



CPA-PR_003_Anatomy Ontology

Foundation Ontology for the City Anatomy

Developed by Task Team – DICI ontology

2 May 2016

This Document Has Been 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 systems 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 diverse cities 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 a seminal work, **City Anatomy**, that establishes the foundational platform for the approach to our work. The City Anatomy document may be found at CPA-I_001-v2_City_Anatomy.pdf

Executive Summary

1. **CPA Summary:** The aim of this document is to develop a foundation ontology that will further define the main building blocks of the City Anatomy model.
2. **Statement of Purpose/Objective** The following specific objectives will be achieved through this document:
 - Development of a common vocabulary and formal knowledge model linked to the City Anatomy model, based on input from experts in diverse domains related to cities.
 - Development of a foundation ontology where individual ontology modules will be extended by domain-specific task teams.
 - Implementation of the ontology using open standards (specifically the current implementation is in OWL).
3. **Approach.** This document enables the construct established in the City Anatomy to become highly adaptable, interoperable and actionable through use of a common vocabulary and machine-readable interpretation of data and content.
4. **Deliverable Description** This document attempts to formalize the concepts put forth in a narrative framework by the City Anatomy Agreement. It ties into the City Foundation and City Transformation Development Themes because it will advance a systems-based science of the city, and utilize a common vocabulary to implement the conceptual framework of the City Anatomy. It also relates specifically to two Protocol Elements: Indicators and Definitions.
5. **Description of Target Users** The target users of this document are: (1) Task Teams, (2) City leaders, officers and/or urban planners, (3) Commercial and Non-profit organizations, and Knowledge institutions, and (4) City-related Institutions/Associations, City Networks and Standards' Organizations.

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1. Introduction

The aim of this proposed recommendation document is to develop a foundation ontology that will support the main building blocks of the City Anatomy model¹. To this end the following specific objectives will be achieved:

- Development of a **common vocabulary** and **formal knowledge model** linked to the City Anatomy model, based on input from a diverse array of subject matter experts related to cities and city transformation processes.
- Development of a **foundation ontology** where individual ontology modules will be extended by domain-specific task teams.
- Implementation of the ontology using open standards (specifically the current implementation of the ontology is in OWL).

2. City Anatomy Ontology (CAO)

Figure 1 depicts the detailed City Anatomy that the City Protocol Society (CPS) proposes 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 by carrying out functions (**Society**), and the **Interactions** through which the Society engages the Structure. Each system element is organized as a layer of components.

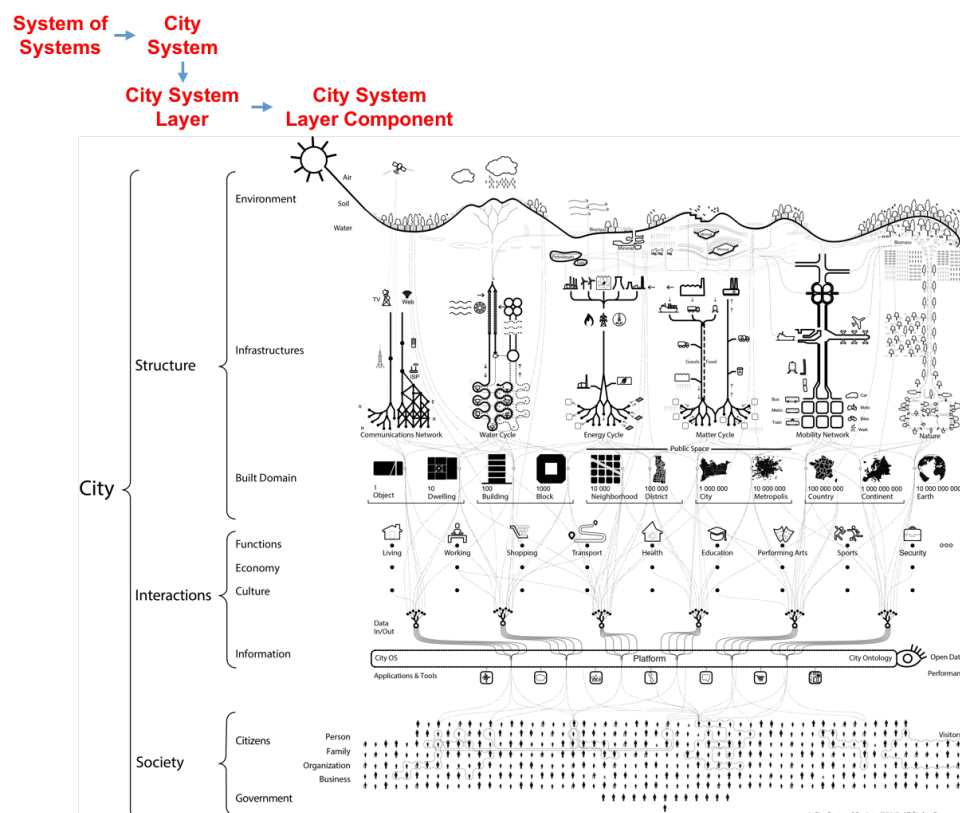


Figure 1. Schematic representation of the City Anatomy

¹ CPA-I_001-v2_City_Anatomy.pdf

2.1 The CPS Key Questions

The CPS has identified seven key questions related to the main strategic objectives of cities worldwide. These key questions are:

- 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?

The foundation ontology will provide the necessary building blocks to formally and unambiguously frame these questions in the context of the City Anatomy.

2.2 Ontologies, taxonomies and controlled vocabularies

An ontology is defined² as “a formal, explicit specification of a shared conceptualization” (Studer et al., 1998). In this context, the term *conceptualization* refers to the development of an abstract model of some real world phenomenon by identifying its relevant concepts. *Explicit* means that the type of concepts identified, and the constraints on their use, are precisely defined without ambiguity as to meaning. *Formal* means that the ontology should be machine-readable. Finally, the term *shared* means that ontology captures consensual knowledge, that is, not a personal view but one accepted by a group.

Ontologies are designed for use in applications that need to process and reason about the content of information. They permit greater machine interpretability of content than that supported by XML, RDF and RDF Schema (RDF-S), by being able to formally define the meaning of concepts/classes.

From a structural point of view, an ontology is composed of sets of concepts, relations, attributes and data types. *Concepts* are sets of tangible and intangible entities with common features. Concepts are classes organized in one or several taxonomies, linked by means of transitive “*is-a*” relationships. Multiple inheritance (*i.e.* a concept with several hierarchical ancestors) is also supported. By default, concepts may represent overlapping sets of entities (*i.e.* an individual may be an instance of several concepts simultaneously). If necessary, ontology languages enable treatment of two or more concepts as disjoint (*i.e.* individuals can only be instances of one of those concepts). *Relations* are binary associations between concepts where the concept in the origin of the relation represents the domain, and those in the destination the range. Relationships may possess properties such as symmetry or transitivity. Finally,

² Studer R., Benjamins R. and Fensel D. Knowledge engineering: Principles and methods. Data & Knowledge Engineering, 25(1-2):161-198, March 1998

attributes represent quantitative and qualitative features of particular concepts, which take values in a given scale defined by its data type.

Standard languages have been designed to codify ontologies. RDF (Resource Description Framework) and OWL (Web Ontology Language) are the most used implementations. There are some differences between them according to their supported degree of expressiveness. In particular, OWL is the most complete, allowing the definition of logical axioms that represent restrictions at a concept level. Axioms are expressed with a logical language and define the meaning of the concepts, by means of specifying limitations on the concepts involved. Several restriction types can be defined:

- **Cardinality:** defines how an instance of a concept can be related (by means of a concrete relation type) to a minimum, maximum or exact number of other concept instances.
- **Universality:** indicates that a concept has a local range restriction (*i.e.* only a given set of concepts can be the range of the relation).
- **Existence:** indicates that a least one concept must be the range of a relation.

All of these restrictions can be defined as *necessary* (*i.e.* an individual should fulfill the restriction in order to be an instance of a particular class) or *necessary and sufficient* (*i.e.* in addition to the previous statement, an individual fulfilling the restriction is, by definition, an instance of that class). This is very useful for implementing reasoning mechanisms when dealing with unknown individuals. In addition, OWL also enables representation of more complex restrictions by combining several axioms using standard logical operators (AND, OR, NOT, etc.).

OWL has been selected to implement the City Anatomy Ontology (CAO). Specifically, OWL-DL has been used, as it offers a high level of expressiveness (it supports all the ontological features described above) and it is based on Description Logics (DL), permitting automatic reasoning to detect inconsistencies in the ontology. OWL-Full offers an increased expressiveness at the cost of the decidability and computational completeness of the language (*i.e.* it is not possible to perform automated reasoning). Therefore, by using OWL-DL, the CAO extensively exploits most of the possibilities offered by modern ontological paradigms in order to design a highly expressive and realistic formal representation of the anatomy of a city, and offers the possibility to perform automated reasoning on the ontology.

2.3 Design Principles

The CAO is designed according to the following regime of tasks:

- Identification of the competency requirements of the ontology (*i.e.*, the questions that the ontology must be able to answer).

- Identification of relevant terms (vocabulary) from the City Anatomy (CPA-I_001-v2_City_Anatomy.pdf) and their properties.
- Organization of terms to form a taxonomy.
- Extraction of relationships between terms and definition of axioms to provide unambiguous interpretation of the terms.

2.4. Elements of the Foundation Ontology for the City Anatomy

This subsection develops the City Anatomy Ontology (CAO) following the City Anatomy framework. The CAO aims to be a foundation (*i.e.*, upper level) ontology that will contribute to the semantic interoperability of domain-specific ontologies that will be developed by individual task teams within the CPTF. In addition, the foundation ontology will facilitate the interoperability with existing “urban” ontologies as well as the exchange of data and best practices among participant cities.

2.4.1 Basic competency questions. The CAO must be able to answer a set of competency questions³ related to the concepts and relationships described by the City Anatomy. Given its foundational nature, the basic competency questions for CAO are:

- Which are the **systems** in a city?
- What is the **structure** of each system?
- How does each system **relate/interact** with other systems?

The foundation ontology has been designed to represent a city from a **systems science perspective** including all the **dynamic processes** that take place in its daily operation. Accordingly, the core elements required to answer the above questions have been organized along two dimensions to facilitate the design of the ontology. The first dimension deals with the *representation of the city from a systems science perspective* whereas the second relates to the *representation of the dynamic processes* that occur in the day-to-day operation of a city.

2.4.2 The city as a “system of systems”. The City Anatomy (CPA-I_001-v2_City_Anatomy.pdf) frames a city as 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. The core entities of the CAO have been designed to model the city and its internal processes from a system science perspective.

³ Gruninger, M. and Fox M.S., The Role of Competency Questions in Enterprise Engineering. Benchmarking – Theory and Practice, Springer US, 1995, 22-31

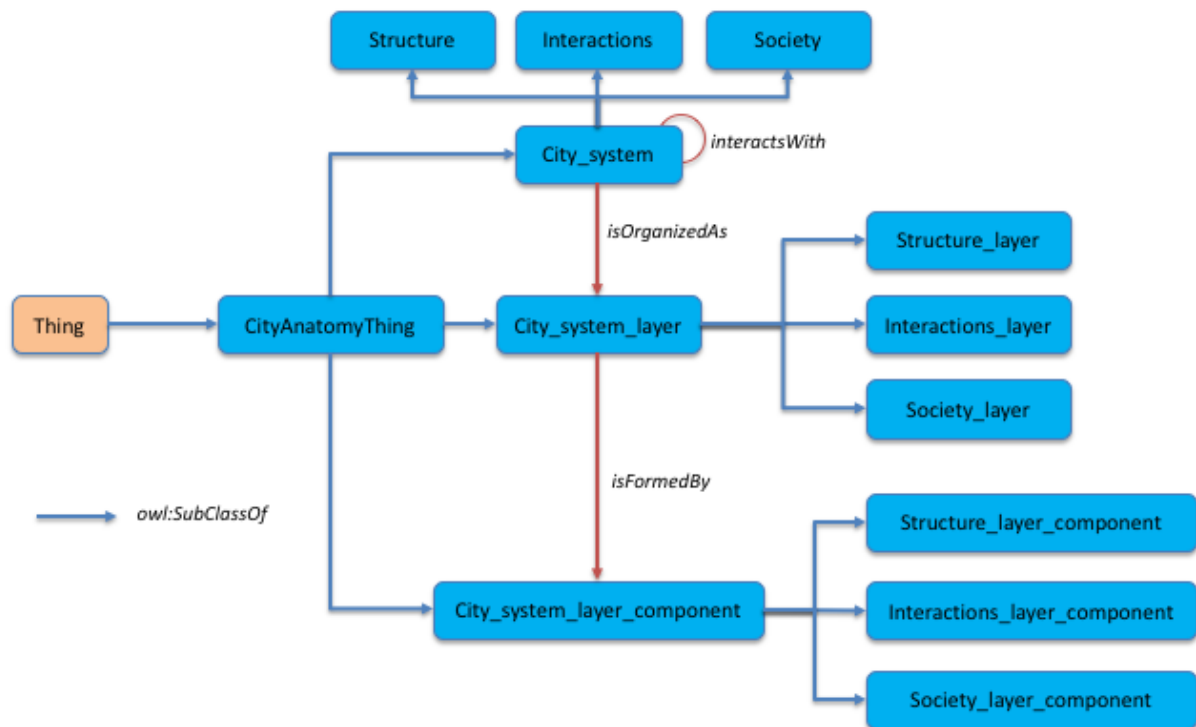


Figure 2. Main CAO elements and relationships that describe a city from a system science perspective as a *system of systems*.

A detailed description of the most relevant elements is provided in Table 1.

Table 1. Core CAO classes used to describe the city from a system science perspective.

Class	Property	Value Restriction
CityAnatomyThing	<i>Convenience class that groups all the city anatomy elements</i>	
City_system	owl:SubClassOf interactsWith isOrganizedAs	CityAnatomyThing some City_system some City_system_layer
City_system_layer	owl:SubClassOf isConstituent isFormedBy	CityAnatomyThing some City_system some City_system_layer_component
City_system_layer_component	owl:SubClassOf isConstituent	CityAnatomyThing exactly 1 City_system_layer

2.4.3 Structure system. Three layer components that correspond to the *Environment*, *Infrastructures* and *Built Domain* compose the Structure of the City Anatomy. Figure 3 depicts the main entities and their inter-relationships.

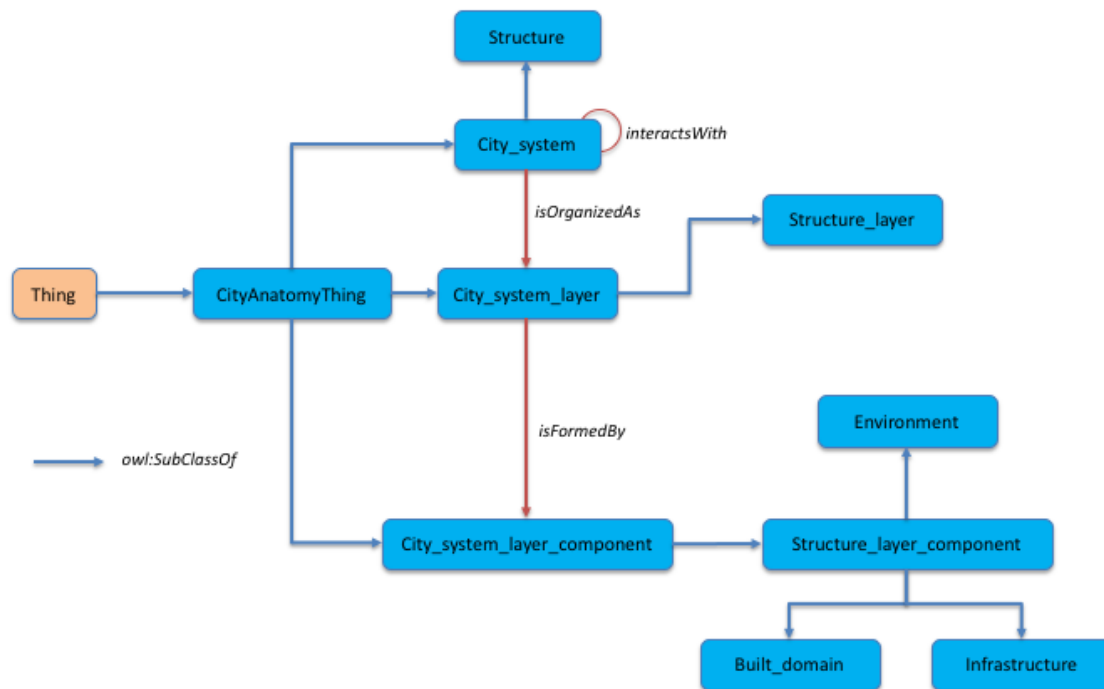


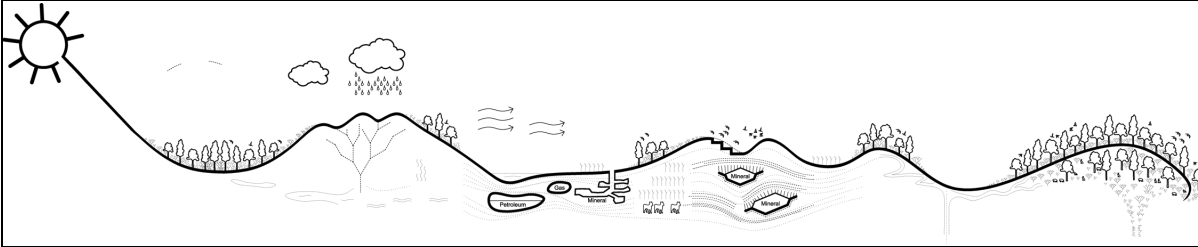
Figure 3. Layer of Structure with the environment, infrastructures and built domain components.

Table 2. CAO classes used to describe the Structure subsystem

Class	Property	Value Restriction
Structure	<i>owl:SubClassOf</i> <i>isOrganizedAs</i> <i>owl:DisjointWith</i> <i>owl:DisjointWith</i>	City_system only Structure_layer Interactions Society
Structure_layer	<i>owl:SubClassOf</i> <i>isFormedBy</i> <i>owl:DisjointWith</i> <i>owl:DisjointWith</i>	City_system_layer only Structure_layer_component Interactions_layer Society_layer
Structure_layer_component	<i>owl:SubClassOf</i> <i>isConstituent</i> <i>owl:DisjointWith</i> <i>owl:DisjointWith</i>	City_system_layer_component only Structure_layer Interactions_layer_component Society_layer_component

2.4.3.1 Environment

The first component of the Structure layer is the Environment. The Environment is formed by nature (plants and animals) and by the three basic environmental compartments: air, soil and water, interacting dynamically in seasonally specific ways. Each of these compartments has its own quality indicators.

Table 3. CAO classes used to describe the Environment Layer


Class	Property	Value Restriction
Environment	<i>owl:SubClassOf</i> <i>isFormedBy</i> <i>isRelatedTo</i>	Structure_layer_component some (Biodiversity and Environmental_compartment) some Settlement
Biodiversity	<i>owl:SubClassOf</i>	CityAnatomyThing
Environmental_compartment	<i>owl:SubClassOf</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i>	CityAnatomyThing Air Soil Water
Settlement	<i>owl:SubClassOf</i>	CityAnatomyThing

2.4.3.2 Infrastructure

The second component within the City Anatomy Structure layer comprises Infrastructures, *i.e.*, connective structures that provide people access to the resources they need, especially from the environment, bringing those resources to the city, and enabling the flows or cycles inside the city itself. Two main types of Infrastructures are considered: **networks** and **cycles**, where a cycle can have a network as one of its interconnected nodes. Table 4 and Figure 4 describe and depict the main entities and relationships in the Infrastructure component

Table 4. CAO classes used to describe the Infrastructure Layer component

The figure consists of six panels illustrating different types of infrastructure components:

- Panel 1 (Network infrastructures):** A tree-like structure representing network infrastructure. The root node is a satellite. It branches into nodes for TV, Web, and ISP. These nodes further branch into a dense network of nodes labeled 'R' (representing routers or repeaters).
- Panel 2 (Network infrastructures):** A tree-like structure representing network infrastructure. The root node is a central hub. It branches into nodes for Bus, Metro, Train, Car, Moto, Bike, and Walk. These nodes further branch into a dense network of nodes labeled 'R' (representing routers or repeaters).
- Panel 3 (Cycle infrastructures):** A tree-like structure representing cycle infrastructure. The root node is a central hub. It branches into nodes for Biomass, Petroleum, and Mineral. These nodes further branch into a dense network of nodes labeled 'R' (representing routers or repeaters).
- Panel 4 (Cycle infrastructures):** A tree-like structure representing cycle infrastructure. The root node is a central hub. It branches into nodes for Goods and Food. These nodes further branch into a dense network of nodes labeled 'R' (representing routers or repeaters).
- Panel 5 (Cycle infrastructures):** A tree-like structure representing cycle infrastructure. The root node is a central hub. It branches into nodes for Goods and Food. These nodes further branch into a dense network of nodes labeled 'R' (representing routers or repeaters).
- Panel 6 (Cycle infrastructures):** A tree-like structure representing cycle infrastructure. The root node is a central hub. It branches into nodes for Biomass. These nodes further branch into a dense network of nodes labeled 'R' (representing routers or repeaters).

Network infrastructures		Cycle infrastructures	
Class	Property	Value Restriction	
Infrastructure	<i>owl:SubClassOf</i> <i>enable</i> <i>transports</i>	Structure_layer_component some Flow some TransportableThing	
Network_infrastructure	<i>owl:SubClassOf</i> <i>isNodeOf</i>	Infrastructure some Network_infrastructure	

Data_communication_network	<i>owl:SubClassOf</i> <i>transports</i> <i>owl:NamedIndividual</i>	Network_infrastructure some Data <i>Internet</i>
Metropolitan_area_network	<i>owl:SubClassOf</i>	Data_communication_network
Local_area_network	<i>owl:SubClassOf</i>	Data_communication_network
Mobility_network	<i>owl:SubClassOf</i> <i>hasElement</i>	Network_infrastructure some Mobility_network_component
Mobility_network_component	<i>owl:SubClassOf</i> <i>isElementOf</i>	CityAnatomyThing some Mobility_network
Subway	<i>owl:SubClassOf</i>	Mobility_network_component
Bus/Bus Rapid Transit	<i>owl:SubClassOf</i>	Mobility_network_component
Road	<i>owl:SubClassOf</i>	Mobility_network_component
Railway	<i>owl:SubClassOf</i>	Mobility_network_component
Pedestrian_way	<i>owl:SubClassOf</i>	Mobility_network_component
Highway	<i>owl:SubClassOf</i>	Mobility_network_component
Bicycle_way	<i>owl:SubClassOf</i>	Mobility_network_component
Airports	<i>owl:SubClassOf</i>	Mobility_network_component
Power_network	<i>owl:SubClassOf</i> <i>isNodeOf</i> <i>transports</i>	Network_infrastructure some Energy_cycle some Electricity
Sewer_network	<i>owl:SubClassOf</i> <i>isNodeOf</i>	Network_infrastructure some Water_cycle
Water_distribution_network	<i>owl:SubClassOf</i> <i>isNodeOf</i> <i>transports</i>	Network_infrastructure some Water_cycle some Water
Cycle_infrastructure	<i>owl:SubClassOf</i>	Network_infrastructure
Energy_cycle	<i>owl:SubClassOf</i>	Cycle_infrastructure
Matter_cycle	<i>owl:SubClassOf</i>	Cycle_infrastructure
Nature_cycle	<i>owl:SubClassOf</i>	Cycle_infrastructure
Water_cycle	<i>owl:SubClassOf</i>	Cycle_infrastructure
Green_infrastructure	<i>owl:EquivalentClass</i>	Nature_cycle
Flow	<i>owl:SubclassOf</i> <i>transports</i>	CityAnatomyThing some TransportableThing
TransportableThing	<i>owl:SubClassOf</i>	CityAnatomyThing
Data	<i>owl:SubClassOf</i>	TransportableThing

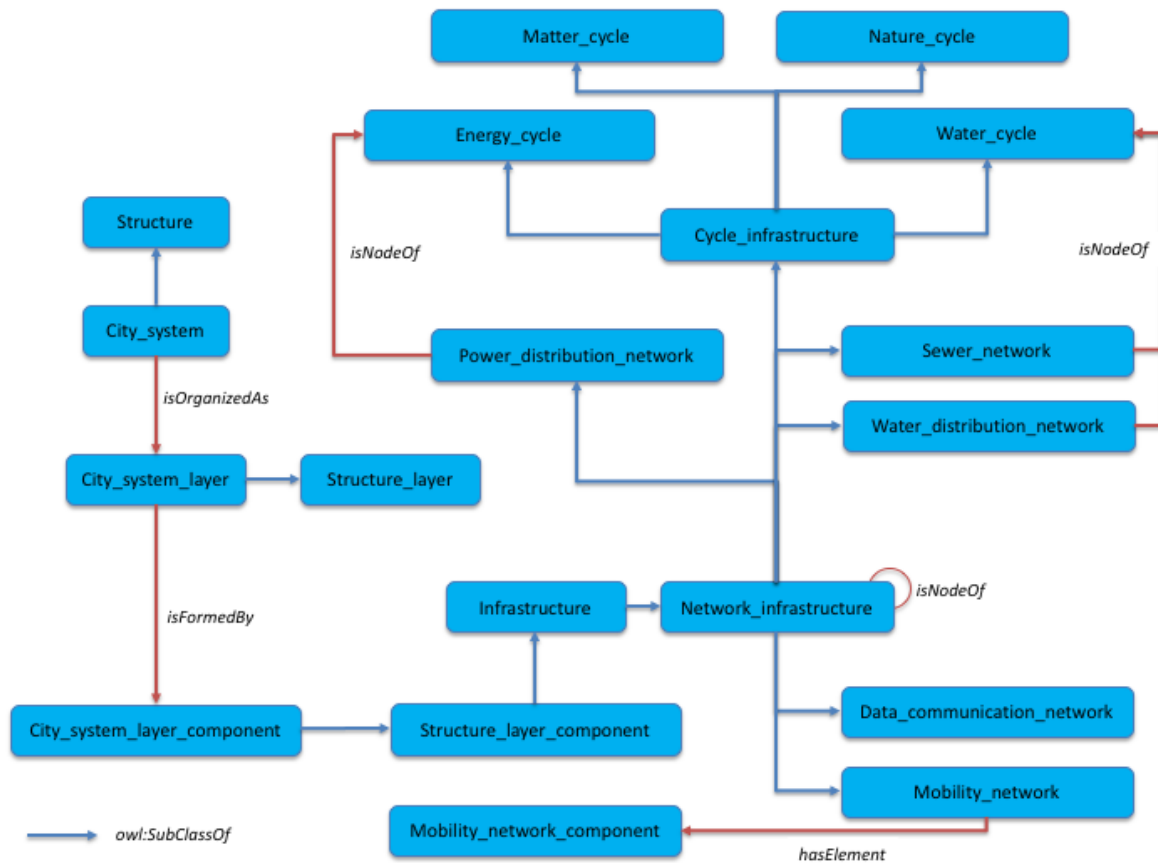










Figure 4. Main classes and relationships in the Infrastructure component of the City Anatomy Structure layer.

2.4.3.3 Built Domain

The third component of the City Anatomy Structure layer 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 is fundamentally multi-scale in nature (*i.e.*, scale is an intrinsic characteristic of the built environment). 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, efficiency and quality of life. The Built Domain, with its public spaces, hosts the more systematic, formal and regulated human functions (services) in the city, (*i.e.* the activities which people engage in or perform). Table 5 describes each of the elements in the Built Domain, which have a specific type of use linked to a particular category of land use (*e.g.*, agricultural, commercial, industrial, recreational, residential). Figure 5 depicts the main entities in the Built Domain together with their inter-relationships.

Table 5. CAO classes used to describe the Built Domain

Public Space							
							
1 Object	10 Dwellings	100 Building	1000 Block	10 000 Neighborhood	100 000 District	1 000 000 City	10 000 000 Metropolis
Class	Property		Value Restriction				
Built_domain	owl:SubClassOf hasConstituent performs		Structure_layer_component some Built_domain_element some Urban_function				
Built_domain_element	owl:SubClassOf		CityAnatomyThing				
Generic_built_domain_element	owl:SubClassOf		Built_domain_element				
Specific_built_domain_element	owl:SubClassOf hasCost hasImpact hasOwnership hasUse isLocated performs		Built_domain_element some Cost some Impact some Ownership some Use some sc:Place some Urban_function				
Object	owl:SubClassOf		Generic_built_domain_element				
Continent	owl:SubClassOf		Generic_built_domain_element				
Earth	owl:SubClassOf		Generic_built_domain_element				
Administrative_built_domain_element	owl:SubClassOf owl:SubClassOf		sc:AdministrativeArea Specific_built_domain_element				
City	owl:SubClassOf		Administrative_built_domain_element				
District	owl:SubClassOf		Administrative_built_domain_element				
Metropolis	owl:SubClassOf		Administrative_built_domain_element				
Country	owl:SubClassOf		Administrative_built_domain_element				
Physical_built_domain_element	owl:SubClassOf		Specific_built_domain_element				
Dwelling	owl:SubClassOf		Physical_built_domain_element				
Building	owl:SubClassOf		Physical_built_domain_element				
Block	owl:SubClassOf		Physical_built_domain_element				
Neighborhood	owl:SubClassOf		Physical_built_domain_element				
Public_space	owl:SubClassOf hasUse hasOwnership		Specific_built_domain_element value public_use some publicly_owned				
Use	owl:SubClassOf owl:NamedIndividual owl:NamedIndividual		CityAnatomyThing private_use public_use				
Land_Use	owl:SubClassOf owl:NamedIndividual owl:NamedIndividual owl:NamedIndividual owl:NamedIndividual owl:NamedIndividual		Use agricultural commercial industrial recreational residential				
org:Ownership	owl:SubClassOf		OrganizationThing				
org:privately_owned	owl:SubClassOf		org:Ownership				
org:publicly_owned	owl:SubClassOf		org:Ownership				
org:charitable_owned	owl:SubClassOf		org:Ownership				
org:government_owned	owl:SubClassOf		org:Ownership				
Cost	owl:SubClassOf owl:NamedIndividual owl:NamedIndividual owl:NamedIndividual		CityAnatomyThing Maintenance_cost Operation_cost Production_cost				
Urban_function	owl:SubClassOf		CityAnatomyThing				
Impact	owl:SubClassOf		CityAnatomyThing				

	owl:NamedIndividual owl:NamedIndividual owl:NamedIndividual	economic_impact environmental_impact social_impact
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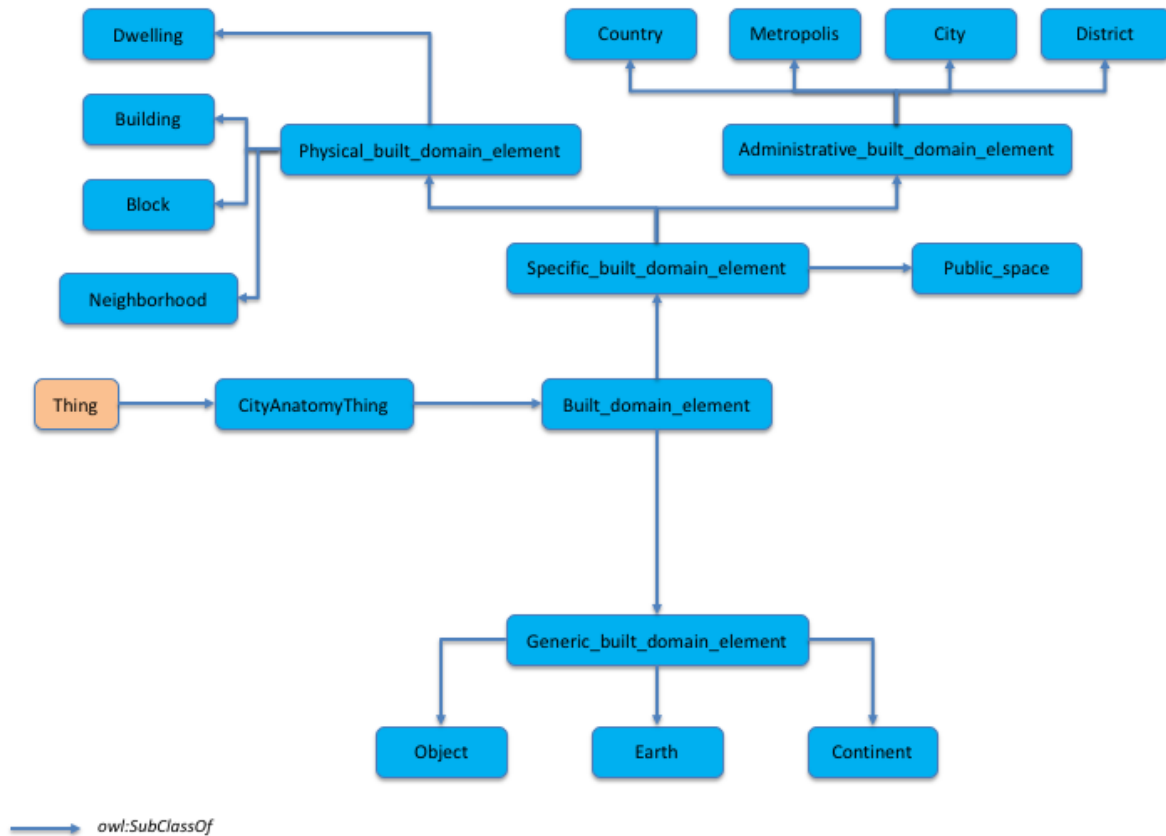


Figure 5. Representation of the main Built Domain entities and relationships.

2.4.4 Interactions system. The Interactions system describes the relationship between Structure and Society, with the nodes where functions take place. The Interactions layer is formed by the following components (Table 6):

- **Functions** are related to activities such as living, working, education, shopping, health care, arts, and tourism (but not with the buildings that host these activities).
- **Economy** determines both the feasibility of transformational projects aimed at increasing the quality of life of citizens, and the fate of cities themselves. Economy also influences urban innovation, including city operations and the life cycles of services provided by cities, with the emphasis on improving their management and quality.
- **Culture** refers to the assets in the City Anatomy that are not part of the material world or built domain such as language, traditions, beliefs, values, and the way that people organize their concepts of the world.

- **Information platform** refers to the integration of all information flows that move data through the different interconnected and integrated layers of systems and subsystems that form the City Anatomy. The platform has four functional elements:
 - City Operating System (CityOS)
 - City Performance Indicators and Indices
 - Information Portal
 - City Applications

Table 6. CAO classes used to describe the Interactions subsystem (components of the information platform are described in Table 7).

Class	Property	Value Restriction
Interactions_layer	<i>owl:SubClassOf</i> <i>isFormedBy</i> <i>owl:DisjointWith</i> <i>owl:DisjointWith</i>	City_system_layer only Interactions_layer_component Society_layer Structure_layer
Interactions_layer_component	<i>owl:SubClassOf</i> <i>owl:DisjointWith</i> <i>owl:DisjointWith</i>	City_anatomy_layer_component Structure_layer_component Society_layer_component
Functions	<i>owl:SubClassOf</i>	Interactions_layer_component
Education	<i>owl:SubClassOf</i>	Functions
Health	<i>owl:SubClassOf</i>	Functions
Transport	<i>owl:SubClassOf</i>	Functions
Living	<i>owl:SubClassOf</i>	Functions
Performing_arts	<i>owl:SubClassOf</i>	Functions
Security	<i>owl:SubClassOf</i>	Functions
Shopping	<i>owl:SubClassOf</i>	Functions
Sports	<i>owl:SubClassOf</i>	Functions
Working	<i>owl:SubClassOf</i>	Functions
Economy	<i>owl:SubClassOf</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i>	Interactions_layer_component Commerce_and_trade Competitiveness Entrepreneurship Finances Wealth_distribution Wealth_production
Culture	<i>owl:SubClassOf</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i>	Interactions_layer_component Diversity Heritage Social_expression

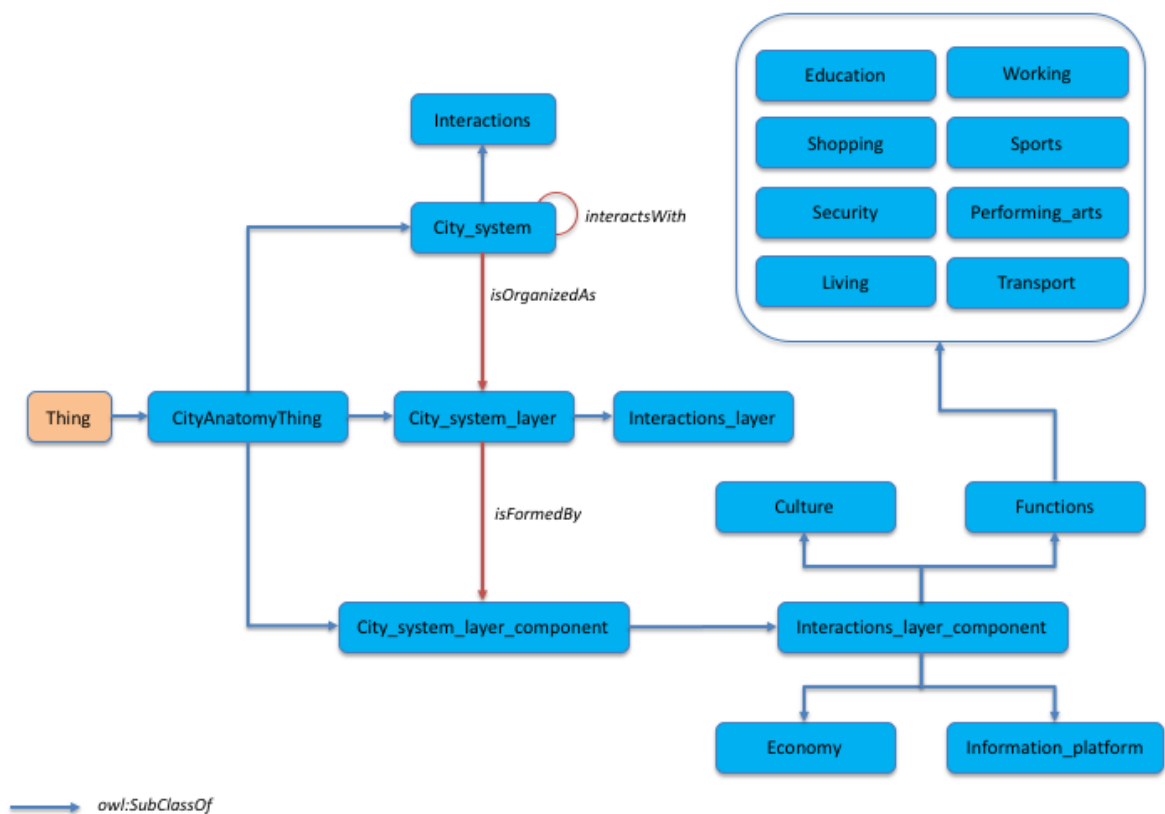


Figure 6. Components of the Interactions subsystem.

Table 7. Main CAO classes in the Information Platform (City indicators are described in full detail in the next section).

Class	Property	Value Restriction
Information_platform	<i>owl:SubClassOf</i> <i>hasElement</i> <i>hasElement</i> <i>hasElement</i> <i>hasElement</i>	Interactions_layer_component some City_information_portal some City_operating_system some City_indicator some City_application
City_operating_system	<i>owl:SubClassOf</i> <i>isElementOf</i> <i>owl:EquivalentClass</i>	CityAnatomyThing some Information_platform CityOS
City_information_portal	<i>owl:SubClassOf</i> <i>isElementOf</i>	CityAnatomyThing some Information_platform
City_application	<i>owl:SubClassOf</i> <i>isElementOf</i>	CityAnatomyThing some Information_platform
City_indicator	<i>owl:SubClassOf</i> <i>isElementOf</i>	CityIndicatorThing some Information_platform

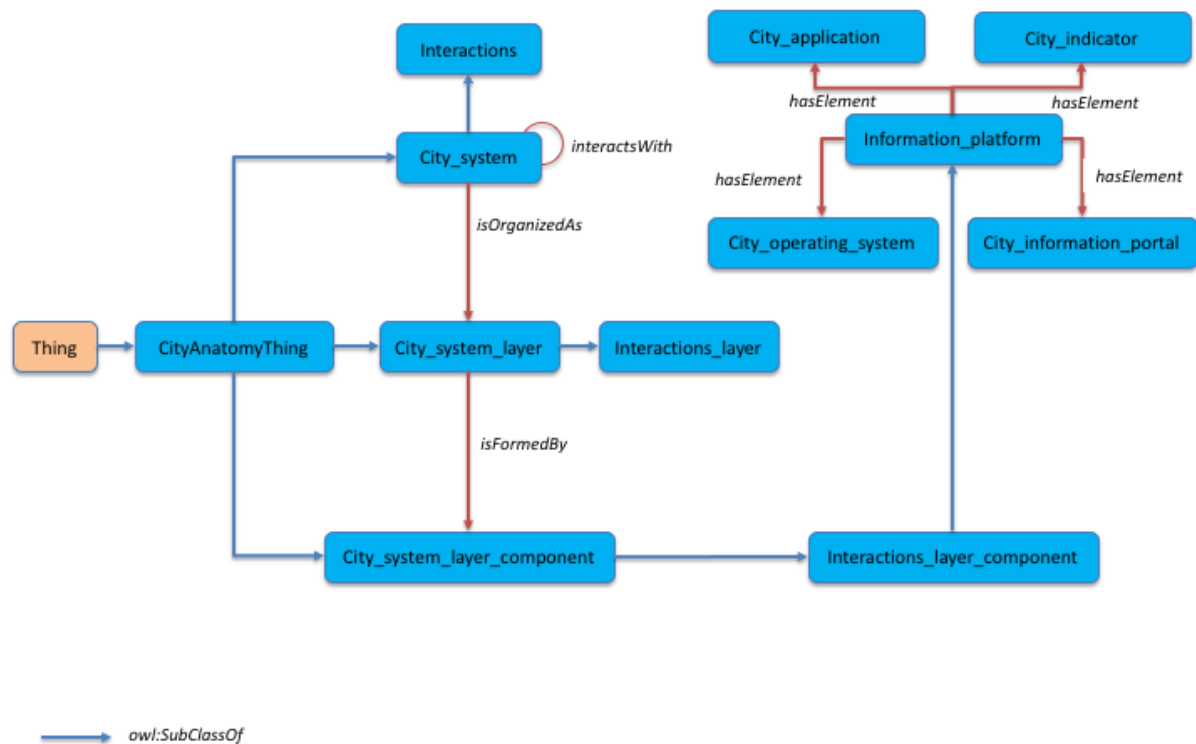


Figure 7. Components and relationships in the Information platform.

2.4.4.1 City Indicator

City indicators are the explicit elements that measure performance in the City Anatomy framework (Table 8). Performance is measured in terms of progress towards the achievement of specific “city objectives” to address the City Protocol’s seven key questions (self-sufficiency, mobility, resilience, investments, equity, entrepreneurship and quality of life). **Figure 8** depicts the way in which city indicators have been modeled in the ontology. At the ontology level, all the classes related to city indicators are grouped under the convenience *CityIndicatorThing* class.



Figure 8. CAO modeling of city indicators

Table 8. CAO classes used to describe the City Indicators

Class	Property	Value Restriction
CityIndicatorThing	<i>Owl:SubClassOf</i>	CityAnatomyThing
Indicator	<i>hasPurpose</i> <i>isDerivedFrom</i> <i>measures</i> <i>hasType</i> <i>hasValue</i>	some Purpose some Raw_data some Measurable_thing some 'unit of measure' some measure
City_indicator	<i>owl:SubClassOf</i> <i>owl:SubClassOf</i> <i>hasSource</i> <i>hasType</i> <i>isElementOf</i> <i>isRelatedTo</i> <i>measuresProgressTowards</i>	Indicator CityIndicatorThing some City_indicator_source some City_indicator_type some Information_platform some City_process some City_objective
City_indicator_source	<i>owl:SubClassOf</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i>	CityIndicatorThing CPS_indicator ISO_indicator
City_indicator_type	<i>owl:SubClassOf</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i>	CityIndicatorThing core_indicator supporting_indicator
City_indicator_selection_criteria	<i>owl:SubClassOf</i>	CityIndicatorThing

	<i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i>	<i>Applicable</i> <i>Easily_calculable_and_updatable</i> <i>Extension_of_ISO37210</i> <i>Measurable</i> <i>Unambiguous</i> <i>Useful</i>
Structure_indicator	<i>owl:SubClassOf</i>	City_indicator
Environment_indicator	<i>owl:SubClassOf</i>	Structure_indicator
Infrastructure_indicator	<i>owl:SubClassOf</i>	Structure_indicator
Built_domain_indicator	<i>owl:SubClassOf</i>	Structure_indicator
Interaction_indicator	<i>owl:SubClassOf</i>	City_indicator
Culture_indicator	<i>owl:SubClassOf</i>	Interaction_indicator
Economy_indicator	<i>owl:SubClassOf</i>	Interaction_indicator
Function_indicator	<i>owl:SubClassOf</i>	Interaction_indicator
Information_platform_indicator	<i>owl:SubClassOf</i>	Interaction_indicator
Society_indicator	<i>owl:SubClassOf</i>	City_indicator
Citizen_indicator	<i>owl:SubClassOf</i>	Society_indicator
Government_indicator	<i>owl:SubClassOf</i>	Society_indicator
City_process	<i>owl:SubClassOf</i> <i>owl:SubClassOf</i>	CityAnatomyThing org:Process
City_objective	<i>owl:SubClassOf</i> <i>owl:SubClassOf</i> <i>isRelatedTo</i>	CityAnatomyThing org:Goal some City_vision
City_vision	<i>owl:SubClassOf</i> <i>isFormedBy</i>	CityAnatomyThing some (City_objective and City_priority)
City_priority	<i>owl:SubClassOf</i> <i>isRelatedTo</i> <i>Ranks</i>	CityAnatomyThing some City_vision some City_objective
CPS_Key_objective	<i>owl:SubClassOf</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i> <i>owl:NamedIndividual</i>	City_Objective <i>Attraction_of_talent_and_investment</i> <i>Entrepreneurship</i> <i>Improved_mobility</i> <i>Livability</i> <i>Resiliency</i> <i>Self-sufficiency</i> <i>Social_equity</i>

Additional details of the interrelationships between indicators and the data used to develop indicators are shown in **Figure 9**.



Figure 9. Indicators, City indicators, data and properties

2.4.5 Society system. The Society system comprises the living entities of the City Anatomy and ecosystem. Specifically, Society includes all the people who occupy the physical space and who often carry out functions. The structure of the Society system is depicted in Figure 10 and described in detail in Table 9. The main components of the Society system are:

Citizens. *Citizens* include persons, family, organizations, and businesses (Table 10). 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. In addition to individuals, *Citizens* encompasses 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 is elected or appointed to serve the community or components of the community. If we consider how society is organized, then we would also consider the various forms of organization (public and private sector) 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 actually running a government, governance, will be used for evaluation purposes and discussed in the next section.

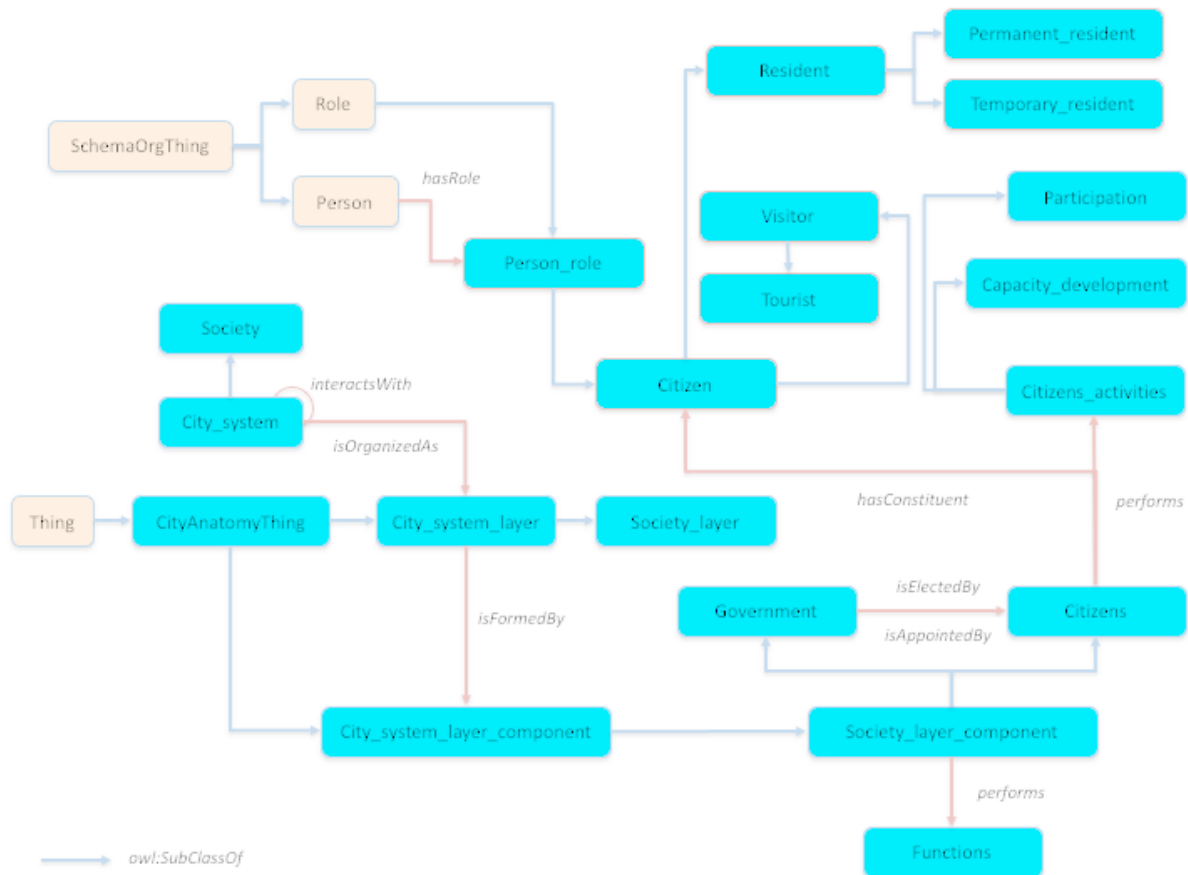


Figure 10. Entities and relationships in the Society system

In the ontology, Society is organized according to the structure shown in **Figure 10**. The ontology allows the differentiation of public, private and social organizations (Table 10). Governmental organizations are defined as a subclass of public organizations managed by the Government. Examples of social organizations include: the family, clubs (e.g., sports clubs), communities and NGOs.

Table 9. CAO classes used to describe the Society subsystem

Class	Property	Value Restriction
Society_layer	<i>owl:SubClassOf</i> <i>isFormedBy</i> <i>owl:DisjointWith</i> <i>owl:DisjointWith</i>	City_system_layer only Society_layer_component Interactions_layer Structure_layer
Society_layer_component	<i>owl:SubClassOf</i> <i>owl:DisjointWith</i> <i>owl:DisjointWith</i> <i>performs</i>	City_system_layer_component Interactions_layer_component Structure_layer_component some Functions
Citizens	<i>owl:SubClassOf</i> <i>hasConstituent</i> <i>performs</i>	Society_layer_component some Citizen some Citizens_activities

Citizens_activities	<i>owl:SubClassOf</i>	CityAnatomyThing
Capacity_development	<i>owl:SubClassOf</i>	Citizens_activities
Participation	<i>owl:SubClassOf</i>	Citizens_activities
Government	<i>owl:SubClassOf</i> <i>isElectedBy</i> <i>isAppointedBy</i> <i>serves</i>	Society_layer_component some Citizens some Citizens some Community

Table 10. Classes used to describe Organizations and Citizens within the Society system

Class	Property	Value Restriction
Organization	<i>owl:SubClassOf</i>	OrganizationThing
For_profit_organization	<i>owl:SubClassOf</i>	org:Organization
Government_organization	<i>owl:SubClassOf</i>	org:Organization
Non_government_organization	<i>owl:SubClassOf</i>	org:Organization
Social_organization	<i>owl:SubClassOf</i>	org:Non_government_organization
Corporation	<i>owl:SubClassOf</i>	org:For_profit_organization
Club	<i>owl:SubClassOf</i>	org:Social_organization
Community	<i>owl:SubClassOf</i>	org:Social_organization
Family	<i>owl:SubClassOf</i>	org:Social_organization
sc:Person	<i>owl:SubClassOf</i> <i>hasRole</i> <i>isRelatedTo</i>	SchemaOrgThing some sc:Role some sc:Person
sc:Role	<i>Owl:SubClassOf</i>	SchemaOrgThing
Person_role	<i>owl:SubClassOf</i>	sc:Role
Citizen	<i>owl:SubClassOf</i>	Person_role
Resident	<i>owl:SubClassOf</i>	Citizen
Permanent_resident	<i>owl:SubClassOf</i>	Resident
Temporary_resident	<i>owl:SubClassOf</i>	Resident
Visitor	<i>owl:SubClassOf</i>	Citizen
Tourist	<i>owl:SubClassOf</i>	Visitor

2.4.6 City Dynamics: City Processes. The City Anatomy can be applied to facilitate the core organizing activities for cities. Activities in the city are considered as processes that take place in a dynamic way along a certain period of time (Table 11). The City Anatomy model defines three different types of city processes: Governance, Evaluation and Transformation (Figure 11).

- **Governance** includes the set of all processes of governing the formal and informal city organization together 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.
- **Evaluation** measures and evaluates the city to identify and prioritize its needs to enable progress according to its vision. As a result of such assessment, a city could begin a transformational process by first evaluating, together with other

stakeholders, its current, specific and unique city anatomy by means of city indicators. The City Anatomy maturity model establishes the metrics for an evaluation process with anatomy-related performance indicators⁴ that can be presented graphically with appropriate dashboards.

- **Transformation** is a process that leads to specific, identifiable change. 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 Anatomy), along with indicators and indexes, tools, shared projects, documents of reference, and guidelines or “de facto” standards.

Table 11. CAO classes used to describe City dynamics and city processes

Class	Property	Value Restriction
Process	<i>owl:SubClassOf</i>	OrganizationThing
City_process	<i>owl:SubClassOf</i> <i>owl:SubClassOf</i>	Process CityAnatomyThing
City_governance_process	<i>owl:SubClassOf</i> <i>governs</i> <i>isSupportedBy</i> <i>requires</i> <i>serves</i> <i>sets</i>	City_process some City_organization some (Law or Policy or Regulation) some Leadership some City_vision some City_priority
City_management	<i>owl:SubClassOf</i> <i>isRelatedTo</i>	City_governance_process some City_objective
City_operation	<i>owl:SubClassOf</i>	City_governance_process
City_organization	<i>owl:SubClassOf</i> <i>owl:SubClassOf</i>	CityAnatomyThing Org:Organization
City_formal_organization	<i>owl:SubClassOf</i>	City_organization
City_informal_organization	<i>owl:SubClassOf</i>	City_organization
City_evaluation_process	<i>owl:SubClassOf</i> <i>measuresProgressTowards</i> <i>sets</i> <i>evaluates</i> <i>measures</i>	City_process some City_vision some Transformational_project some City_maturity some City_performance
City_maturity	<i>Owl:SubClassOf</i>	CityAnatomyThing
Transformational_project	<i>owl:SubClassOf</i> <i>isRelatedTo</i> <i>isImplementedBy</i>	City_project some City_evaluation_process only City_transformation_process
City_project	<i>owl:SubClassOf</i> <i>isImplementedBy</i>	CityAnatomyThing some City_process
City_transformation_process	<i>owl:SubClassOf</i> <i>isRelatedTo</i>	City_process some Transformational_project
Transformational_objective	<i>owl:SubClassOf</i> <i>isRelatedTo</i>	City_objective some Transformational_project

⁴ CPA-PR_002_Anatomy_Indicators.pdf

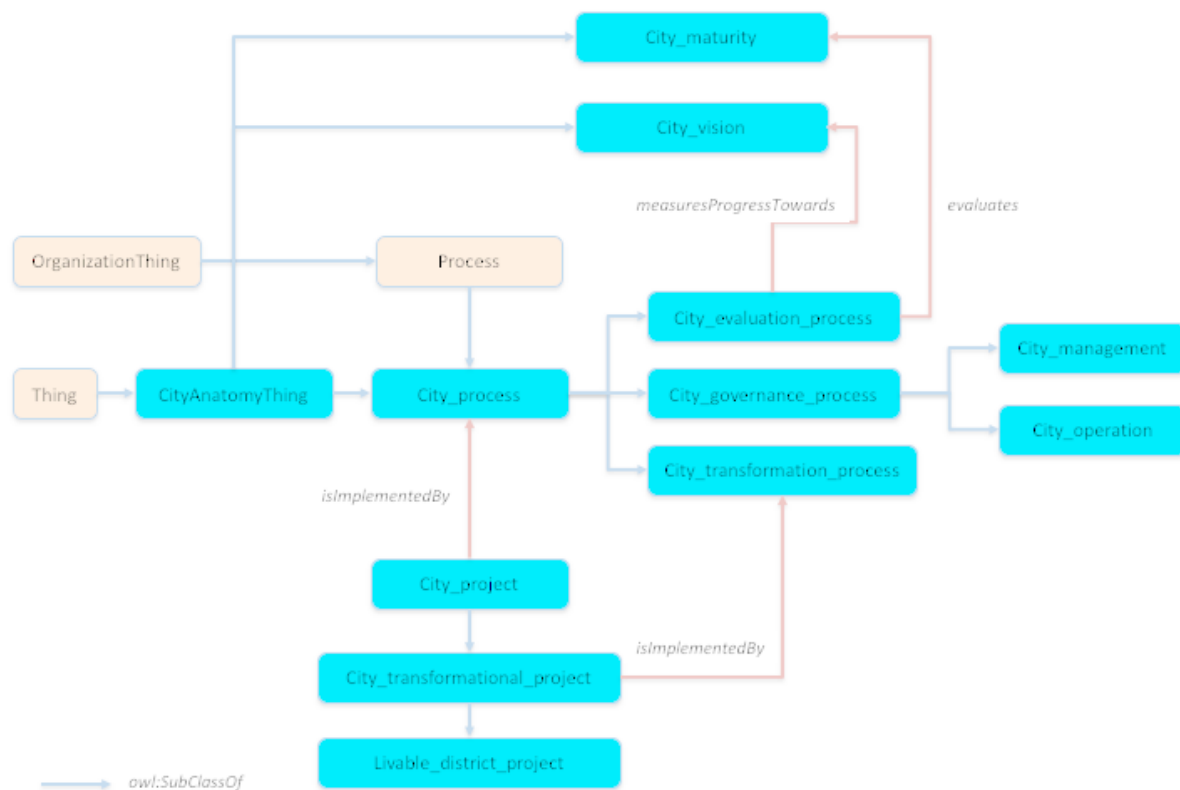


Figure 11. Entities and relationships in the dynamics of a city

3. Protocol Development Themes and Elements

This CPWD-PR_003, Foundation Ontology for City Anatomy, provides a formalization of the concepts and relationships described in a narrative framework in the City Anatomy document CPA-I_001-v2. It relates specifically to two Protocol Development Themes: City Foundations (by furthering a systems-based science of the city and expanding on the foundational work of CPA-I_001-v2), and City Transformation (by advancing a common language that will facilitate improving city service delivery and quality of life). It also relates specifically to the Protocol Elements (i) Indicators (as it provides a highly expressive semantic approach to measuring performance data points and communicating outcomes in ways that are unambiguous and interoperable among cities) and (ii) Definitions (see Section 6).

4. Target Users

The current Agreement targets a broad segment of stakeholders including the following types of users:

- **Task Teams**, whose work contributes to the development of the City Protocol, and that need/ought to develop interoperable data models adapted to the structure of the City Anatomy.
- **City leaders, officers, and/or urban planners** seeking to undertake transformational projects, as the ontology develops an unambiguous semantic description for the elements of the City Anatomy reference model.
- **Commercial and Non-profit organizations, Universities and Research Institutions** to help them develop new IT applications and to facilitate data analysis tasks within the common framework provided by the City Anatomy.
- **City-related Institutions/Associations, City Networks and Standards' Organizations** to help them achieve semantic interoperability among different city models and exchange solutions (best practices) for common problems/challenges.

5. Defined Terms

5.1. The city as a system of systems

Class	Definition
CityAnatomyThing	Convenience class that acts as a placeholder for all the elements of the City Anatomy Ontology. 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 and among them (Interactions).
City_system	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 constituents of the City System are Structure, Interactions and Society.
City_system_layer	Each of the individual components of a City system. Each layer is formed by a number of layer components.
Layer_component	Each of the constituent elements of a city system layer.

5.2 The Structure system

Class	Definition
Structure	The set of physical structures found in a City.
Structure_layer	Container for the individual components of the Structure_system. The structure layer is formed by a number of Structure_layer_components.
Structure_layer_component	Each of the three constituent elements of the structure layer (<i>i.e.</i> , Environment, Infrastructure and Built Domain).
Environment	The first layer in the anatomy structure subsystem. Represents 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 specific way.
Biodiversity	Biodiversity, a contraction of "biological diversity," generally refers to the variety and variability of life on Earth. One of the most widely used definitions defines it in terms of the variability within species, between species, and between ecosystems. It is a measure of the variety of organisms present in different ecosystems.
Environmental_compartment	The environment is usually modeled as a group of five interacting "compartments" (air, soil, water, sediment and biota). Each environmental compartment can be characterized by a set of properties.
Air	Refers to the environmental compartment formed by the air.
Soil	Refers to the environmental compartment formed by the soil.
Water	Refers to the environmental compartment formed by the water.
Settlement	A settlement, locality or populated place is a community in which people live. A settlement can range in size from a small number of dwellings grouped together to the largest of cities with surrounding urbanized areas. Settlements may include hamlets, villages, towns and cities.
Infrastructure	The second layer in the anatomy structure system. Comprises the connective structures that provide people access to the resources they need, especially from the environment, bringing those resources to the city, and enabling the flows or cycles inside the city itself. Infrastructures have the responsibility of moving (transporting) things from one place to another.
Cycle_infrastructure	Connective infrastructure formed by nodes and vertices connecting them in a closed chain.
Energy_cycle	This 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.
Matter_cycle	The matter cycle 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.
Nature_cycle or Green_infrastructure	The “green” infrastructure is formed by the natural elements we bring into the city in a structured way. 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>i.e.</i> , of nature in the public space) which has an effect on the quality of life.
Water_cycle	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. 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.
Network_infrastructure	This infrastructure is an interconnected system of things or people. The system represents a physical realization of the abstract graph concept. A network can be a node of the network infrastructure (<i>e.g.</i> , the Internet is a network of networks).
Data_communication_network	Infrastructure responsible for transporting information using different physical media. Twenty-first century communication networks are mostly digital and follow a distributed organization. Instances of the data communication network are for example, the <i>Internet</i> and <i>Metropolitan Area Networks</i> .
Mobility_network	This infrastructure mostly relates to human transportation, though sometimes to also transporting goods. Everything that enables people to move throughout the city, or cross the city boundaries, falls within the mobility network. Constitutive elements of this infrastructure include: railways, airports, highways, roads, bicycle paths, subways, bus ways

	(including bus rapid transit) and the pedestrian streetscape.
Power_distribution_network	An electric power distribution system is one of the elements of the energy cycle and the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers.
Sewer_network	The principal element of a sewerage system is one of the elements of the water cycle and formed by an aggregate of underground pipelines and sewers receiving and draining waste waters away from population centers and industrial enterprises and toward the appropriate treatment facilities.
Water_distribution_network.	System of engineered hydrologic and hydraulic components which provide water supply.
TransportableThing	Thing that can be transported by some infrastructure (<i>i.e.</i> , cycle or mobility network).
Data	Data as an abstract concept can be viewed as the lowest level of abstraction, from which information and then knowledge are derived.
Built_domain	The third layer in the anatomy structure system. The Built Domain, public and private, includes the surrounding public space. The Built Domain has two distinct and essential characteristics in relation to urbanism (<i>i.e.</i> , urban life and organization): (i) It is the main expression of the material culture of a city (<i>i.e.</i> , it contains most physical artifacts created by people), and (ii) it fundamentally is multiscale in nature (<i>i.e.</i> , scale is an intrinsic characteristic of the built environment).
Built_domain_element	Each of the physical or administrative elements that form the Built Domain. Each of these elements is located in a specific Place. A Place, according to the schema.org ontology, is an entity with some physical extension. Examples of generic built domain elements are: object, continent and earth.
Administrative_built_domain_element	A specific type of Administrative Area in a city. The more general term Administrative Area is defined by the schema.org ontology as a geographical region under the jurisdiction of a particular government.
City	An Administrative_built_domain_element. Represents a large and densely populated urban area and may include several independent administrative districts. In the anatomy model the scale of the city is in the order of 10^6 people.
District	An Administrative_built_domain_element. Represents a region within a city marked off for administrative or other purposes. In the anatomy model the scale of the district is in the order of 10^5 people.
Metropolis	An Administrative_built_domain_element. Represents a large and densely populated urban area and may include several independent administrative districts. In the anatomy model the scale of the metropolis is in the order of 10^7 people.

Physical_built_domain_element	A specific geographical location within a city. Physical built domain elements are not the result of an administrative division of the city.
Dwelling	A place that serves as living quarters for one or more people or families. In the anatomy model the scale of the house is in the order of 10^1 people.
Building	A structure that has a roof and walls and multiple stories. In the anatomy model the scale of the building is in the order of 10^2 people.
Block	Denotes a rectangular area in a city surrounded by streets and usually containing several buildings. In the anatomy model the scale of the block is in the order of 10^3 people.
Neighborhood	An area within a city that has some distinctive features and forms a community. In the anatomy model the scale of the block is in the order of 10^4 people.
Public_space	One of the elements of the Built Domain. The public space has intrinsic qualitative values and a physiological function since this public built space is where infrastructure intersects with the built domain (buildings, neighborhoods, etc.), and provides the space shared by people to meet, relax and/or to carry out activities individually or in community.
Use	Refers to the act of using something.
Land_use	Refers to the category of use assigned to the physical space corresponding to a Built Domain element. Land use involves the management and modification of natural environment or wilderness into built environment such as settlements, and semi-natural habitats such as arable fields, pastures, and managed woods. It can also be defined as the total of arrangements, activities, and inputs that people undertake in a certain land cover type.
Ownership	Refers to the act, state or right of possessing a something. In the context of the Built Domain element, ownership is regulated by Property Laws.
privately_owned	The owner is a specific person or group of persons.
publicly_owned	The owner is the community.
government_owned	The owner is the government.
charitable_owned	The owner is a charitable organization.
Cost	Refers to the amount of economic resources that have to be spent to obtain something. 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. Specific instances of cost are: Operation cost: Refers to expenses that are related to the operation of a built_domain_element. These costs are necessary just to maintain its existence. Production cost: Refers to the costs incurred when manufacturing a built_domain_element. Production costs combine the costs of raw materials and labor.

	Maintenance cost: Refers to the costs incurred to keep a built_domain_element in good condition and/or good working order.
Urban_function	The function of an area is its reason or purpose for being. In urban areas this relates to the purpose of a land use for residential areas, recreation, industry etc. Functions can change over time.
Impact	Refers to the effect or influence of one person, thing, or action, on another.

5.3. The Interactions system

Class	Definition
Interactions	The Interactions between the Structure and Society reflect the activities in the city. These can be analyzed and measured as flows of information. In the context of the City Anatomy, interactions refer to the urban physiology, including its metabolism or cycles, its nervous system, its circulatory system and more.
Interactions_layer	Container for the individual components of the Interactions system. The Interactions layer is formed by a number of Interactions_layer_components.
Interactions_layer_component	The Interactions layer is formed by four components: Functions, Economy, Culture and the Information Platform.
Functions	<p>Refers to the activities that people undertake or perform in the city. The Built Domain, with its public space, hosts the more systematic, formal and regulated people's functions (services) in the city. This layer component is concerned with the activities themselves and not with the built_domain_elements that host them. Specific subclasses of functions include:</p> <ul style="list-style-type: none"> • Education: Education is the process of facilitating learning. Knowledge, skills, values, beliefs, and habits of a group of people are transferred to other people. Education can be delivered electronically at home or anywhere with Internet connectivity (as remote education through the Internet) and, thus, no longer needs to take place in a school. • Health: Health refers to the level of functional or metabolic efficiency of a living organism. In humans it is the ability of individuals or communities to adapt and self-manage when facing physical, mental or social challenges. Health services are provided through specific health care systems, which are organizations of people, institutions, and resources that deliver health care services to meet the specific health needs of target populations. • Transport: Refers to the movement of people, animals and goods from one location to another.

	<ul style="list-style-type: none"> • Living: Refers to the way of life. The act of living is the course and conduct of an individual's life, especially when viewed as the sum of personal choices (or lack of choices) contributing to one's personal identity. • Performing_arts: Refers to 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—as opposed to, for example, purely visual arts, in which artists use paint/canvas or various materials to create physical or static art objects. Performing arts include a variety of disciplines but all are intended to be performed in front of a live or broadcast (TV/Internet-streaming) audience. • Security: Security is the degree of resistance to, or protection from, harm. It applies to any vulnerable and valuable asset, such as a person, dwelling, community, nation, or organization. • Shopping: Shopping is an activity in which a customer browses the available goods or services presented by one or more retailers with the intent to purchase a suitable selection of them. In some contexts, it may be considered a leisure activity as well as an economic one. • Sports: Refers to all forms of usually competitive physical activity which, through casual or organized participation, aim to use, maintain or improve physical ability and skills while providing entertainment to participants, and in some cases, spectators. • Working: Refers to all the activities related to paid employment.
Economy	<p>An Economy or economic system consists of the production, distribution or trade, and consumption of limited goods and services by different agents in a given geographical location. The economic agents can be individuals, businesses, organizations, or governments. 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. 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 aimed at increasing the quality of life of citizens, but also the fate of cities themselves. Specific instances of the economy component are:</p> <ul style="list-style-type: none"> • Commerce and trade • Competitiveness • Entrepreneurship

	<ul style="list-style-type: none"> • Finances • Wealth distribution • Wealth production
Culture	<p>Refers to the way of life, especially the general customs and beliefs, of a particular group of people at a particular time and in a specific geographic location. Includes all assets in the City Anatomy that are not part of the material world or Built Domain (and therefore distinguished from tangible “cultural” objects such as museums, monuments, works of art, archeological sites, city landmarks, etc.). Culture impacts and reflects all dimensions of human life – emotion, intelligence, spirituality, creativity and community – and may influence personal choices (see Functions/Living). Specific instances of culture include:</p> <ul style="list-style-type: none"> • Diversity • Heritage • Social expression
Information_platform	<p>Element of the interactions layer used to integrate all information flows that move data through the different interconnected and integrated layers of systems and subsystems that form the City Anatomy.</p>
City_operating_system	<p>Component of the information platform. Provides 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>i.e.</i>, data flows).</p>
City_information_portal	<p>Component of the information platform that facilitates the access to (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.</p>
City_indicator	<p>Component of the information platform suitable to measure city functions and city performance that provides the city performance language and allows us to look at the city with evaluative or transformational eyes, either in real time or through much more complex and slower processes.</p> <p>City_indicators developed specifically according to the structure of the City Anatomy are divided into core and supporting indicators.</p>
City_application	<p>Component of the information platform that includes Tools and Applications needed for system-level data analysis and representation, decision support and management actions.</p>
Indicator	<p>Measure of performance of a system or component of a system.</p>
Structure_indicator	<p>City_indicator that measures the performance of specific components of the Structure system. Subclasses of structure indicators include:</p> <ul style="list-style-type: none"> • Environment indicators • Infrastructure indicators

	<ul style="list-style-type: none"> • Built Domain indicators
Interactions_indicator	<p>City_indicator that measures the performance of specific components of the Interactions system. Subclasses of interaction indicators include:</p> <ul style="list-style-type: none"> • Function indicators • Economy indicators • Culture indicators • Information platform indicators
Society_indicator	<p>City_indicator that measures the performance of specific components of the Society system. Subclasses of society indicators include:</p> <ul style="list-style-type: none"> • Citizen indicators • Government indicators
City_indicator_source	<p>Indicates the source that defines the indicator. Specific instances are: CPS_indicator and ISO_indicator</p>
City_indicator_type	<p>Categorizes indicators as core_indicator or supporting_indicator. The criteria used to categorize the proposed CP indicators as core or supporting is the following:</p> <ul style="list-style-type: none"> • Core indicators are either related to resilience or to two of the “key CPS questions”. • Supporting CP indicators are all the remaining non-core indicators. • All ISO indicators keep their original ISO 37120 classification
City_indicator_selection_criteria	<p>Refers to the list of criteria used to define an indicator: applicable, easily calculable and updatable, extension of ISO 37120, measurable, unambiguous and useful.</p>
City_vision	<p>Refers to the set of objectives and priorities of a city.</p>
City_priority	<p>Priorities allow the ranking of city objectives. The ranking allows the prioritization of transformational initiatives consistently with citizen's needs, available resources and the city vision.</p>
City_objective	<p>Objectives related to a specific city vision. 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>i.e.</i>, the city protocol), along with indicators and indexes, tools, shared projects, documents of reference, and guidelines or “de facto” standards.</p>
CPS_Key_objective	<p>Each of the seven strategic objectives defined by the City Anatomy for cities. Specific instances include:</p> <ul style="list-style-type: none"> • Entrepreneurship: Refers to fostering a culture that aims at developing and exploiting new commercial opportunities and creating new companies. Entrepreneurship adds value to the city by attracting capital and generating revenue. • Attraction of talent and investment: Refers to the capacity of a city to attract funding and improve its overall economic strength.

	<ul style="list-style-type: none"> • Improved mobility: Refers to transportation patterns and options within the city. (see <i>Mobility_network</i>). • Livability: Refers to the general well-being of individuals and societies. In the context of City Protocol objectives, the term refers to improving the life of citizens in a number of contexts including economic development, healthcare, government policy and employment. • Resiliency: Refers to the capacity for prevention or quick recovery from difficulties or natural disasters. Also refers to the ability of a system to cope with and adapt to, or manage, change. • Self-sufficiency: Refers to the state of not requiring any aid, support, or interaction, for survival; it is therefore a type of personal or collective autonomy. The term self-sufficiency is usually applied to varieties of sustainable living in which nothing is consumed outside of what is produced by the self-sufficient individuals or communities. • Social equity: Refers to the quality of being fair and impartial and achieving equity among citizens.
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5.4. The Society system

Class	Definition
Society	System that includes the people who live, work, visit or stay in a city.
Society_layer	Container for each of the individual components of the Society system. The <i>Society_layer</i> is formed by a number of <i>Society_layer_components</i> .
Society_layer_component	The society layer is formed by two components: citizens and government.
Citizens	Citizens include person (me), family, organizations, and businesses. The term in the context refers to all persons regardless of official national citizenship status. 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. 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.
Organization	An organization is a set of constraints on the activities performed by agents. An organization consists of a set of divisions and subdivisions (recursive definition), a set of organization-agents (said to be members of a division of the organization), a set of roles that the members play in the organization, and an organization-goal tree that specifies the goals (and their decomposition into sub

	goals) the members try to achieve. Includes the following three subclasses: For profit organization, Government organization, Non-government organization <i>[Defined in the Organization Ontology, http://ontology.eil.utoronto.ca]</i>
Social_organization	Is a subclass of 'Non Government Organization' that refers to a social entity comprising multiple people that has a collective goal and is linked to an external environment. Specific instances of this class are: Club, Family and Community.
sc:Person	Entity in schema.org that represents a person who can be alive, dead, undead, or fictional.
sc:Role	Entity in schema.org that represents additional information about a relationship or property. For example, a Role can be used to explain that a 'member' role linking some Sports Team to a player occurred during a particular time period, or that a Person's 'actor' role in a Movie was for some particular character Name. Such properties can be attached to a Role entity, which is then associated with the main entities using ordinary properties like 'member' or 'actor'.
Person_role	Represents the role of a Person in a City.
Citizen	Specific Person_role that corresponds to a person who lives in, works in, or visits a city.
Resident	Specific Person_role that refers to a person who maintains residency (domicile) in a given place. Subclasses of Resident include: <ul style="list-style-type: none"> • Permanent resident • Temporary resident
Visitor	Specific Person_role that refers to a person visiting another person or a place in a city. Subclasses of Visitor include: Tourist: refers to a person who is visiting a city or a place for pleasure.

5.5. City dynamics and City processes

Class	Definition
Process	General term that corresponds to a series of actions or steps taken in order to achieve a particular end.
City_process	A process that occurs in the context of a city.
City_governance_process	Refers to 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.
City_management	A specific type of governance process.

City_operation	A specific type of governance process.
City_organization	Refers to the way in which a city is organized. There are two types of city organization: informal and formal.
City_formal_organization	Refers to the deliberately planned structure of a city. A formal organization has a specific purpose and aims at the efficient accomplishment of city objectives.
City_informal_organization	Refers to the unplanned and many times more “organic” city structure that results from informality in urban areas. In a world marked by globalization processes and deep socioeconomic restructuring, the value of informality seems to be central and increasingly important in the structuring of urban processes, as these reflect the actual organization of life, society and economies.
City_evaluation_process	The process of city evaluation defines the methodologies and actions needed to answer the following question: <i>“What should be measured and evaluated in the city to help identify and prioritize needs to make the city achieve progress according to its vision?”</i>
City_maturity	Score model to measure the performance of a city.
City_performance	Performance is the set of qualitative or quantitative information that guides the assessment of city operations. It also facilitates learning from past transformations undergone by a city and also learning from the transformational experiences of other cities under a sound comparative basis and common frame of reference.
Transformational_project	Individual or collaborative enterprise that is carefully planned and designed to achieve a particular transformational objective. A transformational project ties to a process that leads to specific, identifiable and/or measurable change.
City_transformation_process	The core process through which a city changes and evolves. The transformational process has some transformational objectives that are achieved by implementing some transformational project.
Transformational_objective	Specific goal that aims at transforming some specific aspect in the city.

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