CPA-PR _002_Anatomy Indicators

City Anatomy Indicators

Developed by TAFT – DICI Indicators
6 November 2015

Executive Summary

1. CPA Summary

This document establishes definitions and methodologies that identify a minimum set of city data, from available city data catalogs, suitable for measuring city functions according to the structure of the City Anatomy.[1] These performance-based measures should guide city development towards urban sustainability, resilience, and quality of life. To this end, this document defines a set of indicators to fully map the subsystems and elements of the City Anatomy. The document offers both the necessary multiscale granularity in the ISO 37120 set of indicators as well as appropriate extensions of the ISO set.

The proposed indicators are divided into two categories:

- Core indicators. These are standard measures usable across cities to assess the subsystems in the anatomy that help answer the main questions related to sustainability, resilience or quality of life.

  All 46 ISO 37120 indicators labeled as core have been considered.

  The CPS has extended the core ISO 37120 measures with 59 additional core indicators to conform to the proposed schema required by the City Anatomy.

- Supporting indicators. These are measures that provide further information on city services/functions.

  All 54 ISO 37120 indicators labeled as supporting have been considered.

  The CPS has extended the supporting ISO 37120 measures with 37 additional supporting indicators to cover most of the systems elements included in the City Anatomy.

  The proposed city indicators are related to the City Anatomy systems and subsystems and to the ontology that will be published as “Foundation Ontology for the City Anatomy”. They are classified according to the City Evaluation Framework also described in the City Anatomy document and will inform the city indicators ontology document.

2. Statement of Purpose/Objective.

DICI[2] aims at creating data interoperability protocols to enable transparent and smart data sharing among cities and citizens. It also aims at developing city indicators based on the common framework provided by the City Anatomy.

[1] CPA-I_001_City_Anatomy.pdf
[2] DICI stands for Data Interoperability and City Indicators

The objective of this document is to define foundational city indicators by extending the ISO 37120 set while preserving the ISO definition methodology. These indicators should be easily measurable, unambiguous and easy to calculate over time without additional costs (*i.e.*, values should be available from city legacy or telemetry – Open Sensors Platform - and calculations should only require standard statistics).

Finally, the proposed indicators should be useful to cities and, thus, inform the answers to key questions arising from the City Anatomy language and taxonomy:

- How self-sufficient is our city?
- How can cities improve mobility?
- How resilient is our city?
- How can cities attract talent and investment?
- How can cities improve social equity by increasing personal opportunities?
- How can cities foster entrepreneurship?
- How can cities improve livability?

3. **Approach.**

The approach adopted to meet the aforementioned objectives begins by matching ISO 37120 indicators with the City Anatomy to identify which subsystems need an extension of the ISO 37120 set. This possibility is already considered in ISO 37120:201 #4: “this set of indicators may be complemented by other indicator sets in order to have a more comprehensive holistic approach to analysis on sustainability.” The goal here is to cover most anatomy subsystems with at least 1 core indicator. Extended Indicators have been classified as core indicators when they serve to assess resilience or respond to at least two of the key questions listed above. The methodology included assessing documented city experiences to adopt and adapt indicators to assure coverage of all subsystems in the City Anatomy.

4. **Description.**

This document includes the complete ISO 37120 set and the additional CP indicators that are needed to describe the scale granularity represented in the City Anatomy (CPA-I_001-v2_City_Anatomy.pdf). Every indicator, core and supporting in nature, is unambiguously defined, with a description of the calculation methodology, unit of measure, and references to support the proposal.

Core indicators are considered essential for assessing resilience and responding to the key questions guiding city transformation within the framework of City Anatomy. Since the systems approach of the City Anatomy provides a holistic vision and integration rationale to enable city transformation toward improving urban quality of life, the adoption and implementation of the whole set of core indicators will in turn provide a robust and meaningful assessment of city services/functions to political

leaders, city planners and managers. The system/subsystem classification allows for other contextual analysis of specific topics.

The indicators referenced in this document warrant measurability and can support the definition of more complex city indices as well as different administrative aggregation levels. They have been chosen with a neutral approach so that they can be applied to any city regardless of the specific political environment or local/regional institutional environment (*i.e.*, independent of economy, culture, service delivery customs, and governance interdependencies with regional and/or country governing bodies).

5. **Description of Target Users**

The main target groups of users are city leaders and officials. They will find in this document the basic methodology to:

- Identify city challenges
- Assess the basic city functions and services
- Measure and Compare performance
- Prioritize transformational initiatives
- Evaluate impact of transformations

This document could also be a guide to assist the analysis and further development of the City Anatomy concept, and also support ongoing city standardization processes.

Document prepared under the auspices of the

City Protocol Task Force

City Protocol is a collaborative innovation framework that fosters city-centric solutions to improve efficient service delivery and overall citizen quality of life. City Protocol seeks to define a common system view for all cities regardless of size or type, embracing protocols that will help cities deploy solutions across service areas. City Protocol aims at working across city silos and with diverse city realities by interconnecting them and ultimately creating an “internet of cities”.

In order to accomplish this goal, City Protocol adheres to a common vocabulary to express ideas. That vocabulary emanates from the **City Anatomy** that establishes the foundational platform for the approach of developing city protocols.

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1. Introduction

Efficient city operation requires advanced data management strategies. Even though city-related data are emerging rapidly, there remains a lack of data standards to easily compare, share and identify best practices across cities, or facilitate multi-city solution development. The City Anatomy[3] provides a framework and a way of thinking about cities that enables the development of multi-city solutions in a collaborative environment. There is now a need for protocols to standardize datasets describing the City Anatomy. Raw data are not sufficient to describe high level functions of the anatomy[4] and to best describe and measure city services/functions. There is a need for more complex indicators and indices.

The current availability of advanced computing and sensing platforms facilitates access to massive data repositories, often collected in real time, which contain city information at several levels. However, data repositories provided by different cities and organizations contain heterogeneous information, which is often incomplete or ambiguously described. As a result, data repositories have not been integrated and processed in a coherent way, making comparative city analysis unfeasible and city performance evaluation challenging.

This document aims at developing city indicators based on the common framework provided by the City Anatomy that, in addition to allowing high level analysis of city services and decision making processes, could guide the development of data interoperability protocols to enable comparable intercity evaluations as well as transparent and smart data sharing among cities and citizens. The objective is to establish definitions and methodologies for a minimum set of foundational city indicators to measure city services, sustainability, resilience and quality of life in accordance with the evaluation framework established by the City Anatomy document (CPA-I_001-v2_City_Anatomy.pdf). This general objective can be expressed through the following operational objectives:

- Define a set of foundational city indicators by extending the ISO 37120 set while preserving the ISO definition methodology and making those indicators as useful as possible to other ongoing work at the City Protocol Task Force.
- Measure most City Anatomy layers and systems with at least 1 core indicator.
- Establish the relationship between measurable, comprehensive and useful indicators for cities and the common framework provided by the City Anatomy. These indicators can be obtained from standard statistical methods, city legacy or telemetry (*i.e.,* Open Sensors Platform).
- Propose a list of indicators to guide and help city transformation projects by measuring the different areas of the City Anatomy and its city evaluation framework.

This document proposes indicator definitions for city data that should be used together with the city ontology (*i.e.*, the published city anatomy ontology and the city indicators ontology), to enable transversal city data analysis.

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[3] The City Anatomy establishes a common language to describe the interconnected eco-system of cities - a language based on an analogy to the human anatomy. The City Anatomy evaluates cities through the lens of three key System elements: Structure, Society and Interactions.

[4] The terms “City Anatomy” and “anatomy” are used interchangeably in this document to refer to the City Anatomy framework (CPA-I_001_City_Anatomy.pdf.

2. Methodology

The ability to improve city development in a sustainable way (*i.e.,* by taking into consideration social, economic and environmental constraints and enablers) requires decision making to be based upon reliable information. These performance-based measures and the possibility of visualizing and analyzing results in a standardized way enables the continuous evaluation of transformational city initiatives, assessing their impact and comparing performance with results from other cities.

In order to build city knowledge and learn from experiences in other cities, this document defines a set of additional CP indicators that, building on ISO 37120, extend the city information domain to the whole city systems and subsystems defined in the City Anatomy.

2.1 City Anatomy

Figure 1 depicts the detailed City Anatomy that the City Protocol Society proposes as the holistic integration of the three system elements that form the city ecosystem: the physical structure (Structure), the people who live in and occupy this physical space (Society), and the ways in which the Society engages the Structure (Interactions). Each system element in turn contains layers of subsystems.

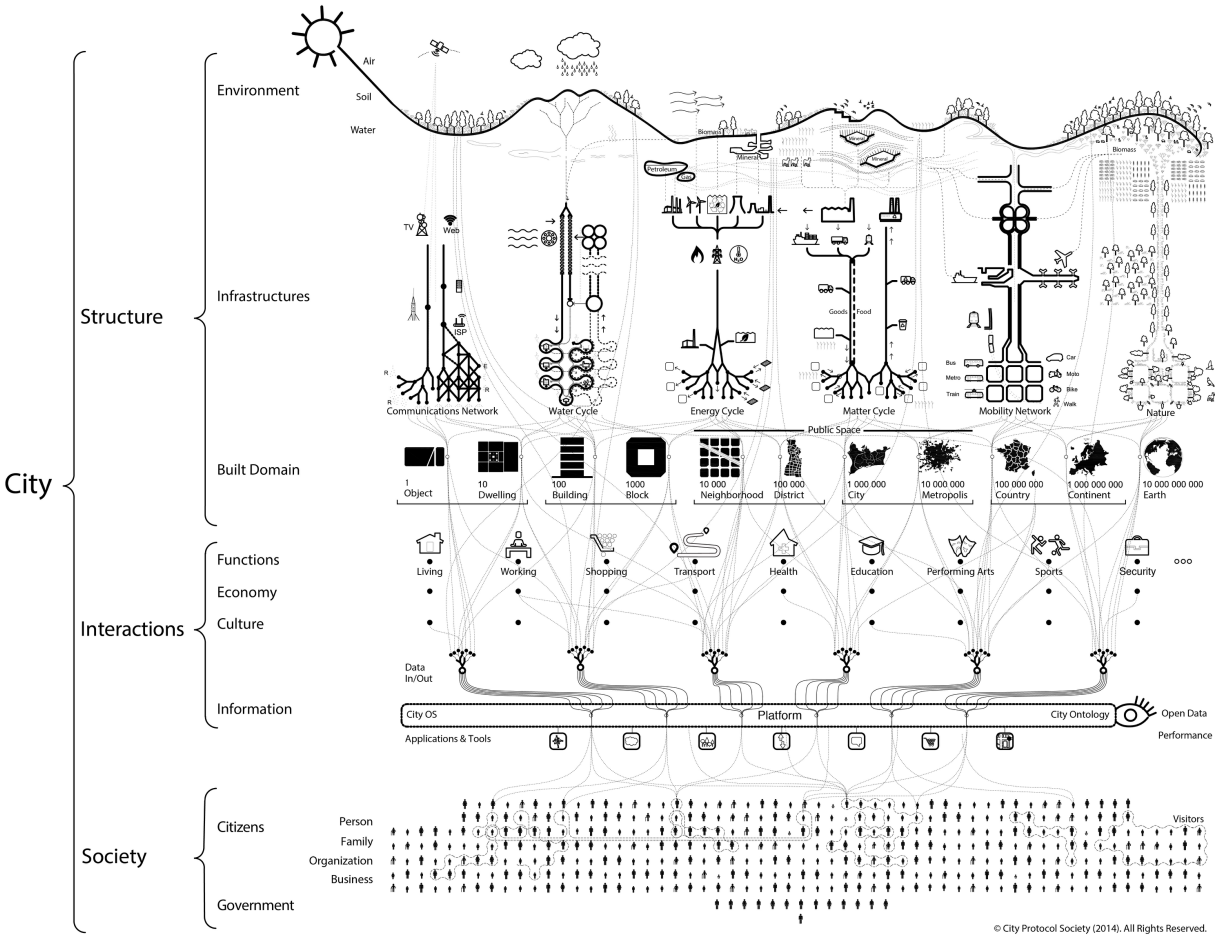

Figure 1. City Anatomy as the common foundation for City Protocol

Figure 2 depicts the high-level evaluation framework established in the City Anatomy document (CPA-I_001-v2_City_Anatomy.pdf) as a dashboard view where city functioning and status quo is visualized using green, yellow, and red indicators for the various systems and subsystems that form a city.

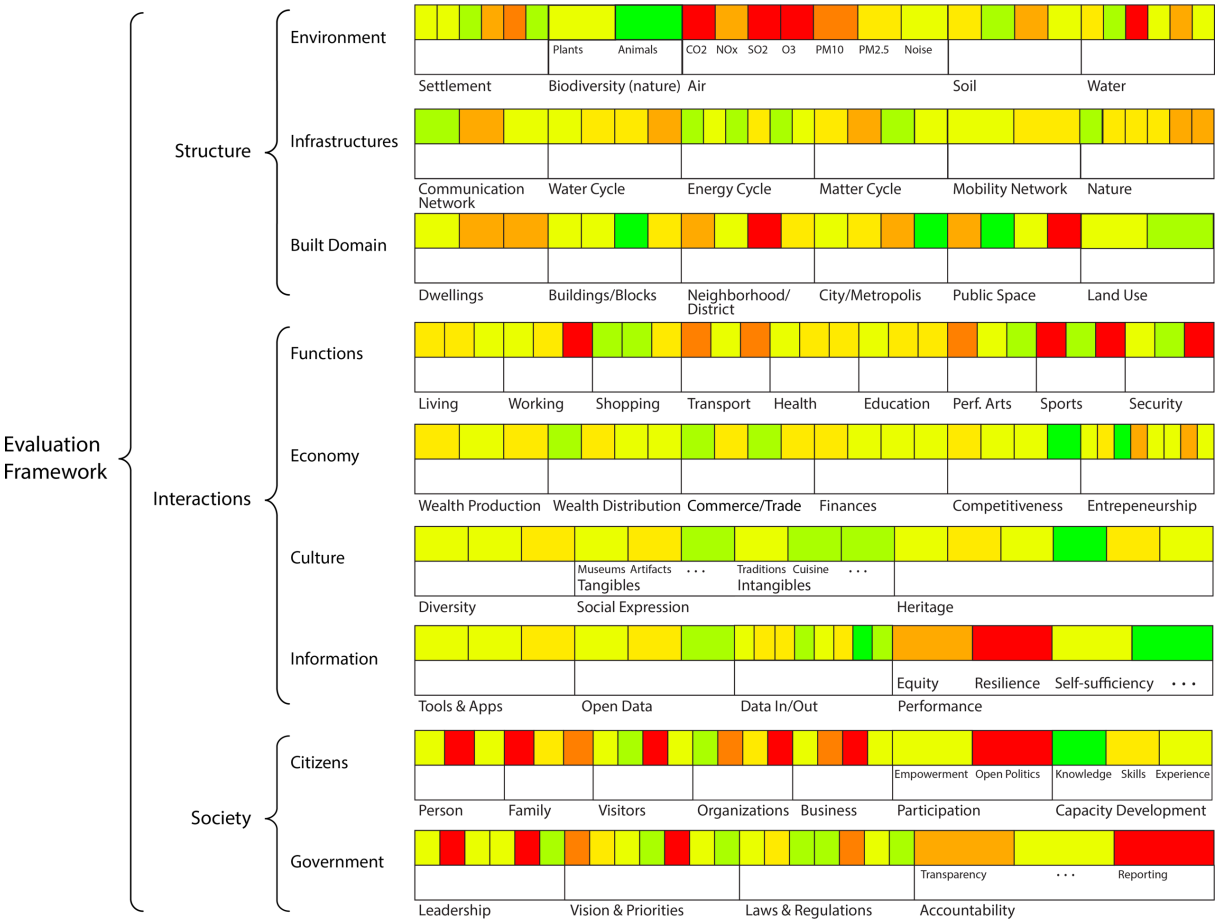

Figure 2. Evaluation Framework with top level indicators for City transformational projects

This evaluation framework facilitates the classification of indicators in terms of the City Anatomy. It also helps identify\ which city subsystems and third level elements of the anatomy have not been assessed by ISO 37120 and, thus, guides the development of CP indicators. A close examination of ISO 37120 indicators shows that the following third level elements (identified in bold) were not assessed by the ISO 37120 standard:

- Environment [**Settlement; Soil; Water**]
- Built Domain [**Dwellings; Buildings/Blocks; Neighborhoods/District; Land Use**]
- Functions [**Shopping; Security**]
- Economy [**Wealth Production**]
- Culture [**Diversity; Social Expression; Heritage**]
- Information [**Tools & Apps; Open data; Data In/Out; Performance**]
- Citizens [**Person/Family; Visitors; Organizations; Business; Capacity Development**]
- Government [**Leadership; Vision & Priorities; Accountability**]

2.2 Anatomy Indicators

Indicators are divided in two categories:

- **Core indicators** are standard measures usable across cities to assess the subsystems in the anatomy that help answer the principal questions related to sustainability, resilience or quality of life.

  All 46 indicators of ISO 37120 labeled as core have been considered. The CPS has extended these core ISO 37120 measures with 59 additional core indicators to describe the scale granularity required by the City Anatomy.

- **Supporting indicators** are measures that provide further information on city services/functions.

  All 54 supporting indicators of ISO 37120 have been considered. The CPS has extended these supporting ISO 37120 measures with 37 additional supporting indicators to increase the scale granularity required by the City Anatomy.

Each CP indicator is tied to a City Anatomy reference, which is explicated through the City Evaluation Framework set forth in the City Anatomy document and illustrated in Figure 2, below. The proposed indicators are also related to the ontology that will be published as Foundation Ontology for the City Anatomy, and they will inform the city indicators ontology under development.

Figure 3 illustrates the proposed indicators classified according to the City Evaluation Framework shown in Figure 2. Note that several third level City Anatomy elements remain unassessed after the current extension of the ISO 37120 indicators.

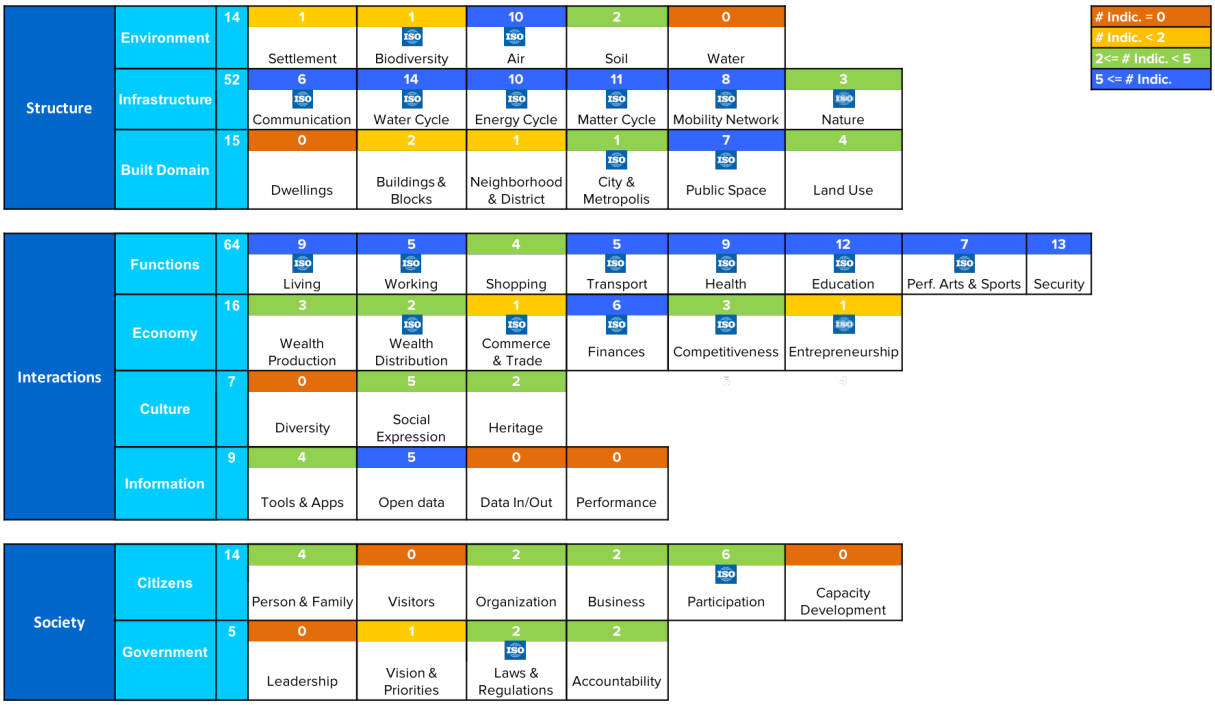

Figure 3. Indicators within the City Evaluation Framework: 96 CP indicators, 59 core and 37 supporting; 100 ISO 37120 indicators, 46 core and 54 supporting.

All additional CP indicators in Figure 3 should be something more than simple measures and be capable of capturing information needed to answer key questions related to current city challenges worldwide:

- How self-sufficient is a city?
- How can cities improve mobility?
- How resilient is a city?
- How can cities attract talent and investment?
- How can cities improve social equity by increasing personal opportunities?
- How can cities foster entrepreneurship?
- How can cities improve livability?

This document defines foundational city indicators by extending the ISO 37120 set with CP indicators while preserving the ISO methodology in their definitions. Relevant thematic documents published in the literature about city structure, interactions and society, together with proposals for city indicators and successful and unsuccessful past city experiences, have been studied and analyzed before selecting the current set of CP indicators. Each indicator is clearly related to the City Anatomy and to the principal factors informing livability and urban sustainability.

Figure 4 illustrates that the scope of the current work focuses on the 'Indicators area' in the certification pyramid, with a bottom-up approach since it's important to start from the basis of existing information (raw data) to define useful and measurable indicators. This figure also identifies ISO standards in relation to raw data, functional indicators, complex indices and certification.

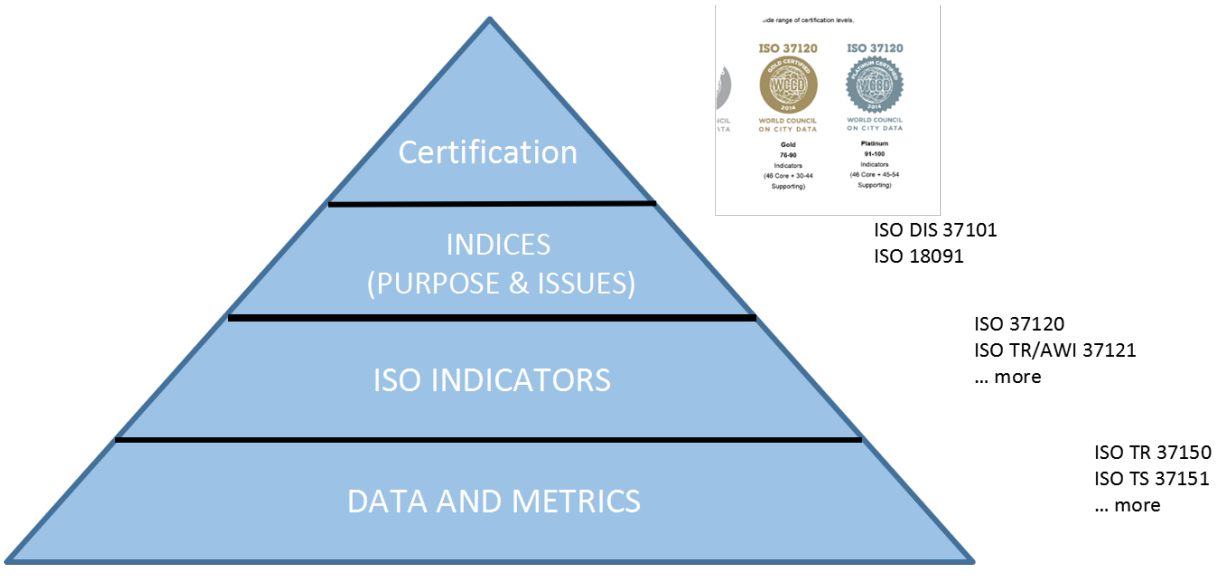

Figure 4. The certification pyramid and ISO standards

Indicators were selected if they met the following criteria:

- be measurable
- be easily calculated and updated
- be useful for cities
- be unambiguous
- be applicable to most first world cities today, and to any city as it evolves
- be an extension of ISO 37120

The proposed CP indicators are listed and classified in the following sections following the layers of the anatomy that they belong to and help measure. The description provided includes a comprehensive definition of the indicator, unit of measurement, and source. Indicators are presented separately within each anatomy layer according to:

- Type: core / supporting;
- Origin: ISO / CP.

The criteria used to categorize the proposed CP indicators as core or supporting is the following:

- Core indicators are either related to resilience or to two of the “key questions” listed above.
- Supporting CP indicators are all the remaining non-core indicators.

All ISO indicators keep their original ISO 37120 classification.

3. Indicators related to Structure

The first city system considered in the City Anatomy is Structure, and its three subsystems: Environment, Infrastructure, and the Built Domain[5].

3.1 List of Indicators: Environment

The first subsystem layer within the anatomy structure (see Figure 1) is the environment, the setting of the city. The natural environment and the physical setting existed at the location of cities before cities.

The environment is formed by three basic compartments, air, soil and water, interacting dynamically in a seasonally dependable way. Water and air are critical for life on earth, and air quality and water footprint are key aspects for city sustainability. Soil is the top layer of the earth's crust with the topsoil supporting all natural and city-built structures. The urban subsoil is generally a source of water and, in some cities, might have historical and archaeological

[5] The built domain includes public spaces.

interest. In some urban areas the subsoil has been contaminated by a number of factors, including previous industrial activities, leakage of underground tanks containing petroleum products, and/or surface runoff of contaminated water which can also cause urban flooding.

The indicators proposed for the Environment subsystem are shown in Table 1.

Table 1. Environment indicators

Layer	ANATOMY ref.	Ref.	Core Indicators: CP	Units
Environment	Soil	3.1.A.1.1	Percentage of paved soil with respect to total surface	%
Environment	Settlement	3.1.A.1.2	Environmental Hazard	Yes/No
Layer	ANATOMY ref.	**Ref.**	**Core Indicators: ISO**	**Units**
Environment	Air	3.1.A.2.1	Fine particulate matter (PM2.5) concentration	PPM
Environment	Air	3.1.A.2.2	Greenhouse gas emissions measured in tonnes (equivalent CO_2 units) per capita (per year)	tonnes/capita/year
Environment	Air	3.1.A.2.3	Particulate matter (PM10) concentration	PPM
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: CP**	**Units**
Environment	Air	3.1.B.1.1	Average wind speed (km/h)	km/h
Environment	Air	3.1.B.1.2	Global solar irradiance yearly average	W/m^2
Environment	Air	3.1.B.1.3	Electromagnetic pollution	V/m
Environment	Soil	3.1.B.1.4	Soil pollution	0-10
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: ISO**	**Units**
Environment	Air	3.1.B.2.1	Noise pollution	dB
Environment	Air	3.1.B.2.2	NO_2 (nitrogen dioxide) concentration	PPM
Environment	Air	3.1.B.2.3	SO_2 (sulphur dioxide) concentration	PPM
Environment	Air	3.1.B.2.4	O_3 (Ozone) concentration	PPM
Environment	Biodiversity	3.1.B.2.5	Percentage change in number of native species	%

The Core and Supporting Environment Indicators are set forth in Annex A.

3.2 List of Indicators: Infrastructure

The second subsystem layer within the anatomy structure comprises city infrastructures, *i.e.,* connective structures that give people access to resources (especially from the environment), bring resources to the city, or distribute resources within the city itself. These include:

Communication Network: Centralized models of communication (radio and television), with one emitter and many receivers, have evolved into a distributed organization of information (Internet), with many emitters and many receivers. Telecommunications networks transporting information through copper and fiber optic cables, and through the electromagnetic spectrum, are also good examples of this information infrastructure.

Water Cycle: Includes supply, sanitation, and management of clean, waste, and surface waters, the latter with its drainage/collector system to avoid rainfall flash flooding.

Energy: We are concerned with the whole energy system: energy generation nodes (nuclear and power plants, wind farms, hydroelectric plants, and solar fields) located outside cities and where most of the energy is produced, and energy distribution and use nodes (including industrial and domestic consumption). The latter is enabled by several energy-related networks installed in cities: gas, electricity, hot water, vapor, etc. Other more distributed energy models are possible for managing energy through generation systems integrated into the city itself.

Matter Cycle: Currently involves the extraction of material resources from nature (including food), their industrial or small-scale manipulation to transform them into products, the transportation and logistics infrastructures to reach consumers, and the management of waste materials.

Mobility Network: Mobility relates to both passenger transportation (vehicular, public transit, heavy rail, bicycling, pedestrian) and freight transportation. It is the system and network of systems that enable people to reach destinations within and across city boundaries.

Nature: The sixth and final infrastructure is the green infrastructure: nature. It is usually formed by the natural elements we bring into the city in an organized manner, such as parks.

Monitoring all of these systems is critical for resilience analysis in cities, as well as for urban transformation.

The indicators proposed for the Infrastructures subsystem are listed in Table 2.

Table 2. Infrastructures indicators

Layer	ANATOMY ref.	Ref.	Core Indicators: CP	Units
Infrastructure	Communication Network	3.2.A.1.1	Number of 3G/4G connections per 100 000 population	number/100 000 people
Infrastructure	Communication Network	3.2.A.1.2	Public space Wi-Fi coverage	%
Infrastructure	Communication Network	3.2.A.1.3	Fiber optic coverage in the city	%
Infrastructure	Water Cycle	3.2.A.1.4	Pluvial regulated volume	Number floods/year
Infrastructure	Energy Cycle	3.2.A.1.5	Percentage of low-emission light private vehicles / Total light private vehicles	%
Infrastructure	Energy Cycle	3.2.A.1.6	Percentage of low-emission light public vehicles /	%

			Total light public vehicles	
Infrastructure	Energy Cycle	3.2.A.1.7	Number of electrical vehicles charging stations	Charging points/vehicle
Infrastructure	Mobility Network	3.2.A.1.8	Percentage parking places off the road	%
Layer	ANATOMY ref.	**Ref.**	**Core Indicators: ISO**	**Units**
Infrastructure	Communication Network	3.2.A.2.1	Number of internet connections per 100 000 population	number/100.000 people
Infrastructure	Communication Network	3.2.A.2.2	Number of cell phone connections per 100 000 population	number/100.000 people
Infrastructure	Water Cycle	3.2.A.2.3	Percentage of population with access to improved sanitation	%
Infrastructure	Water Cycle	3.2.A.2.4	Percentage of city population served by wastewater collection	%
Infrastructure	Water Cycle	3.2.A.2.5	Percentage of the city's wastewater that has received no treatment	%
Infrastructure	Water Cycle	3.2.A.2.6	Percentage of the city's wastewater receiving primary treatment	%
Infrastructure	Water Cycle	3.2.A.2.7	Percentage of the city's wastewater receiving secondary treatment	%
Infrastructure	Water Cycle	3.2.A.2.8	Percentage of the city's wastewater receiving tertiary treatment	%
Infrastructure	Water Cycle	3.2.A.2.9	Percentage of city population with potable water supply service	%
Infrastructure	Water Cycle	3.2.A.2.10	Percentage of city population with sustainable access to an improved water source	%
Infrastructure	Water Cycle	3.2.A.2.11	Total domestic water consumption per capita (liters/day)	liters/day
Infrastructure	Energy Cycle	3.2.A.2.12	Percentage of total energy derived from renewable sources, as a share of the city's total energy consumption	%
Infrastructure	Energy Cycle	3.2.A.2.13	Annual energy consumption of public buildings per year	kWh/m^2
Infrastructure	Energy Cycle	3.2.A.2.14	Total residential electrical energy annual use per capita	kWh/capita
Infrastructure	Energy Cycle	3.2.A.2.15	Percentage of city population with authorized electrical service	%
Infrastructure	Matter Cycle	3.2.A.2.16	Total collected municipal solid waste per capita	kg/capita/year

Infrastructure	Matter Cycle	3.2.A.2.17	Percentage of the city's solid waste that is recycled	%
Infrastructure	Matter Cycle	3.2.A.2.18	Percentage of city population with regular solid waste collection	%
Infrastructure	Mobility Network	3.2.A.2.19	Kilometers of light passenger public transport system per 100 000 population	km/100.000 population
Infrastructure	Mobility Network	3.2.A.2.20	Number of personal automobiles per capita	number/capita
Infrastructure	Mobility Network	3.2.A.2.21	Kilometers of high capacity public transport system per 100 000 population	km/100.000 population
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: CP**	**Units**
Infrastructure	Water Cycle	3.2.B.1.1	Percentage of city groundwater over total city water	%
Infrastructure	Matter Cycle	3.2.B.1.2	Percentage of selective waste collection	%
Infrastructure	Mobility Network	3.2.B.1.3	Interconnectivity between city mobility systems (integration)	number of connections
Infrastructure	Nature	3.2.B.1.4	Total number of animal species	Number
Infrastructure	Nature	3.2.B.1.5	Number of species of urban trees	Number
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: ISO**	**Units**
Infrastructure	Communication Network	3.2.B.2.1	Number of landline phone connections per 100 000 population	number/100.000 people
Infrastructure	Water Cycle	3.2.B.2.2	Total Water consumption per capita (liters/day)	liters/day
Infrastructure	Water Cycle	3.2.B.2.3	Average annual hours of water service interruption per household	Hours
Infrastructure	Water Cycle	3.2.B.2.4	Percentage of water loss (unaccounted for water)	%
Infrastructure	Energy Cycle	3.2.B.2.5	Total electrical energy annual consumption per capita	kWh
Infrastructure	Energy Cycle	3.2.B.2.6	Average number of electrical interruptions per customer per year	number
Infrastructure	Energy Cycle	3.2.B.2.7	Average length of electrical interruptions (in hours)	Hours
Infrastructure	Matter Cycle	3.2.B.2.8	Percentage of the city's solid waste that is disposed of in a sanitary landfill	%
Infrastructure	Matter Cycle	3.2.B.2.9	Percentage of the city's solid waste that is disposed of in an incinerator	%
Infrastructure	Matter Cycle	3.2.B.2.10	Percentage of the city's solid waste that is burned openly	%
Infrastructure	Matter Cycle	3.2.B.2.11	Percentage of the city's solid waste that is disposed of in an open dump	%
Infrastructure	Matter Cycle	3.2.B.2.12	Percentage of the city's solid waste that is disposed	%

			of by other means	
Infrastructure	Matter Cycle	3.2.B.2.13	Hazardous Waste Generation per capita (tonnes)	Tones
Infrastructure	Matter Cycle	3.2.B.2.14	Percentage of the city's hazardous waste that is recycled	%
Infrastructure	Mobility Network	3.2.B.2.15	Number of two-wheel motorized vehicles per capita	number/capita
Infrastructure	Mobility Network	3.2.B.2.16	Kilometers of bicycle paths and lanes per 100 000 population	km/100.000 population
Infrastructure	Mobility Network	3.2.B.2.17	Commercial air connectivity (number of non-stop commercial air destinations)	number
Infrastructure	Nature	3.2.B.2.18	Annual number of trees planted per 100 000 population	number/100000

The Core and Supporting Infrastructure Indicators are set forth in Annex A.

3.3 List of indicators: Built Domain

The third element of the city Structure is the Built Domain, public and private, which includes the surrounding public space. The built domain has two distinct and essential characteristics in relation to urbanism (*i.e.,* urban life and organization): (i) it is the main expression of the material culture of a city (*i.e.,* it contains most physical artifacts created by people), and (ii) it has a multiscale nature (*i.e*., scale is an intrinsic characteristic of the built environment). It can be regarded at the minimum scale of urban functions, in objects, within objects or in the space containing them. Scale is also a factor in dwellings, buildings, blocks, neighborhoods, districts, the city, the metropolis, the country, the continent, and ultimately the whole planet.

The basic physical elements of the public space are streets and squares, where all the infrastructures (water, energy and so on) usually run through, and where vehicles move, and trees are planted. The public space has intrinsic qualitative values (physiological or functional) since it is where infrastructures meet the built domain of buildings, neighborhoods, etc., and also the space shared by people to meet, relax and/or carry out activities individually or in community. Different city models can, thus, be identified or defined based on the scales at which individual needs are met since they, in turn, determine the associated models for mobility, density and social interaction.

The indicators proposed for the Built Domain subsystem are shown Table 3.

Table 3. Built Domain indicators

Layer	ANATOMY ref.	Ref.	Core Indicators: CP	Units
Built Domain	Building/Block	3.3.A.1.1	Building age index: % Housing >=50 years	%
Built Domain	Neighborhood/ District	3.3.A.1.2	Neighborhood homogeneity	%

Built Domain	City/Metropolis	3.3.A.1.3	Coast line (km)	Number
Built Domain	Public Space	3.3.A.1.4	Accessibility of public space: Accessible streets/total	%
Built Domain	Public Space	3.3.A.1.5	Number of street trees / Kilometer urban road	number/km
Built Domain	Public Space	3.3.A.1.6	Surface of pedestrian priority areas and streets/ total street area	%
Built Domain	Land Use	3.3.A.1.7	Density housing	number/km^2
Built Domain	Land Use	3.3.A.1.8	Areal size of mix-use developments as a percentage of city total built area	%
Layer	ANATOMY ref.	**Ref.**	**Core Indicators: ISO**	**Units**
Built Domain	Public Space	3.3.A.2.1	Green area (hectares) per 100 000 population	ha/100000
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: CP**	**Units**
Built Domain	Building/Block	3.3.B.1.1	Building compactness: Average building height	number
Built Domain	Public Space	3.3.B.1.2	Visual perception of urban green	0-10
Built Domain	Land Use	3.3.B.1.3	Industrial available space density	m^2/(km^2 total surface)
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: ISO**	**Units**
Built Domain	Public Space	3.3.B.2.1	Square meters of public indoor recreation space per capita	m^2/capita
Built Domain	Public Space	3.3.B.2.2	Square meters of public outdoor recreation space per capita	m^2/capita
Built Domain	Land Use	3.3.B.2.3	Areal size of informal settlements as a percentage of city area	%

This section also includes indicators related to urbanism and urban development that can be calculated from standard GIS information available in cities.

The Core and Supporting Built Domain Indicators are set forth in Annex A.

4. Indicators related to Interactions

The second system element or city system considered in the City Anatomy is Interactions. The Interactions between the Structure and Society effectively reflect the activities in the city. These can be analyzed and measured as flows of information. Just as Anatomy refers to the city as an anatomical body, Interactions refer to the urban physiology, including its metabolism or cycles, its nervous system, its circulatory system and more.

Interactions include four subsystem layers: (i) functions, (ii) economy, (iii) culture, and (iv) information.

4.1 List of indicators: Functions

This subsystem layer is concerned with activities and not with the buildings that host them. In fact, certain activities, like education, no longer need to take place in a school, but can take place at home or anywhere with internet connectivity. Functions include living, working, education, shopping, caring for health, the performing arts, tourism (business and personal) and more.

Urban functions or services supported by the city are the result of interactions between the city structure and the living entities. The indicators proposed for the Functions subsystem are listed in Table 4.

Table 4. Functions indicators

Layer	ANATOMY ref.	Ref.	Core Indicators: CP	Units
Functions	Living	4.1.A.1.1	Percentage of social housing	%
Functions	Working	4.1.A.1.2	Office space density (m^2/km^2)	m^2/km^2
Functions	Shopping	4.1.A.1.3	Proximity to convenience shopping (% population < 300 m)	%
Functions	Shopping	4.1.A.1.4	Average monthly rental of commercial space	€/m^2
Functions	Transport	4.1.A.1.5	Percentage of population with simultaneous alternative public transport network coverage	%
Function	Transport	4.1.A.1.6	Average daily traffic jams in hours	km h
Functions	Health	4.1.A.1.7	Public expenditure on health per capita	€/capita
Functions	Health	4.1.A.1.8	Annual incidence rate of infectious diseases per 100 000 population	number/100 000 population/year
Functions	Education	4.1.A.1.9	Number of master students per 100 000 population	number/100 000 population/year
Functions	Education	4.1.A.1.10	Percentage of city universities within the world 200 tier / Total number of city universities	%
Functions	Education	4.1.A.1.11	Number of Libraries per 100 000 population	number/100 000 population
Functions	Sports	4.1.A.1.12	Surface public sports facilities (outdoor m^2) per 100 000 population	m^2/100 000 population
Functions	Sports	4.1.A.1.13	Surface public sports facilities (Indoor m^2) per 100 000 population	m^2/100 000 population
Layer	ANATOMY ref.	**Ref.**	**Core Indicators: ISO**	**Units**
Functions	Living	4.1.A.2.1	Percentage of city population living in slums	%
Functions	Working	4.1.A.2.2	City's unemployment rate	%
Functions	Transport	4.1.A.2.3	Annual number of public transport trips per capita	trips/capita/year
Functions	Health	4.1.A.2.4	Number of in-patient hospital beds per 100 000 population	number/100 000 people
Functions	Health	4.1.A.2.5	Average life expectancy	number
Functions	Health	4.1.A.2.6	Number of physicians per 100 000 population	number/100 000 population
Functions	Health	4.1.A.2.7	Under age five mortality per 1 000 live births	number/1 000 births

Functions	Education	4.1.A.2.8	Percentage of female school-aged population enrolled in schools	%
Functions	Education	4.1.A.2.9	Percentage of students completing primary education: survival rate	%
Functions	Education	4.1.A.2.10	Percentage of students completing secondary education: survival rate	%
Functions	Education	4.1.A.2.11	Primary education student/teacher ratio	ratio
Functions	Security	4.1.A.2.12	Number of police officers per 100 000 population	number/100000 population
Functions	Security	4.1.A.2.13	Number of firefighters per 100 000 population	number/100000 population
Functions	Security	4.1.A.2.14	Number of fire related deaths per 100 000 population	number/100000 population
Functions	Security	4.1.A.2.15	Number of natural disaster related deaths per 100 000 population	number/100000 population
Functions	Security	4.1.A.2.16	Number of homicides per 100 000 population	number/100000 population
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: CP**	**Units**
Functions	Living	4.1.B.1.1	Percentage of private housing for sale	number/km^2
Functions	Living	4.1.B.1.2	Percentage of private housing for rent	number/km^2
Functions	Living	4.1.B.1.3	Percentage of empty housing	%
Functions	Living	4.1.B.1.4	Percentage of housing ownership	%
Functions	Living	4.1.B.1.5	Percentage of housing for rent	%
Functions	Shopping	4.1.B.1.6	City food markets per 100 000 population	number/100 000 people
Functions	Shopping	4.1.B.1.7	Malls per 100 000 population	number/100 000 people
Functions	Performing Arts	4.1.B.1.8	Theaters per 100 000 population	number/100 000 people
Functions	Performing Arts	4.1.B.1.9	Auditoriums per 100 000 population	number/100 000 people
Functions	Performing Arts	4.1.B.1.10	Performing arts shows per 1 000 population	number/1 000 citizens
Functions	Performing Arts	4.1.B.1.11	Spectators in music auditoriums per year and 1 000 population	number/1 000 population/year
Functions	Education	4.1.B.1.12	Students per teacher in mandatory education	number
Functions	Education	4.1.B.1.13	Percentage of master's degrees with international recognition	%
Functions	Sports	4.1.B.1.14	Percentage of subscribers to city sports facilities	%
Functions	Security	4.1.B.1.15	Crimes (all Police agencies) per 100 000 population	number/100 000 population
Functions	Security	4.1.B.1.16	Annual average time a crime remains unsolved	Days/crime
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: ISO**	**Units**
Functions	Living	4.1.B.2.1	Percentage of households that exist without registered legal titles	%
Functions	Living	4.1.B.2.2	Number of homeless per 100 000 population	number/100 000 population
Functions	Working	4.1.B.2.3	Percentage of persons in full-time employment	%
Functions	Working	4.1.B.2.4	Youth unemployment rate	%
Functions	Working	4.1.B.2.5	Ratio of jobs to housing	number

Functions	Transport	4.1.B.2.6	Percentage of commuters using a transportation mode to work other than a personal vehicle	%
Functions	Transport	4.1.B.2.7	Transportation fatalities per 100 000 population	number/100 000 people
Functions	Health	4.1.B.2.8	Number of nursing and midwifery personnel per 100 000 population	number/100 000 population
Functions	Health	4.1.B.2.9	Number of mental health practitioners per 100 000 population	number/100 000 population
Functions	Health	4.1.B.2.10	Suicide rate per 100 000 population	number
Functions	Education	4.1.B.2.11	Percentage of male school-aged population enrolled in schools	%
Functions	Education	4.1.B.2.12	Percentage of school-aged population enrolled in schools	%
Functions	Education	4.1.B.2.13	Number of higher education degrees per 100 000 population	number/100 000 population
Functions	Security	4.1.B.2.14	Response time for fire department from initial call	minutes
Functions	Security	4.1.B.2.15	Number of volunteer and part-time firefighters per 100 000 population	number/100 000 population
Functions	Security	4.1.B.2.16	Response time for emergency response services from initial call	response time
Functions	Security	4.1.B.2.17	Violent crime rate per 100 000 population	number/100 000 population
Functions	Security	4.1.B.2.18	Crimes against property per 100 000	number/100 000 population
Functions	Security	4.1.B.2.19	Response time for police department from initial call	minutes and seconds

ISO indicators cover the basic functions like health, education or security. CPS extends to functions like living, working or shopping. The Core and Supporting Functions Indicators are set forth in Annex B.

4.2 List of indicators: Economy

Wealth production and distribution, commerce and trade, innovation and entrepreneurial ecosystems, competitiveness, tax base, and financing vehicles – these are among the many components that make up the Economy of a city. Strategies such as public-private partnerships (P3) provide both success stories, as well as failures, since they are subject to external market forces, long-term revenue collection, and public trust and support. The economy also plays a key role in attracting talent and business to cities.

The Economy was, until recently, considered as a fast interactive flow at the microeconomics scale and slower at the macro scale. Both economic scales require increasingly faster information flows among people, institutions, companies, and economic and financial agencies, given the globalization of city economies, which generate most of the world GDP. Economy influences urban innovation, everyday city operations, and the life cycles of services provided by cities, with the emphasis on improving their management and quality. It is also a key element in the evolution of cities since it determines not only the feasibility of transformational projects aimed at improving the quality of life of citizens, but also the fate of cities themselves.

The indicators proposed for the Economy subsystem are listed in Table 5.

Table 5. Economy indicators

Layer	ANATOMY ref.	Ref.	Core Indicators: CP	Units
Economy	Wealth Production	4.2.A.1.1	Productivity	€/hour
Economy	Wealth Production	4.2.A.1.2	Percentage of employed population	%
Economy	Wealth Distribution	4.2.A.1.3	Gini index	-
Economy	Finances	4.2.A.1.4	Household savings rate	%
Economy	Competitiveness	4.2.A.1.5	Annual GDP growth	%
Economy	Entrepreneurship	4.2.A.1.6	Number of new companies per 100 000 population per year	%
Layer	ANATOMY ref.	**Ref.**	**Core Indicators: ISO**	**Units**
Economy	Wealth Distribution	4.2.A.2.1	Percentage of city population living in poverty	%
Economy	Finances	4.2.A.2.2	Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties	%
Economy	Finances	4.2.A.2.3	Debt service ratio (debt service expenditure as a percentage of a municipality's own-source revenue)	%
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: CP**	**Units**
Economy	Competitiveness	4.2.B.1.1	City debt	€/capita
Economy	Wealth Production	4.2.B.1.2	GDP per capita	€/capita
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: ISO**	**Units**
Economy	Finances	4.2.B.2.1	Tax collected as a percentage of tax billed	%
Economy	Commerce/Trade	4.2.B.2.2	Number of businesses per 100 000 population	%
Economy	Finances	4.2.B.2.3	Capital spending as a percentage of total expenditures	%
Economy	Finances	4.2.B.2.4	Own-source revenue as a percentage of total revenues	%
Economy	Competitiveness	4.2.B.2.5	Number of new patents per 100 000 population per year	%

The Core and Supporting Economy Indicators are set forth in Annex B.

4.3 List of indicators: Culture

Culture refers to language, traditions, beliefs, values, schemata, etc., *i.e.*, assets in the City Anatomy that are not part of the material world or built domain (in contrast to tangible "cultural" objects such as museums, monuments, works of art, archeological sites, city landmarks, etc.). Tacit knowledge requires a personal interaction and the buildup of shared values, understanding and trust among people in a given community. It usually becomes explicit as practices, expressions, representations, knowledge, skills, and organizational behaviors of a given community. Culture impacts and reflects all dimensions of human life – emotion, intelligence, spirituality, creativity and community.

The indicators proposed for the Culture subsystem are listed in Table 6.

Table 6. Culture indicators

Layer	ANATOMY ref.	Ref.	Core Indicators: CP	Units
Culture	Social expression	4.3.A.1.1	Annual average percentage of household consumption expenditures on cultural activities, goods and services	%
Culture	Social expression	4.3.A.1.2	Museums per 100 000 population	number/100 000 people
Culture	Social expression	4.3.A.1.3	Percentage of annual city budget allocated to culture	%
Culture	Heritage	4.3.A.1.4	World Heritage Sites per 1 000 000 population	Number/1m population
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: CP**	**Units**
Culture	Social expression	4.3.B.1.1	Annual average number of visitors to city museums	visitors/museum
Culture	Social expression	4.3.B.1.2	Annual average number of visits to public libraries	visitors/library
Culture	Heritage	4.3.B.1.3	Popularity of sites of architectural interest	visitors/site

The Core and Supporting Culture Indicators are set forth in Annex B.

4.4 List of indicators: Information

The conceptual model of a city as a system of systems, and interactions with different space and time scales, implies the inclusion in the anatomy of the informational or systems platform. This platform highlights the following functional elements (see Figure 5):

City Ontology, with its lexicon, syntax, and semantics, assuring inter-operability and proper integration of city models as well as all structural elements of the anatomy, and enabling the formulation, generation and evaluation of urban planning, design and transformation (this is the topic of a separate City Protocol Agreement);

City Operating System (City OS) that functions as a shared, or trans-disciplinary, set of tools to manage and organize the city as a system of systems for all city activities by defining protocols that standardize methods for improving knowledge acquisition and information transfer (*i.e.*, data flows);

City Performance Indicators and Indices that include broad performance categories, such as resilience, self-sufficiency, habitability, welfare vs. economic empowerment, etc., and that also consider qualitative information in an evaluation framework defined for assessment purposes;

Tools and Applications for system-level data analysis and representation, decision support and management actions;

Information portal for open data and specific learning protocols and related resources, including information on both hard and soft systems, and on the many different mechanisms by which cities acquire and apply knowledge.

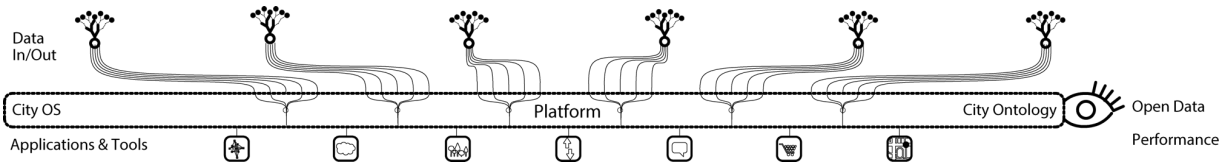

Figure 5. Information platform

It is worth emphasizing that today's cities are adopting and implementing platforms of information to integrate all information flows that move data through the different interconnected and integrated layers of systems and subsystems that form the City Anatomy. These flows pass through niches like, for example, mobility, water, and energy. The information processes and the synergies among them are reinforced by the fact that we live in an information society that facilitates the smooth integration of all information flows produced in the city.

With this flow of information, cities can open their “bodies” to the citizens, making them more participative in city projects and offering a transparent and open view about the City.

A close examination of a city allows the identification of several information systems. This set of basic data collection and processing systems is the basis of what we could call the operating system of the city, the City OS. Furthermore, there are applications designed to manage all systems that exist in the city. With all this information, the government can create open data platforms, enabling society itself to use these data to accelerate innovation, make cities more efficient, or empower citizens to participate actively in city government.

The city performance language in the anatomy allows us to look at the city with evaluative or transformational eyes, either in real time or through much more complex and slower processes, such as urban transformation. This explicit element of performance in the City Anatomy, which at this level is related to key components such as resilience, self-sufficiency, habitability, welfare, equity, etc., should guide the more implicit assessment of how well the city works.

The indicators proposed for the Information subsystem are shown in Table 7.

Table 7. Information indicators

Layer	ANATOMY ref.	Ref.	Core Indicators: CP	Units
Information	Applications & Tools	4.4.A.1.1	Open sensors platform	yes/no
Information	Applications & Tools	4.4.A.1.2	City apps site availability	yes/no
Information	Open Data	4.4.A.1.3	Percentage of core CP indicators that are informed by open datasets	%
Information	Open Data	4.4.A.1.4	Percentage of core ISO 37120 indicators that are informed by open datasets	%
Information	Open Data	4.4.A.1.5	Percentage of supporting CP indicators that are informed by open datasets	%

Information	Open Data	4.4.A.1.6	Percentage of supporting ISO 37120 indicators that are informed by open datasets	%
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: CP**	**Units**
Information	Applications & Tools	4.4.B.1.1	Publicly available applications utilizing open data	number
Information	Applications & Tools	4.4.B.1.2	Number of apps and tools used by non-public sector parties monthly	number/month
Information	Open Data	4.4.B.1.3	Average quality of the datasets	Stars/datasets

The Core and Supporting Information Indicators are set forth in Annex B.

5. Indicators related to Society

The third system element or city system considered in the anatomy is Society. This section describes the proposed framework for this system.

5.1 List of indicators: Citizens

These indicators include citizens, organizations and businesses. The term "citizens" is applied broadly and includes individuals who live or work in and/or visit a city, whether or not they are permanent or legal residents. It extends to include the domestic animals, *i.e*. pets that individuals attach themselves to. Beyond individuals, Society includes the different ways in which citizens organize (*e.g.* into clubs) and work and do business (*e.g.* in corporations and small businesses).

The indicators proposed for the Citizens subsystem are listed in Table 8.

Table 8. Citizens indicators

Layer	CITY ANATOMY Reference	Ref.	Core Indicators: CP	Units
Citizens	Person & Family	5.1.A.1.1	Population Density	citizens/km^2
Citizens	Person & Family	5.1.A.1.2	Fertility Rate: Annual number of live births per 1 000 women aged 15-49 years	# births/year
Citizens	Person & Family	5.1.A.1.3	Cultural Diversity	Dimensionless
Citizens	Organization	5.1.A.1.4	Community work: percentage of population affiliated to NGOs	%
Citizens	Organization	5.1.A.1.5	Number of civic associations per 1 000 population	number
Citizens	Business	5.1.A.1.6	Percentage of Small and Medium Size Companies	%
Citizens	Business	5.1.A.1.7	Average number workers per company	number
Citizens	Participation	5.1.A.1.8	Annual feedback of the citizens on city services performance per 100 000 population	number/100 000 population/year
Citizens	Participation	5.1.A.1.9	Number of open public participation processes in one year	number per 1 000 population
Layer	**CITY ANATOMY Reference**	**Ref.**	**Core Indicators: ISO**	**Units**
Citizens	Participation	5.1.A.2.1	Women as a percentage of total elected to city-level office	%

Citizens	Participation	5.1.A.2.2	Voter participation in last city election (as a percentage of eligible voters)	%
Layer	**CITY ANATOMY Reference**	**Ref.**	**Supporting Indicators: CP**	**Units**
Citizens	Person & Family	5.1.B.1.1	Ageing index	%
Layer	**CITY ANATOMY Reference**	**Ref.**	**Supporting Indicators: ISO**	**Units**
Citizens	Participation	5.1.B.2.1	Number of registered voters as a percentage of the voting age population	%
Citizens	Participation	5.1.B.2.2	Citizens' representation: number of local officials elected to office per 100 000 population	Number/100 000 population

These indicators are a qualitative tool to understand how citizens are organized within a city, and how citizens and city officials interact.

The Core and Supporting Citizens Indicators are set forth in Annex C.

5.2 List of indicators: Government

Government is the part of Society that is elected or appointed to serve the community. If we consider how society is organized then we would be thinking about Society as the government and civil society, and within civil society, we can consider people as individuals, organizations of any type, and companies or businesses that make the urban economy possible. Any type of organization acting in the city would be part of this third city subsystem that we identify as Society.

The indicators proposed for the Government subsystem are listed in Table 9.

Table 9. Government indicators

Layer	ANATOMY ref.	**Ref.**	**Core Indicators: CP**	**Units**
Government	Vision & Priorities	5.2.A.1.1	Consolidated city budget	€/capita
Government	Laws & Regulations	5.2.A.1.2	Number of judges	Number/1.000 population
Government	Accountability	5.2.A.1.3	Index of Transparency and open government	%
Layer	ANATOMY ref.	**Ref.**	**Supporting Indicators: ISO**	**Units**
Government	Laws & Regulations	5.2.B.2.1	Percentage of women employed in the city government workforce	%
Government	Accountability	5.2.B.2.2	Number of convictions for corruption and/or bribery by city officials per 100 000 population	Number per 100 000

The Core and Supporting Government Indicators are set forth in Annex C.

6. Relationship to City Governance, Evaluation and Transformation

The indicators outlined in this document provide a fairly broad view of the city's profile and performance in relation to the City Anatomy, facilitating the evaluation of a city's services and functions, and enabling comparisons with other cities. Through this process of evaluation and comparison a city may make strides toward transformation and utilize the indicators as a general diagnostic tool. Understanding what data to look at to measure effectiveness, or how to effectively use indicators to define an effective system, can often get bogged down by reliance on inputs that are either subjective or untested. Much effort can be saved by adopting common indicator sets achieved through consensus and collaboration. Moreover, cities gain the ability to compare their data, something they can't do when every indicator set is developed on its own.

6.1 Governance

Knowledge of the city's current condition as well as understanding how several areas of its anatomy are interconnected makes governance simpler, more precise and more effective by enabling cities to make decisions in a more informed and responsive way. The data and information made available through the indicators contained in this document can provide cities with a reliable platform for decision-making on routine matters and in crisis scenarios. Particularly when cities may face the need to respond to a situation rapidly, having the understanding gleaned from these indicators can make the difference between a potentially ineffective response and an effective one that is informed by meaningful data.

6.2 Evaluation

Evaluation is where the indicators are the most useful, giving accurate feedback on government actions and the relationship between their intended effects and their consequences. The indicators provide information about the condition of the city (via functional indicators such as GDP or criminality) and context for this information (such as slowly varying measures like urbanism or environment). By searching for similarities with partner cities, city governments can compare situations in a straightforward manner and easily identify opportunities for transformation, improvement, and self-sufficiency. Thanks to shared, open and collaborative data, successful strategies for dealing with situations can be identified, promoting adoption of ideas instead of an unnecessary expenditure of effort and capital to re-invent the wheel.

6.3 City Transformation

The list of indicators has been designed with the aim of aiding cities in their transformative efforts to tackle the challenges of the 21st century. By adopting this set, cities will know clearly which areas are currently addressed and which need further action, promoting new ways of thinking about the city's organization and assisting in setting priorities and clear, attainable goals. With these indicators, cities can, looking at their own and others' historical data, identify successful and failed transformations, and the contexts that influenced them, and evaluate their chances of success.

6.4 Advancing the Internet of Cities

An interoperable common approach on how to gather and measure data across a City Anatomy is a basic step in promoting city interconnectivity and ideas exchange. A common

platform for the development of the smart city cannot be achieved in isolation; collaborative effort is a key component of the modern city. And for cities to be able to collaborate, they must first be able to communicate. This is a key role played by the indicators, making intra-city and inter-city dialogue cleaner and simpler, facilitating the development and flow of ideas. The shared approaches to data acquisition will foster understanding across cities and incentivize them to connect both internally and with each other.

7. References

ISO/TC 268, *Sustainable development of communities.* Geneva, Switzerland, 2014

Agencia de Ecología Urbana, *Guía Metodológica para los sistemas de auditoría, certificación o acreditación de la calidad y sostenibilidad en el medio urbano*. Madrid: Ministerio de Fomento, 2012

8. Target Users

The target users of this Proposed Recommendation Agreement are the following:

Task Teams whose work contributes to the development of the City Protocol and need to gather standardized information about a city's state and context.

City leaders, officers, and/or urban planners seeking to undertake transformational projects who desire feedback on the results of their efforts and information about their city's current state as relative to the rest.

Commercial and non-profit organizations, universities, or research institutions that need to carry out studies across several cities and need uniform data for them, or as a cross-reference for institutions that want to analyze the City Anatomy concept.

City-related institutions and associations, city networks, and standard's organizations are provided with a wide encompassing, standardized, and tested catalogue of indicators to use in further projects.

9. Acknowledgments

Thank you to every collaborator who has aided us in designing, developing, and testing this catalogue of indicators. Special acknowledgements go out to the city of Barcelona, Bismart and Microsoft, and the University Rovira i Virgili for their involvement in the project and all the assistance that we have received from them.

We would like to dearly say thank you to Francesc Giralt for providing us with thoughtful feedback about the document and for its final edition. We would also like to thank the workshop supporting team: Agència ecològica de Barcelona, IESE business school, the university of Toronto, the Smart city congress and world Expo, and Smart Dubai.

Next we would like to thank the Chairs of the CPTF, Sue Lebeck / Francesc Giralt, for their feedback on the present document and for the role they played during the work of the DICI task team. Finally, thank you to CP Editor James Aloisi for his work to improve content, format and expression of this document

10. Authors

Co-chairs: L Sanz, R Rallo

Authors: L Sanz, R Rallo, P Miralles, F Giralt

Contributions: S Gasa, L Lahoz, J Forcadell, R Gil, E Streissel, A Isern, T Franquesa, D Cotrina, F Cárdenas, M Boada, L Torrens, M Fox, D Welsh, M Mulquin, JA Ondiviela, V Guallart, Z Imran, A Bin Bishr, E Martí, N Alsuwaidi.

11. Copyright Statement

Annex A. Structure

The first city system considered in the City Anatomy is **Structure**, and its three subsystems: **environment, infrastructure**, and the **built domain**[6].

Environment

3.1 List of Indicators: Environment

The first subsystem layer within the City Anatomy structure is the environment, the setting of the city.

3.1.A Core Environment indicators

3.1.A.1 Core Environment indicators CP

3.1.A.1.1 Percentage of paved soil with respect to total surface

CITY ANATOMY relationship: Soil

Description: This indicator measures the proportion of paved surface relative to total city surface. Built surface is also considered to be paved. Unpaved surfaces are permeable surfaces[7] (also known as porous or pervious surfaces) that allow water to percolate into the soil to filter out pollutants and recharge the water table.

Uses: This indicator enables cities to know the quality of their soil and paved surface areas. This is related to resilience because a more impervious city can be more easily affected by heavy rainfalls, more prone to flash flooding and increased erosion due to surface runoff. Therefore, a good approximation of the city's soil quality and how much natural infrastructure has been or can be brought into the city is the proportion of paved soil that can be found in it. Natural infrastructure is related to livability and quality of life, as well as self-sufficiency, as green areas are closely linked to the mitigation of contamination.

Calculation: (Paved soil in ha)/(City surface in ha).100

This indicator is expressed as a percentage (%).

3.1.A.1.2 Environmental Hazard

CITY ANATOMY relationship: Settlement

Description: Environmental hazards refer to potential seismic, flooding, hurricanes events that imply a risk of harming the structure and population of the city and/or disrupting city functions, with subsequent economic consequences.

Uses: This indicator serves to assess the potential fragility of the settlement where the city is located and to prioritize actions to make the city more resilient.

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[6] The built domain includes public spaces.
[7] http://extension.udel.edu/factsheet/permeable-vs-impermeable-surfaces/

Calculation: This is a binary “YES/NO” indicator depending on whether the city has experienced at least one event with casualties and or city functions’ disruptions for more than one day in the past 30 years.

3.1.A.2 Core Environment indicators ISO

3.1.A.2.1 Fine particulate matter (PM2.5) concentration

CITY ANATOMY relationship: Air

Reference: See ISO 37120 (Section 8.1)

3.1.A.2.2 Greenhouse gas emissions measured in tonnes (equivalent CO2 units) per capita (per year)

CITY ANATOMY relationship: Air

Reference: See ISO 37120 (Section 8.3)

3.1.A.2.3 Particulate matter (PM10) concentration

CITY ANATOMY relationship: Air

Reference: See ISO 37120 (Section 8.2)

3.1.B Supporting Environment indicators

3.1.B.1 Supporting Environment indicators CP

3.1.B.1.1 Average wind speed (km/h)

CITY ANATOMY relationship: Air

Description: Wind speed, or wind flow velocity, is a fundamental atmospheric rate. Wind speed is caused by air moving from high pressure to low pressure, usually due to changes in temperature. For this indicator to be representative, the average value of wind speed over a minimum of 10 anemometers adequately distributed throughout the city must be used. The average wind speed is taken over a yearly period in order to reduce seasonal effects.

Uses: Cities need to take this indicator into account in order to take action to prevent damage in the event of high-speed winds. It will help cities make decisions in order to protect the population and infrastructure, and to adapt economic activity because high-speed winds can affect weather forecasting, aircraft and maritime operations, construction projects, growth and metabolism rate of many plant species, and countless other implications.

Calculation: Direct measurement.

Unit: km/h

3.1.B.1.2 Global solar irradiance yearly average (W/m^2)

CITY ANATOMY relationship: Air

Description: Global solar irradiance is a measure of the irradiance produced by the Sun in the form of electromagnetic radiation, a part of it being perceived by humans as sunlight, plus diffuse radiation received from other sources. Solar irradiance is essential for life on earth but can also represent a danger to the population. One can measure it with adequate sensors, and a yearly average is taken to correct for seasonal variations. It can also be calculated as the power a square meter of terrain receives on average during a certain period, from parameters such as latitude, solar azimuth, day of the year, and others.

Uses: The measure of solar irradiance is used to learn the population's global exposure to it. At a high level it can cause health concerns to people and affect the general health condition of citizens as well as increase the risk of wildfire, but it also improves the efficiency of solar methods of power generation. Thus, knowledge of the indicator is linked to the city's self-sufficiency and to its citizens' quality of life. It is also closely related to the city's climate and thus can be used to compare the environmental conditions of different cities.

Calculation: The yearly average of global solar irradiance detected by the sensors, averaged over all of them. Based on the equation of the sun's position in the sky throughout the year, the maximum amount of solar insolation on a surface at a particular tilt angle can be calculated as a function of latitude and day of the year.[8]

Unit: $\frac{W}{m^2}$

3.1.B.1.3 Electromagnetic pollution

CITY ANATOMY relationship: Air

Description: Electromagnetic pollution occurs every time electricity is generated. We are surrounded by it whether from mobile communication towers, satellite GPS systems, wireless networks (Wi-Fi, WiMAX), radar, power lines, cell tower transmitters, computer screens and hard drives, wireless internet and so on.[9]

Uses: This indicator enables the city to maintain aspects of its quality of life and control the level of electromagnetic pollution in comparison with the maximum electronic pollution allowed for health security.

Calculation: Direct measurement of electric field strength

Unit: V/m

[8] See how to calculate this amount at: http://www.itacanet.org/the-sun-as-a-source-of-energy/
[9] http://www.who.int/peh-emf/about/WhatisEMF/en/

3.1.B.1.4 Soil pollution

CITY ANATOMY relationship: Soil

Description: Soil pollution is the presence of toxic chemicals in an area's soil in high enough concentrations to be hazardous to human health and/or the ecosystem[10]

Uses: This indicator provides cities with important environmental information. It indicates the quality of life of a city and enables the city to manage its pollution risk via an environment-friendly policy.

Calculation: Soil pollutants include a large variety of contaminants or chemicals, which could be both naturally-occurring in soil and man-made. Unit: between 0 (low pollution) and 10 (high pollution)

3.1.B.2 Supporting Environment indicators ISO

3.1.B.2.1 Noise pollution

CITY ANATOMY relationship: Air

Reference: See ISO 37120 (Section 8.7)

3.1.B.2.2 NO_2 (nitrogen dioxide) concentration

CITY ANATOMY relationship: Air

Reference: See ISO 37120 (Section 8.4)

3.1.B.2.3 SO_2 (sulphur dioxide) concentration

CITY ANATOMY relationship: Air

Reference: See ISO 37120 (Section 8.5)

3.1.B.2.4 O_3 (Ozone) concentration

CITY ANATOMY relationship: Air

Reference: See ISO 37120 (Section 8.6)

3.1.B.2.5 Percentage change in number of native species

CITY ANATOMY relationship: Biodiversity

Reference: See ISO 37120 (Section 8.8)

[10] http://www.environmentalpollutioncenters.org/soil/

Infrastructure

3.2 List of Indicators: Infrastructure

The second subsystem layer within the anatomy structure comprises city infrastructures, *i.e.,* connective structures that give people access to resources (especially from the environment), bring resources to the city, or distribute resources within the city itself.

3.2.A Core Infrastructure indicators

3.2.A.1 Core Infrastructure indicators CP

3.2.A.1.1 Number of 3G/4G connections per 100.000 population.

CITY ANATOMY relationship: Communication Network

Description: 3G and 4G connections are different generations of mobile communications technology that enable a strong, fast, and bidirectional link to the network. Advanced communications give people's smartphones and other devices more power and flexibility, greatly increasing their capabilities. The city population and the number of 3G and 4G connections can be obtained from the city's register, or in the event this information is not recorded in a city, from the service providers themselves.

Uses: This indicator can be used to assess the quality of the population's smartphone connection, which in turn can be used to better decide whether application-oriented smart city projects are worthwhile, or how reliant the city is on mobile internet communications. More importantly, it is a measure of the communications network's capillarity towards citizens and how effectively they can transmit or receive data. This provides the city with more accurate and more frequently updated data and increases its resilience by allowing more precise action, making this a core indicator.[11]

Calculation: $\frac{Number\ of\ 3G\ or\ 4G\ connections}{City\ population} \cdot 100\ 000$

Unit: $\frac{3G\ and\ 4G\ connections}{100\ 000\ Citizens}$

3.2.A.1.2 Public space Wi-Fi coverage

CITY ANATOMY relationship: Communication Network

Description: This indicator measures the percentage of a city's public space that is covered

[11] What constitutes a 3G or 4G connection is defined by the International Telecommunications Union (ITU) and can be found respectively at:
http://web.archive.org/web/20080524050117/http://www.itu.int/osg/spu/imt-2000/technology.html#Cellular%20Standards%20for%20the%20Third%20Generation
http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2134-2008-PDF-E.pdf

by a public Wi-Fi[12] network. Wi-Fi is defined as local area networks compliant with the 802.11 standards. Wi-Fi coverage is defined as the urban surface within 200m of a Wi-Fi node, be it available to the general public or restricted to city officials. The city government often holds a map of publicly owned Wi-Fi nodes, and the surface covered can be obtained from that.

Uses: Firstly, public Wi-Fi coverage has proven instrumental in improving the image of public spaces, as well as the reputation of the city itself. It also improves the city's attractiveness to potential visitors and facilitates basic internet access to those not wealthy enough to afford their own connection, reducing the technology gap, and improving quality of life and equity of opportunities, thus strengthening social tissue. Secondly, Wi-Fi coverage connects the variety of sensors, actuators, and other devices that comprise the "smart city" to the fiber optics network running through the city, providing capillarity to it. Lastly, city officials themselves can connect to this Wi-Fi area, allowing the city administration's data intake and output to reach even further. This strengthening of the communications network provides the city with increased resilience and reaction capabilities, making this a core indicator.

Calculation: $\frac{Sum\ of\ wifi\ nodes\ coverage}{Total\ city\ urban\ surface} \cdot 100$

This indicator is expressed as a percentage (%).

3.2.A.1.3 Fiber optic coverage in the city

CITY ANATOMY relationship: Communication Network

Description: This indicator measures the amount of public fiber optics cable relative to the size of the city. Because fiber optic connections are faster and more reliable than traditional ones, a city with wider fiber optics coverage will enjoy faster and safer connections. By making the network more densely connected its resilience is increased, making this a core indicator. Publicly owned fiber optics networks are recorded by the government, and the influence area of the fiber optics cable can be measured, defined as the surface within 100m of publicly owned fiber optics cables. The indicator is the percentage of this surface to the total urban surface.

Uses: This indicator measures the quality of wired internet connection. This is the backbone of the city's communications network, the conduits through which the bulk of city information, from data sensors and actuators to official reports, run. With knowledge of this indicator a city can determine the effectiveness of prospective sensor platform projects or the vulnerability of their response capabilities to shocks such as massive events or disasters, making this a core indicator.[13]

Calculation: $\frac{Surface\ within\ 100m\ of\ a\ publicly\ owned\ fiber\ optics\ cable}{Total\ urban\ surface} \cdot 100$

[12] What constitutes a WIFI network is defined by the IEEE and can be found at: http://standards.ieee.org/getieee802/download/802.11af-2013.pdf
[13] ITU manual regarding fiber optics: https://www.itu.int/dms_pub/itu-t/opb/hdb/T-HDB-OUT.10-2009-1-PDF-E.pdf

This indicator is expressed as a percentage (%).

3.2.A.1.4 Pluvial regulated volume

CITY ANATOMY relationship: Water Cycle

Description: This indicator measures the pluvial regulated volume of the city. Pluvial regulated volume is defined as the maximum volume of rainwater in a day that a city can manage (*i.e.*, channel through the sewer system, accumulate in specially designed tanks, etc.) without flooding.

Uses: This indicator assists the city in assessing its resilience to flash flooding, heavy rains or storms and the need to implement or increase the capacity of a pluvial regulated system. When uncontrolled (and depending on the city's environment, especially its soil), intense raining will cause floods, sometimes accompanied by mud slides, that could damage infrastructures and impose significant additional costs on the city and its citizens. The ability to properly protect the city from these impacts is linked to its resiliency and quality of life.

Calculation: $Number\ of\ flooding\ events\ in\ one\ year$

3.2.A.1.5 Percentage of low-emission light private vehicles / Total light private vehicles

CITY ANATOMY relationship: Energy Cycle

Description: The indicator measures the percentage of low-emission private vehicles relative to the number of private vehicles used in the city. A low-emission light private vehicle is defined as one not owned by the government and driven by an electric engine, a hybrid engine, or a hydrogen-cell powered engine. The vehicle definition is restricted here to light automotion, *i.e.* cars, vans, motorcycles, and light trucks, as defined by the Environmental Protection Agency (EPA)[14]. This information may be found in national vehicle registers or from car retailers, among others.

Uses: This indicator relates indirectly to the environmental impact of the city's private transportation system, and also provides information for urban planners so that they know what kind of vehicles are used mostly in the city for infrastructure building, planning or refurbishing purposes. Because it is a more environmentally friendly mode of transportation, it is directly linked to self-sufficiency, as well as citizen's quality of life thanks to their generally reduced noise and environmental pollution.[15]

Calculation: $\frac{Number\ of\ registered\ LEV\ private\ light\ vehicles}{Total\ number\ of\ registered\ private\ light\ vehicles} \cdot 100$

This indicator is expressed as a percentage (%).

[14] http://www.epa.gov/oms/imports/glossary.htm#ldv

[15] Report on the positive effect of electric vehicles on pollution http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf

3.2.A.1.6 Percentage low-emission light public vehicles / Total light public vehicles

CITY ANATOMY relationship: Energy Cycle

Description: The indicator measures the percentage of low-emission public vehicles relative to the number of public vehicles used in the city. A low-emission light public vehicle is defined as one owned by the government, both for public transportation or use by public officials and employees, that is powered by an electrical engine, a hybrid engine, or a hydrogen-cell powered engine. The vehicle definition is restricted here to light automotion, *i.e.* cars, vans, motorcycles, and light trucks, as defined by the Environmental Protection Agency or EPA (see reference). This information may be found in national vehicle registers or from car retailers, among others.

Uses: This indicator relates indirectly to the environmental impact of certain (non-transit) elements of the city's public transportation system and vehicle fleet. Because it is a more environmentally friendly mode of transportation, it is directly linked to self-sufficiency and citizen's quality of life thanks to their generally reduced noise and emissions.

Calculation: $\frac{Number\ of\ registered\ LEV\ public\ light\ vehicles}{Total\ number\ of\ registered\ public\ light\ vehicles} \cdot 100$

This indicator is expressed as a percentage (%).

3.2.A.1.7 Number of electric vehicles charging stations

CITY ANATOMY relationship: Energy Cycle

Description: This indicator measures the number of publicly available locations where an electric vehicle can be plugged and recharged, divided over the number of private electrical vehicles in use. A recharge point counts towards this index only if it is available to the general public, be it at a cost or free of charge, and it is publicly owned. Public recharge points exclusively for city owned electrical vehicles are not included. This information is usually held by the city administration and is readily available.

Uses: This indicator assists the government in assessing the strength and viability of electric vehicles in a city. A higher number of electric vehicles charging points is vital to stimulating the transformation of the private vehicle fleet from gas driven to electric vehicles. Thus, they work in unison with the previous indicators in driving down pollution and preserving the environment, as well as enabling higher urban self-sufficiency and resiliency by allowing a reduction of dependence on exterior goods, making it a core indicator.

Calculation: $\frac{Number\ of\ publicly\ available\ electric\ vehicle\ charging\ points}{Number\ of\ private\ electric\ vehicles}$

Unit: $\frac{Charging\ points}{Vehicle}$

3.2.A.1.8 Percentage parking places off the road[16]

CITY ANATOMY relationship: Mobility Network

Description: This indicator measures the percentage of parking places in the city that are off the road. The indicator is calculated as the number of parking places off the road over the total number of parking places.

Uses: By freeing more road space for uses other than parking, good levels of this indicator improve the population's mobility by any mode of transportation, even the car itself, as the street will be much less congested. It may also enhance the ability to introduce additional mobility choices such as bus rapid transit. Furthermore, by indirectly stimulating other modes of transportation and denser cities, equity in opportunities is achieved as walking is a means of transportation that, unlike the car, is available to all able-bodied citizens. Lastly the extra space contributes to improving the overall quality of life as it enables citizens to use the street for other purposes such as green spaces or spaces dedicated to social activity.

Calculation: $\frac{Number\ of\ parking\ places\ off\ the\ road}{Total\ amount\ of\ parking\ places} \cdot 100$

This indicator is expressed as a percentage (%).

3.2.A.2 Core Infrastructure indicators ISO

3.2.A.2.1 Number of internet connections per 100 000 population

CITY ANATOMY relationship: Communication Network

Reference: See ISO 37120 (Section 17.1)

3.2.A.2.2 Number of cell phone connections per 100 000 population

CITY ANATOMY relationship: Communication Network

Reference: See ISO 37120 (Section 17.2)

3.2.A.2.3 Percentage of population with access to improved sanitation

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 21.3)

3.2.A.2.4 Percentage of city population served by wastewater collection

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 20.1)

3.2.A.2.5 Percentage of the city's wastewater that has received no treatment

[16] G.M. page 509

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 20.2)

3.2.A.2.6 Percentage of the city's wastewater receiving primary treatment

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 20.3)

3.2.A.2.7 Percentage of the city's wastewater receiving secondary treatment

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 20.4)

3.2.A.2.8 Percentage of the city's wastewater receiving tertiary treatment

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 20.5)

3.2.A.2.9 Percentage of city population with potable water supply service

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 21.1)

3.2.A.2.10 Percentage of city population with sustainable access to an improved water source

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 21.2)

3.2.A.2.11 Total domestic water consumption per capita (liters/day)

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 21.4)

3.2.A.2.12 Percentage of total energy derived from renewable sources, as a share of the city's total energy consumption

CITY ANATOMY relationship: Energy Cycle

Reference: See ISO 37120 (Section 7.4)

3.2.A.2.13 Annual energy consumption of public buildings per year

CITY ANATOMY relationship: Energy Cycle

Reference: See ISO 37120 (Section 7.3)

3.2.A.2.14 Total residential electrical energy annual use per capita

CITY ANATOMY relationship: Energy Cycle

Reference: See ISO 37120 (Section 7.1)

3.2.A.2.15 Percentage of city population with authorized electrical service

CITY ANATOMY relationship: Energy Cycle

Reference: See ISO 37120 (Section 7.2)

3.2.A.2.16 Total collected municipal solid waste per capita

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.2)

3.2.A.2.17 Percentage of the city's solid waste that is recycled

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.3)

3.2.A.2.18 Percentage of city population with regular solid waste collection

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.1)

3.2.A.2.19 Kilometers of light passenger public transport system per 100 000 population

CITY ANATOMY relationship: Mobility Network

Reference: See ISO 37120 (Section 18.2)

3.2.A.2.20 Number of personal automobiles per capita

CITY ANATOMY relationship: Mobility Network

Reference: See ISO 37120 (Section 18.4)

3.2.A.2.21 Kilometers of high capacity public transport system per 100 000 population

CITY ANATOMY relationship: Mobility Network

Reference: See ISO 37120 (Section 18.1)

3.2.B Supporting Infrastructure indicators

3.2.B.1 Supporting Infrastructure indicators CP

3.2.B.1.1 Percentage of city groundwater over total city water

CITY ANATOMY relationship: Water Cycle

Description: This indicator measures how much of the city's water consumption comes from groundwater. Groundwater is underground trapped water, such as that contained in aquifers, which is used for several city services such as automated irrigation or urban cleaning. The indicator is defined as the volume of water used during a year coming from groundwater sources, divided over the volume of water of all kinds used during a year in the city. Responsible aquifer management and preservation are key to maintaining a self-sufficient city as many of the city's water related services rely on phreatic resources to function.

Uses: Proper aquifer management and preservation are key to maintaining a self-sufficient city as many of the city's water related services rely on phreatic resources to function correctly. Knowledge of total groundwater use is related directly to groundwater sources depletion and thus the indicator plays a role in self-sufficiency.

Calculation: $\frac{Volume\ of\ used\ groundwater\ in\ the\ last\ year}{Volume\ of\ used\ water\ from\ any\ source\ in\ the\ last\ year} \cdot 100$

This indicator is expressed as a percentage (%).

3.2.B.1.2 Percentage of selective waste collection

CITY ANATOMY relationship: Matter Cycle

Description: This indicator measures how much of the city's waste is divided into different categories. It is calculated as mass of sorted waste produced in the city divided by total waste mass produced in it over a year to correct for seasonal effects. Selective waste collection is the sorting of waste into different categories which each receive different treatment, *i.e.* selective dumping or recycling.

Uses: This indicator provides a quantitative measure of how effective the city's waste separation efforts are, and how viable different recycling policies are. Selective collection also plays a key role in effective waste management, which greatly affects self-sufficiency.

Calculation: $\frac{Mass\ of\ sorted\ collected\ waste}{Total\ mass\ of\ collected\ waste} . 100$

This indicator is expressed as a percentage (%).

3.2.B.1.3 Interconnectivity between city mobility systems (integration)

CITY ANATOMY relationship: Mobility Network

Description: This indicator measures the degree of interconnectivity between several public transport systems. Interconnectivity is defined as the degree to which the several transport systems owned by the public sector are linked to each other. Formally, two nodes of the

transport system are connected if they belong to different lines of transportation and are at a maximum distance of 300m of each other. A line of transportation is a series of stops that are passed through by a single specific mode of transportation in a predetermined order. Only transport modes internal to the metropolitan area are counted. Thus, the indicator is calculated as the average number of connections of each node in the network.

Uses: Mobility system interconnectivity is correlated with shorter transport times and more direct routes. Therefore, a highly connected and reticulated transport system works towards the objective of improving city mobility and reducing the city's dependence on cars and other privately owned modes of transport. By equating the public transport's versatility to that of private means of transport, equity of opportunities is also achieved.

Calculation: $\frac{Sum\ of\ total\ node\ connections}{Number\ of\ nodes}$

Unit: $\frac{Connections}{Node}$

3.2.B.1.4 Total number of animal species

CITY ANATOMY relationship: Nature

Description: This indicator measures the total number of animal species present in the urban area as a measure of the animal biodiversity

Uses: This indicator enables a better understanding of the importance of wildlife protection, the biodiversity and the environment health. The protection of species contributes to a thriving, healthy planet for people's health and well-being - from forests that slow climate change and filter water to oceans that provide more than one-sixth of the world's food. Diversity in particular brings resilience to the ecosystem; for example, if a food chain is disrupted, alternatives exist. In a less diverse ecosystem, the removal of a link in the chain can bring down the whole system. Moreover, wildlife variety increases the attractiveness of parks and the city's natural infrastructure. Consequently, this indicator has a correlation with quality of life.

Calculation: Number

Units: Species

3.2.B.1.5 Number of species of urban trees

CITY ANATOMY relationship: Nature

Description: This indicator measures the number of different species of trees present in the city. It is an indicator that gives information about the biodiversity of the city's arboreal environment. Biodiversity is measured here as "species richness", that is, the number of different species to be found in a given environment.

Uses: This is helpful in measuring the impact of the city on its environment, as species richness is a non-renewable resource that, besides its possible usefulness, possesses intrinsic value. Therefore, the indicator is related to self-sufficiency. Trees can also be home

to an immense variety of animal biodiversity, making the quality of the arboreal ecosystem intimately linked to that of the whole urban ecosystem.

Calculation: $\frac{Number\ of\ different\ tree\ species}{Number\ of\ planted\ trees}$

Unit: Species

3.2.B.2 Supporting Infrastructure indicators ISO

3.2.B.2.1 Number of landline phone connections per 100 000 population

CITY ANATOMY relationship: Communication Network

Reference: See ISO 37120 (Section 17.3)

3.2.B.2.2 Total Water consumption per capita (liters/day)

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 21.5)

3.2.B.2.3 Average annual hours of water service interruption per household

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 21.6)

3.2.B.2.4 Percentage of water loss (unaccounted for water)

CITY ANATOMY relationship: Water Cycle

Reference: See ISO 37120 (Section 21.7)

3.2.B.2.5 Total electrical energy annual consumption per capita (kWh)

CITY ANATOMY relationship: Energy Cycle

Reference: See ISO 37120 (Section 7.5)

3.2.B.2.6 Average number of electrical interruptions per customer per year

CITY ANATOMY relationship: Energy Cycle

Reference: See ISO 37120 (Section 7.6)

3.2.B.2.7 Average length of electrical interruptions (in hours)

CITY ANATOMY relationship: Energy Cycle

Reference: See ISO 37120 (Section 7.7)

3.2.B.2.8 Percentage of the city's solid waste that is disposed of in a sanitary landfill

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.4)

3.2.B.2.9 Percentage of the city's solid waste that is disposed of in an incinerator

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.5)

3.2.B.2.10 Percentage of the city's solid waste that is burned openly

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.6)

3.2.B.2.11 Percentage of the city's solid waste that is disposed of in an open dump

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.7)

3.2.B.2.12 Percentage of the city's solid waste that is disposed of by other means

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.8)

3.2.B.2.13 Hazardous Waste Generation per capita (tonnes)

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.9)

3.2.B.2.14 Percentage of the city's hazardous waste that is recycled

CITY ANATOMY relationship: Matter Cycle

Reference: See ISO 37120 (Section 16.10)

3.2.B.2.15 Number of two-wheel motorized vehicles per capita

CITY ANATOMY relationship: Mobility Network

Reference: See ISO 37120 (Section 18.6)

3.2.B.2.16 Kilometers of bicycle paths and lanes per 100 000 population

CITY ANATOMY relationship: Mobility Network

Reference: See ISO 37120 (Section 18.7)

3.2.B.2.17 Commercial air connectivity (number of non-stop commercial air destinations)

CITY ANATOMY relationship: Mobility Network

Reference: See ISO 37120 (Section 18.9)

3.2.B.2.18 Annual number of trees planted per 100 000 population

CITY ANATOMY relationship: Nature

Reference: See ISO 37120 (Section 19.2)

Built Domain

3.3 List of indicators: Built Domain

The third element of the city structure is the built domain, public and private, which includes the surrounding public space.

3.3.A Core Built domain indicators

3.3.A.1 Core Built domain indicators CP

3.3.A.1.1 Building age index: % Housing >=50 years

CITY ANATOMY relationship: Building/Block

Description: This indicator measures the antiquity of buildings in a given area, defined as the percentage of housing in an area that hasn't been extensively rebuilt for 50 years or more.

Uses: Knowledge of the age of buildings in a city is fundamental to assessing its characteristics, which can be related to a variety of issues such as its energy efficiency, expansion capabilities, structural integrity, seismic resilience, and many others. Thus, proper knowledge of the building age index in a given area is key to assessing many of the objectives defined in the introduction of this document.

Calculation: $\frac{Number\ of\ buildings\ with\ an\ age\ index\ greater\ than\ 50\ years}{Total\ number\ of\ buildings} \cdot 100$

This is calculated as a percentage (%).

3.3.A.1.2 Neighborhood homogeneity[17]

CITY ANATOMY relationship: Neighborhood/District

Description: Percentage of population with simultaneous nearby access to at least 4 different types of services from a range of 6 categories. These categories are: cinemas, gyms, basic public or private healthcare, public transport access, social welfare points, and social meeting centers.

Uses: Appropriate levels of this indicator work in favor of several of the objectives outlined in this document, for example: self-sufficiency (thanks to a more compactly built city contributing to less energy usage and emissions), improved mobility (because of the effects of compactness on car usage), and improved quality of life (thanks to the access to different kinds of public and private services).

Calculation: $\frac{Population\ with\ access\ to\ 4\ everyday\ activities}{Total\ population} \cdot 100$

This indicator is expressed as a percentage (%).

[17] G.M. page 529

3.3.A.1.3 Coast line (km)

CITY ANATOMY relationship: City/Metropolis

Description: This indicator measures the proportion of coast line of a city relative to its surface. The coast line is measured in km and the surface in km^2. Port length is measured by its perimeter, which is the length of a curve that followed the outline of all its piers, quays, and any other surface next to the water. Beach length is measured as the length from one side of the beach to the other.[18]

Uses: This indicator helps the City government assess the viability of measures that involve the coast in some manner. The presence and magnitude of a coast line is also directly linked to several objectives, most notably resilience as coastal cities are the most vulnerable to water height rising levels due to global warming effects[19]. Coastal cities have also been shown to improve perceived healthiness and happiness of the population[20], indirectly affecting quality of life. Lastly coastal cities enjoy increased tourism and therefore coast line is indirectly linked to investment.

Calculation: $\frac{Coast\ line\ length\ in\ km}{City\ surface\ in\ km^2}$

Unit: $\frac{Coast\ km}{km^2}$

3.3.A.1.4 Accessibility of public space: Accessible streets/total[21]

CITY ANATOMY relationship: Public Space

Description: This indicator measures the degree of accessibility of the city's streets as a function of their width and slope. Street width is calculated as the width of the widest street's sidewalk, while street slope refers to the longitudinal slope, *i.e.* the slope in the direction the pedestrians walk. The following criteria can be used to assess the quality of a stretch: for width criteria, a stretch of street is considered accessible when one of its sidewalks are at least 2.5 meters wide, while for slope criteria the longitudinal slope cannot be greater than a 6%, or 3,4º (approximately). If the stretch is compliant with both criteria, it is considered accessible. The indicator is calculated as the ratio of accessible street length to total street length.

Uses: High values of this indicator are correlated with a more accessible city, meaning improved mobility for its citizens. This is true not only for citizens who are elderly or disabled,

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[18] In the image, the length of each beach would be the distance between the red lines perpendicular to the coast that mark their limits: https://upload.wikimedia.org/wikipedia/commons/thumb/a/a7/Playas_de_Barcelona.jpg/700px-Playas_de_Barcelona.jpg

[19] http://oceanservice.noaa.gov/facts/sealevel.html

[20] Study regarding increased healthiness of those living near the coast http://www.sciencedirect.com/science/article/pii/S1353829212001220

[21] G.M. page 314

but for all citizens, since a more accessible street promotes the use of alternative private means of transportation such as the bicycle. This is also related to self-sufficiency since it reduces the number of motorized vehicles in use. Lastly it improves quality of life by improving the habitability of the public space and enticing more citizens to make use of it.

Calculation: $\frac{Accessible\ stret\ length\ in\ linear\ meters}{Total\ street\ length\ in\ linear\ meters} \cdot 100$

This indicator is expressed as a percentage (%).

3.3.A.1.5 Number of street trees / Kilometer urban road[22]

CITY ANATOMY relationship: Public Space

Description: Tree density evaluates the number of trees located on the road in relation to the total length of the stretch of road.

Uses: This indicator is directly related to sustainability, as tree-lined streets can become green corridors, connections for the local ecosystems to use and assisting certain species to survive and reproduce. Tree-lined streets also contribute to self-sufficiency in four additional different ways: First, they reduce temperatures with their shadow, transpiration, and change in the wind patterns; Second, vegetal surface generates water vapor and cools down the air; Third, they also function as a windshield, blocking wind gusts and reducing their effect on street elements; and Fourth, they reduce contamination levels via the absorption and consumption of greenhouse effect gases such as NO_x or CO_2.

Calculation: $\frac{Amount\ of\ street\ trees}{Street\ length\ in\ km}$

Unit: $\frac{Trees}{km}$

3.3.A.1.6 Surface of pedestrian priority areas and streets/ total street area[23]

CITY ANATOMY relationship: Public Space

Description: This indicator measures the percentage of urban space dedicated to pedestrian use such as sidewalks, avenues, and pedestrian-only streets in a target area.

Uses: Pedestrian-only areas discourage the use of motorized vehicles and free more space for other activities that improve quality of life such as green areas or areas dedicated to social activities. Pedestrian-only areas promote human interactions and help make the street look livelier, strengthening the links of social tissue. Coupled with strong public transportation systems and availability of several means of transportation, wide pedestrian zones improve mobility as well, reducing the number of cars and allowing for other means of transport.

Calculation: $\frac{Surface\ of\ pedestrian\ street\ areas}{Total\ street\ surface}.100$

[22] G.M. page 372
[23] G.M. page 318

This indicator is expressed as a percentage (%).

3.3.A.1.7 Density housing[24]

CITY ANATOMY relationship: Land Use

Description: This indicator describes the density of housing in a city or an area (this indicator is easily scalable). Housing is understood as any dwelling where people permanently live (*i.e.* flats, condos, suburb houses, etc.).

Uses: This indicator helps to incentivize the building of density housing. Density housing is beneficial to several of the outlined objectives including self-sufficiency: studies (*see reference*) show that denser housing uses less water and energy than their less dense counterparts, up to 30-40% less in the case of energy. This happens because less heating is needed, and there are fewer gardens associated with denser housing. Density housing also greatly improves mobility, being one of the key factors in making cities more compact and bringing the Society and Systems closer together. A more densely housed city also occupies less area, making public transportation a more viable option and greatly reducing energy consumption. Lastly it improves quality of life through greater social activity. Public or private social spaces require a minimum of participants to function correctly, a minimum that is harder to satisfy when these live farther away. This is directly linked to the benefits of more compact cities.

Calculation/Units: $\frac{Number\ of\ dwellings\ in\ an\ area\ or\ city}{Surface\ of\ that\ area\ or\ city\ in\ m^2}$

Unit: $\frac{Dwellings}{m^2}$

3.3.A.1.8 Areal size of mix-use developments as a percentage of city total built area [25]

CITY ANATOMY relationship: Land Use

Description: This indicator measures the percentage of constructed surface with mix-of-uses relative to the total constructed surface. This is a measure to be evaluated locally and not globally, since its benefits come from mixed functional areas. It is thus defined as the average, among all city neighborhoods, of the percentage of built area with mixed functions relative to the total city constructed surface. Built areas with mixed use are identified as block scale developments (*i.e.*, 100x100 m; 1 Ha or approximately 2.5 acres) or superblock developments (300x300 m; 9 Ha or approximately 22.5 acres) in the Built Domain of the City Anatomy that mix or physically integrate the residential function with at least two other city functions such as commercial, professional offices, cultural, or industrial. Physical and functional integration also imply good connectivity in the mobility network and transport

[24] This and other indicators of the built domain section have been extracted or inspired from the “Guia metodológica”, a document on urbanism indicators developed by the Spanish government. The page of the document where they can be found is referenced as G.M. page x, for this indicator: G.M. page 287.
[25] G.M. page 351

function. Some jurisdictions legally require that all residential developments design with a mix-of-use approach. In these cases, the indicator is simply the percentage of city residential area.

Uses: This indicator is closely related to several objectives such as self-sufficiency (a city where housing is located closer to functions needs less fuel-driven transportation, and therefore, there is less contamination and energy use), mobility (appropriate ratings of this indicator make car usage unnecessary and therefore promote less of it), and quality of life (aggrupation and mixing of services and housing promotes permanently used spaces instead of areas that are only used at certain times of the day).

Calculation: $\left(\frac{Total\ constructed\ area\ with\ mix-of-use\ functionaly}{Total\ constructed\ area}\right).100$

This indicator is expressed as a percentage (%).

3.3.A.2 Core Built domain indicators ISO

3.3.A.2.1 Green area (hectares) per 100 000 population

CITY ANATOMY relationship: Public Space

Reference: See ISO 37120 (Section 19.1)

3.3.B Supporting Built Domain indicators

3.3.B.1 Supporting Built Domain indicators CP

3.3.B.1.1 Building compactness: Average building height

CITY ANATOMY relationship: Building/Block

Description: This indicator is calculated as the ratio of the volume built on the surface area of study. The result equals the average building height over the entire area.

Uses: This indicator promotes a model of compact occupation of the territory in order to seek an efficient use of natural resources and reduce pressure on urban support systems, through a decrease in the distances between users, public spaces, facilities and other activities. Compactness is also linked to shorter travel times for any activity, promoting walking as a means of transport and reducing the usage of cars. Lastly the probability of contact, exchange and communication between actors and elements of the urban system is increased, and quality of life with it.

Calculation: $\frac{Built\ volume\ in\ an\ area\ (m^3)}{Surface\ of\ that\ area\ (m^2)}$

Unit: meter

3.3.B.1.2 Visual perception of urban green[26]

CITY ANATOMY relationship: Public Space

Description: This indicator measures how much of the citizen's field of view is filled with treetops. The formula used comes from a document from the Spanish government that tries to greatly simplify the calculation and obtain reasonable results.

Uses: This indicator assists in improving the citizens' quality of life by assessing their perception of nature in the street. This presence is beneficial to the public mood and the street's aesthetics, resulting in increased quality of life and a better image for the city.

Calculation: $\frac{Visual\ volume\ of\ treetops}{Street\ Visual\ Field}$

Where:

- Cup volume = $\frac{4 \cdot \pi \cdot r^3}{3}$, where r is the cup's radius, which is pre-classified according to tree species.

- Visual Volume of treetops = $\sum Cup\ volume$, for the trees in a given street

- Visual Field = $Length\ of\ street\ stretch * street\ width * 8m\ height$

Unit: $\frac{m^3 of\ treetops}{m^3 of\ street}$

3.3.B.1.3 Industrial availability: space density

CITY ANATOMY relationship: Land Use

Description: This indicator gives the total of available industrial[27] spaces in the city by km^2. Industrial purposes include: heavy and light manufacturing buildings; research and development parks; factory-office multiuse property; factory-warehouse multiuse property; and industrial parks.

Uses: This indicator shows the number of industrial spaces located in a city that are available for rent or sale to industries/factories because they are empty. This shows the strength of the industrial sector in an area relative to others and can help the city attract new or expanded industry to an area.

Calculation: $\frac{Total\ industrial\ space\ available}{Total\ studied\ area}$

Unit: $\frac{m^2 of\ industrial\ space}{km^2}$

[26] G.M. page 325
[27] http://womeninbusiness.about.com/od/commercialleasingterms/g/industrialspace.html

3.3.B.2 Supporting Built Domain indicators ISO

3.3.B.2.1 Square meters of public indoor recreation space per capita

CITY ANATOMY relationship: Public Space

Reference: See ISO 37120 (Section 13.1)

3.3.B.2.2 Square meters of public outdoor recreation space per capita

CITY ANATOMY relationship: Public Space

Reference: See ISO 37120 (Section 13.2)

3.3.B.2.3 Areal size of informal settlements as a percentage of city area

CITY ANATOMY relationship: Land Use

Reference: See ISO 37120 (Section 19.3)

Annex B. Interactions

The Indicators outlined in this Annex relate to Interactions. The Interactions between the Structure and Society effectively reflect the activities in the city. Interactions include four subsystem layers: (i) functions, (ii) economy, (iii) culture, and (iv) information.

Functions

4.1 List of indicators: Functions

Urban functions or services supported by the city are the result of interactions between the city structure and the living entities. The indicators proposed for the Functions subsystem are set forth below.

4.1.A Core Functions indicators

4.1.A.1 Core Functions indicators CP

4.1.A.1.1 Percentage of Social housing[28]

CITY ANATOMY relationship: Living

Description: This indicator measures the number of social dwellings relative to the total number of dwellings in an area. Social housing is understood as rental housing the price of which is set by the administration and is generally rented as part of social welfare programs (not through typical market dynamics based upon economical profit). Although it is not directly measured by the indicator, it is important that social housing be varied in type to accommodate the different types of families that will inhabit them, from large families to more nuclear ones.

Uses: This indicator provides cities with information that may help ensure that the composition of the housing stock does not exclude any citizen on grounds of income. The indicator is related to objectives such as improving quality of life by granting access to housing and all the services derived from it to more citizens, as well as promoting equity of opportunities.

Calculation/Units: $\frac{number\ of\ social\ dwellings}{Total\ number\ of\ dwellings} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.A.1.2 Office space density (m^2/km^2)

CITY ANATOMY relationship: Working

[28] G.M. page 613

Description: This indicator gives the proportion of available office[29] spaces in the city relative to its surface. Office spaces are generally defined as a room, set of rooms, or building where the business of a commercial or industrial organization or of a professional person is conducted.

Uses: This indicator shows the surface of offices located in a city that are available to be rented or sold to new businesses because they are empty. It is an indicator that enables the city to know the importance of the service sector in the economy and its capacity to attract new businesses or encourage expanded business.

Calculation: $\frac{Sum\ of\ all\ office\ spaces\ (m^2)}{City\ surface\ (km^2)}$

Unit: $\frac{m^2}{(km^2)}$

4.1.A.1.3 Proximity to convenience shopping (% population < 300 m)[30]

CITY ANATOMY relationship: Shopping

Description: Percentage of population with simultaneous nearby access (< 300 m) to at least 6 different types of convenience shopping from a range of 8 categories. These categories are: Bread, Fish, Meat, Fruits, Vegetables, General food shops (*i.e.* supermarkets), Press, and Pharmaceutical products. Because of its effect on quality of life, dedicated shops such as bakeries are valued over large all-purpose commercial surfaces such as supermarkets. To measure this, the city can be analyzed with a package of spatial statistics.

Uses: High levels of this indicator work in favor of several objectives including, for example, self-sufficiency (thanks to a more compactly built city), mobility (because of the effects of compactness on car usage), and improved quality of life (thanks to the access to different kinds of commodities).

Calculation: $\frac{Population\ with\ access\ (<300\ m) to\ 6\ everyday\ shopping\ activities}{Total\ population} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.A.1.4 Average monthly rental of commercial space

CITY ANATOMY relationship: Shopping

Description: This indicator is the rental price of a commercial space[31] in the city. A commercial space is defined as a property that is used solely for business purposes. Examples of commercial real estate include malls, office parks, restaurants, gas stations, convenience stores and office towers.

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[29] http://dictionary.reference.com/browse/office
[30] G.M. page 529
[31] http://www.investopedia.com/terms/c/commercialrealestate.asp

Uses: This indicator enables the city to know the average rental price of commercial spaces. This process regulates supply and demand within the city, its outskirts, and suburban neighborhoods.

Calculation: Average across all commercial spaces of $\frac{Commercial\ \ space\ renting}{Surface\ of\ commercial\ space}$

Unit: $\frac{€}{m^2}$

4.1.A.1.5 Percentage of population with simultaneous alternative public transport network coverage

CITY ANATOMY relationship: Transport

Description: This indicator describes the percentage of population with simultaneous nearby access to several public transport networks. It is calculated as the sum of buildings with simultaneous access to public transport networks multiplied by their inhabitants. A building is considered to have simultaneous access to several transport networks if two points of access are located within 300m of the building. A point of access is defined as the location where a mode of transportation can be accessed.

Uses: High levels of this indicator are correlated with an increase in the number of daily trips made by alternative means of transport instead of using the private car, thus increasing citizen mobility. It is also linked to increased sustainability thanks to the reduction in motorized vehicle transit, as well as quality of life and equity of opportunities since the indicator values spreading the coverage of mobility instead of favoring a few highly connected areas at the expense of others.

Calculation: $\frac{\sum P_i}{Total\ population} \cdot 100$

where Pi is the population of the building with simultaneous access, and i from 1 to B denotes a building from B buildings with simultaneous access.

This indicator is expressed as a percentage (%).

4.1.A.1.6 Average daily traffic jams in hours[32]

CITY ANATOMY relationship: Transport

Description: This indicator measures the average intensity of all traffic jams in a given day. A traffic jam is an accumulation of vehicles in a stretch of road that, because of its density, slows down traffic below what is optimal for that road. Traffic jams are frustrating for citizens and account for large economic losses since they prevent people from commuting in a timely manner and effectively go about their business. They also have negative environmental impacts as they cause increased emissions and use of fossil fuels. Traffic jams are defined

[32]

here as traffic conditions that rank D, E, or F in the roadway level of service[33], and they are measured in hours x length, meaning: how long did the traffic jam last and how long of a road stretch did it occupy? If real time data of the traffic jam is available, this can be easily obtained from it. If not, average length can be approximated and then multiplied by total traffic jam time.

Uses: This measures the congestion level of the city's transportation system, allowing urban planners to compare different layouts' effectiveness, as well as assisting them in improving their own. A city with fewer traffic jams and a better layout supports several objectives such as: Improved quality of life through reduced stress and noise from daily traffic jams, improved self-sustainability through reduced emissions, since a car in a traffic jam pollutes much more per km travelled than a cruising vehicle, and improved resiliency, since roads are among the first elements to collapse in big events or catastrophes.

Calculation: Daily average across all traffic jams of $Jam\ duration * Jam\ length$,

Units: km h

4.1.A.1.7 Public expenditure on health per capita

CITY ANATOMY relationship: Health

Description: Public expenditure on health is expenditure incurred by public authorities like central, state and local governments to satisfy the collective health needs of the people.

Uses: This indicator enables the city to know its expenses on health per inhabitant, and therefore manage its budget prudently and according to the evolution of the population's needs. Universal access health services are related to equity of opportunities and improving overall quality of life.

Calculation: $\frac{Total\ health\ expenditure}{City\ population}$

Unit: €/capita.

4.1.A.1.8 Annual incidence rate of infectious diseases per 100 000 population

CITY ANATOMY relationship: Health

Description: This indicator shows the number of infectious incidences in a city during a year. It is calculated as the total number of diagnosed cases of an infectious disease in an area divided by that area's exposed population[34], meaning the number of people who have been at risk of contracting the disease. If this number is not known, the total city population will be used.

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[33] http://www.vtpi.org/cong_relief.pdf, page 14
[34] Further clarification available at http://whqlibdoc.who.int/publications/2006/9241547073_eng.pdf page 47

Uses: This indicator provides the city with knowledge about its sanitation and global healthiness as well as its vulnerability to transmittable diseases. This is clearly related to the city's resiliency, especially so in cases of great epidemics. Even when no such epidemic is present, appropriate levels of this indicator can do much to improve quality of life by reducing the effects of known common diseases.

Calculation $\frac{Infectious\ incidences\ in\ a\ year}{City\ population} \cdot 100\ 000$

Unit: $\frac{Infectious\ incidences}{100\ 000\ population * year}$.

4.1.A.1.9 Number of master students per 100 000 population

CITY ANATOMY relationship: Education

Description: This indicator shows the number of students pursuing a master's degree[35] in one of the city's colleges or universities. A master's degree is an academic degree awarded by a college or university to someone who has studied a subject for at least one year beyond the bachelor's degree.

Uses: This indicator enables the city to know the percentage of students who continue after their bachelor's degree in one of the city's colleges or universities. It is an important socio-demographic indicator for the economic development of a city.

Calculation: $\frac{Master's\ degree\ students}{City\ population} \cdot 100\ 000$

Unit: $\frac{Master's\ degree\ students}{100\ 000\ citizens}$

4.1.A.1.10 Percentage of city universities within the world 200 tier

CITY ANATOMY relationship: Education

Description: This indicator shows the number of universities located in the city that are in the world top 200 according to the "QS top universities ranking" international ranking[36].

Uses: The indicator enables the city to know the level of excellence of their universities and their position in an official and international classification. The universities' reputation is linked to their capacity to attract new and more qualified students. These are linked to an improvement in the city's human capital and its capacity to attract investors and to create new entrepreneurs, as well as improvement of the city's image.

Calculation: $\frac{Number\ of\ city\ universities\ within\ the\ world\ 200\ tier}{Total\ amount\ of\ city\ universities} \cdot 100$

This indicator is expressed as a percentage (%).

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[35] http://www.thefreedictionary.com/master's+degree
[36] QS top universities ranking: http://www.topuniversities.com/

4.1.A.1.11 Number of libraries per 100 000 population

CITY ANATOMY relationship: Education

Description: This indicator gives the total number of public libraries[37] in a city. A library can be defined as a place set apart to contain books, periodicals, and other material for reading, viewing, listening, study, or reference, and as a room, set of rooms, or building where books may be read or borrowed.

Uses: This indicator enables the city to know the level of cultural equipment and access to culture and knowledge available to its citizens. As libraries allow the population to access great amounts of information at a reduced cost, they empower people and spread equity of opportunities, as well as increase general quality of life.

Calculation $\frac{Total\ number\ of\ libraries}{City\ population} \cdot 100\ 000$

Unit: $\frac{Libraries}{100\ 000\ people}$

4.1.A.1.12 Surface public sports facilities (outdoor m^2) per 100 000 population

CITY ANATOMY relationship: Sports

Description: Outdoor public sports facilities are sports structures and public buildings or groups of structures designed for exterior exercising, sports training and practice, and competition in various sports.

Uses: This indicator enables the city to know the total surface of public outdoor sports facilities and the opportunities available to citizens for access to outdoor sports installations. It correlates with the health level of the population and helps to anticipate future health and sports expenses for the city. These factors are all linked to quality of life.

Calculation: $\frac{Total\ surface\ of\ public\ outdoors\ sports\ facilities}{City\ population} \cdot 100\ 000$

Unit: $\frac{m^2 of\ public\ outdoors\ sport\ facility}{100\ 000\ population}$

4.1.A.1.13 Surface public sports facilities (Indoor m^2) per 100 000 population

CITY ANATOMY relationship: Sports

Description: Indoor public sports facilities are sports structures and public buildings or groups of structures designed for interior exercising, sports training and practice, and competition in various sports.

Uses: The indicator enables the city to know the total surface of public indoor sports facilities and through it, the opportunities available to citizens for access to indoor sports installations.

[37] http://dictionary.reference.com/browse/library?s=t

It correlates with the health level of the population and helps to anticipate future health and sports expenses for the city. These factors are all linked to quality of life.

Calculation: $\frac{Total\ surface\ of\ public\ indoors\ sports\ facilities}{City\ population} \cdot 100\ 000$

Unit: $\frac{m^2 of\ public\ indoors\ sport\ facility}{City\ population} \cdot 100\ 000$

4.1.A.2 Core Functions indicators ISO

4.1.A.2.1 Percentage of city population living in slums

CITY ANATOMY relationship: Living

Reference: See ISO 37120 (Section 15.1)

4.1.A.2.2 City's unemployment rate

CITY ANATOMY relationship: Working

Reference: See ISO 37120 (Section 5.1)

4.1.A.2.3 Annual number of public transport trips per capita

CITY ANATOMY relationship: Transport

Reference: See ISO 37120 (Section 18.3)

4.1.A.2.4 Number of in-patient hospital beds per 100 000 population

CITY ANATOMY relationship: Health

Reference: See ISO 37120 (Section 12.2)

4.1.A.2.5 Average life expectancy

CITY ANATOMY relationship: Health

Reference: See ISO 37120 (Section 12.1)

4.1.A.2.6 Number of physicians per 100 000 population

CITY ANATOMY relationship: Health

Reference: See ISO 37120 (Section 12.3)

4.1.A.2.7 Under age five mortality per 1 000 live births

CITY ANATOMY relationship: Health

Reference: See ISO 37120 (Section 12.4)

4.1.A.2.8 Percentage of female school-aged population enrolled in schools

CITY ANATOMY relationship: Education

Reference: See ISO 37120 (Section 6.1)

4.1.A.2.9 Percentage of students completing primary education: survival rate

CITY ANATOMY relationship: Education

Reference: See ISO 37120 (Section 6.2)

4.1.A.2.10 Percentage of students completing secondary education: survival rate

CITY ANATOMY relationship: Education

Reference: See ISO 37120 (Section 6.3)

4.1.A.2.11 Primary education student/teacher ratio

CITY ANATOMY relationship: Education

Reference: See ISO 37120 (Section 6.4)

4.1.A.2.12 Number of police officers per 100 000 population

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 14.1)

4.1.A.2.13 Number of firefighters per 100 000 population

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 10.1)

4.1.A.2.14 Number of fire related deaths per 100 000 population

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 10.2)

4.1.A.2.15 Number of natural disaster related deaths per 100 000 population

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 10.3)

4.1.A.2.16 Number of homicides per 100 000 population

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 14.2)

4.1.B Supporting Functions indicators

4.1.B.1 Supporting Function indicators CP

4.1.B.1.1 Percentage of private housing for sale

CITY ANATOMY relationship: Living

Description: This indicator gives the total number of private dwellings for sale in the city relative to the total number of dwellings in the city. Private housing means places where persons, families, or small self-formed groups live independently. Occupiers of these spaces have full expectation of general privacy, as well as general control over their living spaces whether or not they own them.

Uses: This indicator enables the city to know the percentage of its housing stock available for sale and describes the city's socio-demographic situation. It reflects the offer/demand of the real estate market, its potential growth, and the financial situation of the citizens.

Calculation: $\frac{Total\ number\ of\ dwellings\ for\ sale}{Total\ number\ of\ dwellings} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.B.1.2 Percentage of private housing for rent

CITY ANATOMY relationship: Living

Description: This indicator gives the total number of private dwellings available for rent in the city relative to the total number of dwellings. Private housing means places where persons, families, or small self-formed groups live independently. Renters of these spaces have full expectation of general privacy, as well as general control over their living spaces.

Uses: This indicator enables the city to know the percentage of citizens who want to rent their dwelling, the condition of the real estate market, how transient the population may be, and the financial situation of the citizens, *i.e*. citizens who may not have a strong financial situation are more likely to need to rent a place to live.

Calculation: $\frac{Total\ \ number\ of\ dwellings\ for\ rent}{Total\ number\ of\ dwellings} \cdot 100$ This indicator is expressed as a percentage (%)

4.1.B.1.3 Percentage of empty housing

CITY ANATOMY relationship: Living

Description: This indicator gives the percentage of empty housing[38] relative to the total number of dwellings in the city. Empty housing means those dwellings that would normally be occupied but are temporarily vacant for reasons not connected with second dwellings or holiday accommodation, *e.g.* housing in probate, in the process of being sold, or not in a fit state for habitation.

[38] http://www.cornwall.gov.uk/media/3642937/BN7-Empty-Homes-v4-Nov-13.pdf

Uses: This indicator enables the city to know the percentage of the housing stock that is unattended. Unattended dwellings have negative impacts on the local community, including the devaluing of neighboring properties, rise in crime, loss of social activity, economic loss to the local community, and pest infestations. They may also need maintenance and repairing. Therefore, it is an indicator related to the citizens' quality of life.

Calculation: $\frac{Total\ number\ of\ empty\ dwellings}{Total\ number\ of\ dwellings} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.B.1.4 Percentage of housing ownership

CITY ANATOMY relationship: Living

Description: This indicator measures what percentage of houses in a given area is on a tenure regime of ownership. A house is owned if its inhabitants are its legal owners. The indicator is calculated as the percentage of all housing that is held in an ownership tenure regime.

Uses: Properly assessing the predominant tenure regime in different areas of the city reveals a variety of their characteristics, including income distribution and inhabitant origins.

Calculation/Units: $\frac{NUmber\ of\ dwellings\ in\ ownership\ tenure\ regime}{Total\ number\ of\ dwellins} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.B.1.5 Percentage of housing for rent

CITY ANATOMY relationship: Living

Description: This indicator measures what percentage of houses in a given area is on a tenure regime of rent. A house is rented if its inhabitants are not its legal owners but instead pay a periodical fee to said owners in exchange for permission to inhabit it. The indicator is calculated as the percentage of all housing that is held in a rent tenure regime.

Uses: Properly assessing the predominant tenure regime in different areas of the city reveals a variety of their characteristics, including income distribution and inhabitant origins.

Calculation/Units: $\frac{Number\ of\ dwellings\ in\ rent\ tenure\ regime}{Total\ number\ of\ dwellings} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.B.1.6 City food markets per 100 000 population

CITY ANATOMY relationship: Shopping

Description: This indicator shows the quantity of food markets in the city relative to the total population. These must be permanent markets. A market is defined as a regular gathering of people for the purchase and sale of food.

Uses: This indicator shows the availability of food markets to the citizens, and how far they must travel in order to acquire food. Accessible food markets stimulate the local economy by encouraging proximity consumption and may influence mobility by reducing time/length of transportation.

Calculation:

$$\frac{Total\ number\ of\ city\ food\ markets}{City\ population} \cdot 100\ 000$$

Unit: $\frac{Food\ Markets}{100\ 000\ citizens}$.

4.1.B.1.7 Malls per 100 000 population

CITY ANATOMY relationship: Shopping

Description: This indicator gives the total number of malls located in a city, relative to its population. A mall is a large retail complex containing a variety of stores and often restaurants and other business establishments housed in a series of connected or adjacent buildings or in a single large building. A mall is any commercial surface over 1500 m^2 in surface.

Uses: This indicator enables the city to know the total numbers of shopping malls and to understand the economic conditions, the degree of purchasing power of the citizens and the quality of life of the city.

Calculation: $\frac{Total\ number\ of\ malls}{City\ population} \cdot 100\ 000$

Unit: $\frac{Malls}{100\ 000\ citizens}$

4.1.B.1.8 Theaters per 100 000 population

CITY ANATOMY relationship: Performing Arts

Description: This indicator gives the total number of theaters in a city. A theater can be defined as a building, part of a building, or outdoor area for housing dramatic presentations, stage entertainments, or motion picture shows.

Uses: This indicator enables the city to know the level of cultural infrastructure and the access its citizens have to leisure and knowledge. This improves their quality of life while it also attracts tourism and improves the city's image, attracting investment and entrepreneurship.

Calculation: $\frac{Total\ number\ of\ theaters}{City\ population} \cdot 100\ 000$

Unit: $\frac{Theaters}{100\ 000\ citizens}$

4.1.B.1.9 Auditoriums per 100 000 population

CITY ANATOMY relationship: Performing Arts

Description: This indicator gives the total number of auditoriums in a city. An auditorium can be defined as a space set apart for the audience in a theater, school, or another public building.

Uses: This indicator enables the city to know the level of cultural infrastructure and the access its citizens have to leisure and knowledge. This improves their quality of life while it also attracts tourism and improves the city's image, attracting investment and entrepreneurship.

Calculation: $\frac{Total\ number\ of\ auditoriums}{City\ population} \cdot 100\ 000$

Unit: $\frac{Auditoriums}{100\ 000\ citizens}$

4.1.B.1.10 Performing arts shows per 1 000 population

CITY ANATOMY relationship: Performing Arts

Description: This indicator gives the total of performing arts[39] performances in a city. Performing arts are art forms in which artists use their voices and/or the movements of their bodies, often in relation to other objects, to convey artistic expression.

Uses: This indicator enables the city to know the citizens' level of interest in culture and their level of knowledge of available performing arts options. It also enables a city to assess the popularity of its performing art shows. It provides insight into the attractiveness of art places. These factors all influence quality of life, support tourism and improve the city's image, attracting investment and entrepreneurship.

Calculation: $\frac{Total\ number\ of\ performances}{City\ population} \cdot 1\ 000$

Unit: $\frac{Performances}{1\ 000\ citizens}$

4.1.B.1.11 Annual number of spectators in music auditoriums per 1 000 population

CITY ANATOMY relationship: Performing Arts

Description: The indicator shows the average number of spectators attending the city's auditorium events in a given year.

Uses: This indicator enables the city to know the citizens' level of interest in culture (specifically music). It also offers insight into the attractiveness of music venues and how citizens utilize their free time. Furthermore, auditoriums also attract citizens outside the city

[39] http://en.wikipedia.org/wiki/Performing_arts

and tourists to the shows, making this correlated with city attractiveness and therefore, investment attraction.

Calculation:

$$\frac{Annual\ number\ of\ spectators\ in\ musics\ auditoriums}{City\ population} \cdot 1\,000$$

Unit: $\frac{Spectators}{1\,000\ population * year}$

4.1.B.1.12 Students per teacher in mandatory education

CITY ANATOMY relationship: Education

Description: This indicator is defined as the number of students relative to the number of teachers in the city's mandatory education system.

Uses: This indicator shows the average classroom's size. This is an important factor in assessing the system's effectiveness as overcrowded classrooms have a slower pace and lower learning quality. Balancing the costs of reduced classroom sizes with the benefits of improved learning is one of the key decisions in designing education systems and the indicator helps in comparing the city's model with another city's model. As an education related indicator, this is linked to fostering entrepreneurship and improving the population's quality of life.

Calculation: $\frac{Total\ students\ in\ mandatory\ education}{Total\ teachers\ in\ mandatory\ education}$

Unit: $\frac{Students}{Teacher}$

4.1.B.1.13 Percentage of master's degrees with international recognition

CITY ANATOMY relationship: Education

Description: An international master's degree is an academic degree conferred by a college or university upon those who complete at least one year of prescribed study beyond the bachelor's degree and which has similar educational value all around the world.

Uses: This indicator enables the city to know the excellence level of their post-graduate system, to know the international recognition of its master's degrees, and the city's ability to attract new and talented students. Therefore, this is closely linked to entrepreneurship, investment, and the city's quality of life.

Calculation: $\frac{Total\ number\ of\ internationally\ recognised\ master's\ degrees}{Total\ number\ of\ master\ degrees} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.B.1.14 Percentage of subscribers to city sports facilities

CITY ANATOMY relationship: Sports

Description: Subscribers to city sports facilities are citizens who have access to city buildings or groups of structures designed for exercising, sports training and practice, and competition in various sports, who need to pay a subscription before being able to use them. This indicator does not include subscriptions to organized team sport events.

Uses: This indicator enables the city to know the number of citizens who use city sports facilities via a subscription. Therefore, the indicator measures the population's interest in fitness and exercise, as well as how frequently those kinds of fitness destinations are being used and whether future investments in similar facilities are necessary. Like other sports-related measures, this indicator is linked to the population's quality of life, as fitness has been shown to be linked to overall improved health and happiness[40].

Calculation: $\frac{Total\ number\ of\ suscribers\ to\ city\ sports\ facilities}{City\ population} \cdot 100$

This indicator is expressed as a percentage (%).

4.1.B.1.15 Crimes (all Police agencies) per 100 000 population

CITY ANATOMY relationship: Security

Description: A crime is an act or omission that constitutes an offence punishable by law.

Uses: This indicator enables the city to know the extent of criminal activity and assess the effectiveness of its crime fighting policies and how they compare to other cities' measures. High levels of criminality are disruptive to the city's functions, as crimes are actions detrimental to the city's interests. For that reason, low criminality levels are linked to almost all of the objectives, from city's resilience, as an already chaotic city is more vulnerable to disasters, to investment, entrepreneurship, quality of life or mobility.

Calculation: $\frac{Total\ number\ of\ reported\ crimes}{City\ population} \cdot 100\ 000$

Unit: $\frac{Crimes}{100\ 000\ citizens}$

4.1.B.1.16 Annual average time a crime remains unsolved

CITY ANATOMY relationship: Security

Description: This indicator measures how long crimes go unsolved. An unsolved crime is an act or omission which constitutes an offence and is punishable by law but which is not solved. A crime is considered solved when a sentence or punishment has been passed by an appropriate official or when the case has been archived as unsolvable. The indicator is the average number of days a crime remains unsolved.

Uses: This indicator enables the city to know the efficiency and swiftness of the police force in detecting and punishing criminal activity. High levels of criminality are disruptive to the

[40] http://www.sciencedirect.com/science/article/pii/S0167487012000402

city's interactions, structure, and people; therefore, keeping it under control is of key importance to all of the objectives outlined in the introduction.

Calculation: $\frac{Sum\ for\ all\ crimes\ of\ the\ number\ of\ days\ a\ crime\ has\ reamined\ unsolved}{Total\ number\ of\ crimes\ reported\ in\ a\ year}$

Unit: Day/crime

4.1.B.2 Supporting Functions indicators ISO

4.1.B.2.1 Percentage of households that exist without registered legal titles

CITY ANATOMY relationship: Living

Reference: See ISO 37120 (Section 15.3)

4.1.B.2.2 Number of homeless per 100 000 population

CITY ANATOMY relationship: Living

Reference: See ISO 37120 (Section 15.2)

4.1.B.2.3 Percentage of persons in full-time employment

CITY ANATOMY relationship: Working

Reference: See ISO 37120 (Section 5.4)

4.1.B.2.4 Youth unemployment rate

CITY ANATOMY relationship: Working

Reference: See ISO 37120 (Section 5.5)

4.1.B.2.5 Ratio of jobs to housing

CITY ANATOMY relationship: Working

Reference: See ISO 37120 (Section 19.4)

4.1.B.2.6 Percentage of commuters using a transportation mode to work other than a personal vehicle

CITY ANATOMY relationship: Transport

Reference: See ISO 37120 (Section 18.5)

4.1.B.2.7 Transportation fatalities per 100 000 population

CITY ANATOMY relationship: Transport

Reference: See ISO 37120 (Section 18.8)

4.1.B.2.8 Number of nursing and midwifery personnel per 100 000 population

CITY ANATOMY relationship: Health

Reference: See ISO 37120 (Section 12.5)

4.1.B.2.9 Number of mental health practitioners per 100 000 population

CITY ANATOMY relationship: Health

Reference: See ISO 37120 (Section 12.6)

4.1.B.2.10 Suicide rate per 100 000 population

CITY ANATOMY relationship: Health

Reference: See ISO 37120 (Section 12.7)

4.1.B.2.11 Percentage of male school-aged population enrolled in schools

CITY ANATOMY relationship: Education

Reference: See ISO 37120 (Section 6.5)

4.1.B.2.12 Percentage of school-aged population enrolled in schools

CITY ANATOMY relationship: Education

Reference: See ISO 37120 (Section 6.6)

4.1.B.2.13 Number of higher education degrees per 100 000 population

CITY ANATOMY relationship: Education

Reference: See ISO 37120 (Section 6.7)

4.1.B.2.14 Response time for fire department from initial call

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 10.6)

4.1.B.2.15 Number of volunteer and part-time firefighters per 100 000 population

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 10.4)

4.1.B.2.16 Response time for emergency response services from initial call

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 10.5)

4.1.B.2.17 Violent crime rate per 100 000 population

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 14.5)

4.1.B.2.18 Crimes against property per 100 000

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 14.3)

4.1.B.2.19 Response time for police department from initial call

CITY ANATOMY relationship: Security

Reference: See ISO 37120 (Section 14.4)

Economy

4.2 List of indicators: Economy

Wealth production and distribution, commerce and trade, innovation and entrepreneurial ecosystems, competitiveness, tax base, and financing vehicles – these are among the many components that make up the Economy of a city. The indicators proposed for the Economy subsystem are set forth below.

4.2.A Core Economy indicators

4.2.A.1 Core Economy indicators CP

4.2.A.1.1 Productivity[41]

CITY ANATOMY relationship: Wealth Production

Description: This indicator describes the output of a city relative to the input, or how efficiently the workforce produces wealth. GDP is taken as a measure of the output while total number of hours worked by the workforce is taken as the input.

Uses: Wealth production enhances city functions. It is also related to quality of life if it is distributed with equity among the population.

Calculation: $\frac{City\ GDP}{Hours\ worked\ by\ the\ city's\ active\ workforce}$

Units: €/hour

4.2.A.1.2 Percentage of employed population

CITY ANATOMY relationship: Wealth Production

Description: The employment rate is defined here the percentage of employed population with respect to the economically active population (*i.e.*, all persons of either sex above a specified legal age who furnish the supply of labor for the production of economic goods and services (employed and unemployed, including those seeking work for the first time), as defined by the System of National Accounts (SNA) of the UN, during a specified time reference period.

Uses: This indicator reflects the percentage of the population that generates wealth in a city with respect to the population that generates, can generate, or that is legally retired.

Calculation: $\frac{\text{Employed population}}{\text{Economically active population}} \cdot 100$

This indicator is expressed as a percentage (%).

[41] http://www.oecd.org/std/productivity-stats/40526851.pdf

4.2.A.1.3 Gini index

CITY ANATOMY relationship: Wealth Distribution

Description: The Gini index[42] measures the extent to which the distribution of income or consumption expenditure among individuals or households within an economy deviates from a perfectly equal distribution.

Uses: This indicator enables the city to measure the extent of socio-economic differences and the inequalities in the distribution of its wealth. Unequal wealth distribution influences greatly the inequity of opportunities of all kinds for the population, and at some levels it also affects their quality of life. Under extreme cases, anger and civil unrest arising from a perceived unfairness can affect directly the resilience of the city.

Calculation: A Lorenz curve plots the cumulative percentages of total income received against the cumulative number of recipients, starting with the poorest individual or household. The Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality and is expressed as the quotient between the real and equal distributions.

Unit: between 0 and 1. Gini index of 1 represents perfect equality, while an index of 0 implies perfect inequality.

4.2.A.1.4 Household savings rate

CITY ANATOMY relationship: Finances

Description: According to the OECD[43], household savings rate is obtained by dividing household savings by household disposable income (plus the change in households' net equity in pension funds).

Household savings is obtained by subtracting household consumption from household disposable income and adding the change in households' net equity in pension funds.

Household disposable income is obtained by adding: income from employment and from the operation of unincorporated enterprises, plus receipts of interest, dividends and social benefits minus payments of current taxes, interest and social contributions.

Uses: This indicator gives cities a clear idea of the funds that are available to finance household needs with respect to income. In turn, it gives a sense of the prospects for long term city growth.

Calculation: $$\frac{\text{household savings}}{\text{household disposable income}} \cdot 100$$

This indicator is expressed as a percentage (%).

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[42] http://data.worldbank.org/indicator/SI.POV.GINI
[43] http://www.oecd-ilibrary.org/sites/9789264067981-en/02/05/index.html?itemId=/content/chapter/9789264075108-10-en&_csp_=334d58e261bd2a29e227b29622ca5b0a

4.2.A.1.5 Annual GDP growth

CITY ANATOMY relationship: Competitiveness

Description: Gross Domestic Product[44] is the sum of the gross value added by all resident producers in the city (plus the taxes and minus the subsidies on the products which are not included in their value).

The GDP annual growth is obtained by subtracting the value of the $GDP_{(t-1)}$ of the previous year from that of the current one $GDP_{t,}$ divided by the $GDP_{(t-1)}$ of the previous year and multiplied by 100 to obtain the annual percentage of growth.

Uses: Annual GDP growth reflects the latest trend in GDP while avoiding the effects of seasonality and is among the most meaningful indicators to assess the performance of the economy as a whole.

Calculation: $\frac{\mathrm{GDP}t - \mathrm{GDP}t-1}{\mathrm{GDP}t-1} \cdot 100$

This indicator is expressed as a percentage (%).

4.2.A.1.6 Number of new companies per 100 000 population per year

CITY ANATOMY relationship: Entrepreneurship

Description: Number of new companies registered within a year with respect to the population (per 100 000 inhabitants).

Uses: This indicator is useful to assess the level of entrepreneurship of a city and may also reflect indirectly the ease of setting up a company.

Calculation: $\frac{\text{Number of new companies registered}}{\text{Total Population}} \cdot$ 100 000 population

4.2.A.2 Core Economy indicators ISO

4.2.A.2.1 Percentage of city population living in poverty

CITY ANATOMY relationship: Wealth Distribution

Reference: See ISO 37120 (Section 5.3)

4.2.A.2.2 Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties

CITY ANATOMY relationship: Finances

Reference: See ISO 37120 (Section 5.2)

[44] https://data.oecd.org/gdp/gross-domestic-product-gdp.htm

4.2.A.2.3 Debt service ratio (debt service expenditure as a percentage of a municipality's own-source revenue)

CITY ANATOMY relationship: Finances

Reference: See ISO 37120 (Section 9.1)

4.2.B Supporting Economy indicators

4.2.B.1 Supporting Economy indicators CP

4.2.B.1.1 City debt

CITY ANATOMY relationship: Competitiveness

Description: This indicator shows the allocation of the city debt by citizen.

Uses: This indicator allows city to understand the ability to repay its debts if they were all due at the same time. The government may be a municipality, a county, or a national government. This measure helps analysts and investors understand whether the city is over- or underleveraged -- that is, whether a city can "afford" its debt, whether it needs to raise its tax revenue, or whether it might default. The measure may affect the credit rating of the city's debt.

Calculation: $\frac{Total\ city\ debt}{City\ population}$

Unit: €/capita

4.2.B.1.2 GDP per capita

CITY ANATOMY relationship: Wealth Production

Description: Gross Domestic Product per capita[45] is the sum of the gross value added by all resident producers in the city (plus the taxes and minus the subsidies on the products which are not included in their value) divided by the total population of the city.

Uses: GDP per capita is an indicator of economic performance and it is usually used as an indicator of average living standards. This indicator reflects the average wealth produced by the city but it doesn't reflect its distribution.

Calculation: $\frac{GDP\ of\ the\ city}{Total\ population\ of\ the\ city}$

Unit: $\frac{€}{capita}$

[45] http://www.oecd-ilibrary.org/sites/9789264067981-en/01/03/index.html?itemId=/content/chapter/9789264075108-5-en

4.2.B.2 Supporting Economy indicators ISO

4.2.B.2.1 Tax collected as a percentage of tax billed

CITY ANATOMY relationship: Finances

Reference: See ISO 37120 (Section 9.4)

4.2.B.2.2 Number of businesses per 100 000 population

CITY ANATOMY relationship: Commerce/Trade

Reference: See ISO 37120 (Section 5.6)

4.2.B.2.3 Capital spending as a percentage of total expenditures

CITY ANATOMY relationship: Finances

Reference: See ISO 37120 (Section 9.2)

4.2.B.2.4 Own-source revenue as a percentage of total revenues

CITY ANATOMY relationship: Finances

Reference: See ISO 37120 (Section 9.3)

4.2.B.2.5 Number of new patents per 100 000 population per year

CITY ANATOMY relationship: Competitiveness

Reference: See ISO 37120 (Section 5.7)

Culture

4.3 List of indicators: Culture

Culture refers to language, traditions, beliefs, values, schemata, etc., *i.e.*, assets in the City Anatomy that are not part of the material world or built domain (unlike tangible "cultural" objects such as museums, monuments, works of art, archeological sites, city landmarks, etc.). The indicators proposed for the Culture subsystem are set forth below.

4.3.A Core Culture indicators

4.3.A.1 Core Culture indicators CP

4.3.A.1.1 Annual average percentage of household consumption expenditures on cultural activities, goods and services

CITY ANATOMY relationship: Social expression

Description: This indicator measures how much of total household expenditures are allocated annually to cultural activities, goods and services.

Uses: This indicator measures the average social relevance of culture in a city.

Calculation: $\frac{Household\ expenditures\ on\ cultural\ activities}{Total\ household\ consumption\ expenditures} \cdot 100$

This indicator is expressed as a percentage (%).

4.3.A.1.2 Museums per 100 000 population

CITY ANATOMY relationship: Social expression

Description: This indicator is calculated as the total of museums in a city relative to its population. A museum can be defined as a building or place where works of art, scientific specimens, or other objects of permanent value are kept and displayed.

Uses: This indicator enables the city to know the level of cultural infrastructure and the access its citizens have to institutions providing knowledge and leisure opportunities. This improves their quality of life while it also attracts tourism and improves the city's image, attracting investment and entrepreneurship.

Calculation: $\frac{Total\ number\ of\ museums}{City\ population} \cdot 100\ 000$

Unit: number of museums/100 000 people.

4.3.A.1.3 Percentage of annual city budget allocated to culture

CITY ANATOMY relationship: Social Expression

Description: This indicator measures how much of the total city budget is allocated to culture expenses every year.

Uses: The amount of money flowing into the city's culture sector from the city budget is the fuel for the public cultural sector. Higher spending in this area signals the city administration's commitment to the city's legacy and image and is directly related to an improved quality of life through the improvement in the variety of activities for both citizens and visitors. And because investment fosters popularity, and popularity fosters investment, high values of this indicator attract foreign investment into the city and can create entrepreneurship among the city population. Lastly, the indicator is also useful for comparisons of the effectiveness of cultural programs in different cities, so that different approaches and strategies can be exchanged among them.

Calculation: $\frac{Total\ city\ budget\ allocated\ to\ culture}{Total\ city\ budget} \cdot 100$

This indicator is expressed as a percentage (%).

4.3.A.1.4 World Heritage Sites per 1 000 000 population

CITY ANATOMY relationship: Heritage

Description: This indicator measures the proportion of World Heritage sites in the city relative to the city's total population (in millions). World Heritage sites are internationally defined by the UNESCO[46], containing both cultural and natural sites.

Uses: World Heritage sites are, like sites of architectural interest, promoters of tourism and internal demand. Furthermore, they also correlate with the antiquity and variety of the city's culture, helping the city's administration assess the potential for attracting cultural tourism.

Calculation: $\frac{Number\ of\ city's\ World\ Heritage\ Sites}{City\ population} \cdot 1\ 000\ 000$

Unit: $\frac{World\ Heritage\ Site}{1\ 000\ 000\ population}$

4.3.B Supporting Culture indicators

4.3.B.1 Supporting Culture indicators CP

4.3.B.1.1 Annual average number of visitors to city museums

CITY ANATOMY relationship: Social expression

Description: This indicator measures the annual average number of visitors to the city's museums[47] and exhibitions. A museum is considered as any building listed in the footnote

[46] UNESCO list of World Heritage sites: http://whc.unesco.org/en/list//en/news/1049/en/list

[47] List of museums in the world, according to the catalogue "Museums of the World" by Lochar, Meinhold, et al.
http://en.wikipedia.org/wiki/List_of_museums

reference.

Uses: As with popularity of sites of architectural interest, renowned popular museums are a boost for the city's image, and thus for tourism, as well as internal demand for culture. For the same reasons, they attract investment and foster entrepreneurship, as well as improve the city's quality of life. Furthermore, through the recruitment and formation of reputed professionals maintaining the museums, the city's cultural strength is boosted, providing better education for students pursuing a career in this sector.

Calculation: $\frac{Total\ visitors\ of\ city's\ museums\ in\ one\ year}{Total\ number\ of\ museums\ in\ the\ city}$

Unit: $\frac{Visitors}{Museum}$

4.3.B.1.2 Annual average number of visitors to public libraries

ANATOMY relationship: Social expression

Description: This indicator measures the success of the city's public libraries according to the number of visitors they receive on average. A library is defined as a publicly or privately owned building that contains collections of books, periodicals, and sometimes films and recorded music for use or borrowing by the public or the members of an institution.

Uses: This indicator enables the assessment of the city's public libraries and the comparison of their performance in contrast to other systems in different cities. The indicator is related to achieving equity of opportunities by allowing all citizens to access vast sources of knowledge regardless of their purchasing power.

Calculation: $\frac{Total\ visitors\ to\ the\ city's\ public\ libraries\ in\ one\ year}{Total\ number\ of\ libraries}$

Unit: $\frac{Visitors}{Library}$

4.3.B.1.3 Popularity of sites of architectural interest

CITY ANATOMY relationship: Heritage

Description: This indicator measures how popular the city's sites of architectural interest are, based on the average number of visitors they receive. This is related both to how successful the city's culture is at exporting itself to foreign visitors as well as the population's interest in it. Existing lists of sites of architectural interest should be used whenever possible to define what buildings are considered as such.

Uses: Popular sites of architectural interest are an attraction for tourism as well as business. Higher popularity is linked to higher income from tourism and higher profitability of related businesses, attracting investments of several kinds and fostering entrepreneurship. This alone suffices to make this a core indicator but highly popular cultural sites such as this also foster internal demand for culture, educating the population and stimulating its intellectual interest, in the end becoming an investment in human capital. Thus, the increased popularity, if properly managed, can turn into a quality of life improvement.

Calculation: $\frac{Total\ visitors\ to\ sites\ considered}{number\ of\ sites\ considered}$

Unit: $\frac{Visitors}{Site}$

Information

4.4 List of indicators: Information

The conceptual model of a city as a system of systems, and interactions with different space and time scales, implies the inclusion in the anatomy of the informational or systems platform. This platform has the following five functional elements: City Ontology, City Operating System, City Performance Indicators and Indices, Tools and Applications, and Information Portal. The indicators proposed for the Information subsystem are set forth below.

4.4.A Core Information indicators

4.4.A.1 Core Information indicators CP

4.4.A.1.1 Open sensors platform[48]

CITY ANATOMY relationship: Applications & Tools

Description: Existence of a horizontal, interoperable and open platform, which is aimed at collecting/managing the data coming from the sensors of the city.

Uses: Having a horizontal platform is useful when working to break the traditional silos in which the solutions of the cities are built because it is a way to enhance efficiency in its management. In an Open Sensors Platform, all the vertical solutions (for example, involving light levels or parking information, air quality measurement, etc.) can be integrated so that all the data about the city that comes from sensors can be collected by the same platform regardless of where it comes from.

Calculation: This is a binary “YES/NO” indicator depending on whether the city has implemented such a platform (YES) or not (NO).

4.4.A.1.2 City apps site availability

CITY ANATOMY relationship: Applications & Tools

Description: Existence of an online site where all the applications which are useful for life in the city, created by the city or by third parties, are included after an evaluation process according to each city’s criteria.

Uses: The existence of such a site promotes the use of Apps in the city making it easier for citizens to access those and provides them with increased security since the Apps have been previously screened and evaluated. Furthermore, a city apps site can promote App creation by third parties.

Calculation: This will be a binary indicator with possibilities “YES/NO” depending on whether the city has created such a site (YES) or not (NO).

[48] From CPA-PR_005_Open_Sensor_Platform.pdf

4.4.A.1.3 Percentage of core CP indicators that are informed by open datasets

CITY ANATOMY relationship: Open Data

Description: Percentage of the datasets available through an open data portal that are needed to calculate core CP indicators.

Uses: Relevance of available open datasets to assess core city systems, interactions and *status quo*.

Calculation: $\frac{\text{Number of core CP indicators that can be calculated from open datasets}}{\text{Total number of of core CP indicators}} \cdot 100$

This indicator is expressed as a percentage (%).

4.4.A.1.4 Percentage of core ISO 37120 indicators that are informed by open datasets

CITY ANATOMY relationship: Open Data

Description: Percentage of the datasets available through an open data portal that are related to city resilience.

Uses: Relevance of available open datasets to assess core city systems, interactions and *status quo*.

Calculation: $\frac{\text{Number of core ISO 37120 indicators that can be calculated from open datasets}}{\text{Total number of of core ISO 37120 indicators}} \cdot 100.$

This indicator is expressed as a percentage (%).

4.4.A.1.5 Percentage of supporting CP indicators that are informed by open datasets

CITY ANATOMY relationship: Open Data

Description: Percentage of the datasets available through an open data portal that are related to the areas of quality of life and social equity.

Uses: Relevance of available open datasets to assess supporting city systems, interactions and *status quo*.

Calculation: $\frac{\text{Number of supporting CP indicators that can be calculated from open datasets}}{\text{Total number of of supporting CP indicators}} \cdot 100$

This indicator is expressed as a percentage (%).

4.4.A.1.6 Percentage of supporting ISO 37120 indicators that are informed by open datasets

CITY ANATOMY relationship: Open Data

Description: Percentage of the datasets available through an open data portal that are related to investment attraction and entrepreneurship.

Uses: Relevance of available open datasets to assess supporting city systems, interactions and *status quo*.

Calculation: $\frac{\text{Number of supporting ISO 37120 indicators that can be calculated from open datasets}}{\text{Total number of of supporting ISO 37120 indicators}} \cdot 100$

This indicator is expressed as a percentage (%).

4.4.B Supporting Information indicators

4.4.B.1 Supporting Information indicators CP

4.4.B.1.1 Publicly available applications utilizing open data

CITY ANATOMY relationship: Applications & Tools

Description: Number of applications available to the public through conventional channels (city app stores) that use one or more of the open datasets published on the city website.

Uses: This indicator is useful in determining how much of the data being made available by the city is being used to develop applications. Development of applications is one of the key objectives of open data since it can directly benefit the citizens and the economy.

Calculation: This indicator is an integer and it can be calculated by counting the number of applications that are available to the public through conventional channels (app stores), and that use at least one or of the open datasets published on the city website.

4.4.B.1.2 Number of apps and tools used by non-public sector parties monthly

CITY ANATOMY relationship: Applications & Tools

Description: This indicator is aimed at measuring the number of uses by non-public sector parties (citizens, businesses, entrepreneurs), on an annual average, of the datasets opened by the City during the period of a month.

Uses: The aim of opening data is to make it accessible to non-public sector parties.

Calculation: Average monthly accesses to a city's official Open Data website during past 12 months.

Unit: $\frac{number\ of\ accesses}{Month}$

4.4.B.1.3 Average quality of the datasets

CITY ANATOMY relationship: Open Data

Description: Average quality of the data sets from the point of view of the openness or the ease of use of the data.

Uses: The ease of use of open data is an important quality because the main aim of opening data is to make it widely available to the public. Therefore, evaluating the quality of the open

data from this perspective is important to promote the ease of use and the openness of municipal data.

Calculation: Average stars across all datasets according to the 5 star deployment scheme for Open Data defined by Tim Berners Lee.

Unit: $\frac{Stars}{Dataset}$

Annex C. Society

The Indicators outlined in this Annex relate to Society – the citizens, the government and how people live in, occupy and govern their physical environment.

Citizens

5.1 List of indicators: Citizens

These indicators include citizens, organizations and businesses. The term "citizens" is applied broadly, and includes individuals who live, work and/or visit within a city, whether or not they are permanent or legal residents. It extends to include the domestic animals, *i.e.* pets that individuals attach themselves to. Beyond individuals, Society includes the different ways in which citizens organize (*e.g.* into clubs) and work and do business (*e.g.* in corporations and small businesses).

5.1.A Core Citizens indicators

5.1.A.1 Core Citizens indicators CP

5.1.A.1.1 Population Density

CITY ANATOMY relationship: Person & Family

Description: This indicator is the average population by square kilometer, counting all residents regardless of legal status or citizenship, in a defined area.[49]

Uses: This indicator shows the living conditions and the quality of life in a city. It is an indicator that allows the city to anticipate the evolution of its needs in terms of infrastructure, transport, and security into the future, and it has deep implications for the governance of the city in the present.

Calculation: $\frac{Total\ city\ population}{Total\ urban\ area}$

Unit: $\frac{Citizens}{km^2}$

5.1.A.1.2 Fertility Rate: Annual number of live births per 1 000 women aged 15-49 years

CITY ANATOMY relationship: Person & Family

Description: This indicator is a population measure that is related to development, which tends to correlate with infant mortality rate, except in cities where the number of household children is limited by state laws.

[49] Population density definition: http://data.worldbank.org/indicator/EN.POP.DNST

Uses: The fertility rate is a useful indicator of development. If its value is 2.1 or higher the population will replace itself.

Calculation: $\frac{Annual\ number\ of\ live\ births}{Number\ of\ women\ aged\ 15{-}49\ years} \cdot 1\ 000$

Unit: $\frac{Annual\ live\ births}{1\ 000\ women\ aged\ 15{-}49\ yr}$

5.1.A.1.3 Cultural diversity

CITY ANATOMY relationship: Person & Family

Description: This indicator gives a quantitative measure of the cultural diversity of the target population in a given geographical area such as a city, according to that population's nationality. The Theil index is used as it gives a larger marginal influence on small groups, as it is logical to consider the first immigrant in a population to bring more diversity than the 1000th one of the same origin. The contributions of these groups are then weighted according to the cultural difference between the target population and the group being studied. These weights are chosen to be the geographical distance between the target nationality and the nationality of the group being studied, as we assume cultural difference to increase with geographical distance.[50]

Uses: Cultural diversity leads to a wider availability of consumption goods, increasing quality of life for the population with preferences towards variety. Additionally, workers from several ethnic origins bring different values and skillsets to the workforce, increasing its versatility and the overall human capital of society. An increasingly able workforce is related to every subject (*e.g.* different approaches to resilience, governance, etc.) relating diversity to many of the City Anatomy's objectives.[51]

Calculation: $\sum_n (s_{nr} \cdot ln(\frac{1}{s_{nr}}))$, where s_{nr} is the share of population of nationality n in the studied region r. This is a dimensionless coefficient.

5.1.A.1.4 Community work: percentage of population affiliated to NGOs

CITY ANATOMY relationship: Organization

Description: A non-governmental organization (NGO)[52] is any non-profit, voluntary citizens' group that is organized on a local, national or international level. Task-oriented and driven by people with a common interest, NGOs perform a variety of service and humanitarian functions, bring citizen concerns to Governments, advocate and monitor policies and encourage political participation through provision of information. Some are organized around specific issues, such as human rights, environment or health.

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50 http://www.foreurope.eu/fileadmin/documents/pdf/Workingpapers/WWWforEurope_WPS_no010_MS99.pdf

51 http://faculty.arts.ubc.ca/nfortin/econ495/WesleySze_thesis.pdf

52 http://www.ngo.org/ngoinfo/define.html

Uses: This indicator shows the percentage of citizens involved in NGOs and their level of participation. An active social environment, especially in city centered activities, is instrumental to improving the city's quality of life and fostering entrepreneurship in it, as citizens participating in NGO activities may choose to form organizations of their own, either for profit or not.

Calculation: $\frac{Citizens\ affiliated\ to\ 1\ or\ more\ NGO's}{City\ population} \cdot 100$

This indicator is expressed as a percentage (%).

5.1.A.1.5 Number of civic associations per 1 000 population

CITY ANATOMY relationship: Organization

Description: This indicator measures quantitatively the population's involvement in the social tissue through association. A civic association[53] is a type of organization whose official goal is to improve neighborhoods through volunteer work from its members.

Uses: This indicator shows the number of civic associations located in a city relative to its population. Civic organizations improve the quality of life of their members and the rest of citizens in a number of ways, from their direct intended effects such as the improvement of certain urban areas to the enrichment and dynamization of the social environment, fostering new relationships and activities.

Calculation: $\frac{Total\ \ number\ of\ civic\ associations}{City\ population} \cdot 1\ 000$

Unit: $\frac{Associations}{1\ 000\ citizens}$

5.1.A.1.6 Percentage of Small and Medium Size Companies

CITY ANATOMY relationship: Business

Description: Small and medium-sized companies[54] (SMCs) are non-subsidiary, independent firms which employ less than a given number of employees. This number varies across countries. The most frequent upper limit designating an SMC is 250 employees, as in the European Union. However, some countries set the limit at 200 employees, while the United States considers SMCs to include firms with fewer than 500 employees. Small firms are generally those with fewer than 50 employees.

Uses: This indicator shows the proportion of SMCs in the total number of companies in the city. This indicator allows the city to see the weight of the SMC in the city's economic development and provides information on what actions and regulations may be the most effective for working towards the city's goals. Furthermore, it also helps the city compare

[53] Further reference on civic associations: http://www.hoover.org/sites/default/files/uploads/documents/0817939628_59.pdf
[54] https://stats.oecd.org/glossary/detail.asp?ID=3123

itself with other cities as different economic fabrics may change the way other indicators behave and interact.

Calculation: $\frac{Total\ amount\ of\ SMCıs}{Total\ amount\ of\ companies} \cdot 100$

This indicator is expressed as a percentage (%).

5.1.A.1.7 Average number of workers per company

CITY ANATOMY relationship: Business

Description: This indicator measures how many workers on average work for a company operating in a city. A worker is a person who does a particular job in exchange for monetary compensation and is actively involved in a particular company.

Uses: This indicator enables the city to know the average number of citizens working in companies located in the city. Therefore, it is a measure of the composition of the city's economical tissue and it allows the government to assess the average size and power of companies operating in it.

Calculation: $\frac{Total\ amount\ of\ workers}{Total\ amount\ of\ companies}$

Unit: $\frac{Workers}{Company}$

5.1.A.1.8 Annual feedback of the citizens on city services performance per 100 000 population

CITY ANATOMY relationship: Participation

Description: This indicator represents the number of feedbacks given to the city government by the citizens who used the city's services, which refers to basic services that residents of a city expect the city government to provide in exchange for the taxes that they pay.

Uses: This indicator is linked to the effectiveness of the city's services and their correlation with the citizens' expectations. Effective services improve the population's quality of life and, depending on the type of service, also contribute to improving the equity of opportunities for citizens. Feedback could be collected via an online survey or paper surveys after citizens have used a city service.

Calculation: $\frac{Number\ of\ feedbacks\ in\ one\ year}{City\ population} \cdot 100\ 000$

Unit: $\frac{Feedbacks}{100\ 000\ population * year}$

5.1.A.1.9 Number of open public participation processes in one year

CITY ANATOMY relationship: Participation

Description: Public participation encompasses varied opportunities for citizens, nongovernmental organizations, businesses, and others outside the government to contribute to and comment on a variety of civic issues, including proposed rulemaking and policymaking. The city will widen public exposure to the processes of policy planning and determination and will invite the public to respond to key issues on its agenda. It promotes democratic legitimacy by strengthening the connections between government agencies and the public they serve.

Uses: This indicator shows the citizens' level of commitment to the politics of the city. Higher numbers of public participation processes promote an increased sense of belonging to the community and a better adjustment between what the citizens want and what is decided.[55]

Calculation: $\frac{Total\ number\ of\ open\ public\ participation\ processes\ in\ one\ year}{City\ population} \cdot 1\,000$

Unit: $\frac{Open\ public\ participation\ processes}{1\,000\ Citizens * year}$

5.1.A.2 Core Citizens indicators ISO

5.1.A.2.1 Women as a percentage of total elected to city-level office

CITY ANATOMY relationship: Participation

Reference: See ISO 37120 (Section 11.2)

5.1.A.2.2 Voter participation in last city election (as a percentage of eligible voters)

CITY ANATOMY relationship: Participation

Reference: See ISO 37120 (Section 11.1)

5.1.B Supporting Citizens indicators

5.1.B.1 Supporting Citizens indicators CP

5.1.B.1.1 Ageing index

CITY ANATOMY relationship: Person & Family

ANATOMY relationship: Person & Family

Description: This indicator enables a city to evaluate the ageing of its population by comparing the population over 60 years old to that under 15 years old.

Uses: Ageing populations may be one of a city's greatest concerns as they weaken the economy by requiring smaller working populations to sustain greater numbers of non-active

[55] http://www.opengovpartnership.org/country/commitment/public-participation-policymaking-processes

citizens. As such the ageing index is vital to assessing the vulnerability of the city to this phenomenon and informing on whether the city needs to implement measures to respond to this. This indicator is linked to the city's citizens' quality of life, since it will be considerably worsened for all if the working population finds itself incapable of supporting the rest. An older population also will have disproportionate impacts on health care systems and their costs, and other subsidies (meals, in-home care, special transit) that may impact city expenditures.

Calculation: $\frac{Population\ over\ 60\ years\ old}{Population\ under\ 15\ years\ old} \cdot 100$

This indicator is expressed as a percentage (%).

5.1.B.2 Supporting Citizens indicators ISO

5.1.B.2.1 Number of registered voters as a percentage of the voting age population

CITY ANATOMY relationship: Participation

Reference: See ISO 37120 (Section 11.6)

5.1.B.2.2 Citizens' representation: number of local officials elected to office per 100 000 population

CITY ANATOMY relationship: Participation

Reference: See ISO 37120 (Section 11.5)

Government

5.2 List of indicators: Government

Government is the part of Society that is elected or appointed to serve the community.

5.2.A Core Government indicators

5.2.A.1 Core Government indicators CP

5.2.A.1.1 Consolidated city budget

CITY ANATOMY relationship: Vision & Priorities

Description: This indicator shows the size of the city's consolidated budget relative to the city's size. The consolidated budget is the budget made by public entities once they have compensated for internal transfers.

Uses: This indicator helps the city assess its financial condition relative to other cities and helps in comparing its capability to implement measures. This is a key indicator in measuring the city's governing power.

Calculation: Calculated as the total budget divided by the number of inhabitants of the city.

$$\frac{Total\ city\ budget}{City\ population}$$

Units: €/capita

5.2.A.1.2 Number of judges per 1 000 citizens

CITY ANATOMY relationship: Laws & Regulations

Description: A judge is a public officer appointed to decide cases in a law court.

Uses: This indicator shows the total of judges taking into account the different courts of the city. It is an indicator that allows a city to get a better understanding of how efficient its criminal and civil justice systems may be.

Calculation: Calculated as the number of judges divided by 1 000 city citizens.

$$\frac{Total\ amount\ of\ judges}{City\ population} \cdot 1\,000$$

Units: $\frac{Judges}{1\,000\ citizens}$

5.2.A.1.3 Index of Transparency and open government

CITY ANATOMY relationship: Accountability

Description: This indicator measures the degree of government transparency. Transparency refers to public access to information held by government policy makers as well as information about their decision making. This indicator uses four dimensions: publicized laws and government data, right to information, civil participation, and complaint mechanisms.

Uses: This indicator promotes democratic legitimacy by strengthening the connections between government agencies and the public they serve. By increasing transparency, trust between the government and the citizens is strengthened, enabling more efficient interactions between both. And by providing data, a more active and engaged population can be created, fostering participation and improving quality of life.

Calculation/Unit: Score from 0 to 1[56]

5.2.B Supporting Government indicators

5.2.B.2 Supporting Government indicators ISO

5.2.B.2.1 Percentage of women employed in the city government workforce

CITY ANATOMY relationship: Laws & Regulations

Reference: See ISO 37120 (Section 11.3)

5.2.B.2.2 Number of convictions for corruption and/or bribery by city officials per 100000 population

CITY ANATOMY relationship: Accountability

Reference: See ISO 37120 (Section 11.4)

[56] Paper regarding government transparency: http://www.hks.harvard.edu/hepg/Papers/transparencyReport.pdf