]: "*The transformation of the European economy will only succeed if it is fair and inclusive and if everybody can gain from the opportunities the twin transition brings*".

The twin transition is at the core of the ICC and central to the European Agenda, as reflected in the EU new Industrial Strategy[3], the EU Digital Decade's founding principles[4], and the European Green Deal[5]. **Digital technologies** are catalysers for the green transition **and have the potential to support sustainability, energy-efficiency, and industrial transformation**. The Joint Research Centre draws attention to the key role of cities in this system[6]. It presents smart cities as a solution to reduce CO_2 emissions in a holistic manner, by using ICT technologies and data analysis for optimisation and systems management, for monitoring and tracking, for simulation and forecasting – notably with the development of a city Digital Twin– and for virtualisation. These guidelines are fully aligned with the initiatives developed by the cities in the frame of the ICC project.

1 *European Commission, 2020. European Commission Communication – A New Industrial Strategy for Europe.*

2 *European Commission, 2022. European Commission Communication – Towards a green, digital and resilient economy: our European Growth Model.*

3 *European Commission, 2021. European Commission Communication – Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery.*

4 *European Commission, 2022. European Declaration on Digital Rights and Principles for the Digital Decade.*

5 *European Commission, 2019. European Commission Communication – The European Green Deal.*

6 *Joint Research Centre, 2022. Towards a green & digital future.*

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2 Objectives of the report

Monitoring is a key aspect when pursuing ambitious transformations, such as the implementation of initiatives that support the green and Digital Twin transition. It is essential to track progress of an initiative and to evaluate its impacts[7]. A monitoring framework typically includes Key Performance Indicators (KPIs) that cover the entire lifecycle of an initiative – inputs, outputs, results, and impacts – and that serve different stages of the policy cycle. While indicators can inform the initial situation and help target the intervention, the monitoring framework measures the progress (i.e. implementation, uptake) and the outcomes, with respect to pre-identified targets and ambitions.

In the ICC, cities developed sets of KPIs to monitor local initiatives and to measure their immediate outputs and long-term impacts. Although comprehensive monitoring frameworks have been set up by several cities, the monitoring exercise in ICC highlighted the struggle of cities to develop KPIs at the local level and the lack of resources to get inspiration from. The rationale for this report is to fill this gap and to provide concrete resources to cities including practical models and illustrative monitoring frameworks that work in practice in peer cities. Cities' needs include specific examples of computations for quantitative (often environmental) impact indicators, details on the development of qualitative indicators, and the link between both. The means used for collection of data are also relevant to this report as municipalities are interested in understanding how KPIs can be developed in collaboration with external stakeholders, including private parties, for example tele-communication infrastructures providers.

Given the increasing demand for Key Performance Indicators (KPIs), cities will require support to meet the monitoring requirements of relevant initiatives that aim to assist cities in their twin transition, addressing both the green and digital aspects. City initiatives such as the ICC also emphasise the necessity to monitor progress and impacts at the city-level. The report highlights the possibilities of local monitoring by showcasing good practices and examples from cities within the ICC network, as well as European initiatives. These examples aim to facilitate the development of Key Performance Indicators (KPIs) for cities and provide insights into effective monitoring approaches.

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7 *European Commission, 2021. Better Regulation Toolbox – November 2021 edition.*

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3 Tracking progress and impact through KPIs – the ICC approach

3.1 What to measure

In the ICC four types of measurable concepts come together to drive success: local enablers, activities, outputs, and city performance. In the context of the ICC, four types of measurable concepts play a crucial role in driving the success of cities: local enablers, activities, outputs, and city performance. These concepts are interconnected and represent the effects of cities' strategies, which can be directly or indirectly attributed to them.

These four concepts are described in *Table 1* below, while the ICC approach is further developed in *Appendix - ICC Approach to monitoring*.

Table 1: Description of ICC measurable concepts: local enablers, activities, outputs, city performance

	DESCRIPTION	EXAMPLES
Local enablers	Determinants that influence the timeframe, scale and dynamics of city strategies, often depending on the local context	• Relevant infrastructure • Trust from citizens • National regulation that facilitates the foreseen activities
Activities	City initiatives and resources mobilised for the implementation of the strategy, actions that are at the core of the city projects	• Organisation of a campaign to raise awareness • Citizen participation projects • Eco-renovation or installation of new sustainable infrastructure • Introduction of a sustainable and green financial scheme for companies or citizens • Applying nature-based solutions for new city planning projects
Outputs	Short-term products or services produced as a direct result of projects cities are running or participating in	• Increase in an observed behaviour (e.g. reduction of waste production) • Use of infrastructure (e.g. utilisation of e-bikes, better waste management schemes, increase green areas) • Change in consumption (e.g. more purchase of local products, more production of CO_2-neutral and pollutant free goods, ethical and biological food)
City performance	Outcomes: consequential effects of city initiatives on beneficiaries	Increased productivity, cost savings, efficient use of resources (e.g. water management, heat resilience infrastructure)
	Impacts: Longer-term effects on society, economy, environment that are typically changes that can only be indirectly attributed to a city's strategy	Reduction in CO_2 emissions, economic growth, job creation, cleaner air, more water efficiency, less noise, reduction in municipal waste and landfilling more biodiversity and nature in the city

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3.2 How to measure

Assessing and tracking city strategies requires the design of indicators and data collection processes. Indicators can be quantitative or qualitative and should be chosen by cities based on availability of data and appropriateness to their specific needs.

In the ICC, cities followed design criteria as guidance on how to assess the quality of individual indicators, set out as follows:

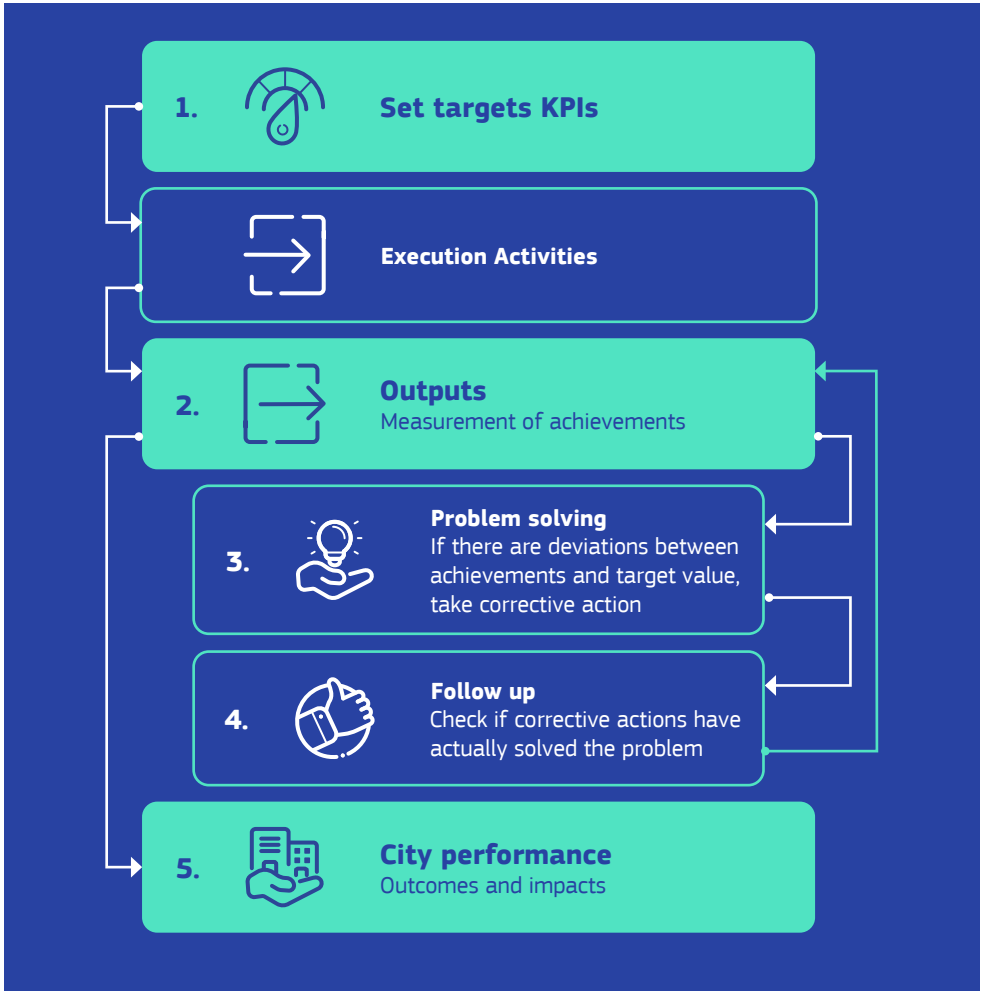
- **Meaningful:** Represents a key dimension of intelligent cities in line with policy objectives and vision;
- **Actionable:** Provides insights that helps steer corrective action, and cities have a meaningful way to influence;
- **Available:** Is accessible to city representatives or local stakeholders without substantial cost or effort;
- **Comparable:** Allows benchmarking with other (similar) cities;
- **Trackable:** Captures improvements within short timeframes (3 months to 2 years); and
- **Valid:** Ensures objective and does not include biases.

Designing and collecting the necessary data is resource intensive especially considering the need for regular monitoring over time. Three components impacting resource allocation include:

- Distinguish between **slow-moving and fast-moving indicators** with corresponding data collection plans;
- Decide the **intervals for data collection** such as data that need to be collected 'live', versus data that can be collected at specific moments in time; and
- Allocate the **responsibility for data collection**. Considerations may include long term collaborations with universities for the collection of data or via procurement.

By creating a system of indicators on enablers, inputs, outputs and city performance, cities can set up a long-term tool enabling them to work out if they are on track and what can be done if not, following four steps as illustrated in *Figure 1*

Figure 1: Problem-solving approach based on KPIs to mitigate effects of disturbances



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3.3 Measured KPIs by ICC cities

Cities need assessment methods for monitoring measures, optimising the potential for scalability, benchmarking, replication, and dissemination of their services. Assessing an achieved result facilitates the successful tracking of its progress and outcomes. It also allows for determining the overall value of the smart solution implemented. For this purpose, the development and selection of indicators for measuring the smartness of a city and the effectiveness of a project are critical.

Creating and measuring a system of indicators helps cities assessing and tracking their distance to targets and progress over time. It supports cities to address their core questions on the evolution of their performance. The table below shows examples of twin transition KPIs that were used and measured by ICC cities during the initiative. The 'where we started column' refers to the baseline situation, i.e. the situation before the implementation of the initiative.

Bratislava
Slovakia

Alicante
Spain

Métropole Rouen Normandie
France

Gdańsk
Poland

Brno
Czech Republic

Porto
Portugal

Issy-les-Moulineaux
France

Ljubljana
Slovenia

Sarajevo
Bosnia and Herzegovina

Metropolitan City of Capital Rome
Italy

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Figure 2: ICC success stories measured by KPIs – Achievements in the green transition

	Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
 **CARTAGENA** milosk50 - stock.adobe.com	**Algameca space**	**Natural space recovered**	**0**	**5,400 m²**	**12,000 m²**
 **CATANZARO** comune.catanzaro.it	**Creation of naturalistic'green road' with sea / mountains cycle path**	**Length of new cycle path**	**18 km**	**25 km**	**40 km**
		Number of citizens using the Green road cycle path	**100**	**200**	**500**

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	Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
Traffic monitoring		Citizens using means of transport other than personal vehicle	36%	40%	48%
		Bicycles available for shared services per 100,000 inhabitants	36	80	120
		Estimated greenhouse gas emissions	5,830,000 ton CO_2 (2011)	not available	4,960,000 ton CO_2 (2023)
Monitoring and promoting environmental quality		Concentration of fine particles PM2.5 / PM10	3.0 µg/m³ 7.0 µg/m³	2.8 µg/m³ 6.8 µg/m³	2.3 µg/m³ 5.9 µg/m³

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	Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
	Sustainable mobility in the city of Pescara	Mobility breakdown (Local Public Transit – Bike – Pedestrian)	10% 5% 15%	not available 6% not available	15% 10% 25%
		Number of trips in shared e-scooters per year	0	not available	500,000 trips per year
	Sofia chooses GREEN – a contest where citizens vote for sustainable project proposals put forward by citizens	Number of sustainable proposals put forward by citizens, and reach of proposals towards the population	0	20 (2021)	38 (2022) with reach of more than 200,000 (equal to around 10% of population)

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	Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
TIMISOARA	Mobility platform with objective to increase the modal share of public transport via real time data availability	% of population that uses the mobility platform	0%	0%	50%

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Figure 3: ICC success stories measured by KPIs – Digital technologies as enabler for the green transition

	Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
 Leonid Andronov – stock.adobe.com	Open sensor data on Brno data portal	Number of open datasets obtained via environmental sensors available on the city portal: cycling sensors, parking sensors, public transit positional data, WAZE data, air quality data, traffic flow intensities data	0	limited	10 datasets
 milosk50 – stock.adobe.com	Smart pedestrian areas	Sensors installed	48	60	97

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Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
E-charging stations	Number of e-charging points installed	6	13	15
	Number of vehicles using the e-charging points	54	132	187
E-bikes	Number of trips requested	3211	5433	7533
	Number of e-bikes and e-scooters available	255	288	299

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Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
Sustainable freight logistics	Number of digital parking spaces activated	2	12	32
	Decrease in atmospheric pollution	-8%	-12%	-20%
Digitalisation of car parking management through mobile revolution system	Increase of electric vehicles in the urban areas	+8%	+15%	+25%
	Number of cars using the app	15	80	300

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	Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
 GUIMÃRAES	Sustainable and smart grids & ecodigizens	Energy consumption of public buildings	99,104 GJ/m²	69,737 GJ/m²	49,552 GJ/m²
		Public buildings with installed smart electricity meters	7	14	20
 L'AQUILA	Freight consolidation center to optimise last mile logistics	Number of identified shops (for which logistics information was collected)	0	557	not available

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	Link to initiative/ strategy	KPI selected	Where we started	Midway through the challenge	Final results by the end of ICC phase 1
 MECHELEN	Digital twin	Availability of data on energy supply and demand	10%	30%	40%
		Penetration of smart energy meter throughout the city	5%	10%	15%
 TRIKALA	Common open data[8] and public consultation porta	Community engagement	not available	10% adults 5% youth	20% adults 10% youth
	Data openess	Increase of open consultations	0	+ 15%	+ 30%

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8 *E.g. network of meteorological stations with integration of Precision Agriculture application*

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4 Building synergies with existing city transformation frameworks – a selection of related initiatives and KPIs

4.1 Shortlisted initiatives aligned to the ICC thematic priorities

As smart cities are a complex concept that entails numerous interrelated dimensions, evaluating cities transformation through a common KPIs framework is challenging. There exists a range of initiatives that aim at assessing urban development from sustainability or digitalisation perspectives through different indicator frameworks. However, the need for uniform monitoring throughout Europe has led to initiatives promoting cooperation and standardisation of monitoring approaches among European cities.

With this in mind, it is important to build synergies between the ICC monitoring approach and European monitoring initiatives for smart cities. Based on the scanning of various monitoring frameworks, a shortlisted set of initiatives that are aligned with ICC in terms of dimensions and KPIs is described in *Appendix - Mapping of EU initiatives for city monitoring*. The results of this exercise emphasises the alignment of ICC dimensions with other key European monitoring frameworks for smart cities, in particular with the Smart Cities Information System (SCIS), CITYKeys, +CityxChange and Green City Accord.

4.2 Shortlisted KPIs per ICC thematic track

The monitoring frameworks of the shortlisted initiatives went through a screening exercise to extract their KPIs, which resulted in a list of 340 indicators, that can potentially be adopted by smart city projects. The full list of indicators from shortlisted initiatives is available *here*.

While each city should design a tailored system of indicators meeting its own needs, it is useful to identify a limited set of indicators to benchmark performance between cities and track their progress. In this perspective, the subsequent five tables present essential KPIs for each thematic track of ICC, linking together KPIs developed in the frame of shortlisted EU monitoring initiatives, and concrete examples implemented by cities (within and outside ICC).

The relationship between KPIs extracted from shortlisted European monitoring initiatives and the ICC thematic tracks is further explored in *Appendix - Mapping initiatives with thematic areas*. In addition to the mapping of the ICC thematic track, the 340 indicators collected have been clustered into different levels necessary for a transparent, all-inclusive, and properly defined monitoring and evaluation process. This exercise (available in Appendix as well) aims to serve as a reference for cities who need to identify the most relevant monitoring initiatives for their specific needs.

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Table 2: Government services and social connectedness – shortlisted KPIs

INDICATOR	GOVERNMENT SERVICES AND SOCIAL CONNECTEDNESS		
	Accessibility of online city services	*Use of open datasets*	*Local community involvement*
	Source: CITYKeys, LORDI	*Source: CITYKeys*	*Source: CITYKeys*
Indicator Definition	The total number of city services offered to people and businesses through an Internet interface compared to the total number of city services offered by the city	Number of applications of open datasets that are publicly available on the city website/platform	% of citizens participating in online platforms
Measurement	% share of total city services	Number of applications	% of citizens
Rationale	Digitising services increases efficiency, transparency, and resilience. It creates opportunities for innovation by connecting governments with start-ups and entrepreneurs	Open data which can be readily and widely accessed and re-used generate value for the economy and society	Greater engagement of citizens with governments helps source ideas, co-create solutions, and tackle policy problems. It also addresses issues on trust and accountability
City Example	**Thessaloniki - Digital Transformation of Municipality:** Share of municipal public services available online, share of citizens' and businesses' procedures completed online[9]	**Sofia - Open data:** 1. More/New business because of open source availability; 2. Municipal projects based on open source solutions; 3. Citizen project proposals based on open source (academia, business etc.)[10]	**Cork - Digital Placemaking Tool:** Number of users using the Digital Toolkit Webpage[11]
Level	**Output**	**Outcome**	**Outcome**
Meaningful	**High**	**High**	**High**
Actionable	**High**	**Satisfies this sufficiently**	**Satisfies partially**
Available	**High**	**Satisfies this sufficiently**	**High**
Comparable	**High**	**Satisfies partially**	**High**
Trackable	**High**	**High**	**High**
Valid	**High**	**Satisfies this sufficiently**	**Satisfies this sufficiently**

9 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Thessaloniki_0.pdf

10 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Sofia.pdf

11 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Cork.pdf

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Table 3: Green economy and local green deals – shortlisted KPIs

INDICATOR	GREEN ECONOMY AND LOCAL GREEN DEALS		
	Amount of greenhouse gas emissions	*Energy efficiency*	*Circular economy and resources consumption*
	Source: SCIS, SDGs, CITYKeys, Net Zero Cities, +CityxChange	*Source: SCIS, +CityxChange (European Green Capital Award)*	*Source: CITYKeys*
Indicator Definition	The KPI calculates the amount of emissions for six major GHGs; carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6)	This indicator assesses the energy efficiency of a system for each sector of buildings, transport, industry, public services (e.g. lighting), ICT, etc., also broken down into energy sources (electricity, heating, natural gas, etc.). The energy demand and consumption correspond to the energy entering the system in order to keep operation parameters (e.g. comfort levels)	Evolution of material consumption compared with total material consumption of previous year
Measurement	CO_2/capita per year	kWh/m² per year improved energy efficiency	Billion kilograms of material use
Rationale	Showing the greenhouse gas emissions from all activities within the city, and hence summarises the adverse contribution the city is making to climate change	Including energy efficiency measures that will reduce the overall energy demand of individual buildings (as part of the larger block)	Understanding material flows is essential to track the environmental impact caused by a city outside its territory. Reducing (primary) material consumption mitigates a city environmental footprint and can be achieved through circular economy and resource efficiency initiatives
City Example	**Trondheim – +CityxChange:** Tons of CO_2-equivalent emission reduction per year	**Trondheim – +CityxChange:** Energy Efficiency	**Amsterdam – Circular Economy Monitor:** (Evolution of) overall material use, (Evolution of) use of primary, abiotic material
Level	**Impact**	**Outcome**	**Outcome**
Meaningful	**Satisfies this sufficiently**	**High**	**High**
Actionable	**High**	**Satisfies partially**	**Satisfies this sufficiently**
Available	**High**	**High**	**High**
Comparable	**High**	**Satisfies this sufficiently**	**Satisfies this sufficiently**
Trackable	**Satisfy partially**	**Satisfies this sufficiently**	**Satisfy partially**
Valid	**Satisfies this sufficiently**	**Satisfies this sufficiently**	**High**

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Table 4: Upskilling and reskilling – shortlisted KPIs

INDICATOR	UPSKILLING AND RESKILLING		
	Digital Literacy	*City start-ups*	*Science and Technology resources*
	Source: CITYKeys	*Source: CITYKeys, European Handbook for SDG Voluntary Local Views*	*Source: Eurostat*
Indicator Definition	Percentage of target group reached by activities to increase digital literacy	Number of newly created start-ups	Persons employed in science and technology occupations (HRST)
Measurement	% share of total target group	Number per 100,000 population	Number per 100,000 population
Rationale	The expansion of digital technologies across sectors is increasing and basic to advanced digital skills are required for professionals and consumers	Start-ups are according to the European Start-up Network independent, organisations, which are younger than five years and aimed at creating, improving, and expanding a scalable, innovative, technology-enabled product with high and rapid growth. It is an indicator of economic activity and performance and indicates attitudes towards innovation and entrepreneurship	Increased need for persons employed in science and technology including scientists, engineers, technicians and associate professionals
City Example	**Ventspils - Science and Innovation Centre «VIZIUM»:** Number of adults following educational activities to improve digital literacy[12]	**Patras - Upskilling and Reskilling Academy:** Number of new start-up companies out of upskilled persons[13]	**Guimaraes - Extending digital infrastructure and services:** STEM higher education degrees per 100,000 population[14]
Level	**Outcome**	**Outcome**	**Output/Enabler**
Meaningful	**High**	**High**	**Satisfies this sufficiently**
Actionable	**Satisfies this sufficiently**	**Satisfies this sufficiently**	**Satisfies this sufficiently**
Available	**Satisfies this sufficiently**	**Satisfy partially**	**High**
Comparable	**Satisfy partially**	**Satisfies this sufficiently**	**Satisfies this sufficiently**
Trackable	**Satisfies this sufficiently**	**Satisfies this sufficiently**	**High**
Valid	**High**	**Satisfies this sufficiently**	**High**

12 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final_Deliverable_Ventspils.pdf

13 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Patras.pdf

14 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Guimaraes.pdf

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Table 5: Supply chains, logistics and the economics of mobility – shortlisted KPIs

INDICATOR	SUPPLY CHAINS, LOGISTICS AND THE ECONOMICS OF MOBILITY		
	Modal Split (Passengers/Vehicles/Trips)	*Public transport system performance*	*Access to shared mobility services*
	Source: SCIS	*Source: SCIS, SDG, (CITYKeys)*	*Source: (CITYKeys)*
Indicator Definition	The indicator determines the distribution of transport over the modalities of public and collective transport, private vehicles, biking and walking	Kilometers of high-capacity public transport system compared with number of residents	Number of e-vehicles and bicycles that are operated by shared mobility platforms compared with number of residents
Measurement	% share of modal split	Number per 100,000 population	Number per 100,000 population
Rationale	Determining the distribution of transport over the modalities of public and collective transport, private vehicles, biking and walking	Providing insight into traffic congestion, transportation system flexibility	Determining if a range of innovative mobility trends complement local public transportation such as buses and trains, even in rural regions, and support the transformation of transportation
City Example	**Groningen - Making City:** percentage of shares of different modes of transportation within the city	**Oulu - Making City:** Modal Split; Share of population with access to a public transport stop within 500 meters	**Milan - Sharing Cities:** Shared eMobility (which contains EV car sharing, eBike sharing, eLogistics, EV charging facilities and Smart Parking)
Level	**Outcome**	**Outcome**	**Outcome**
Meaningful	**Satisfies this sufficiently**	**High**	**High**
Actionable	**Satisfies this sufficiently**	**High**	**High**
Available	**Satisfies this sufficiently**	**High**	**Satisfies this sufficiently**
Comparable	**High**	**High**	**High**
Trackable	**Satisfies this sufficiently**	**High**	**High**
Valid	**Satisfies this sufficiently**	**High**	**High**

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Table 6: Green and digital transition in tourism – shortlisted KPIs

INDICATOR	THEMATIC AREAS OF ICC - GREEN AND DIGITAL TRANSITION IN TOURISM		
	Tourism intensity	*High-quality open datasets related with tourism*	*Tourism industry GHG emissions*
	Source : SDGs, CITYKeys, EU Tourism Dashboard	*Source : Ivars-Baidal, Josep Antoni et al[15].*	*Source : EU Tourism Dashboard*
Indicator Definition	Number of nights spent at tourist accommodations per capita. This indicator assesses the dependence of the local economy on the tourism activity and over-tourism	Number of high-quality open datasets related to tourism	Amount of greenhouse gas (GHG) emissions produced by the tourism ecosystem compared with Gross Value Added (GVA) in the tourism sector
Measurement	Nights spent per capita	Number of datasets	Kilograms per million euro
Rationale	Tourism intensity shows economic dependence on tourism and can reveal over-tourism and vulnerability to shocks (if high) or low attractiveness (if low). Monitoring enables cities to design measures such as the case of Amsterdam with their "Stad in Balans" catalogue	Tourism-related open data supports the tourism industry by both providing the actors with insights on their activities and customers, and by fostering the attractiveness of the city for potential visitors	The indicators shows the environmental impact of tourism, as it indicates how much carbon emissions are emitted for each million euro generated by the tourism industry
City Example	**Vratsa – Sustainable tourism:** Number of nights spent by tourists in the city, average length of stay of tourists[16]	**Heraklion – Creation of an open digital repository of Cultural and Tourist material:** Number of content items, number of end-users, number of licenses and requests for content[17]	**Granada – Refurbishment of tourism buildings to improve energy efficiency:** CO_2 emissions reduction induced by the project[18]
Level	**Outcome**	**Output**	**Impact**
Meaningful	**High**	**Satisfies this sufficiently**	**High**
Actionable	**Satisfies this sufficiently**	**High**	**Satisfies this sufficiently**
Available	**High**	**High**	**Satisfies this sufficiently**
Comparable	**High**	**Satisfies this sufficiently**	**High**
Trackable	**High**	**High**	**Satisfies this sufficiently**
Valid	**High**	**Satisfies this sufficiently**	**High**

15 Ivars-Baidal, J. A., Vera-Rebollo, J. F., Perles-Ribes, J., Femenia-Serra, F., & Celdrán-Bernabeu, M. A. (2021). Sustainable tourism indicators: What's new within the smart city/destination approach? Journal of Sustainable Tourism, doi:10.1080/09669582.2021.1876075

16 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Vratsa.pdf

17 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Heraklion.pdf

18 https://www.intelligentcitieschallenge.eu/sites/default/files/2023-04/ICC_Final%20deliverable_Granada.pdf

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City examples using KPIs to track progress and monitor impact

With the European industrial strategy, the EU has pledged to transition towards a green and digital economy, an even more competitive industry, and open strategic autonomy. While these objectives are overarching, cities are at the forefront of this transition, and there is a growing need to understand and monitor key pillars of cities' transition.

From this perspective, the city cases presented in this section focus on the monitoring of essential aspects of the twin transition at the local level – circular economy, data-driven economic growth, connectivity.

These monitoring cases are considered exemplary approaches of how cities can address their local monitoring needs – raising awareness on circular economy, supporting economic sectors, improving connectivity – in proactive and innovative ways, and with evidence of their effectiveness. They also have been selected for this report because of their thematic relevance for current and future policymakers, in diverse geographies. Given their relevance and maturity, the monitoring approaches presented have the potential to be replicated in other cities with a likely efficiency gain.

The city cases are presented according to a similar structure, starting with the general vision of the city related to the monitoring initiative and contextual elements: inputs and actors activated (resources, local stakeholders), and enablers (conditions facilitating or hampering the initiative). The initiative itself and its different activities are described in the actions section, followed by the assessment of the results in terms of outcomes and impacts. The cases conclude with key learnings shared by the local stakeholders, but key take-aways can also be found at the end of each section.

Each city case was constructed based on interviews with city stakeholders and a review of strategy documents. The ICC consortium thanks the contributors for sharing their approach, the inputs on the knowledge gained and their reflections on the recommendations. It should be noted that the monitoring practices presented in this section were developed independently of the ICC project, at the initiative of the cities solely.

Emanuel Corso - stock.adobe.com

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Vladyslav – stock.adobe.com

5.1 Circular Economy Monitor – Amsterdam

Actions

Amsterdam monitors the uptake of circular economy activities and reports about the city progress on a regular basis – two public versions of the Amsterdam Circular Economy Monitor have been published in 2020, 2022 and 2023. Besides pure measurement purposes, the Monitor shows the magnitude of the circularity issue and demonstrates the importance to put circularity at the core of the policy cycle.

The Amsterdam city team performed most of the calculations for the Circular Economy Monitor in-house. They computed the environmental footprint of material supply chains combining several data sources and methodologies and found out that food, consumption goods, and the built environment contribute most to the city's environmental footprint. They also surveyed citizens on their circular behaviors to assess the degree of circularity of different sectors and identify the main barriers to circular economy: low availability of second-hand stores, inadequate location of sharing platforms services, lack of price incentives for repair, poor perception of shared services/second-hand goods quality.

Main KPIs and data sources

- Environmental Cost Indicator (source: Idemat App public database)
- Commodity flows (source: derived from public national transport statistics (CBS))
- Supply chains environmental footprint (source: internal calculations based on two sources above)
- CO_2 emissions, split by scope (source: internal calculations based on two sources above)
- Labour market KPIs: circular employment, vacancies in the circular economy (source: web-crawling of job advertisement websites, city enterprises data)

Recommendations

Monitoring with purpose: monitoring should take place in accordance with each city's needs, objectives, and current policy agenda, and not for the sake of creating indicators.

Use actionable KPIs: measuring a performance that the city has the power/ability to influence.

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5.1.1 Vision

Amsterdam aspires to use 50% less raw materials by 2030, and to be fully circular by 2050. To reach its circularity goals, Amsterdam monitors the uptake of circular economy activities on multiple aspects, and reports on progress on a regular basis – three public versions of the Amsterdam circular economic monitor have been published, in 2020[19], 2022[20] and 2023[21]. The monitoring exercise covers all stages of a supply chain (input indicators, material use indicators, waste management indicators (both by public authorities and by industry), socio-economic indicators) and refines the measurements year after year.

Besides monitoring distance to 2030 and 2050 targets, the Circular Economy Monitor's objectives are to influence the local policy agenda and to raise awareness of circularity. While there are uncertainties in the data that can hamper the pure measurement aspect, the results of the monitor show the magnitude of the issue and demonstrate the importance of circularity at the core of the policy cycle to reach the 2030 and 2050 goals. The two published versions of the monitor have contributed to the circularity economy agenda setting. The local team focuses on policy and implementation of circular solutions. More widely, circular economy activities feed into Amsterdam's **objective of achieving a doughnut economy[22] and meeting climate ambitions.**

TAKE – AWAY

A circular economy monitoring plan designed with a longer-term perspective, directly linked to the city's vision and revisited yearly to adapt to new information and city needs.

Massimo Todaro - stock.adobe.com

19 Gemeente Amsterdam, 2020. Amsterdam Circulair Monitor.

20 Gemeente Amsterdam, 2022. The Circular Economy Monitor: An Outline.

21 Gemeente Amsterdam, 2023. Circular Economy available at https://onderzoek.amsterdam.nl/artikel/circular-economy

22 The doughnut economy model describes how societies and businesses can contribute to economic development while still respecting the limits of the planet and our society. Amsterdam doughnut economy strategy is available at https://assets.amsterdam.nl/publish/pages/867635/amsterdam-city-doughnut.pdf

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5.1.2 Inputs and actors

Several public stakeholders have a role to play in circular economy activities, where the initial impetus to analyse circular economy in the city was given by the City of Amsterdam, the Amsterdam Economic Board, and Amsterdam Metropolitan Area together.

At the initial stages of the project, the development of the Circular Economy Monitor was outsourced to a local start-up hired by the municipality, but responsibility for conducting the monitoring exercise was shifted to the City of Amsterdam after about a year. It is currently run by the city's departments of Innovation and of Research & Statistics. According to the city, it is more enriching to conduct the exercise in-house in order to retain full ownership of the decisions on the data computation – the Monitor deals with complex estimates which require a complete understanding of the figures meaning to make informed decisions. In addition, developing the circular economy in-house allows the monitoring team to interact closely with local policymakers, in particular to provide them with detailed insights and to translate technical knowledge into policy language.

The decision to run the Monitor in-house was made possible because the City of Amsterdam could dedicate sufficient resources to this. In terms of human capital, 2 to 5 FTEs have been working fully on the Monitor since it started (2020) and around EUR 300,000 per year has been dedicated to the project.

TAKE – AWAY

People within public administrations engaged in supporting decision making processes with results from the monitoring framework need to have a good understanding and control over methodological choices and assumptions which impact results.

Gorodenkoff - stock.adobe.com

5.1.3 Enablers

Building environmental estimates at the municipality level generally requires local data or to adapt aggregated data, i.e. to derive city estimates from data at national or higher levels. For Amsterdam, the availability of environmental data at the national, regional, and local level provided by the Netherlands statistics authorities was therefore very useful. In particular, to compute the commodity flows' environmental footprint at the city-level, a key input for Amsterdam was the datasets provided by Statistics Netherlands (CBS) on transport freight and commodity consumption based on local transport data (see section 5.1.4.1).

In addition, the development of Amsterdam's Circular Economy Monitor was facilitated by the Netherlands' positive culture towards circular economy – significant attention is given to the topic at the national level whereby the country has a national circular economy framework that served as inspiration for Amsterdam.

TAKE – AWAY

Cooperation with entities such as National statistical offices, universities or research centres with knowledge and data can facilitate the work and assure continuity. Also increased awareness of the general public on issues with high societal value helps prioritise and sustain monitoring initiatives.

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5.1.4 Actions

The objective of the circular monitoring is to collect enough data to track the circular economy uniformly across sectors, and to provide a complete overview of all materials flows in the city. In this perspective, Amsterdam implemented several actions to collect key data through different means.

Brother's Art - stock.adobe.com

Identification of most polluting supply chains

To maximise the impact of the circularity efforts and to raise awareness of citizens, Amsterdam aimed to **identify the supply chains that have the most negative environmental impact** in the economy, as those have a high potential to be improved by circular actions. To identify these priority supply chains, Amsterdam used advanced measurement methods that account for the hidden environmental costs and the local commodity usage. More specifically, the most polluting commodities were identified by relying on the Environmental Cost Indicator (ECI) – a composite indicator that combines eleven environmental measurements into a metric reflecting how environmentally friendly distinct materials are.

The results obtained show the environmental impact of commodities, considering their importance in the economy, and the environmental cost of the materials. In Amsterdam, food, consumption goods and the built environment are the commodities that contribute the most to the city's environmental footprint. However, their high environmental impact is due to different reasons – while consumption goods have high impact per unit but are small in terms of volume, construction materials have low impact per unit, but high volumes.

ENVIRONMENTAL COST INDICATOR (ECI) – METHODOLOGICAL NOTES

The ECI is based on Life Cycle Assessments (LCA) which includes 'shadow costs' along the entire material supply chain[23]. Amsterdam uses the data available on the public Idemat App database developed by Delft Technology University[24] that measures the environmental impact for EU products. Other databases – in general private and with charges, can provide more advanced and detailed ECI data, but Idemat is sufficient to estimate the magnitude of material footprint. The limitations of the ECI is that it represents the environmental cost of products and materials, with no model or brand distinction, while in reality these product features make a big difference in the environmental impact.

In Amsterdam's Monitor, the ECI measurement is used in parallel with the weight of the commodity flows in the total economy, as the weight of the commodity group in the total material consumption is also determinant for its overall environmental impact. Commodities are grouped in 24 commodity groups and the weight of each group in the economy is defined based on national transport statistics (freight transport of materials). Within each commodity group, an estimation weight method was applied to define the distribution of different products based on national statistics on goods consumption.

23 Ecochain, 2019. Environmental Cost Indicator (ECI) – Overview. https://ecochain.com/knowledge/environmental-cost-indicator-eci/

24 http://idematapp.com/

Consultation of citizens

Amsterdam assesses the degree of circularity of different economic sectors using the R-ladder, a qualitative barometer that defines the degree of circularity. Based on the circular economy literature, the R-ladder developed by the Netherlands Environmental Agency ranges the different circular economy strategies (R-strategies) according to their associated reduction of new resources – Refuse & Rethink, Reduce, Reuse, Repair & Refurbish, Recycle, Recover[25]. To better understand how the city could improve their performance on the R-ladder and what are the main obstacles in doing so, Amsterdam consulted their citizens through an online survey to get more information on their circular behaviours. The Research & Statistics Department of the City of Amsterdam has an established panel of 1,000 citizens representative of the population in terms of age, education, and nationality (some remaining biases are corrected through weighting), who were surveyed online.

25 PBL Netherlands Environmental Assessment Agency, 2019. Outline of the circular economy.

The consultation aimed at understanding the sustainable consumption habits and obstacles to adopting circular behaviours (second-hand consumption, use of sharing platforms, prioritising repair instead of buying new). The questionnaire contained 30 closed questions with multiple nuanced answers. An example of closed question regarding food waste is provided in *Table 7*. The results of the consultation showed that to increase the degree of circularity, Amsterdam has to address the low availability of second-hand stores, the inadequate location of sharing platforms services, the lack of price incentives for repair, the poor perception of shared services/second-hand goods quality.

Table 7: Example of question in citizens survey about sustainable consumption and circular economy behaviours

WHAT WAS/WERE THE REASON(S) WHY YOU DISCARDED ONE OR MORE PRODUCTS IN THE PAST TWO DAYS?	
Too much of the product in the packaging	Product prepared incorrectly
Too much of the product cooked	Product did not taste good
Too much of the product poured in	Leftover product no longer used
Product stored incorrectly and it spoiled	Product incorrectly transported/dropped
The expiry date had passed	Did not have time to consume the product
Other:	Do not know

TAKE – AWAY

Mixed methods including data analysis and stakeholders' consultations are required for a well function monitoring framework. Environmental measurements are data intensive and use complex methods, but existing applications and public databases can be used as basis for replication.

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kasto - stock.adobe.com

5.1.5 Outcomes and impacts

In its circular economy monitoring, Amsterdam assesses longer-term effects of the circular activities from economic and environmental points of view. It does so through a dual analysis of the labour market impact and cutting-edge computation of CO_2 emissions.

The impact of the circular economy activity on the labour market is monitored by using two different labour market indicators: existing employment and vacancies, both expressed as the share of circular jobs out of total. The use of two complementary labour market indicators brings nuance to the results. Indeed the 2022 version of the Circular Economy Monitor shows that while the share of circular jobs is 6.6% and only slightly increasing – not showing a significant role of circularity on the labour market, the share of vacancies related to circular jobs is 10% – a more promising figure indicating a high demand for circular skills and a possible increase of employment in circular sector in the future.

LABOUR MARKET INDICATORS – METHODOLOGICAL NOTE

Computing indicators on circular employment and vacancies requires to define what is a circular job. For this, Amsterdam used two slightly different methods.

For the employment indicator, a company-based approach was used: after listing the industries that are considered as circular, based on the Dutch Standard Business Categories (SBI codes, a similar system as the NACE codes widely used in EU), the share of circular employment is calculated as employment in companies in circular industries out of total employment.

The vacancies indicator is based on web-crawling of Dutch job advertisement websites. Advertisements containing any keyword from a pre-established list of circular keywords and expressions were considered as circularity-related, and the share of circular vacancies is therefore the number of circular vacancies out of total vacancies.

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shock - stock.adobe.com

By reducing the consumption of raw materials, circular activities have the potential to significantly decrease CO_2 emissions. However, tracking emissions is tedious as it requires to account for every stage of the supply chain. To better understand and monitor their CO_2 emissions, Amsterdam uses the scope categorisation of CO_2 emissions defined by the Greenhouse Gas Protocol in their Global Protocol for Community-Scale[26]. Scope 1 emissions includes emissions from the combustion of fuels, scope 2 emissions are those from the consumption of energy (electricity, heating, etc.), while scope 3 emissions comprise all other energy sources, including CO_2 emissions occurring outside Amsterdam caused by the city's consumption and production.

For the City of Amsterdam, the CO_2 emissions split shows that scope 3 emissions are by far the most important – about 78% of total emissions. To fine-tune the estimate, Amsterdam aims at quantifying the environmental pressure caused by the production of raw materials by material flow and incorporating it in the calculation of the CO_2 emissions beyond the city limits. As scope 3 emissions mostly occur upstream the supply chain, reducing the commodity flow to the city, (i.e. implementing circular activities) is even more important in order to reduce overall CO_2 emissions and reach climate targets – especially given the high share of scope 3 emissions in Amsterdam emissions mix.

26 Greenhouse Gas Protocol, 2014. Global Protocol for Community-Scale Greenhouse Gas Emission Inventories – An accounting and reporting standard for cities.

CO_2 EMISSIONS BY SCOPE – METHODOLOGICAL NOTES

The practical guidelines to compute CO_2 emissions by scope are provided in the Global Protocol for Community-Scale document by the Greenhouse Gas Protocol[27], and any city can use this categorisation to estimate the most polluting segments of its economy. In Amsterdam, the computation of the indicator was performed in-house based on data from the environmental cost calculator Idemat (same database as used for ECI). Similar to the calculation of the ECI (see section 5.1.4), the computation of CO_2 emissions by scope is dependent on the availability of data on local material flows. Amsterdam used data provided by the national statistics authorities (see section 5.1.3). However, other data sources and computation methods can be used, for example, London scaled city material flows by surveying citizens on their consumption and spending habits and estimated CO_2 emissions through input-output analyses.

27 Ibid. Available at https://ghgprotocol.org/ghg-protocol-cities#:~:text=The%20Global%20Protocol%20for%20Community,on%20city%20greenhouse%20gas%20emissions.

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5.1.6 Key learnings

Amsterdam emphasises that cities should not monitor for the sake of monitoring, but instead monitor with a purpose. Each municipality has different needs and objectives, corresponding to distinct policy cycle stages, and it is key to first identify those before developing a monitoring approach. If there is a lack of awareness and the city ambitions to show the magnitude of the problem or the importance of a policy, estimated indicators can be sufficient rather than complex, and often resource-intensive, exact measurements. In this perspective, the circular economy monitoring of Amsterdam has been extremely useful for agenda setting and awareness raising – it shows the enormous potential for the circular transition, despite using estimations.

The next step will be to track intermediate progress, and the city aims at relying more on a bottom-up measurement to achieve the most accurate measurements (in contrast to for example top-down approach to monitor material flows). Also, the effort to measure intermediate progress should be made on aspects the municipality actually has an impact on. Indicators related to the built environment, public procurement, and in-house municipality processes are easier to measure with precision at the city level, as the data usually belongs to the municipality (in opposition to indicators tracking progress in the industry for example). The evolution of Amsterdam Circular Economy Monitor illustrates how a city monitoring approach can adapt according to the needs of the city.

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To support the local economy in response to the recent crises in the retail sector

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5.2 Retail sector monitoring – Mechelen, Leuven, Antwerp, Roeselare

Actions

Together with their academic partner, a consortium of 4 Belgian cities has implemented the Data-driven shopping area project to generate data that support the retail and hospitality sector and encourage data-driven decisions in both businesses and policy-making. The project is a pilot to be replicated in other Belgian cities.

The collection of the data is supported by three external data providers (through public procurement) that provide live telecom data, sensor data and spending data. Based on this data, two dashboards have been developed: a retailer dashboard and a policy dashboard that give up-to-date information on crowd flows and spendings. In addition, the dashboards are complemented by a forecasting model that predicts visits and spending patterns, also based on local conditions.

A co-creation approach with local actors from the retail and hospitality sector has been adopted during the entire project to align to the needs of the sector. So far, their feedback was collected through survey, review of the paper prototyping of the dashboards, and consultation.

Main KPIs and data sources

- Crowd flow: Unique visitors (source: external private data provider)
- Spending behaviors: Conversion, Total transactions, Average spending (source: external private data provider)
- Visitors profile: Postal code, Type of visitor (structural/non-structural/resident) (source: external private data provider)
- Local conditions: Weather, Events (source: municipality data)

Recommendations

GDPR constraints: GDPR must be accounted for from the tendering stage as it impacts data quality and possibilities.

Consortium: Joining forces with peer cities increased transparency, cost effectiveness and potential impacts.

Knowledge transfer: As the project is aimed at being replicated in more cities, all recommendations and guidelines have been stored in a set of knowledge transfer documents.

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5.2.1 Vision

In the data-driven shopping area project, four Belgian cities - Mechelen, Leuven, Antwerp, and Roeselare[28] joined forces **to create a bustling city through co-creation and data-driven insights for different stakeholders, with the support of the research department in data driven entrepreneurship of the University of applied Sciences Thomas More.** A successful shopping area is an engine for a successful local economy. The entrepreneurs and retailers who have data are more knowledgeable of their environment and can make better decisions. With the data-driven shopping area project, the city encourages entrepreneurs to become more data-driven. Based on the needs of the retail and hospitality industry, the cities were able to identify the most useful data for the users, and how data derived intelligence can be offered in a user-friendly manner. **The objective of the consortium of cities is to provide data that is reliable, unambiguous and future-proof to the retail and hospitality industry in a user-friendly way, so that they can make more data-driven decisions.**

The project also aims at encouraging the local economy, in particular the retail and hospitality industry, into the digital era. It pushes entrepreneurs to explore data-driven business operations and decisions, and contributes to **establishing a data culture and raising interest and trust of the population for data – open data, data-based decisions in both businesses and policymaking.**

The data-driven shopping area ambition is to expand and disseminate it more widely. The current project run by the four municipalities is a pilot for a wider Data-driven shopping area project in Flanders. Mechelen, Leuven, Antwerp and Roeselare are pioneers for testing and validating the design and content of the project (in particular, the data dashboards), but the ambition is to expand the initiative and learnings to more mid-sized Flemish cities.

TAKE – AWAY

Cities can play an enabling role in the stimulation of data driven entrepreneurship in low tech sectors which are of critical importance for well-functioning local economies.

5.2.2 Inputs and actors

The Data-driven shopping area project is developed jointly by a consortium composed of four Belgian cities - the City of Mechelen, the City of Leuven, the City of Antwerp and the City of Roeselare and an academic partner, the University of Applied Sciences Thomas More. The project development requires the work of about four FTEs, and this workload is spread between the local governments of the four cities and their academic partner.

To finance its development, the Data-driven shopping area project relies on several different sources of funding from various public authorities:

- European level: The project is financed by the European Regional Development Fund, coordinated by VLAIO (the Flemish Agency for Innovation and Entrepreneurship;
- Provincial level: The two provinces where cities are located (province Antwerp and province West-Flanders) participate to the financing of the project as well;
- Municipal level: The project benefits from local investment from the four cities; and
- Academic source: Co-financing from their academic partner that supports the cities in the development of the project (Thomas More).

TAKE – AWAY

Joint projects between cities facilitate access to funding, human resources and lead to overall efficiency gains reducing risks and maximising impact.

28 Mechelen (2020) and Leuven (2028) were both winners of the European Green Leaf Awards.

5.2.3 Enablers

Public procurement through group purchase (rather than individual contract for each city) facilitated the work with the external suppliers and allowed the consortium to benefit from better contract conditions – ease of installation, timing of data delivery, support, cost, and accuracy.

Cities' **previous experience with highly data driven projects** made them more open to the Data-driven shopping area initiative, and more inclined to dedicate the necessary resources. In terms of political environment, **openness to innovation is key for implementing a local data ecosystem.**

Similarly, the **acceptance of the project by part of the retail and hospitality sector** has been an enabler allowing the consortium to develop the project together with the concerned actors. However, the degree of interest towards the project has been quite heterogenous among retail and hospitality entrepreneurs. Three main types of reactions towards the project could be observed:

- Entrepreneurs who are strongly engaged in monitoring and data represent a group with a high acceptance of the project;
- Entrepreneurs seeking inspiration and improving their activities with good practices from others represent a group with medium acceptance of the project; and
- Entrepreneurs who are critical of the added value of shopping area related data represent a group with low acceptance of the project.

TAKE – AWAY

Nurturing a local ecosystem open to innovation enables change and creates opportunities for public-private strategic cooperation.

5.2.4 Actions

Tendering for data collection

The project relies on external suppliers for the collection of the data, engaged through public procurement by issuing a group purchase. One of the key activities at the beginning of the project was the evaluation and awarding of the public tender. It resulted in the selection of **three external (private) data providers** that respectively provide (1) telecom data for crowd data; (2) sensor data for crowd data and (3) spending patterns.

Preliminary analysis and desk research

At the beginning of the project, a scoping/preparatory exercise was conducted to understand the state-of-play of the 'smartness' of the retail and hospitality sector before implementing the project. In particular, they measured the levels of crowds and spending in the cities and listed an inventory of suppliers. The desk research also summarised the smart city initiatives already implemented and identified good practices.

Consultation of the retail and hospitality sector

The ambition of the data-driven shopping area project is to support the main shopping area actors, in particular the retail and hospitality sectors, and to facilitate the development of their activities. For this reason, a co-creation approach was adopted to ensure that the project meets the needs of the sector. The retail and hospitality economic actors were involved from the design phase of the project and their feedback was collected through various means.

First, the project team circulated a survey to the concerned actors from the retail and hospitality sectors (e.g. shops restaurants, hotels) to understand their data needs, e.g. what information would be the most useful for their activities. This question was further discussed during three online workshops that went from the needs to the definition of the data fields and of the parameters.

Before the launch of the actual data dashboard, the team conducted a paper prototyping to get approval from concerned actors. Paper prototyping is a process where designers create paper versions of digital tools to improve the concept and design. They also developed a beta version of the tool that went through user testing, both in groups and individually, to ensure that the intelligence could be properly used by end-users. The user testing involved a test panel of retail and hospitality entrepreneurs per city. In addition, the consortium organised coaching sessions for the users.

The KPI that was used to monitor the co-creation approach was the number of individual retail and hospitality organisations involved in the process. In total, 230 different organisations were involved in the creation of the project, by participating in co-creative workshop sessions, surveys, and testpanels for the dashboards.

Data management

To facilitate the management and the transfer of the datasets between the consortium and the data suppliers, several digital tools were used. An automatic dataflow system was established to automatically transfer the data from suppliers to the academic partner (Thomas More), based on the Azure API. To combine the datasets of the different variables and aggregate them with local data on local weather and events, an SQL-based database was used. The two dashboards are also powered by digital software's.

TAKE – AWAY

Knowledge gained on the collection, processing, analysis and management of telecom, sensor and spending data for the retail sector can be easily transferred to many other cities with widespread impact considering the importance of the retail sector in cities.

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5.2.5 Outputs

Dashboards

Two dashboards have been developed in the context of this project with the objective to centralise and showcase the data through data visualisations. Two dashboards have been designed for specific audiences: a policy dashboard (for the city, local policymakers), and a retailer dashboard (for local entrepreneurs, especially in the retail and hospitality sectors). A 'cheat sheet' was also developed to help entrepreneurs navigate the dashboard and interpret its content, guiding them from use case and data to actionable insights. An illustration of the dashboard is provided in the next section.

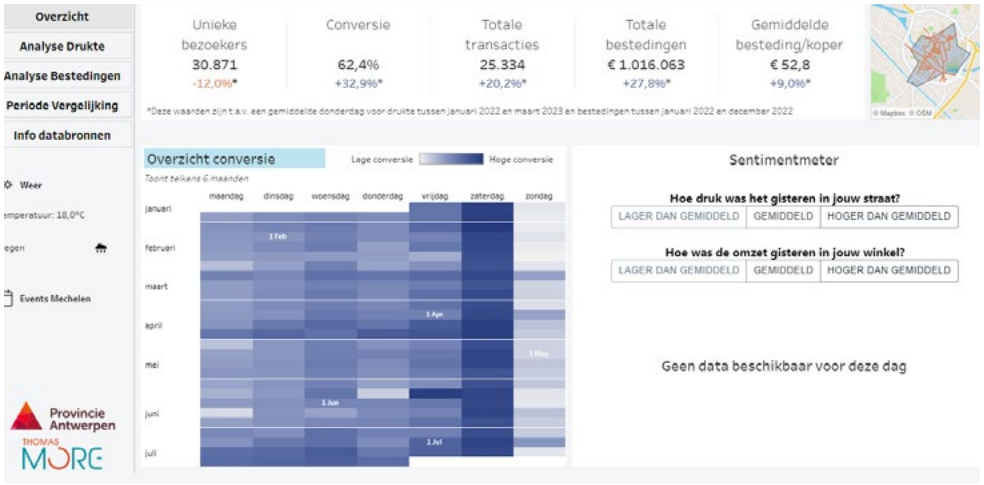
Output KPIs

The outputs of the Data-driven shopping area project are monitored in the retailer dashboard through a series of metrics that describe crowd flows and spending behaviors:

- (Evolution of) conversion in target area (visitors who purchase a product)
- (Evolution of) unique visitors in the target area (daily and hourly)
- (Evolution of) sentiment of entrepreneurs in the area
- (Evolution of) total transactions in the area
- (Evolution of) average spending per unique shopper in the shopping area;
- (Evolution of) origin of visitors (zip code); and
- (Evolution of) type of visitors (structural visitor, non-structural, resident, etc.)

Figure 4 shows how the KPIs are displayed in the dashboard and the type of information that is available at a glance. As (most of) the data is live data, the view of the dashboard updates daily.

Figure 4: Visual of the retailer dashboard



Source: Screenshot of the retailer dashboard provided by the consortium

Trends analysis

The main data analysis of the project consists in building and testing a prediction model for spending patterns. The model is based on econometrics methods – time series and prophet prediction based on historical data – and aims at forecasting the spending behaviors of the visitors of the shopping area to help the retail and hospitality sector to adjust their activity. This analysis aspires to show the impact of local events and of local weather on the number of visitors and the spending patterns.

The forecasting model has been tested and validated by the consortium, together with retail and hospitality entrepreneurs. It is used to make predictions of spending patterns (daily prediction and hourly prediction).

TAKE – AWAY

Data analysis and visualisations need to be tailored for each end user, especially policy makers and industry, accounting for their specific needs and intended use patterns.

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5.2.6 Outcomes and impacts

Long-term impacts of the Data-driven shopping area initiative are largely economic. They relate to the **preservation and development of the economic activity in the city centers, and in particular, the retail and hospitality sectors.**

Due to several factors, the retail function of inner-city centers is under pressure (e.g. popularity of online shopping, limited parking, outdated business models), further accelerated by the Covid-19 crisis. To preserve the vibrant core shopping area, parties are working to make the urban environment future-proof, livable with sustainable economic activity. As a sector, retail trade and the hospitality industry represent a significant part of the cities value added, both economically and through job creation. In addition, the sector has an accelerator effect on many other sectors such as tourism, mobility, and culture.

Monitoring the long-term effects on economic activity, and livability of the city centers is particularly complex and for this reason, the consortium has not yet developed a set of indicators assessing the long-term impacts. However, key indicators that could be accounted for are:

- **Employment and job creation** in the retail and hospitality sector
- **Added value** in the retail and hospitality sector
- **Start-up birth rate** (number of new businesses created)

TAKE – AWAY

Data intelligence is expected to play a key role in helping policy makers support local economies and industry to respond to changing consumer behaviours not just in the short term but mid to longer term.

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5.2.7 Key learnings

As the Data-driven shopping area project was developed with the ambition to be extended to more Flemish cities, thorough **recording of learnings and knowledge transfer** are key elements to optimise dissemination. The consortium has therefore developed several documents to support the cities involved in the future data-driven shopping area extension:

- An action plan with concrete advice on the implementation of the project, e.g. on the co-creation with the retail and hospitality sector, on the use of public procurement for external data;
- A report with the user test conclusions and recommendations;
- Guidelines on the implementation of the dashboard;
- A manual compiling the lessons learned; and
- An ROI-calculator to evaluate the cost-effectiveness of implementing the project based on three different scenarios.

One of the main lessons learnt from the data-driven shopping area project has been the advantages generated by joining forces with peer cities. Creating a consortium with cities increased transparency, improved the cost effectiveness of public procurement, helped leverage effects and created knowledge sharing mechanisms. A drawback is the increased administrative complexity.

The experience also showcased the importance of GDPR considering the high reliance on data for the project implementation. GDPR constraints must be considered from the outset as they affect the quality of the data and consequently the outcomes of the project.

Finally, the experience of collecting data from external providers showed that until an agreement is reached with the supplier, it is difficult to understand how the data will look (e.g. structure and content). This means that during the initial phases of the project (design, stakeholders onboarding), the outcome can still be imprecise. This can potentially be an obstacle in the activation of resources, stakeholder engagement and overall project management. Potential leads to overcome this issue are proposed in the action plan developed by the consortium, including practical advice on the information that should be covered in the tender and asked from the data suppliers[29].

Boyan Georgiev - stock.adobe.com

29 For more information: https://www.thomasmore.be/datagestuurde-winkelgebieden

To unlock the potential of digital infrastructures for tackling environmental and societal policy challenges

NatRomero - stock.adobe.com

5.3 Free Wi-Fi Network – Porto

Actions

With its project "Porto Free Wi-Fi Network", the city of Porto has addressed the most fundamental digital need of any aspiring smart city, connectivity. The city has deployed a large-scale Wi-Fi network in the city, based on routers installed on urban furniture and on the 7,564 kilometers of fibre optics network. With its wide coverage, the network fosters significantly the connectivity of citizens – which is assessed through a range of quantitative metrics, but it is also used as a way to support and monitor Porto's green transition.

The Free Wi-Fi Network is linked to a network of environmental sensors deployed over the city to record data on air quality, noise pollution and waste activity. This live tracking of environmental features allows municipality services to adjust their activities according to the situation: rerouting buses in the case of traffic jams, organizing waste collection according to the actual amount of waste. The network of sensors is powered by the Free Wi-Fi Network that provides the necessary connectivity to transmit live data to the concerned municipality services.

The digital infrastructure and related projects are fully owned and managed by Porto Digital, a unique and independent entity composed of key local actors including Porto municipality.

Main KPIs and data sources

- Deployment of the infrastructure: number of routers, access points, sensors (source: Porto Digital)
- Users profile and needs: status, interests, type of usage (source: survey to network users)
- Utilisation of the network: users, devices, sessions, uploads and downloads (source: Porto Digital)
- Environmental data: Air quality, noise pollution, meteorological data, waste management (source: environmental sensors, Porto Digital)

Recommendations

Efficient communication with municipal departments and local utility companies to ensure availability of the necessary infrastructure such as power and cabling, and coordination to avoid efficiency loss.

Adequate preparation for public tendering of large-scale projects, including **qualifying providers, benchmarking technology, selecting multiple vendors, opting for professional** and **carrier solutions, and establishing a robust architecture.**

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5.3.1 Vision

Porto's vision is that connectivity is at the core of digitalisation, and that the first step to build any digital and smart city is to connect the citizens. From this perspective, the city of Porto is developing a free, reliable, high-speed internet access that should **ensure connectivity for all citizens.** This is the most fundamental initiative to transition towards a smart city and is a key piece of infrastructure for the growth and development of a real-time city.

The development of connectivity projects in a public, free, and open manner is key to achieving an inclusive digitalisation that leaves no one behind – an aspect that is particularly emphasised in the European digital agenda[30].

At the heart of Porto's Digital mission is a focus on innovation and digital transition as the key drivers of the city's transformation. By leveraging technology, Porto Digital aims at enhancing the quality of life for its citizens and to promote sustainable development and social inclusion. Digital transformation supports the twin transition and a just transition, with policy applications of digital technologies infrastructure that go far beyond digital connectivity.

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TAKE – AWAY

The establishment of a private non-profit association working closely with the various departments of the municipality and other types of stakeholders like academia and utilities on the implementation of the vision of the city.

30 See for example Europe's Digital Decade: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

5.3.2 Inputs and actors

Digitalisation of the City of Porto is planned, coordinated, and carried out by a dedicated entity - the Porto Digital Association (also called Porto Digital). Porto Digital is composed of key local actors:

- Municipality of Porto (holds the majority position)
- The University of Porto
- Portuguese Business Association (AEP)
- Metro do Porto

Porto Digital is responsible for implementing the digitalisation strategy of the city and oversees the infrastructure and operations of the Wi-Fi network in the city.

Another actor that has been involved in the Free Wi-Fi Network project is Águas de Portugal (state-owned water company) that partnered with Porto Digital for the deployment of the network near beaches.

Funding for the development of the digital infrastructure supporting the Porto Free Wi-Fi comes solely from the municipality of Porto. They harnessed competitive public procurement to build the Wi-Fi Network, bolstering cost-effectiveness for the Porto Digital Association. By integrating access points from two distinct market competitors, with each contributing 50% to the network, Porto cultivated a dynamic atmosphere that fosters price competition averting vendor lock-in scenarios. Moreover, the adoption of professional, carrier-grade technology guaranteed resilience, safety and support while keeping operational costs low.

Despite engaging external providers through a public tender process for the construction of the Wi-Fi Network, Porto Digital maintains full ownership of the infrastructure. This self-sufficiency is crucial for the city to ensure that it is not reliant on the providers for the network's ongoing operation and management, granting Porto Digital greater autonomy and control over the system.

TAKE – AWAY

Avoidance of vendor lock-in by engaging more than one vendor while retaining control over the system by maintaing full ownership of the infrastructure.

skyNext - stock.adobe.com

5.3.3 Enablers

The development of the Free Wi-Fi Network in the city of Porto was facilitated by the **prior presence of a strong and secure optical fiber optics network deployed in the city.** The deployment of the fibre optic network in Porto is considerable as it exceeds 7564 kilometres – a unique case in Portugal, and a success among European cities.

The fiber optical infrastructure is named the Metropolitan Area Network (MAN) and is owned and managed by Porto Digital. It provides low-cost and free broadband connection covering the city widely, including the sites where the Free Wi-Fi Network is accessible. The MAN consists of a backbone, a distribution network, and an access network that uses fiber optic cables to provide high-speed internet connectivity to the different Free Wi-Fi access points.

The **status of the Porto Digital Association** is unique to the city of Porto and has been an enabler of digitalisation initiatives, including the installation of the Free Wi-Fi Network. Porto Digital Association has a specific status, role and knowledge that facilitates the coordination and cooperation of the different stakeholders, and centralises the operation activities in a single entity. Porto Digital is registered as a telecommunications carrier and is therefore aware of the related regulatory limitations. They have been managing the city's fibre optics infrastructure and has the technical skills in-house for planning, implementing and maintaining this type of network.

In addition, Porto Digital operates as a **neutral provider**, meaning it does not favour any particular segment, or base its expansion interventions on market positioning. By building and controlling the infrastructure throughout the city, it ensures that all citizens have access to Free Wi-Fi internet, regardless of whether they have contracts with private providers or not. Thanks to the Porto Digital infrastructure, private providers have an incentive to expand their networks into economically disadvantaged areas, and to invest in infrastructure there. However, with Porto Digital's infrastructure already established, private providers can leverage this existing framework to offer their services at reduced costs.

Ecosystem acceptance has been critical to the success of Porto Digital's Wi-Fi network. By managing the city's fibre optics infrastructure and working closely with city officials, the project has been able to engage with the community through outreach efforts, public forums, and other initiatives. These efforts have helped to ensure that the residents understand the benefits of Wi-fi access and support the expansion of the network, particularly in schools. They underline the importance of inclusiveness in Porto's digitalisation journey and digital literacy of all citizens.

TAKE – AWAY

Access to in-depth technical and regulatory knowledge for the successful implementation of the city's digital solutions.

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5.3.4 Actions

Expansion of the Free Wi-Fi Network and installation of the routers

To allow more citizens to connect to the Free Wi-Fi Network, the area covered by the network was expanded. The number of connection access points in the Free Wi-Fi Network more than doubled because of the city's investment increasing from 70 access points to 200. This increase allowed to broaden the coverage area, to grow the network capacity and to reach buildings and schools with limited internet access.

The Free Wi-Fi access points consist in small routers that are installed on urban furniture. The routers and cables are provided and owned by Porto Digital infrastructure team.

Initially, the urban furniture selected for the installation of the Wi-Fi access routers were traffic light poles. However, during the implementation process, it was decided to extend the coverage area to bus shelters and street public lights as well. When expanding the Free Wi-Fi network access points to such urban furniture, it has been essential to ensure that they can support the installation of Wi-Fi access points. The specific considerations for the installation of the access points were the availability of **sufficient power supply and cabling** and whether the structures could support the weight and size of the equipment. **Consultation with different city departments and site surveys** were necessary to determine the feasibility of installing the equipment.

Improvement of the Wi-Fi quality

The Wi-Fi Network has not only grown in terms of access points, but the quality of the connection was also improved – going from the outdated Wi-Fi 4 and Wi-Fi 5 public infrastructure to the latest Wi-Fi 6, allowing high bandwidth and reliability.

To ensure that a minimum quality of service is achieved, the number of users per access point is limited, and a web filter and application control are in place to prevent the use of bandwidth-intensive applications by a few users alters the quality of the connection for all.

Installation of sensors

The Porto Free Wi-Fi Network project also supports the deployment of a network of environmental sensors across the city[31]. Sensors are small devices fixed on urban infrastructure that capture various environmental measures. In Porto, the network is composed of 30 sensors that are located strategically in the city. The network of sensors is powered by the Free Wi-Fi Network because it provides the wireless connection that is necessary to transmit the data captured by the sensors to the concerned municipality services. The sensors are equipped with wireless communication technology that enables them to send real-time data.

Four different types of environmental sensors have been installed in Porto:

- SmartAIRSense: Sensors that monitor outdoor air quality by measuring pollutants density;
- SmartNOISESense: Sensors designed to measure noise levels;
- SmartMETEOSense: Sensors that measure a range of meteorological parameters, including wind speed and direction, atmospheric pressure and precipitations; and
- Waste management sensors: Sensors installed in different waste bins to evaluate the fill level of waste containers.

31 *Santos et al., 2018. PortoLivingLab: An IoT-based sensing platform for Smart Cities.*

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Collection of feedback from users

In 2019, Porto Digital Association conducted a study on the Free Wi-Fi Network which aimed at evaluating the usage patterns of the network and users' preferences. More than 83,000 users were surveyed[32] over two months. The results showed that users particularly value broadband speed (62%), security and privacy (31%) and the ease of connection (23%). The survey also informed Porto Digital about the profile of the network users which showed that the majority are first-time users.

Based on the information collected from the survey, the offer of the network was slightly adapted. In particular, Porto Digital Association included in the Free Wi-Fi Network a communication platform to inform users on relevant information about Porto. While this interface should be relevant for both Porto citizens and visitors (and is therefore available in Portuguese and in English), visitors are a target audience of this interface. The fact that most of network users are first-time users demonstrates the importance of this offer as a way of sharing information about the city to visitors who are looking for it. Provision of information on cultural events was ranked as a priority for most respondents (56%)[33].

TAKE – AWAY

Connectivity as a foundation enables scaling innovation for green transition. Monitoring digital infrastructure quality and uptake helps improve services for citizens and visitors.

5.3.5 Outcomes and impacts

The implementation of the Free Wi-Fi Network has been successful in reaching its objectives and is foreseen to generate an impact that goes beyond connectivity and impacts complementary policy areas.

Improvement of citizens connectivity

Porto's Free Wi-Fi network has been a success in the city, registering more than 2.5 million connected devices with almost 120 million sessions since the launch. By effectively deploying 200 access points throughout the city, Porto managed to provide a high-quality, secure, and free connection to many of the citizens.

The uptake of the Wi-Fi Network in the city is monitored through a series of KPIs that reflect the importance placed on the network by users.

Table 8: KPIs used to monitor the output of Porto's Free W-Fi Network

KPI	INDICATOR DESCRIPTION	VALUE
Total sessions	Total number of sessions open by users in 2019	49.8 million
Total connected devices	Total number of connected devices in 2019	2.5 million
Total users	Total number of users in 2019	1.2 million
Monthly users	Average number of users that connect to the network per month	248,000
Monthly uploads	Average amount of data that is uploaded online through the network per month	12.6TB
Monthly downloads	Average amount of data that is downloaded from online sources through the network per month	52.4TB

Source: Porto Digital. 2019.

32 Associacao Porto Digital, 2019. Relatorio de Gestao 2019.

33 Porto Municipality, 2019. Porto Digital will expand the city's public Wi-Fi network based on a study on who uses it and how.

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Paul Hanaoka - unsplash.com

The number of new devices connected to the Free Wi-Fi Network has been growing fast, and has almost tripled every month, reaching a maximum of 140,000 new connections (data from 2019).

In addition, detailed aspects of the use of the Free Wi-Fi Network are also monitored:

- Number of users per access point
- Bandwidth usage per access point
- Data use per user
- Bandwidth usage of interfaces

Digital infrastructure as an enabler for the green transition

The network of environmental sensors deployed by Porto Digital across the city and powered by the Free Wi-Fi Network supports the city's green transition and illustrates a practical case of twin transition. The four types of environmental sensors installed by the cities have different applications for urban planning and city management and help make Porto more sustainable in various ways. Their applications and the measures captured are described in *Table 9*.

Table 9: Applications and measurement of environmental sensors

TYPE OF SENSORS	POLICY APPLICATION	MEASUREMENT
Air quality (SmartAIRSense)	Monitor air quality to identify areas with high pollution levels, informing the implementation of measures to reduce emissions and protect public health	O_3 concentration
		NO_2 concentration
		PM10 concentration
		PM2.5 concentration
		CO concentration
Noise pollution sensors (SmartNOISESense)	Monitor noise levels to enhance sound isolation in public buildings and prevent noise concentration in residential areas.	Class 2 sound level meter
Meteorological sensors (SmartMETEOSense)	Monitor meteorological parameters to predict potential climate-related hazards and take appropriate mitigation measures.	Wind speed and direction
		Temperature variation
		Humidity
		Air pressure
		Precipitations
Waste management sensors	Monitor the fill level of the container they are installed in, and periodically transmit the information to the waste collection service to enable more efficient garbage collection routes and provides valuable data about waste generation patterns, minimising the impact on traffic congestion and emissions	Fill level

By monitoring city resources, the installation of sensors is expected to result in efficiency gains that can lead to savings in both resources and financial costs. Looking to the future, Porto Digital plans to further leverage wireless sensor technology to optimize infrastructure development, reduce energy costs and support business operations.

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Reduction of the digital divide and equal opportunities

Porto Free Wi-Fi Network was deployed with substantial coverage of Porto, with routers installed evenly across the city. The wide network coverage translates into high-speed internet availability in the entire city, including in underprivileged communities and social housing neighbourhoods. Porto Digital measured that the Free Wi-Fi Network was already deployed in 15 underprivileged neighbourhoods, impacting more than 6000 houses.

Expanding connectivity to social neighbourhoods (social housing) is essential to reduce the digital divide and providing equal opportunities to all citizens, regardless of their socio-economic status. However, the concept of digital divide extends beyond the disparity of those who have internet access and those who do not. It also encompasses the divide between those who have access to high-speed internet and those who can only access slower speeds. With Porto Free Wi-Fi Network, the city ensures that all citizens not only have internet access , but to cutting-edge connectivity, powered by fibre optics.

The benefits of this expansion can extend to small businesses , as they too can utilise the improved connectivity to enhance operations and reach a wider audience. The outcomes are equal opportunities promoted for SMEs while also encouraging expansion in digital-focused businesses.

Economic impacts

Connectivity is expected to **accelerate the digital transition** and benefit industry and citizens. The overall efforts of Porto Digital to make the city more digital impact local industry and **strengthen local ICT, advanced technology entrepreneurs and start-ups**. This is illustrated by the success story of Veniam, a Porto start-up that has contributed to the provision of the city's ICT infrastructure which has been growing internationally[34]. These economic impacts are complicated to monitor but are accounted for in Porto's digital strategies.

34 Nexar, 2022. Nexar acquires Veniam to open unlimited possibilities for a new breed of data-rich mobility applications.

Cavan- stock.adobe.com

In addition, the increasing exploitation of the Free Wi-Fi Network by tourists brings additional benefits. The Free Wi-Fi increases the attractiveness of Porto which is likely to have an impact on the tourism industry turnover and competitiveness. Also, communication with tourists through the Wi-Fi interface embedded in the Free Wi-Fi Network interface (under development) has the potential to increase interest in more local events and cultural activities. The next phase of expansion and improvement of the Free Wi-Fi Network project will have support from the Porto Tourism Association and the Tourism Agency of Portugal.

TAKE – AWAY

Digital infrastructure as an enabler for the social, green, and economic objectives of cities generates and enables the collection of large volumes of data which can be turned into Key Performance Indicators and analytics which in turn inform on progress and distance to targets set in cities' strategies (be it sustainability strategies, industrial strategies, digital strategies or other).

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5.3.6 Key learnings

The successful implementation of the Free Wi-Fi Network project has led to some valuable insights that can be applied to future urban projects.

One of the critical learnings is the importance of **efficient communication with municipal departments and local utility companies**. The flow of information between parties is essential to ensure availability of the necessary infrastructure such as power and cabling, and coordination to avoid efficiency loss.

The deployment of the Free Wi-Fi Network by the City of Porto underlines the possibility of **synergies across projects while serving the city's digitalisation objectives.** In addition to its impact on connectivity, the Wi-Fi Network supports efficiency in the use of resources through the deployment of a parallel network of sensors. This provides a concrete example of a city using digital technologies as an enabler of sustainable growth. Similarly, the Free Wi-Fi Network demonstrates that connectivity for citizens and as a positive objective to attract tourists can be combined in a common project. In addition, cost savings can be achieved from these multiple objectives, helping cover investment costs.

Another lesson learnt is that it is essential for the city to prepare adequately when using public tenders for large-scale projects, including **qualifying providers, benchmarking technology, selecting multiple vendors, opting for professional and carrier solutions, and establishing a robust architecture.**

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APPENDIX

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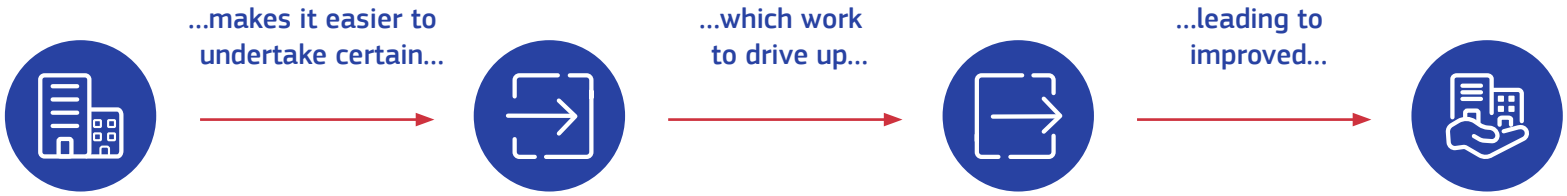
ICC Approach to monitoring

The ICC approach to monitoring is based on four measurable concepts that feed into each other.

Figure 5: Four types of measurable concepts for the assessment and tracking of city strategies



IDEA	LOCAL ENABLERS **City characteristics**	ACTIVITIES **Inputs and initiatives**	OUTPUTS **Results directly produced**	CITY PERFORMANCE **Outcomes and impacts**
DESCRIPTION	Each city has **unique strengths and weaknesses that help action happen.** These can be stakeholder networks, local capabilities, cultural factors or many more that drive success in ICC projects.	Cities main intervention on the ICC is to **take actions.** These can be **direct** (e.g. procuring technology), or **indirect** (e.g. forming a working group on a topic). The right actions can lead to the right **inputs going in to the ICC** (e.g. funding, time).	**Cities can drive technological solutions** to try and improve city performance. **How well these solutions are currently used can be described as their 'maturity'**, - considering whether they are available for stakeholder use, what stakeholders think of them, and so on.	Success of an intelligent city is ultimately measured by its ability to **address city needs**. These can be considered an increased productivity, cost savings, efficient use of resources **i.e. consequential effects on beneficiaries** (outcomes) and **improved quality of citizen life** and a **better environment for stakeholder**s (impact).
EXAMPLE	A history of strong collaboration between city and a local university...	...allows the creation of a new e-health pilot project using social housing in the city...	...leads to the launch a new tele-health solution utilising 4G data connections...	...resulting in pre-emptive diagnosis and lower wait times at medical facilities

Source: Intelligent Cities Challenge

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Creating and measuring a system of indicators helps cities assess and track distance to targets and progress over time, providing answers to key questions every city is faced with.

Figure 6: Assessment and tracking through a system of KPIs

ASSESS	TRACK
Where is my city performing well?	How well does my city deliver in citizen needs?
Where could my city's performance be improved?	How does my city compare to other cities?
What actions should be prioritised?	Has there been tangible progress towards better city performance?
Are my city's ambitions still reachable?	How far is my city from its ambitions?

Source: Intelligent Cities Challenge

Mapping of EU initiatives for city monitoring

In Europe, the smart city concept is widely based on innovation and green investment opportunities. However, supporting the development of smart cities requires more than cultivating innovative solutions to deliver benefits for cities.

Given that the smart city concept entails numerous interrelated dimensions, evaluating cities through a common KPIs framework is challenging. A well-designed KPIs framework should allow effective benchmarking on a national or international level with other cities or smart city projects. Ultimately, every smart city project adopts its own KPI list, which makes the inter-comparison of the outcomes among different projects and solutions difficult. Each city faces the choice of defining indicators for systematic monitoring. This choice is crucial as it directly affects city management and decision-making. Indicator systems are typically developed for specific use purposes. However, an informed choice of the most suited indicators remains difficult for city managers, as it requires expert knowledge to understand the usefulness and weaknesses of indicator systems for specific use. Appendix introduces a library to help cities identify the initiatives and corresponding indicators matching their measurement requirements.

Various indicator frameworks and tools for assessing urban development from sustainability or smartness angles exist. However, standardised frameworks of city indicators have very recently been introduced. The need for uniform monitoring throughout Europe has led to initiatives promoting cooperation and exchanging know-how among European cities. Initiatives such as the Smart Cities Information System (SCIS) and CITYkeys have created interaction platforms for cities along with a set of KPIs, each for evaluating systems and technologies demonstrated in smart city projects. Several Smart Cities and Communities Lighthouse projects, as well as international and European standards (e.g. ISO 37120:2018, ISO 37123:2019) and strategic plans and initiatives, e.g. UN's Sustainable Development Goals, are also providing indicators for assessing the performance of smart city solutions. The rest of the Section below summarises these various sources offering.

Funded by the European Union HORIZON 2020 programme, CITYKeys developed and validated, with support from cities, KPIs and data collection procedures for the common and transparent monitoring of smart city solutions across European cities. CITYKeys was built on existing smart city and sustainable city assessment frameworks. The initiative has reviewed well-known frameworks, including ISO 37120, Civitas, European SCI, GDC, PLEEC, BREEAM, CASBEE 2012/2014, DGNB, Euro-District, Eurban Lab, LEED and many others to develop a database of indicators.

Launched with support from the European Commission, SCIS encompasses data, experience and stories collected from completed, ongoing and future projects, including the CITYKeys. The SCIS focuses on developing indicators to measure technical and economic aspects related to measures.

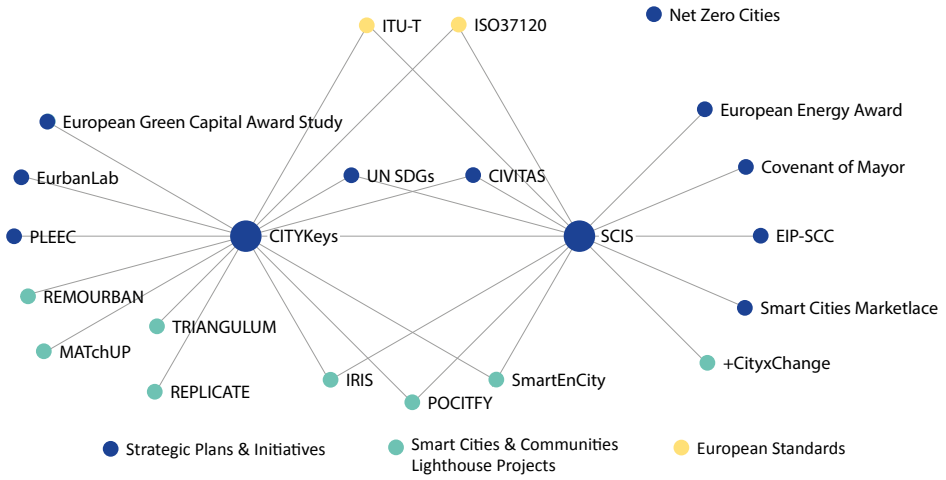
The smart city concept led to the need for knowledge exchange about monitoring and evaluation among smart cities and communities, and relevant information is available in the SCIS and CITYKeys platforms. As shown in the figure below, there are multiple feeding mechanisms among different initiatives, in which CITYKeys and SCIS seem to be the core ones. The figure below presents some EU-funded projects with KPI Frameworks developed in alignment with the SCIS and CITYKeys, as well as aligned to the ICC thematic priorities.

It includes nine lighthouse projects, 11 strategic plans and initiatives, and two standards and represents interrelations between them. Each of these initiatives adopts a specific assessment framework to evaluate smart city performances and expected impacts based on data, experience, and stories from other completed or ongoing projects and broader methodological frameworks. It should be noted

that only projects for which a detailed list of all KPIs was publicly available are included in the analysis (serving as potential sources for feeding the ICC KPI pool).

KPIs included in the below-illustrated initiatives frameworks have various definitions of the term 'smart city' and also refer to the quality of life. This lack of uniformity of smart city definitions leads to diverse results and poses challenges to pilot cities. Indeed, there are noticeable differences between smart cities and urban sustainability frameworks of initiatives, especially regarding their tendency to highlight environmental, social and economic aspects. This is why SCIS and CITYKeys indicators have been formed through alignment with other initiatives and already existing indicator sets.

Figure 7: Mapping of shortlisted initiatives with KPI frameworks aligned to the ICC thematic priorities



Source: Intelligent Cities Challenge

The review of KPI frameworks associated with EU cities-related initiatives followed three main steps:

- First, the shortlisting of a selection of European city initiatives (i.e. Programmes, Missions) with a strong alignment with twin transition and sustainable development objectives;
- Second, the analysis and mapping of monitoring frameworks underpinning each initiative, summarising the complexity of each;
- Third, the shortlisting of KPIs drawn from all benchmarks, which could be applicable to different ICC thematic areas. A further KPI assessment is provided through the Meaningful/ Actionable/ Available/ Comparable/ Trackable criteria.

CITYKeys

CITYKeys is a project funded as a 'horizontal activity'[35] of the H2020 Smart Cities and Communities call[36] to develop an indicator framework focused on city-level smart solutions. The aim of CITYKEYS is to develop and validate a holistic performance measurement framework for future harmonised and transparent monitoring and comparability of European city activities during the implementation of Smart City solutions.

The evaluation framework is primarily performance oriented and supports Smart Cities in strengthening their strategic planning, evaluating the success of smart city projects and the possibility of replicating the projects in other contexts. The CITYkeys evaluation framework: (a) Evaluates the impact of a smart city project; (b) Monitors the progress of the city as a whole towards smart city goals; (c) Assess how the project has contributed to the objectives of the city level. This requires

35 Horizontal activities: to address specific challenges (e.g. regulatory barriers, standardisation, public procurement and performance monitoring)

36 The reference of the call under H2020 is: H2020-SCC-2014-2015 : CALL – SMART CITIES AND COMMUNITIES

connecting the outcomes of a project evaluation with corresponding indicators on the city level. The consortium includes 3 multidisciplinary research organisations, 1 cities association and 5 partner cities covering different geographical regions in Europe. In addition to the 5 partner cities, 15 other cities showed their commitment to join the project stakeholders' advisory group.

Monitoring Framework

The majority of the indicators in the CITYkeys selection have been derived from existing indicator frameworks before 2015. The selection was based on an inventory of 43 existing indicator frameworks for (sustainable) cities and projects. New indicators have been suggested to fill gaps in existing frameworks, mostly related to specific characteristics of smart city projects. The CITYkeys assessment framework structure focuses on evaluating social sustainability (People) (27-22 KPIs), environmental sustainability (Planet) (25 KPIs), economic sustainability (Prosperity) (18 KPIs), governance (13 KPIs) by means of developing and implementing smart city projects and propagation (18 KPIs) by means of the potential of individual smart city projects to be replicated in other cities and contexts. The framework consists of 99 indicators.

Reference: https://cordis.europa.eu/project/id/646440

Timeline: 2015 - 2017

Smart Cities Information System (SCIS)

SCIS is a knowledge platform to exchange data, experience and know-how and to collaborate on creating smart cities. SCIS brings together project developers, cities, research institutions, industry, experts and citizens from across Europe. It encompasses data and experience collected from completed, ongoing and future projects. It showcases solutions in the fields of energy efficiency in buildings, energy system integration, sustainable energy solutions on the district level, smart cities and communities and strategic sustainable urban planning. The monitoring KPI Guide was reviewed as it focuses on the development of indicators to measure technical and economic aspects of smart technology and sustainability-related measures applicable to the project. The SCIS KPI guide describes key performance indicators and their application to the different assessment objectives. Involved countries in this initiative are mainly Belgium, Germany, Netherlands and Spain.

Monitoring Framework

The framework consists of 37 indicators. The implementation of SCIS indicators has been done through alignment with other initiatives such as CITYKeys and ISO officials already existing indicator sets. The framework groups city indicators into two clusters. 1) Core KPIs: technical (3 KPIs), environmental (3 KPIs), economic (5 KPIs), ICT (7 KPIs), mobility (9 KPIs). These are KPIs identified as the most relevant for SCIS and should be implemented by the projects in the scope of SCIS. 2) Supporting KPIs (10 KPIs): relevant for SCIS, their use is recommended.

Reference: *https://smart-cities-marketplace.ec.europa.eu/node/3022*

Timeline: 2017 - 2020

+CityxChange

+CityxChange is a smart city project granted funding by the European Union's Horizon 2020. The project aims the development a framework and supporting tools to enable a common energy market supported by a connected community. This leads to recommendations for new policy intervention, market (de)regulation and business models that deliver positive energy communities integrating e-Mobility as a Service. The 7 cities represented in the project include 2 Lighthouse cities (Trondheim, Norway; Limerick, Ireland), 5 Fellow cities (Alba Lulia, Romania; Pisek, Czech Republic; Smolyan, Bulgaria; Sestao, Spain; Voru, Estonia.) with other different partner countries (Germany, Netherland and Italy)

Monitoring Framework

The KPI Framework developed includes KPIs defined by the SCIS, as well as KPIs that are specifically defined for this project. While the SCIS KPIs focus on the technical and economic aspects of energy-related measures, the project-described KPIs focus on indicators to measure interventions and social indicators to measure the project's impact on citizens. The KPI Framework is divided into three core themes; 1) Integrated Planning and Design (7 KPIs); 2) Common Energy Market (19 KPIs), and 3) CommunityxChange (7 KPIs).

Reference: *https://cityxchange.eu/*

Timeline: 2021 - Ongoing

+Net Zero Cities

Net Zero Cities is a European initiative designed to support participating European cities cutting their carbon emissions and achieving climate neutrality. The Net Zero Cities initiative supports the newly launched EU's Mission '100 Climate-Neutral and Smart Cities by 2030' that is part of the Horizon Europe programme. The objectives of the mission are to achieve 100 climate-neutral and smart European cities by 2030 and to ensure that these cities act as experimentation and innovation hubs to enable all European cities to follow suit by 2050. 100 cities from European Union Member States plus 12 cities from associated countries have been selected to join the initiative.

Monitoring Framework

The monitoring framework used for the Net Zero Cities initiative is under preparation as this report is being developed (May 2023) since the initiative was only recently launched (announcement of the selected cities in April 2022). While the detailed final model is not available, the foreseen structure of the monitoring framework has been communicated.

Reference: *https://publications.jrc.ec.europa.eu/repository/handle/JRC129381*

Timeline: 2021 - Ongoing

European Handbook for SDG Voluntary Local Views

SDG Voluntary Local Views is a report prepared by local governments on their achievements, shortcomings, strategies, and measures for sustainable development using the SDG framework (goals, targets and indicators). The handbook aims to offer cities and regions the best use of knowledge and practical activities that are part of the localisation of the 2030 Agenda. This document provides policymakers, urban practitioners and experts with a method and examples of indicators that European local and regional governments can use to monitor the achievement of the Sustainable Development Goals (SDGs). Specific clusters of cities and regions with similar approaches across Europe take part in this process, particularly in Germany, Finland, and Spain.

Monitoring Framework

The European Handbook includes detailed and updated information on 72 indicators depending on SDGs and related data sources, which can enable cities to measure their progress toward the 2030 Agenda for Sustainable Development.

Reference: *https://publications.jrc.ec.europa.eu/repository/handle/JRC129381*

Timeline: 2022

Smart Cities Marketplace

The Smart Cities Marketplace is an initiative for a knowledge platform to exchange data, experience and know-how and collaboration for investment for delivering Smart City solutions in any ICT, Energy or Transport & Mobility areas. Under the umbrella of the Smart Cities Marketplace, the European Commission aims to gather all actors in the European Smart City community to help citizens, cities, research institutions and industry deliver more sustainable, resilient, and smart urban areas. The Smart Cities Marketplace was created by merging the two former EU Commission

projects, 'Marketplace of the European Innovation Partnership on Smart Cities and Communities' (EIP-SCC) and the 'Smart Cities Information System' (SCIS) into one single platform in 2020 - Active since 2020. The 120 cities represented in Scalable Cities with 18 projects include 48 'Lighthouse cities[37]' and 72 'Fellow cities[38].

Reference: *https://smart-cities-marketplace.ec.europa.eu/*

Timeline: 2020 - Ongoing

European Green Capital Network

European Green Capital Network is a knowledge society in which previous winners and finalists of the Green Capital award share inspiration and information. The project recognises and rewards local efforts to improve the environment, economy, and quality of life in cities. The Award is given each year to a city leading the way in environmentally friendly urban living. All previous winners and finalist cities of the European Green Capital Award are eligible to become network members. The Network counts 36 member cities.

Monitoring Framework

The specific study proposes a framework for assessing and ranking cities based on how smart and sustainable they are. Cities are asked to provide information on their performance across the 12 environmental indicators. 4 sections per indicator are defined as follows: Describing the present situation; describing the measures implemented over the last five to ten years; describing the short- and long-term objectives for the future and proposed approach to achieve these; listing how the above information can be documented.

Reference: *https://environment.ec.europa.eu/topics/urban-environment/european-green-capital-award/about-eu-green-capital-award_en*

Timeline: 2008 - Ongoing

Local and Regional Digital Indicators (LORDI)

The LORDI project aims at developing an indicator framework to monitor digitalisation in cities and regions that is being developed in the frame of the Living in EU initiative. The framework will allow cities and communities to benchmark against each other on their digital transformations, and to learn from peers. The LORDI project is led by the Committee of the Regions and ESPON.

Monitoring Framework

In the LORDI monitoring framework, digital maturity is assessed against five dimensions: **local digital infrastructure, local digital skills and capacity building, local digital economy and services, governance & Digital Single Market**, completed by some context indicators. More than 170 indicators that feed into these dimensions have been identified, but the pilot version of the LORDI focuses on 29 indicators.

Reference: *https://digital-strategy.ec.europa.eu/en/news/survey-local-and-regional-digital-indicators*

Timeline: 2022 - ongoing

37 Lighthouse cities are cities that pilot and deploy the most advanced and innovative solutions

38 Fellow cities are those that follow the lead of Lighthouse cities and engage in the replication of already deployed solutions.

Green City Accord

The Green City Accord was initiated in 2020 and has reached 104 signatory cities by now. They commit to report on five indicator areas: air quality, noise, water quality and management, circular economy, and biodiversity & nature. A simple set of 3 data sets per indicator, e.g.. 15 data sets will be required to be reported. The scheme is being developed for a first reporting by the end of 2023.

Monitoring Framework

AIR:	• PM2.5 concentration levels (highest annual mean observed at (sub) urban background stations) • PM10 daily concentration levels (highest number of days exceeding the WHO recommendation of 45 µg/m³ per year, observed at any (sub) urban background or traffic station) • NO2 concentration levels (highest annual mean observed at traffic stations)
WATER:	• Household water consumption (litres/capita/day) • Infrastructure Leakage Index (ILI) • Percentage of urban wastewater meeting the requirements of the Urban Wastewater Treatment Directive (UWWTD) (regarding collection and secondary treatment)
NATURE AND BIODIVERSITY:	• Percentage of protected natural areas, restored and naturalised areas on public land in municipality • Percentage of tree canopy cover within the city • Change in number of species of birds in urban area/built-up areas in the city
WASTE AND CIRCULAR ECONOMY:	• Municipal waste generated per capita (tons) • Recycling rate of municipal waste (%) • Percentage of municipal waste landfilled
NOISE:	• Percentage of the population exposed to average day-evening-night noise levels (Lden) ≥ 55 dB • Percentage of the population exposed to night-time noise (Lnight) ≥ 50 dB • Percentage of (adult) population with High Sleep Disturbance

Reference: *https://digital-strategy.ec.europa.eu/en/news/survey-local-and-regional-digital-indicators*

Timeline: 2022 - ongoing

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The Intelligent Cities Challenge is funded by COSME, the EU programme for the Competitiveness of Enterprises and SMEs

Mapping initiatives with thematic areas

This section introduces a library which aims to help cities identify the initiatives and corresponding indicators matching their measurement requirements. The tables described below answer the following questions:

- Which EU initiatives can help me choose KPIs that are aligned with the thematic priorities and strategies of my city?
- Which EU initiatives help me design a holistic monitoring framework for my city?
- Which EU initiatives help me identify dimensions and KPIs to monitor over a longer period in my yearly monitoring mechanisms and activities?

Table 10: Which EU initiatives can help me choose KPIs in my ICC thematic priorities

	EXPLORE KPI RELATIONSHIPS OF INITIATIVES FOR ICC				
	Government services and Social connectedness	*Green economy and local green deals*	*Skills*	*Supply chains, logistics and the economics of mobility*	*Tourism*
CITYKeys Project	31	31	15	7	3
SCIS	2	14	5	16	0
European Handbook for SDG Voluntary Local Views	25	24	12	6	3
+CityxChange	15	4	8	0	6
European Green Capital Award	1	9	1	1	0

0-5	6-10	11-20	21 and above

The darkest the color, the highest the number of indicators

An essential step of the proposed methodology lies in defining KPIs dimensions: technology (technical), environmental, economic (business), social-economical and institutional. These dimensions complement each other to set the holistic approach for smart cities.

- KPIs measuring technology (technical): Effectiveness of a given solution concerning the operating parameters and technical constraints such as energy consumption, people utilising apps which enable the residents to monitor and analyse their energy consumptions;
- KPIs measuring Environmental Performance: Efficiency of the solutions demonstrated from the viewpoint of the expected environmental impact, such as CO_2 emissions reduction;
- KPIs measuring Economic (Business) Performance: Usage scenario from the market stakeholder perspective and cost/benefit ratio, such as the average estimation of cost savings;
- KPIs measuring Social-Economical Performance: Impact of technology, scheme or policy on social factors, such as the degree of users' satisfaction; and
- KPIs measuring Institutional (Legal) Performance: Interoperability of the technology solutions in institutions and the engagement of stakeholders, such as the level of adaptation of legal barriers for using biofuels for energy exploitation purposes.

The currently proposed dimension categorisation is not the only one that can be adopted. There are other relevant frameworks, either close to the one presented (e.g. SCIS) or entirely different (e.g. CITYKeys). In the context of the ICC, we showcase a more holistic version, given that the current EU framework is currently rather fragmented across the various EU initiatives and projects. The table below shows the number of KPIs in the analysed framework according to the KPIs Dimensions.

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Table 11: Which EU initiatives help me design a holistic monitoring framework?

INDICATOR-BASED FRAMEWORKS ASSESSMENT						
INITIATIVES		Number of KPIs according to the KPIs Dimensions				
		Technology (Technical)	Environmental	Economic (Business)	Social - Economical	Institutional
Key city transformation measurements of other European initiatives	CITYKeys Project	10	20	15	22	11
	SCIS - Smart Cities Information System	20	3	6	7	1
	European Handbook for SDG Voluntary Local Views	5	22	11	23	7
	+CityxChange	15	4	8	0	6
	European Green Capital Award	**1**	**7**	**3**	**0**	**1**

As smart and sustainable city indicators often evaluate the extent to which a single or several interventions are being deployed and the impacts they generate, the categories of outcomes and impacts require KPIs to be monitored over the longer term and hence be integrated in cities yearly activities. It is also at the level of outcomes/impacts were benchmarking with other cities can be informative for the identification of good practices, success factors, etc. The resulting typology described below thus consists of several Outcome - oriented KPIs and a number of Impact - oriented KPIs.

For more details on the KPIs of each initiative please consult the library available *here*.

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Table 12: Which EU initiatives help me design a holistic monitoring framework?

INDICATOR-BASED FRAMEWORKS ASSESSMENT						
INITIATIVES		*What to measure - City Performance*				
		Number of KPIs	*Detail level of KPI List*	*Number of Outcome - oriented KPIs*	*Number of Impact - oriented KPIs*	*Relevancy across the analysed frameworks*
Key city transformation measurements of other European initiatives	*CITYKeys Project*	**Total 99 KPIs** under the 5 thematic categories (People, planet, prosperity, governance, propogation) defined by the project	High	60	27	High
	SCIS - Smart Cities Information System	**Total 37 KPIs** under the 2 thematic areas (Core KPIs: technical, environmental, economic, ICT, mobility; and Supporting KPIs) defined by the initiative	High	29	5	High
	European Handbook for SDG Voluntary Local Views	**Total 72 KPIs**, according to 17 SDGs defined by the initiative	Medium	50	13	Low
	(+)CityxChange	**Total 33 KPIs**, under the 3 thematic areas (Integrated planning and design; common energy market, Theme: community x Change) defined by the project	High	24	4	Medium
	European Green Capital Award	**Total 12 KPIs** under the 4 thematic areas defined by the initiative	Low	5	7	High

EA-04-23-659-EN-N

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of the European Union