# CPA-I_001-v2_City Anatomy

## City Anatomy:
A Framework to support
City Governance, Evaluation and Transformation

Developed by Task Team - ancha
6 November 2015

**Changes in v2**

The City Protocol Editor and the Chair of the CPS/CPTF have incorporated into the original City Anatomy agreement *CPA-I_001 Anatomy* the body of knowledge generated by the foundational protocols *CPA-PR_002 _Anatomy_Indicators*, *CPA-PR_003_Anatomy_Ontology* and *CPC_004_Livable_Districts*. The updated version v2 updates terminologies and ensures consistency of approach and nomenclature among the City Protocol foundational documents. For more detailed information regarding this or other City Protocol documents, please contact: fgiralt@fundacio.cat.

## Executive Summary

**Statement of Need.** A city is a system of systems and interactions that fosters emergent human behavior. It can be regarded as an arrangement of, and set of relationships between, multiple layers of a relatively large and permanent human settlement, with an administrative and legal status supported by local laws, and one that is recognized as such worldwide. The world of cities has ambiguous and porous political, economic and social borders, and governance is carried out locally, pragmatically and collaboratively. Since people's needs and the chronic global societal challenges are mainly fulfilled and dealt with in Cities, a common platform for generating solutions together and sharing knowledge within and between cities is needed. City Protocol will create that common platform. This document, City Anatomy, provides the platform's foundation.

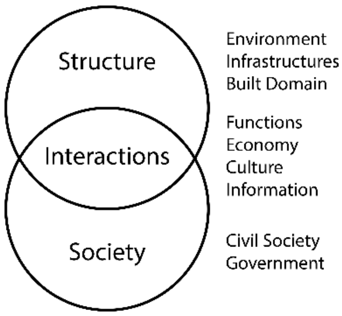
**What is the City Protocol?** The City Protocol is a common communications vehicle and a collaborative innovation framework that fosters city-centric solutions that benefit citizens and their quality of life. It also seeks to better define a common systems view for cities of any size or type, and then embraces or develops protocols that will help innovators create - and modern cities deploy – cross-sectorial solutions that can connect and/or break city silos. As a consequence, innovators enjoy a robust market for their solutions, and cities enjoy solution choice, reduced cost and risk, and increased collaboration and learning – all while supporting the development of a Science of Cities. City Protocol also aims at working across diverse cities by interconnecting them and ultimately creating the Internet of Cities.

City-centric solutions facilitated by the City Protocol should aim at providing and maintaining a high quality of life to citizens over time. According to sustainable development principles, these solutions should meet the needs of the present without compromising the ability of future generations to meet their own needs[1]. The three pillars of Sustainable Development promoted by the United Nations (i.e., economic development, social development - social justice, opportunities and equality - and environmental protection) are dissected and the

[1] World Commission on Economic Development. (1987) Our Common Future. Oxford: Oxford University Press.

parts incorporated in the taxonomy of the proposed City Anatomy, together with other relevant city systems, elements and concepts. While keeping sustainability in mind, the reader should also realize that this broad and important concept is a declaration of intentions. The more operational and measurable one of self-sufficiency (i.e., resources cannot be depleted faster than they can be replenished over time to be available for the future) will be preferably used herein after in this document.

**What is the City Anatomy? Why is it valuable?** The City Anatomy, an analogy to the human anatomy and its dynamic physiology, is an organizing framework for the City Protocol. It creates a foundation upon which to build a collaborative platform and tools to support effective city governance, evaluation and transformation. It offers a common language describing the city ecosystem as three key system elements: a set of physical structures (*Structure*); the living entities that make up a city's society (*Society*); and the flow of interactions between them (*Interactions*). In so doing, City Anatomy helps understanding and mapping interconnections between city systems.




### Basics of the City Anatomy.

***Structure:*** The first layer within the Structure system element is the *Environment*, the physical and geographic setting of the city, including the natural environment ("nature"). It is formed by the three basic elements, air, earth and water, interacting dynamically in a seasonally dependable way. The second layer of Structure comprises *Infrastructures,* the connective structures that enable people to get resources, especially from the environment, and bring them to the city or that enable flows or cycles within the city itself. These infrastructures include those that support *communications*, the *water and energy cycles*, the *matter cycle* that supports the movement of goods and food as well as the resultant waste, the *mobility networks*, and *nature* or green infrastructure. The third layer is the *Built Domain* that can best be organized according to the approximate number of people that it can accommodate on a physical basis. So, within the *Built Domain*, an *object* corresponds to a single person, and a *dwelling*, *building*, *block*, *neighborhood,* *district, city* and *metropolis* or region each increase the scale by an order of magnitude. Private and public spaces are contained within each level of scale.

***Interactions:*** The first layer within the Interactions system element comprises urban *Functions* including *living*, *working*, *education*, *shopping*, *transport*, caring for *health*, *education*, the *performing arts*, and more. The second layer is the *Economy*, which influences urban innovation and the everyday city operation and the life cycles of services provided by cities. The third layer is *Culture* -- the language, traditions, beliefs, values, and the way that people organize their concepts of the world etc., i.e., the non-material assets in the city anatomy. The fourth and final layer is *Information*. It includes the *City Operating System*; *Performance Indicators and Indexes*; *Tools and Applications; City Ontology*; and an *Information portal* for open data and specific learning protocols and related resources.

***Society:*** The Society system comprises the living entities of the City Anatomy and ecosystem. The first layer is *Citizens*, which can be broken down into: *person (me), family*, *visitors*, *organizations and businesses.* The second layer is the city's *government*, whose head is (normally) the mayor. The term *governance* will be adopted when the city anatomy is used for evaluation purposes because it is the process of running a government and, as such, it focuses on the effectiveness of the executive branch of government.

## Applying the City Anatomy

City Anatomy provides a hierarchically sound and well established description, identification, nomenclature, and classification of all city systems, subsystems and interactions, i.e., a ready-to-use city taxonomy for any city and city model to express its livability model from forward-thinking and game-changing projects, policies and practices. It is designed as a common tool which can be applied to facilitate city initiatives related to the core organizing activities for cities -- governance, evaluation and transformation. City Anatomy supports *governance* by providing a common language and model for framing the broad Internet of Things as it applies to Cities. It supports a framework for *evaluation* which helps a city assess its specific anatomy based on a commonly agreed systems layout and dashboard view. Finally, it serves a city's path toward *transformation*, offering a reliable city model and framework on which can be built well assessed and commonly accepted methodologies and tools for city transformation (i.e., the city protocol) and evaluation (i.e., indicators and indexes), and where shared projects, documents of reference, and guidelines or "de facto" standards can be expressed and realized. The City Anatomy[2] could be adopted by ongoing city evaluation and standardization initiatives as a convenient common description of city systems and interactions, and for describing emerging processes as well. Partnerships could facilitate this adoption by linking all initiatives worldwide.

## City Anatomy at the Core of City Protocol

City Anatomy is at the core of City Protocol, an interoperable framework and collaborative innovation platform for city-centric solutions. City Protocol will be developed by applying the following key approaches: Performance is the objective; Practice is the method; Platform is the product.

The target users of the City Anatomy are the following:

- Task Teams (TT), whose work contributes to the development of the City Protocol, and that need to relate all work back to this organizing framework.
- City leaders, officers, and/or urban planners seeking to undertake transformational projects as it helps addressing the interdependency of city systems and subsystems, and identifying the tools needed to inform, compare and support transformations.
- Commercial and Non-profit organizations, Universities and Research Institutions to help framing their products/services and projects in the city market, and assessing impacts.
- City-related Institutions/Associations, City Networks and Standards' Organizations to help aligning ongoing activities and facilitating communications.

[2] The common language of the City Protocol's Anatomy incorporates past and current city-related thoughts and proposals from the Advanced Architecture Institute of Catalonia (IAAC), the United Nations, and also from work, analysis and projects carried out in cities worldwide. As it evolves, it will incorporate additional work carried out by cities and city-serving organizations around the world.

## Contents

## 1. Introduction

A city is a system of systems and interactions, an arrangement of, and set of relationships between, multiple layers of a relatively large and permanent human settlement, with an administrative and legal status supported by local laws, and one that is recognized worldwide. The world of cities has ambiguous and porous political, economic and social borders, and governance is carried out locally, pragmatically and collaboratively. Since people's problems are mainly dealt with and solved in Cities, a common platform for generating and sharing knowledge and solutions within and between these human settlements is needed.

The City Protocol supports this reality by proposing a common foundation and understanding for these complex and diverse urban settlements. It proposes an anatomy of urban habitat, or "City Anatomy", with the following qualities:

- *timeless*, i.e., compatible with any human settlement at any time in history;
- *acultural*, i.e., valid for any culture and any type of city;
- *scalable*, i.e., valid for a metropolis, a city, a small town or a village; and
- *generic*, so that everything we could define as a "human settlement", as a "city", would have a place in this structure.

A city can best be viewed and understood as an ecosystem. According to Margalef[3], we can identify and define three elements in an ecosystem:

(i) The *physical structure* of that ecosystem;

(ii) The *living entities* that it contains; and

(iii) The *flow of interactions and information*.

The City Anatomy offers a common language describing the city ecosystem as: a set of physical structures, the living entities that make up a city's society, and the flow of interactions between them. In so doing, it suggests an analogy to the human anatomy and its

[3] http://en.wikipedia.org/wiki/Ramon_Margalef

dynamic physiology. Ultimately, it aims to enable vibrant governance, evaluation and transformation by helping, among others:

(i) Measure areas of strengths and weaknesses in the light of a rapidly changing “city life” and market conditions;

(ii) Identify opportunities and threads and set up strategies for innovation, anticipation and collaboration between cities to maintain and improve competitiveness;

(iii) prioritize transformational initiatives consistently with citizen’s needs, resources and vision;

(iv) improve communications between city service owners;

(v) address the cultural, economic, technological, and structural elements that have the largest impact on self-sufficiency. This could also be analyzed in terms of sustainability by integrating and better balancing social, economic and environmental factors;

(vi) set and communicate transformational objectives and priorities to citizenship and providers;

(vii) frame and support emerging processes and citizens demands;

(viii) identify new needs and new markets to strengthen the competitiveness of all actors involved; and

(ix) help maintaining the focus on the different levels (or city domains) that should be described in any city, with clear transformational objectives while addressing related market opportunities.

## 2. City Anatomy

Figure 1 depicts the detailed city anatomy proposed by the City Protocol as the holistic integration of the three system elements that form the city ecosystem: the physical structure (Structure), the people who live in it and occupy this physical space while carrying out functions (Society), and the Interactions through which the Society engages the Structure.

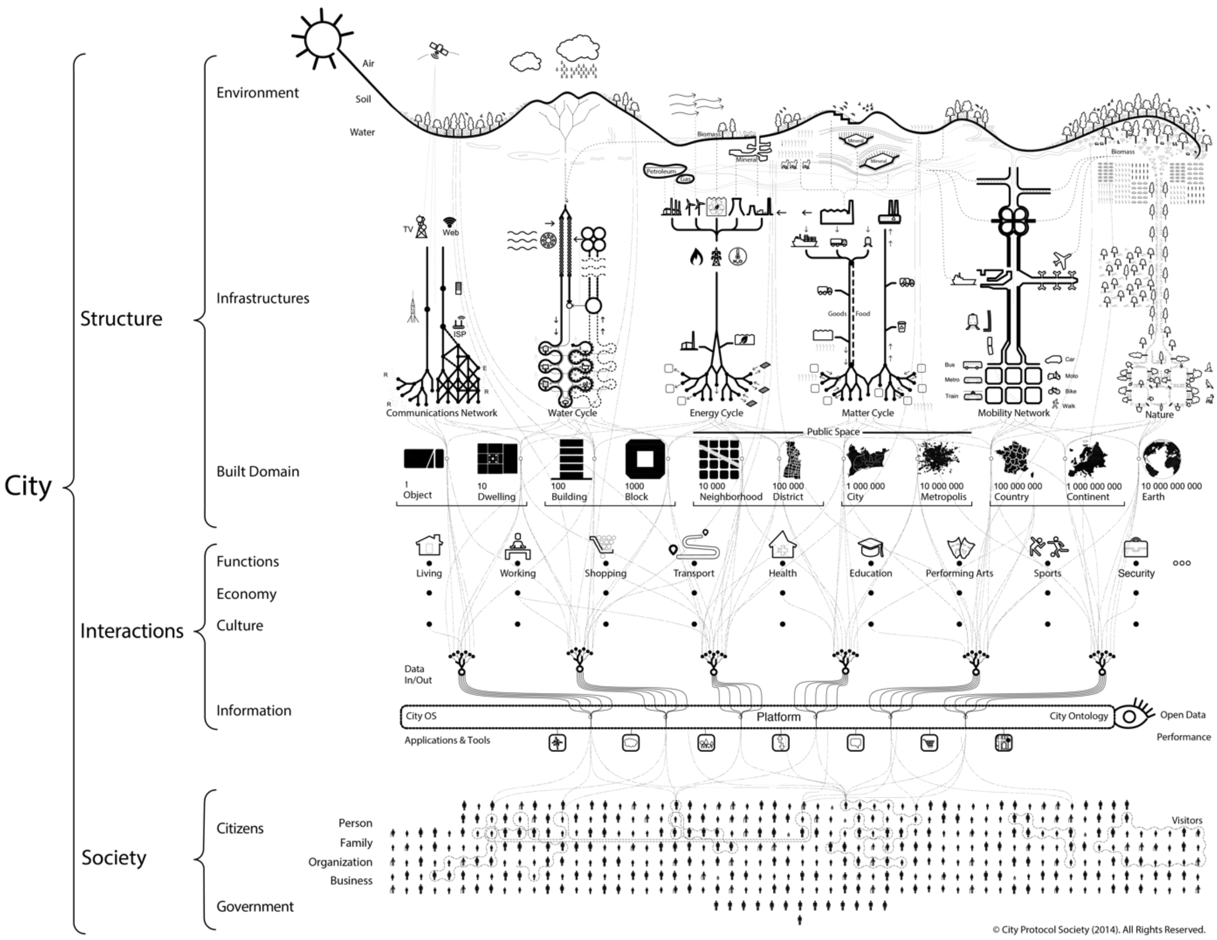



*Figure 1: City Anatomy as the common foundation for the City Protocol*

## 2.1 Structure

**Environment**. The first subsystem layer within the anatomy structure (see Figure 1) is the environment, the setting of the city, as shown in Figure 2. The environment and the physical

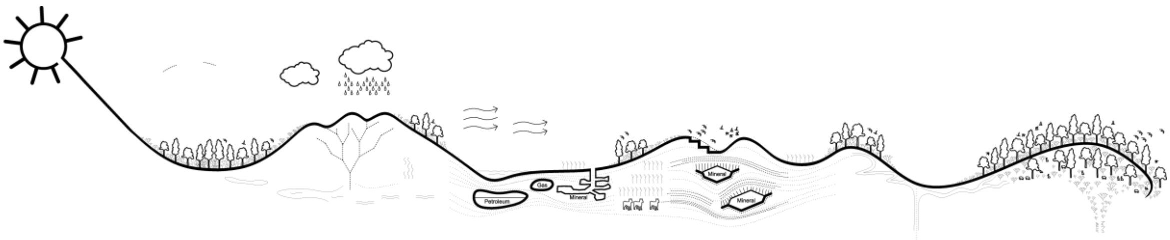


*Figure 2: Environment*

setting were in existence before cities were established. The form of the territory that existed at the location of cities before they existed, and where natural flows, that have existed since the earth began, continue to take place. This environment is formed by nature (plants and animals) and the three basic compartments, air, soil and water, interacting dynamically in a seasonally dependable way. Each of these compartments has its own quality indicators.

*Air* quality is assessed using the levels of $CO_2$, concentration of particles, ozone levels, etc., and also in terms of climate and temperature for estimates of global warming. The topography of the earth's surface is fundamental for siting cities. We have extracted minerals and materials from the *soil* throughout history, digging underground for the resources we use today, such as oil, gas, etc. Above ground are the plant structures, such as trees - and the area where animals move; and this is where farming was developed. Then we have *water*, which functions in a continuous cycle, with clouds, rain, rivers, lakes, the sea, and the processes of evaporation and production by combustion. So all the aspects relating to the shape and quality of earth, air and water, which existed before cities were settled, and which we then organize within cities, are the environmental factors that we need to consider in the functioning of a city.

**Infrastructures**. The second subsystem layer within the anatomy structure comprises the infrastructures, i.e., connective structures that enable people to get the resources they need, especially from the environment, and bring them to the city or that enable the flows or cycles inside the city itself.

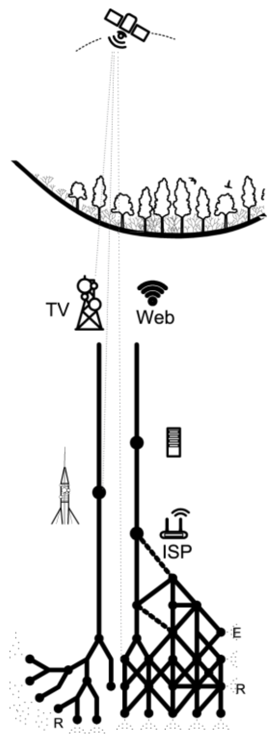


*Figure 3: Communications Network*

*Communications Network*. The first infrastructure, depicted in Figure 1, is the communications network, as shown in detail in Figure 3. Communications have shifted from analog to digital, e.g., from letters to bits. Over the past 110 years we have seen the emergence of the telegraph, the telephone, radio, television and the Internet. 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 good examples of this information infrastructure (Figure 3).

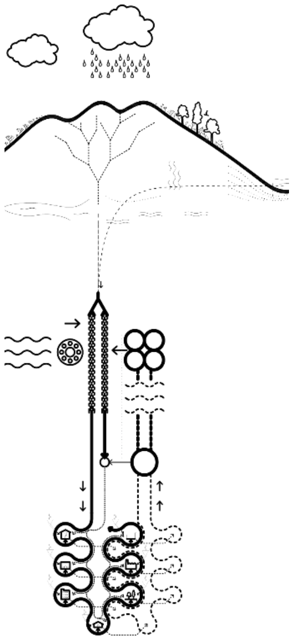


Figure 4: Water cycle

*Water Cycle*. The second infrastructure is the water cycle, which includes supply, sanitation, and the management of clean, waste, and surface waters, the latter with its drainage/collection systems to avoid rainfall causing flash flooding (see example, Figure 4). There can be no life, and no cities, without water. We take water from nature (wells, rivers, lakes and/or desalinization/desalting plants), clean it, bring it to the cities, consume it, produce it by combustion, and generate grey and waste waters, which are usually either disposed into nature or treated and put back into the city water system. We can use the term water infrastructure to describe all the physical elements forming part of the water cycle (clean and waste water) as it operates in a structured way in a city.

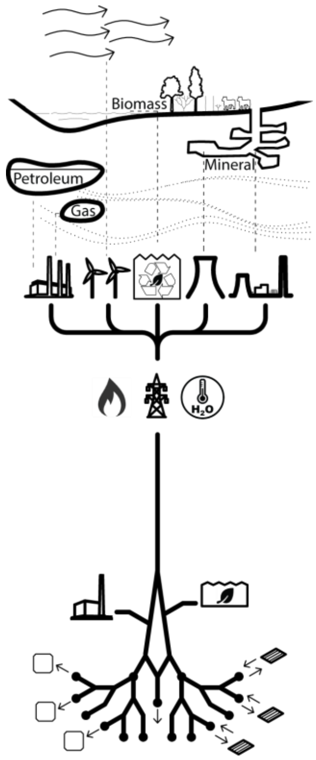



Figure 5: Energy

*Energy*. The third infrastructure is the energy cycle (depicted in Figure 5). It is formed by the whole energy system: functional nodes (nuclear and power plants, wind farms, biomass/bioenergy power plants, hydroelectric plants, and solar fields) located outside cities and where most of the energy is produced; energy networks to transport mainly electricity or natural gas into the city; and pipelines and ships to transport oil to produce fuels and chemicals that are finally consumed in cities as raw or refined products. This results in the currently branched energy network structure from large production nodes outside the city to smaller nodes for industrial and domestic consumption. The latter are formed by various energy-related networks installed in cities, including district energy and also bio-energy systems; gas, electricity, hot water, vapor, chilled water, etc.

Other more distributed energy models are possible for managing energy through generation systems integrated within the city itself (e.g., thermal energy from solar collectors and electricity from photovoltaic systems at rooftops are increasingly generated in city buildings).

*Matter Cycle*. The fourth infrastructure is the materials or matter cycle, as depicted in Figure 6. This infrastructure 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 also the management of waste materials. The matter cycle includes: (i) everything which extracts goods from nature and transports them to factories or production centers; (ii) distribution around the world via logistic platforms, containers and other means; (iii) deliveries within cities; (iv) consumption in cities; (v) waste generation; (vi) transporting waste to dumps; and (vii) in some cases, recycling or producing energy or new products from that waste.

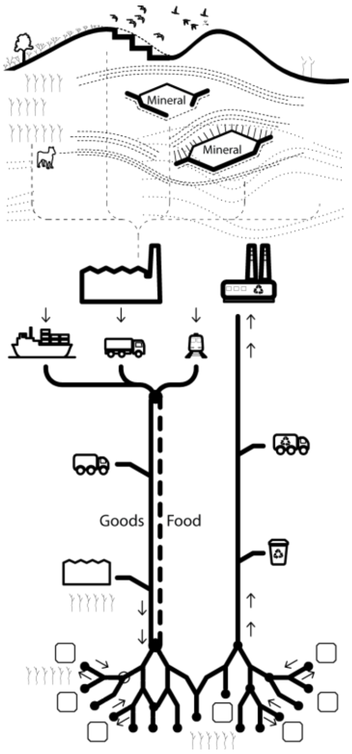



*Figure 6: Matter cycle*

We can distinguish two main types of materials in Figure 6: (i) all matter used in consumer goods[4], construction, etc., in the city, shown as a solid line in Figure 6; and (ii) food from vegetables and animals, shown as a dotted line. The specific cycle of food is of uttermost importance since roughly one third of the food produced annually in the world for human consumption gets wasted and its impact is both financial and environmental [5].

[4] The incorporation of new technologies like 3D printing will alter the distribution of some manufactured products since they will be produced within the city individually upon demand.
[5] http://www.unep.org/wed/2013/quickfacts/

*Mobility Network*. The fifth type of infrastructure is mobility, which mostly relates to human transportation, though sometimes to also transporting goods, as illustrated in Figure 7. Some airports have areas just for logistics and some harbors platforms for just the same purpose. In the case of mobility, there are large systems, such as railways, airports, highways systems, and roads, which normally end in the streets of cities. Streets are today a key infrastructure for people's mobility. They have been segregated in many cases into subsystems organized according to the type of mobility/transportation: pedestrians, bicycles, cars, public transportation, etc. City streets and squares represent the spaces for human mobility; in traditional cities, they are also meeting places or part of the public space in the built domain, where paths cross and become spaces for social interaction. Thus, everything that enables people to get around or cross the city boundaries falls within the mobility cycle.

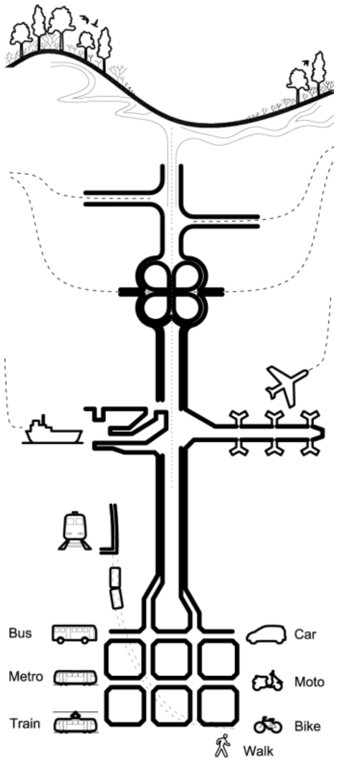


*Figure 7: Mobility Network*

*Nature*. The sixth and final infrastructure is the green infrastructure (represented in Figure 8), the infrastructure of nature. It is usually formed by the natural elements we bring into the city in a structured way. This infrastructure includes all flows related to nature (flora and fauna) in the city. It encompasses information about all living non-human entities at all scales, from seeds to trees, animals, and so on. It is the infrastructure that is involved in the reincorporation of nature in city streets, squares, etc., i.e., of nature in the public space, which has an effect on the quality of life.

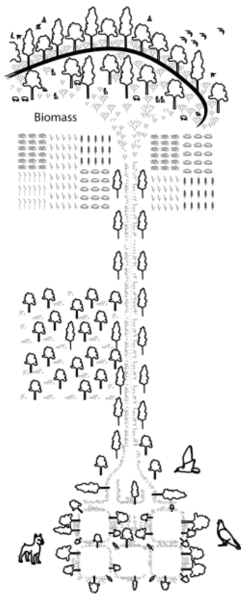


*Figure 8: Nature*

**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 fundamentally is multiscale in nature (i.e., scale is an intrinsic characteristic of the built environment), as illustrated in Figure 9. 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.

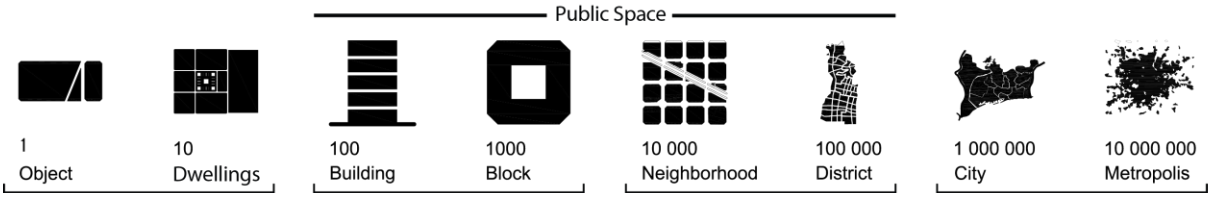



*Figure 9: Built Domain*

*Objects* are the structures with the smallest scale that can have their own identity in the global network of the Internet of Things (IoT). Most objects belong to a functional category since they carry out a function for human life. In many cases they become part of a larger scale network made up of other elements and systems (e.g., buildings or the city itself).

The built domain in both Figures 1 and 9 is ordered according to the number of people that each level of scale can be approximately related to on a physical basis: 1 object; 10 house; 100 building; 1000 block; 10,000 neighborhood; 100,000 district; 1,000,000 city; 10,000,000 metropolis or region; etc.

The built domain with the corresponding land uses determines where the essential functions attached to human life and living take place, both publicly and privately. It includes blocks of flats/apartments, hospitals, places of work, etc., i.e., buildings, and public spaces as well. The basic physical elements of the public space are streets and squares, where all the infrastructures of water, energy and so on usually run through, and where vehicles move and trees are planted. The public space, however, is not just a question of anatomy and infrastructure. It has intrinsic qualitative values. It has a physiological nature since this public built space is where infrastructures meet the built domain of buildings, neighborhoods, etc., and also the space shared by people to meet, relax and/or to carry out activities individually or in community. Different city models can, thus, be identified or defined based at the scales at which individual needs are met since they, in turn, determine the associated models for mobility, density and social interaction and exchanges. Every node in the built domain has a production and an operational cost, with an economic, social and environmental impact on its setting and, ultimately, on city finances and efficiency. These costs have to be accounted for in any refurbishing or new building initiative.

The three subsystems of the *Structure* – the environment, infrastructures, and the built domain, including the public space, would be the only physical part of the city that would be left, if one day humans should disappear. These three structure layers, in fact, let us make the physical world and physical structures compatible with information networks, and also enable us to understand cities as a system of systems and interactions (i.e., as networked networks). These networks are made up of lines and infrastructures through which information moves, and nodes where information processing and storage take place, in a given technological environment.

The relationship between Structure and Society, with the nodes where functions take place, is defined as Interactions, the second system element considered in the anatomy (Fig. 1).

### 2.2 Interactions

The second system element or city system considered in the 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 includes four subsystem layers: (i) functions, (ii) economy, (iii) culture, and (iv) information.

**Functions**. The built domain, with its public space, hosts the more systematic, formal and regulated people's functions (services) in the city, i.e. the activities which people do. Functions include *living*, *working*, *education*, *shopping*, *transport*, caring for *health*, *education*, the *performing arts*, *tourism* (business and personal) and more. This subsystem layer is concerned with the activities themselves and not with the buildings that host them. In fact, some of these activities, like education, can be delivered electronically as distant education through the Internet and, thus, no longer happen in a school, but at home or anywhere with internet connectivity. From the interaction between the container and the living entities in the city, we get urban functions (services) supported by the city.

**Economy**. Wealth production and distribution, commerce and trade, innovation and entrepreneurial ecosystems, competitiveness, tax base, and financing vehicles – these are among the many dimensions that make up the Economy of a city. Strategies such as public-private-people partnerships (P4) provide both success stories, as well as failures, since they are subject to external market forces, long-term revenue collection, and people’s trust. 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. However, both economic scales require increasingly faster information flows between people, institutions, companies, and economic and financial agencies, given the globalization of the local city economies, which generate most of the world GDP. The Economy influences urban innovation and the everyday city operation 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 aiming at increasing the quality of life of citizens, but also the fate of cities themselves.

**Culture**. Culture refers to language, traditions, beliefs, values, and the way that people organize their concepts of the world, etc. In other words, these are 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.). Tacit knowledge requires a personal interaction and the buildup of shared understanding and trust among people in a given community. It usually becomes explicit as the 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 qualitative results of such dimensions such as these are explored and measured in *Happy City*, by Charles Montgomery[6].

**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 depicted in Figure 10. This platform has the following functional elements:

- *City Ontology*, with its lexicon, syntax, and semantics, is needed to assure the inter-operability and proper integration of city models, bringing together all the structural elements of the anatomy, time and spatial reasoning coupled with people's information systems that are involved in the formulation, generation and evaluation of urban planning, design and transformation; and
- *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 indexes* 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

[6] http://thehappycity.com/the-happy-city/

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.

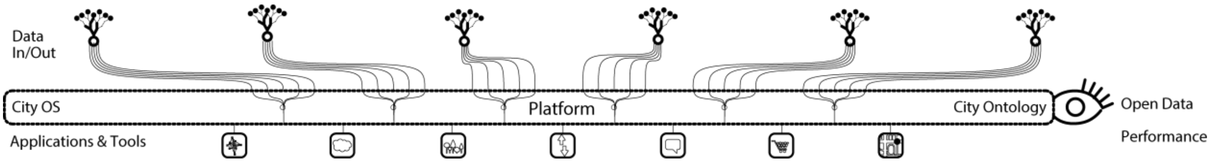



*Figure 10: Information platform*

It is worth emphasizing that today's cities are adopting and implementing information platforms to integrate all information flows that move data through the different interconnected and integrated layers of systems and subsystems that form the anatomy in Figure 1. These flows pass through niches like, for example, water, energy, or others. The information processes and the synergies among them are reinforced by fact that we live in an information society that facilitates the smooth integration of all city information flows.

A close examination of a city allows the identification of several information systems. We can distinguish, for example, a system to collect data in real time from the administration, the citizens or from organizations, connected to a platform to integrate and process this data. This set of basic data collection and processing systems are the basis of what we could call the operating system of the city, the City OS (see Fig. 10). 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 this data to accelerate innovation, to make cities more efficient, or to empower citizens to participate actively in city government.

The city performance language in the platform allows us to look at the city with evaluation 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. For example, it is fundamental in a systems approach to integrate all methodologies that aim at understanding how a city works in order to guide its efficient transformation towards self-sufficiency[7]. Performance facilitates learning from past transformations undergone by a city and also learning from the transformational experiences of other cites under a sound comparative basis and common frame of reference, i.e., the common anatomy.

To further understand the importance of information flows related to city evaluation in the anatomy let's examine several city characteristics, trends and abilities that might put city transformation at risk. Resilience is a key performance indicator since it measures the ability or capacity of cities to withstand sudden changes to the system and to recover their normal state afterwards. Its relevance has increased even further recently given the potential impact of climate change on the city environment, infrastructures, including food supplies, and in the built domain. Another relevant performance indicator is self-sufficiency, which is the city's capacity to produce the resources it needs internally. We could add many more relevant city performance measures such as habitability, quality of life, capacity to innovate, etc. In other words, the information on how an efficient city should work according to the proposed anatomy should frame the definition of methodological recommendations to guide city transformation worldwide.

City information is generated in real time over a spectrum of speeds, analogous to slow and fast thinking in the human brain. Slow information comprises the elements that remain

[7] The term self-sufficient (i.e., resources of any kind cannot be depleted faster than they can be replenished over time to be available for the future) is preferred over sustainability because this broad and important concept promoted by the United Nations, and accepted worldwide, is a declaration of intentions that embraces simultaneously many elements of the City Anatomy.

unchanged over relatively long periods of time, such as the material culture in the built domain that exist in cities as an observable attribute. Flows of fast information, on the other hand, are needed to enable cities to function/operate efficiently on a continuous basis (*e.g.*, by enabling the simple act of turning on a streetlight whenever and wherever needed). Fast information flows are also linked to each interaction that occurs in a city and involve people -- such as a person who takes a bus, and thus consumes energy, or the act of a person who teaches a child somewhere. Emergencies are another example of fast information that trigger immediate action.

### 2.3 Society

The third city system is Society, including *citizens* and *government*.

**Citizens**. Citizens include *person (me)*, *family*, *organizations*, and *businesses*. The term person is applied broadly, and includes individuals who live, work and/or visit within a city, whether or not they are permanent or legal residents[8]. Visitors are identified in Figure 1 as a cluster of individuals that cross city borders as a flow of people. Beyond individuals, Citizens includes the different ways in which people organize themselves (*e.g.*, into clubs) and work and do business (*e.g.*, in corporations and small businesses).

**Government.** Government is the part of Society that at some point is elected or appointed to serve the community. If we talk about how society is organized then we would be talking about the government and citizens, about people as individuals, families, 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 process of running a government, governance, will be used for evaluation purposes in this document since it focuses on the effectiveness of the executive branch of government.

[8] It can be extended to include domestic animals, i.e. pets that individuals attach themselves to.

# 3. Core Organizing Activities for City Governance, Evaluation and Transformation

This section outlines how the city anatomy can be applied to facilitate the core organizing activities for cities. These are: governance, evaluation and transformation.

To understand cities (i.e., to understand structure, interactions and society) and convert this understanding into systems knowledge to guide governance, facilitate evaluation and establish adequate leadership for the successful transformation of cities, it is essential to understand flows. That is, it is essential to understand networks in terms of relations between objects/entities that constitute the three system elements of a city. This layered anatomy thus provides a convenient framework to study the science of cities both at the macroscopic and microscopic scales. It also facilitates the setting up of policies and conceiving sound strategies to implement the most essential city transformations.

Let us consider, for example, the challenges that the Internet of Things (IoT) or the Internet of Everything (IoE) will pose to cities and how they can become opportunities when dealt with in the city anatomy, i.e., with the systems approach in Figure 1. The IoT consists in setting people, processes, data, and things as a connected network in the Internet. These four elements of the IoE, together with the relationships between them, i.e., their networked structure, can be described in detail using the subsystem layers that constitute the city anatomy.

## 3.1 Governance

Governance is understood as the set of all processes of governing the formal and informal city organization, along with concrete activities and actions. It requires leadership to guide and influence city organization, by setting the objectives and priorities needed to achieve the city vision within a political, administrative and legal framework -- both within the election cycle and over the long term. All processes of governance are established, sustained and supported by city-specific policies, laws and regulations, and also in compliance with higherlevel laws applicable in the territory where a city is located. Laws are balanced by citizens' engagement and empowerment, applied both to individuals and also to organizations.

The systems approach of the city anatomy frames how governance relates with urbanism, which in turn frames how city inhabitants interact with the city structure (environment, infrastructures and built domain) via societal functions. These interactions are fueled by the information flows (enabled by information and communication technology, or ICT) and the functional, economic, and cultural subsystem layers which together extend the urban mode of living beyond the confines of the city itself, while at the same time keeping the character of urban life and organization established by urbanism.

The role of the anatomy in relation to governance could be illustrated, for example, by mapping into the anatomy a hypothetical proposal made by a city council to implement a smart city architecture. An example of such approach is depicted in Figure 11 where the anatomy guides this implementation process by framing all smart elements consistently with the city systems and subsystems and also with the specific character of urban life and organization (urbanism) of the city being considered.

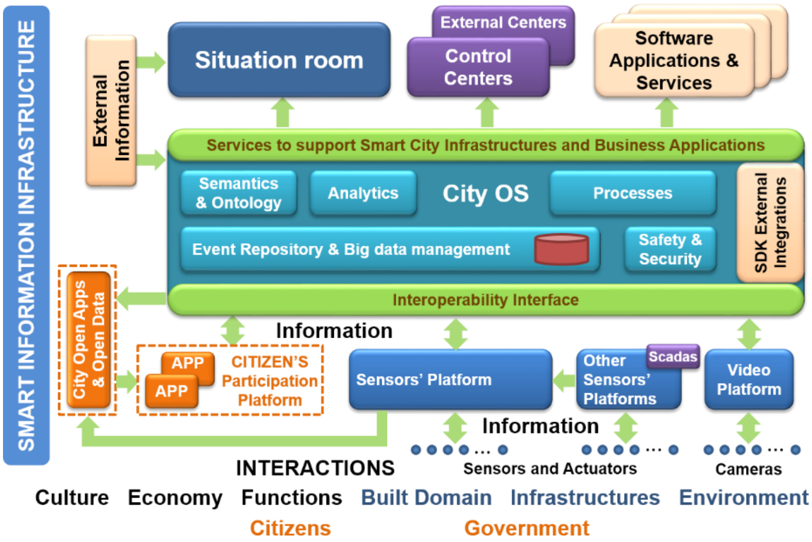



*Figure 11: Example of a Smart City Architecture with infrastructure and flows of information*[9]

[9] This figure takes most of the elements of the Smart Architecture proposed by Barcelona City Council and merges them with the Anatomy

Governance in the context of a Smart City can be depicted by the matrix table format given in Figure 12, which is inspired by the Smart Cities Readiness Guide[10] to relate City Responsibilities (e.g., day-to-day governance and smart city initiatives) with ICT Enablers embedded in the City Anatomy (e.g., *Communications network* within the Infrastructure layer of the Structure system element, plus *Information* within the Interactions system element).

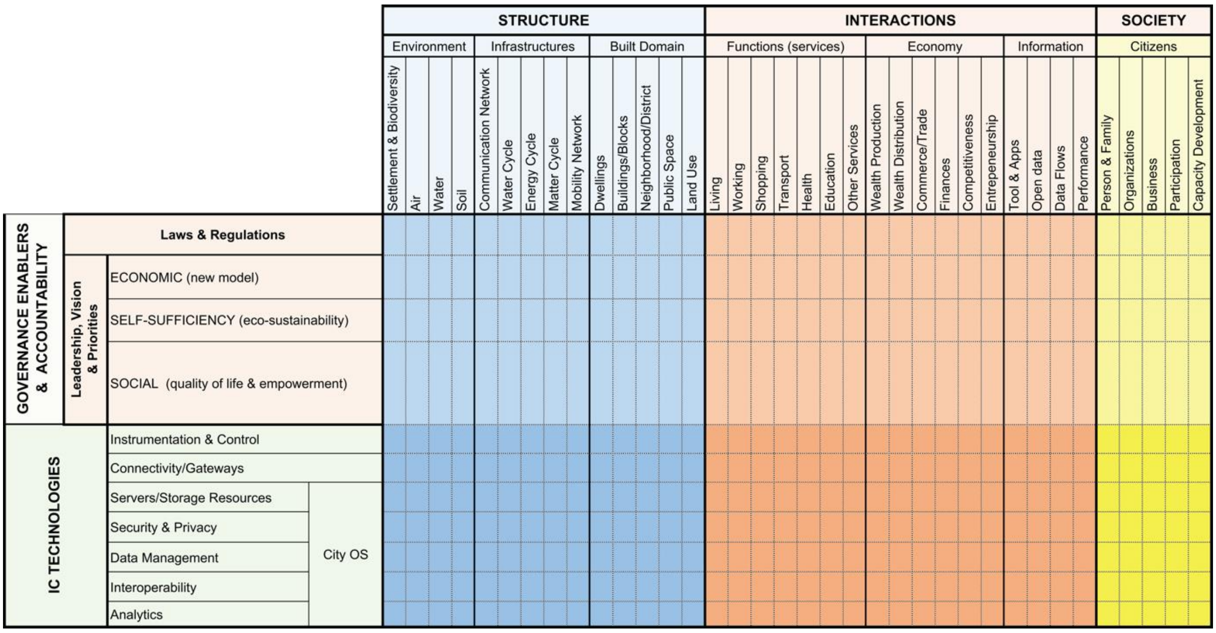



*Figure 12: Smart City Deployment matrix consistent with Figs. 1 and 11*

While it is important that each system and subsystem of a city works effectively, city governance should also ensure that these systems and subsystems can work and be managed together to deliver key city services. This may imply the need to reorganize governance to best serve city objectives and priorities (i.e., its vision).

### 3.2 Evaluation

Cities should consider, among others, the following question to help frame the scope of city evaluation and future transformation: What should be measured and evaluated in the city to help identify and prioritize needs to make the city to progress according to its vision?

As a result of such measurement, a city could start a transformational process by first

[10] http://smartcitiescouncil.com/smart-cities-information-center/the-scc-readiness-guide

assessing, together with other stakeholders, its current and specific anatomy based on the commonly agreed systems layout depicted in Figure 1. This would generate high-level dashboard views, such as qualitative ones where city performance could be visualized using green, yellow, and red indicators for the various systems and subsystems accounted for in the city anatomy to show how well each is functioning. This information, together with a more detailed analysis of specific success stories, previous “no-go” decisions, unaccomplished goals, and existing cultural and management barriers, would in turn help focus city objectives into real city problem-solving. As a consequence, any city, both on its own and also collaboratively with other cities, would be able to define and implement feasible and useful transformational projects, and evaluate them with embedded indicators, like the ones categorized in Figure 13, which can also be used as tools to reliably track and assess their progress and impact over time.

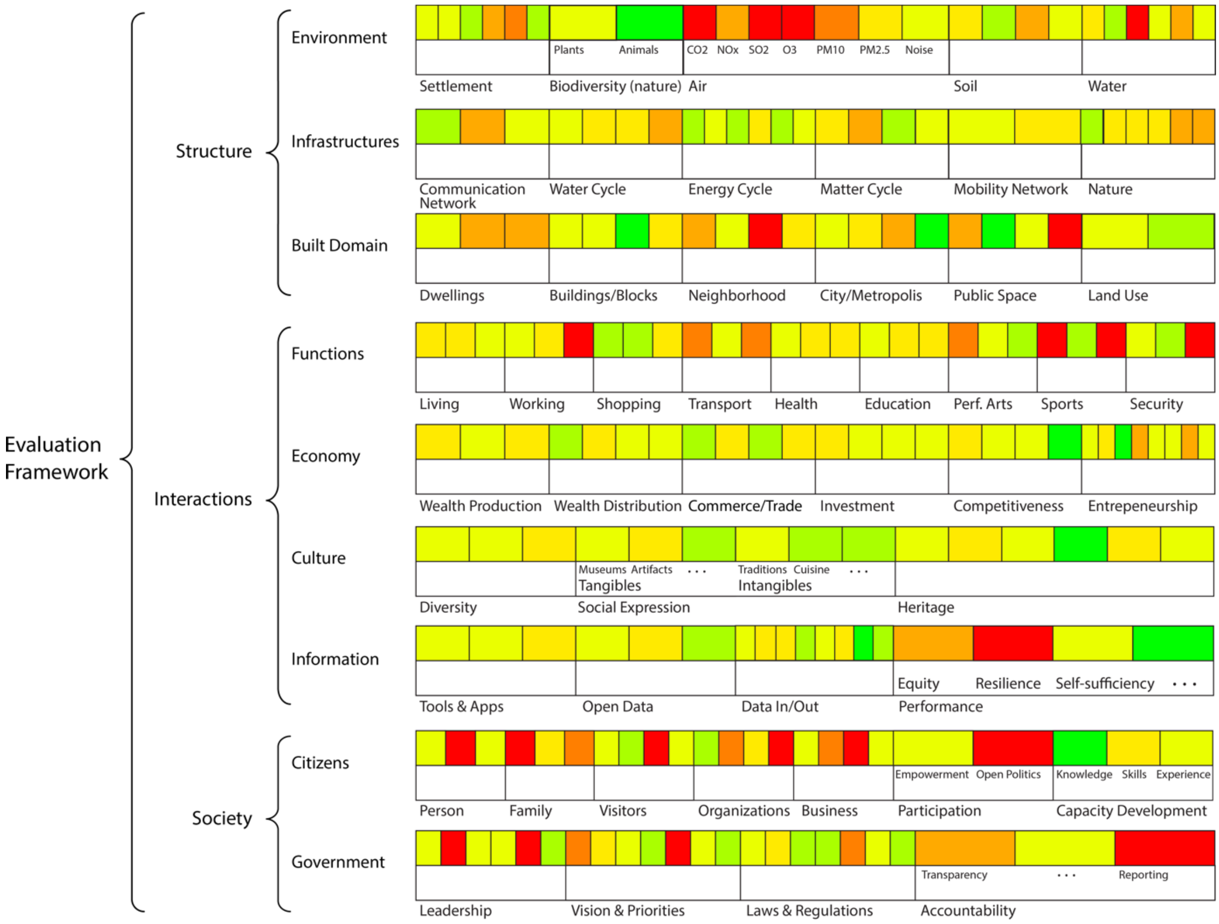



*Figure 13: Evaluation Framework with top level terminology for City transformational projects*

The anatomy in Figure 1 could also be used as a means of producing a maturity model of a city. Each city is the result of events and changes taking place during their history. By leveraging the terminology and framework of the anatomy, cities could analyze the events, crises, wars, discoveries, people, industrialization, catastrophic events, and migrations that create the tale of any city. This information is essential for knowing and sharing how to build a self-sufficient future in the areas of city economics, demographics, heritage, environment, and even future dreams for the city.

### 3.3 City Transformation and the Internet of Cities for Knowledge Sharing

The use of the anatomy helps highlight the strategies that are most valuable when rethinking city management and leadership. City-specific opportunities and motivations, which will guide a given city, will be grounded in tradition-based constraints, organizational behaviors, and unique city history. They will also be grounded in performance evaluation findings and transformational objectives. Additional inspiration may arise from any city model concepts (e.g. the Slow City[11]) followed by the city. Laws and regulations could be a critical limiting step when sharing/adopting transformational projects in cities worldwide. Additional constraints may arise from the availability of ICT enablers (e.g. Information), and factors deriving from the Functions, Economy and Culture of a city.

Cities should further consider the following questions to help frame the scope of city transformation:

(i) What are the most feasible projects that could be undertaken to cover the agreed needs and whom do they benefit?

(ii) What infrastructures, buildings, scales, functions, information/data, and context (environment, legal and regulatory, economic, etc.) do the agreed initiatives impact?

(iii) What examples of good practice and/or of reference projects exist that are relevant to

[11] http://www.citymayors.com/environment/slow_cities.html

the proposed transformational project?

(iv) What would be the basis to compare the effectiveness of the different approaches available?

Cities can achieve their strategic objectives by establishing appropriate policies and by applying well assessed and commonly accepted methodologies for city transformation stemming from a reliable city model and framework (i.e., the city protocol), along with indicators and indexes, tools, shared projects, documents of reference, and guidelines or “de facto” standards. The proposed anatomy is the genesis of such common processes.

The taxonomy of city elements and concepts present in the anatomy visualized in Figure 1, including the principles underlying such classification, enables cities to develop and share transformational projects together and to systematically identify services and modeling tools that could be adopted across multiple cities and a variety of community contexts.

To go beyond isolated intercity solutions and establish, via rough consensus, de facto common standards for city operation and the improvement of infrastructures, the refurbishment or transformation of the built domain, the adoption of new economic models, more effective governance and provision of services it is necessary to:

(i) Adopt a common language to name city objects and interactions according to a common framework, i.e., the city anatomy shown in Figure 1.

(ii) Build a connectivity layer above all specific solutions and best practices for individual cities, in order to facilitate the progressive universal adoption of a number of common city models to respond to the diversity of city needs, stages of development and systems architectures, with minimum risks and costs, i.e., to build the Internet of Cities.

## 4. City Anatomy at the Core of City Protocol

City Protocol is a collaborative framework that serves as a platform for, and facilitator of, solutions that cities can use to improve efficient service delivery and overall citizen quality of life. City Protocol seeks to define a common systems view for all cities regardless of size or type, embracing protocols based upon practice that will help cities deploy solutions across service areas. City Protocol aims at working across city systems and also across diverse cities, interconnecting them and 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.** The anatomy establishes the foundational platform for the approach to our work and is at the core of all City Protocol content.

City Protocol organizes content through an open forum where shared protocol elements for cities are collaboratively developed in accordance with relevant standards, informed by real-world city experience and cross-sector expertise. Protocol Development compiles information provided by Task Teams, society members and partners, and other contributors to facilitate work and collaboration in connection with improving the delivery of city services and quality of life.

Protocol submittals are sourced from City Projects. These come from City Protocol Task Teams (resulting in **Agreements**) or from Society Members, Partners and global contributors (resulting in **Contributions**).

City Protocol will be developed by applying the following key approaches, as summarized in Figure 14:

- Performance is the objective of City Protocol
- Practice is the method of City Protocol
- Platform is the product of City Protocol
- Cities and their Initiatives are the users of City Protocol
- Task Teams (TTs) build on City Anatomy to address physiologic subsystems within the living system that is a City. TTs will collectively address the nervous system; of the

Smart City; the metabolic systems which affect the flows of energy, water, and materials; the circulatory systems which distribute goods, services and wealth within the economy; and more.

- TT Charters define specific scopes of work which act as portals to discover and develop City Protocol platform elements. Platform elements may include such things as information ontologies, interoperable data mechanisms, application programmatic interfaces (APIs) and measurement indicators and indices. They also may include such things as common architectures, reference models, design principles, operational procedures, policy best practices and more. Platform elements are defined by City Protocol where needed, embraced from the work of others where available and appropriate, and discovered through cross-city collaborative practice.

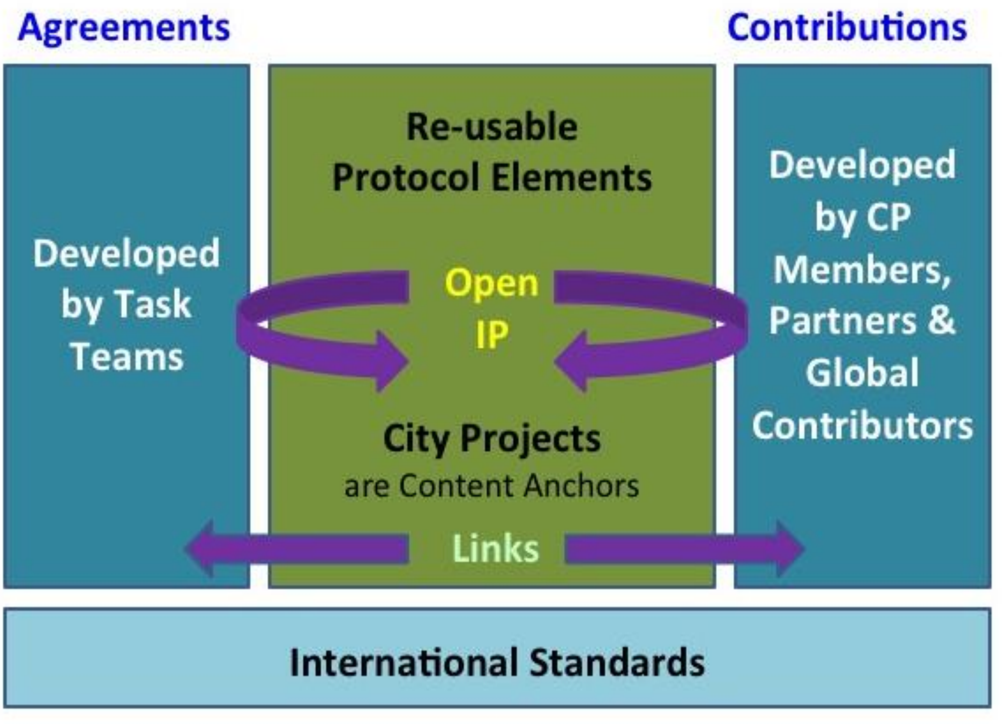



*Figure 14: Key elements for the development of the City Protocol*

When cities within the City Protocol community build their initiatives systematically on the City Anatomy, individual initiatives will work better together -- enhancing the overall performance of the City.

## 5. Acknowledgment

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## 6. Copyright Statement

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