RETURN Project

Ontology Requirements Specification

Version 4.0

Technical References

Project Acronym	RETURN
Project Title	multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate
Project Coordinator	Domenico Calcaterra UNIVERSITA DEGLI STUDI DI NAPOLI FEDERICO II domcalca@unina.it
Project Duration	December 2022 – November 2025 (36 months)

Deliverable No.	DV 5.2.4
Dissemination level*	PU
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Task	Risk-Oriented Taxonomy and Ontology of Urban Subsystems and Functional Models
Lead by	EURAC
Contributing beneficiary/IES	UNIBO, UNINA, UNIFI, UNIGE

* PU = Public

PP = Restricted to other program participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

Eurac Research
Center for Climate Change and Transormation
Viale Druso, 1
39100 Bolzano
T +39 0471 055 055
info@eurac.edu
www.eurac.edu

Author: Cristine Griffo
Group Leader: Massimiliano Pittore

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Revision History

Date	Version	Description	Author
30.11.2023	1.0	Deliverable Document, containing the 1st sprint results (taxonomies and ontologies)	EURAC – Massimiliano Pittore, Cristine Griffo
30.01.2024	2.0	Technical report, containing improvements on soft infrastructure, studying storylines for representing risks and their elements in the urban context. In addition, a series of tests with Vocbench and SKOSMOS were performed to build a controlled vocabulary from the ontologies.	EURAC – Cristine Griffo
30.01.2025	3.0	This report describes the changes and additions conducted in the third ontology engineering cycle, pointing out the design of taxonomies (e.g., taxonomy of vulnerabilities, taxonomy of hazardous events), the refinement of the risk-driven ontology of urban systems.	Cristine Griffo
30.09.2025	4.0	This report describes the changes and additions conducted in the fourth ontology engineering cycle, pointing out the refinement of the risk-driven ontology of urban systems and the validation of the models using a case study called Casette Inglesi.	Cristine Griffo

Table of Contents

Introduction

This document, the *Technical Report v4.0* for the RETURN Project – SPOKE TS1, presents the updated ontological and taxonomic frameworks developed for modeling urban and metropolitan settlements from a multi-risk perspective. It covers the latest refinements made during the fourth ontology engineering cycle, including the risk-driven ontology of urban systems, taxonomies of hazardous events and vulnerabilities, and controlled vocabularies for urban subsystems and functional models. The aim is to provide a structured, standardized knowledge representation to support risk assessment, resilience planning, and decision-making for urban systems under changing climate conditions.

Purpose

The purpose of this document is to define, describe, and provide the ontological and taxonomic models developed within the RETURN Project. It is intended to serve as a reference for researchers, urban planners, risk analysts, and developers who are involved in modeling urban systems and multi-risk scenarios. By reading this document, end users will gain a clear understanding of the conceptual framework, while designers and developers will obtain the necessary foundations to implement these models in software systems, decision-support tools, or data integration platforms.

Scope

This document focuses on the ontological and taxonomic work conducted under SPOKE TS1 (“Urban and Metropolitan Settlements”) of the RETURN Project. It includes:

- The definition of urban system components (e.g., population, infrastructure, geosphere, agents).
- Risk-related concepts (e.g., hazard, vulnerability, exposure, impact).
- Service-oriented models (e.g., urban services, transportation, health, education).
- Taxonomies for hazardous events and vulnerabilities.

The primary stakeholders include project partners (EURAC, UNIBO, UNINA, UNIFI, UNIGE), urban planners, risk management professionals, and public administrators. The document does not describe a specific software system but provides the semantic foundations for future system development.

Problem Statement

Current urban risk assessment and management approaches often lack a standardized, interoperable semantic framework. This leads to:

- Inconsistent terminology across domains and stakeholders.
- Difficulty in integrating heterogeneous data sources.
- Limited capacity to model complex interactions between hazards, vulnerabilities, and urban systems.
- Challenges in simulating multi-risk scenarios under climate change conditions.

Definition, Acronyms, and Abbreviations

RETURN	**Multi-Risk Science for Resilient Communities Under a Changing Climate**
SPOKE TS1	Thematic Spoke 1: Urban and Metropolitan Settlements
Ontology	A formal representation of knowledge as a set of concepts and relationships
Taxonomy	A classification scheme organized in a hierarchical structure
SKOS	Simple Knowledge Organization System
Hazardous Event	An event with the potential to cause harm to urban systems
Vulnerability	Susceptibility of a system to adverse effects from hazardous events
Urban System	A human-made system composed of population, infrastructure, and geosphere

Constraints

The models are conceptual and not tied to specific software implementation.

The ontologies are developed within the context of European urban systems and may require adaptation for other regions.

The framework does not include real-time data processing or dynamic risk simulation capabilities.

Limited to the domains and risk types explicitly modeled (e.g., seismic, flood, fire, biological hazards).

Dependency on external vocabulary and standards (e.g., SKOS, GEM Taxonomy).

References

- EU Artificial Intelligence Act. Retrieved from: https://artificialintelligenceact.eu/article/3/
- GEM Building Taxonomy Version 2.0. Retrieved from: https://cloud-storage.globalquakemodel.org/public/wix-new-website/pdf-collections-wix/publications/GEM%20Building%20Taxonomy%20Version%202.0.pdf
- ISTAT Population Statistics. Retrieved from: https://www.statista.com/statistics/789270/population-in-italy-by-age-group/
- Top Level Ontology L0 - https://schema.gov.it/lode/extract?url=https://w3id.org/italia/onto/l0
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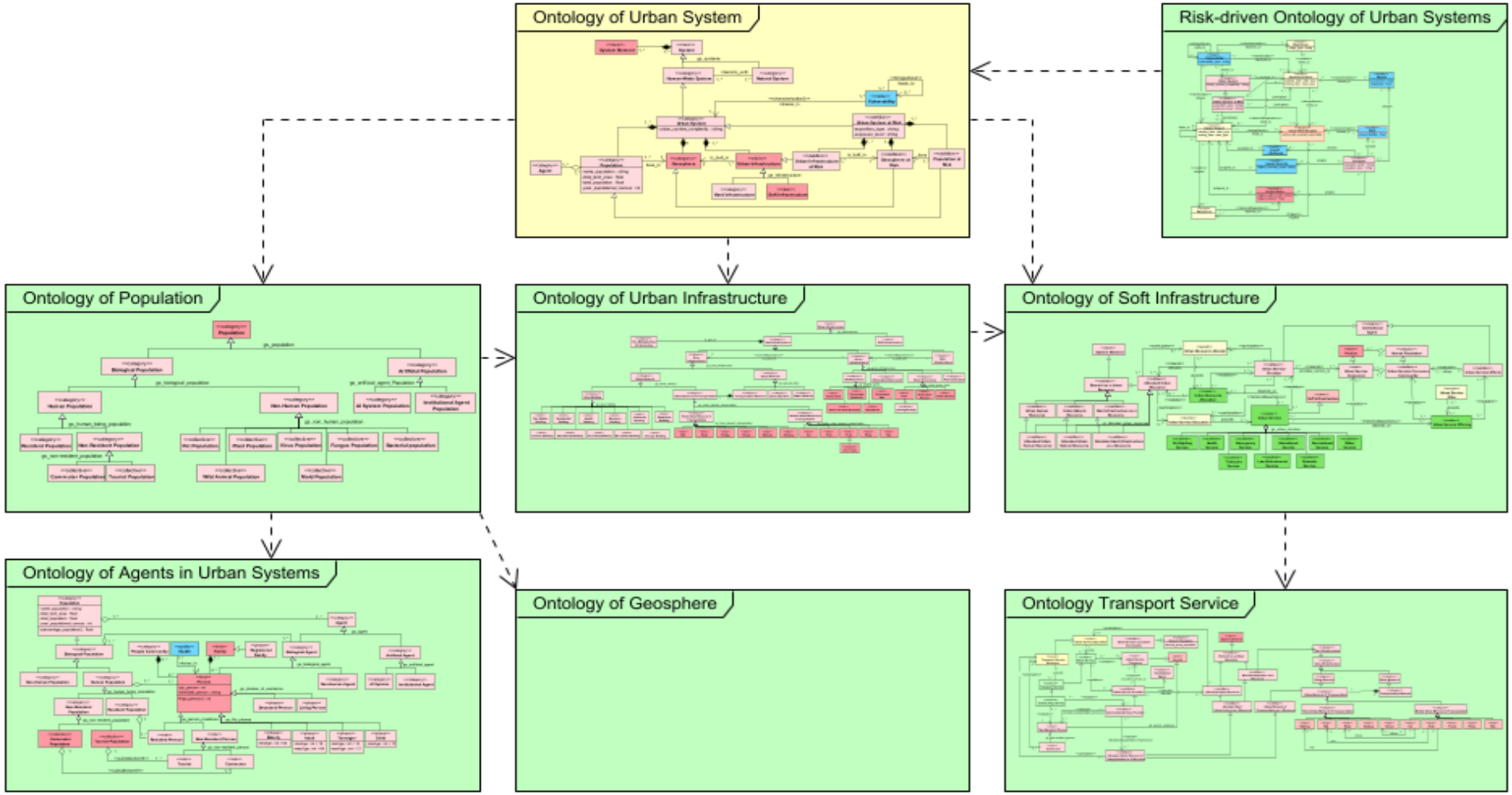
- ISO/IEC 15288:2015 – Systems and software engineering – System life cycle processes

1. Ontologies - Model Preview - Return Project



1.1. Ontology of Agents in Urban Systems

This ontology presents the categories of Agents: 1) Biological Agent, and 2) Artificial Agent. Biological Agents are subcategorized as Human Beings (i.e., Person), and Non-Human Agents (e.g., Pets, Wild Animals, Plants, Mobile Genetic Element (MGE), Fungi, and Bacteria). A Person plays different roles: Resident Person, Non-Resident Person (e.g., tourist, commuter).

1.2. Ontology of Geosphere

This model is the conceptualization of the mineral, non-living portion of the Earth that provides a foundation for the existence of all living organisms. It includes the atmosphere, hydrosphere, soil, and peripheral lithosphere within an urban system.

1.3. Ontology of Population

This ontology aims to represent populations of agents in the context of an urban system from a risk perspective. Attached to it is an ontology of agents that might act as risk drivers or play other roles in the risk-driven modeling of urban systems.

1.4. Ontology of Soft Infrastructure

Soft Infrastructure is related to the organizational, institutional, or service nature. It refers to public and private systems that provide certain utilities within the city, such as local government, healthcare services, or educational services. In the ontological model proposed here, a difference is made between the (physical) distribution networks of basic infrastructure (water, sewage, energy, waste, telecommunications, transportation, mobility) and the services provided by public or private companies employing the hard infrastructure.

1.5. Ontology of Urban Infrastructure

This ontology represents the infrastructure of an urban system. In this model, urban infrastructure is categorized into Hard Infrastructure - concrete elements - and Soft Infrastructure - the intangible infrastructure, i.e., the set of services available to the population in an urban system.

1.6. Ontology of Urban System

An urban system consists of two primary components: the “living” component, and it is arguably that population is indeed the core of the urban system. The other main component is generally indicated as the “infrastructure” that includes non-population elements found in an urban system. This component is further divided into hard infrastructure, which consists of all physical components such as roads, metros, railways, buildings, and utilities; and soft infrastructure, which includes the set of relevant functions necessary for the ordinary and extraordinary management of the urban system, for instance, health, emergency, law enforcement, mid-term services (e.g., waste management), and long-term services including education.

1.7. Ontology of Transportation Service

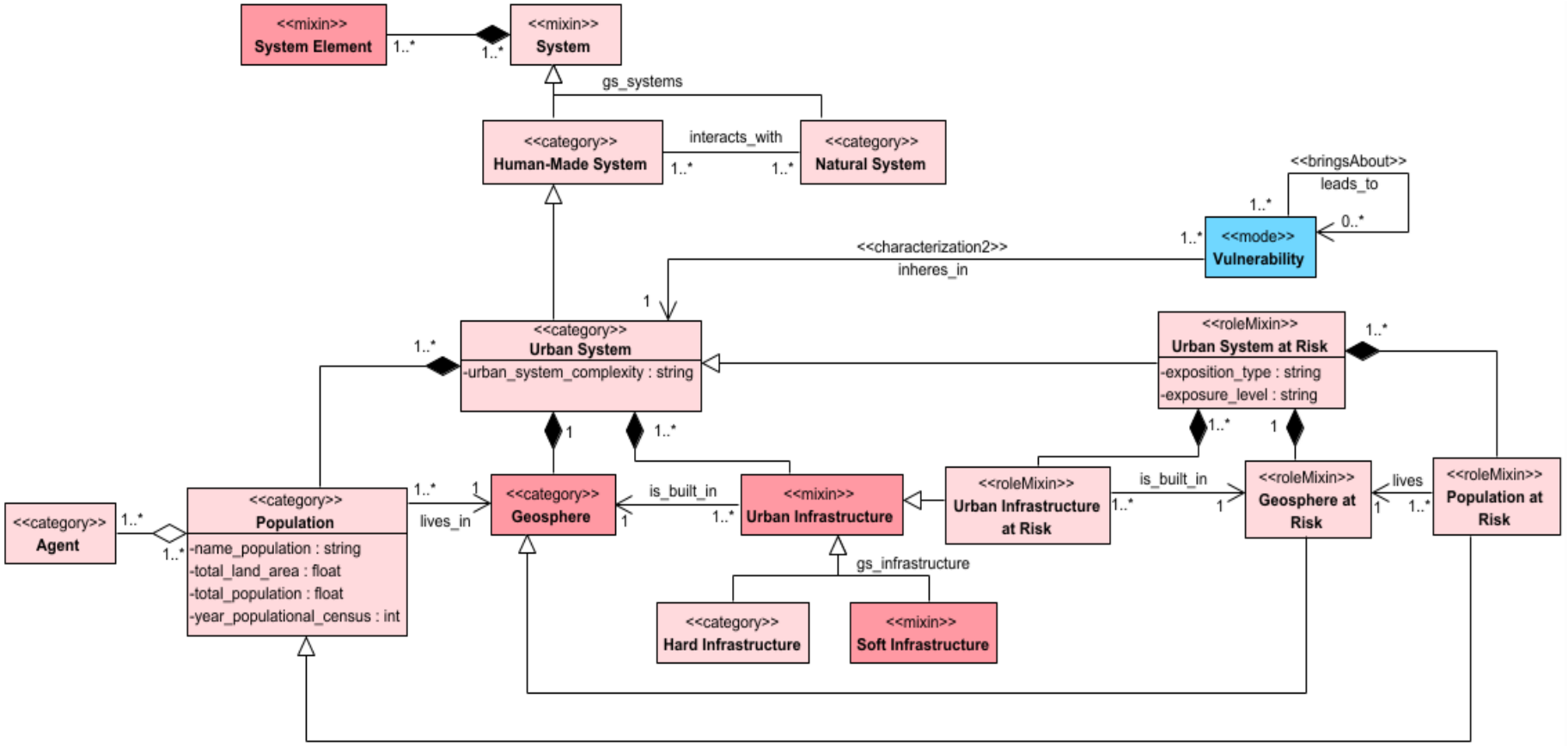
In the context of an urban system, service providers allocate urban resources, which are defined as the various built structures (roads, bridges, buildings), energy sources (oil, gas, eolic), and natural elements (rivers, land, subsoil, forests, etc.) available. Humans

can utilize these resources for their needs and activities. Furthermore, urban resources encompass the human capital allocated to delivering various services within an urban setting. In this relational context of service allocation, agents and infrastructure are provided and arranged, mediating the roles played by agents and urban infrastructure as resources.

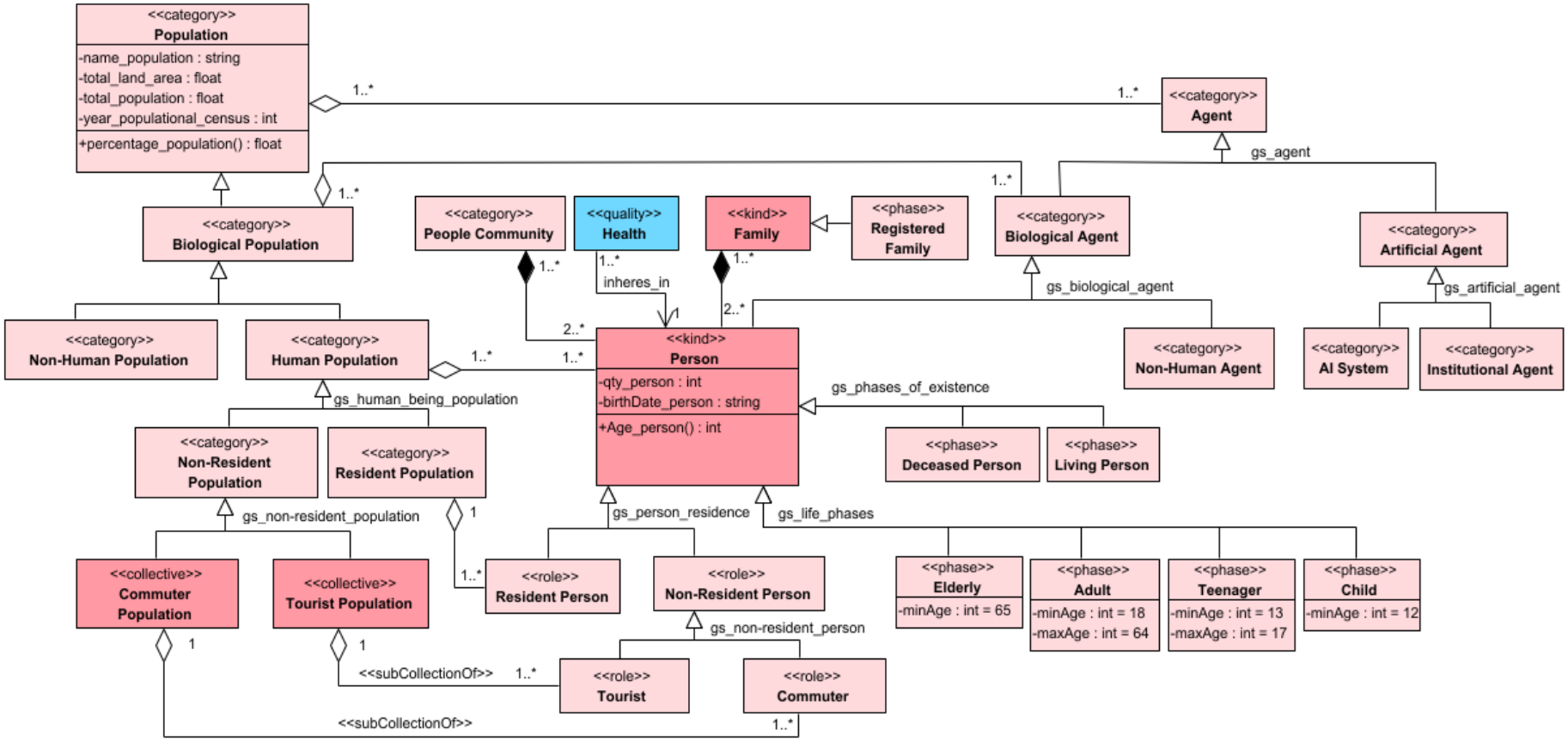
1.8. Risk-driven Ontology of Urban Systems

Risk is presented in the context of urban systems through the interrelated concepts of vulnerability, exposure, and hazard, using theories of relational risk, uncertainty, and probability.

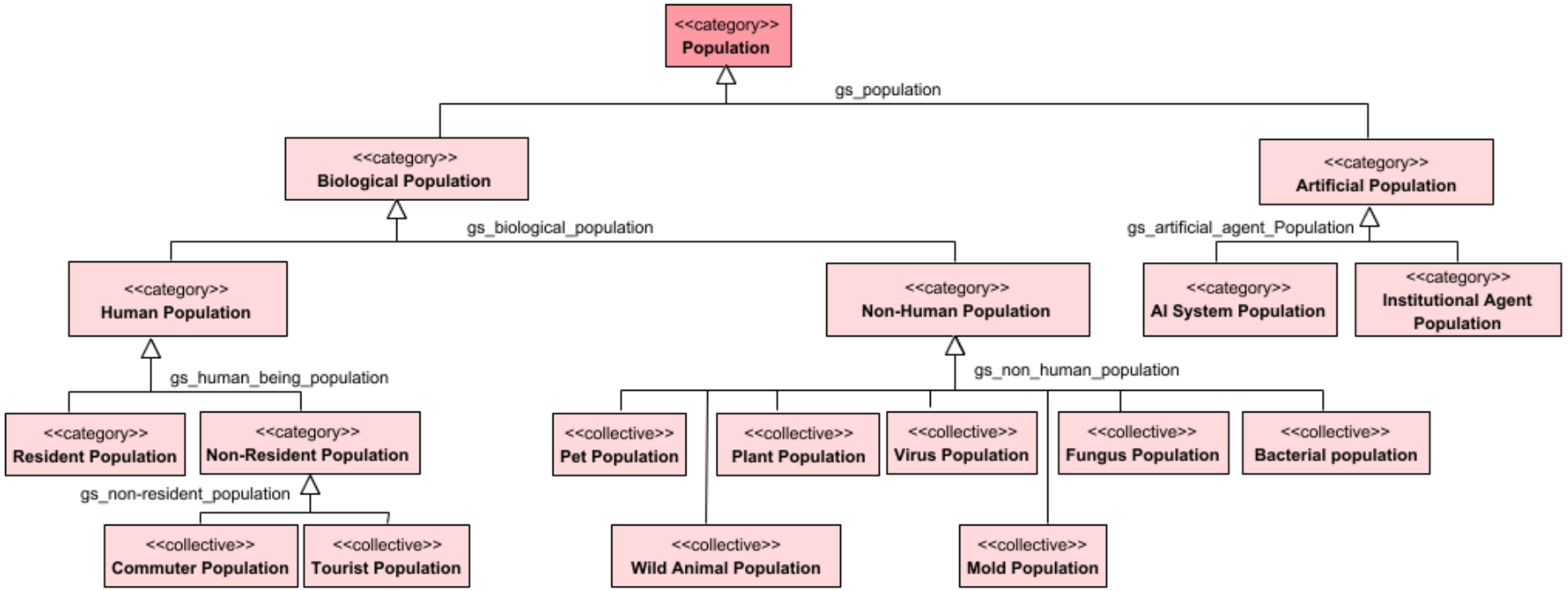
1.1. Ontology of Urban System



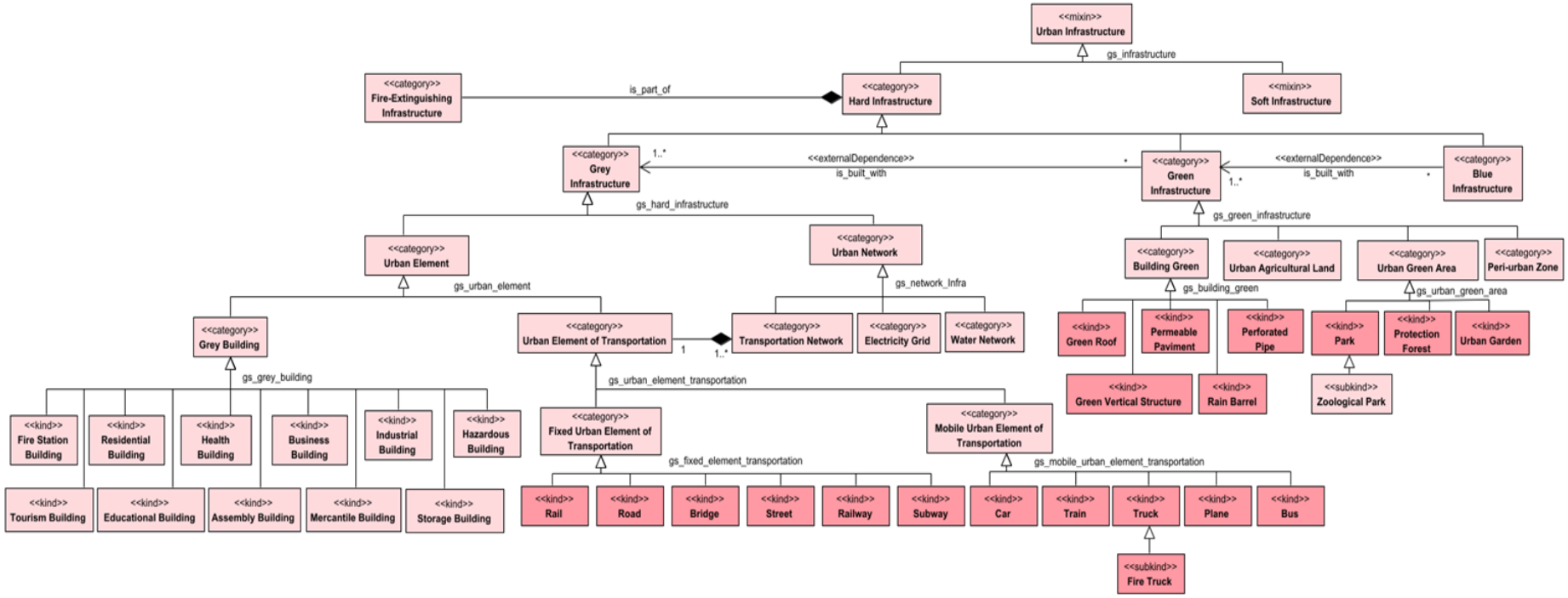
1.2. Ontology of Agents in Urban Systems



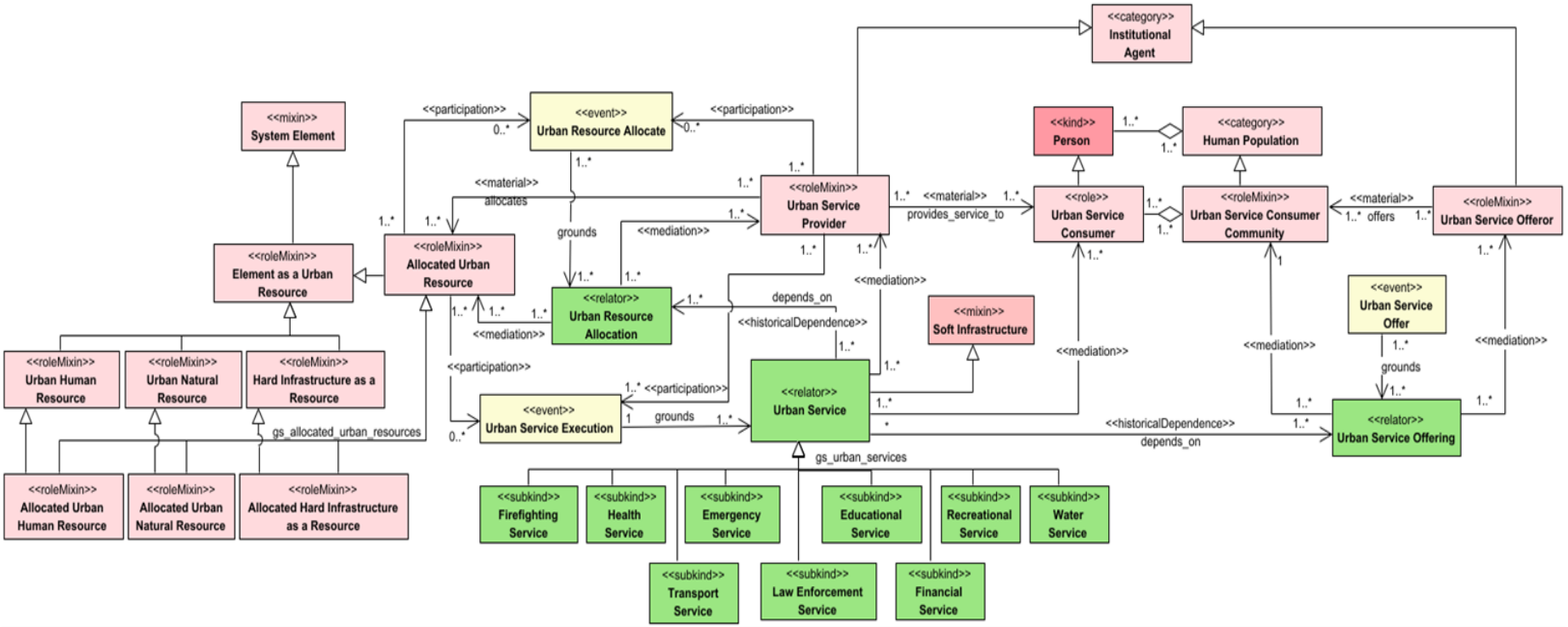
1.3. Ontology of Population



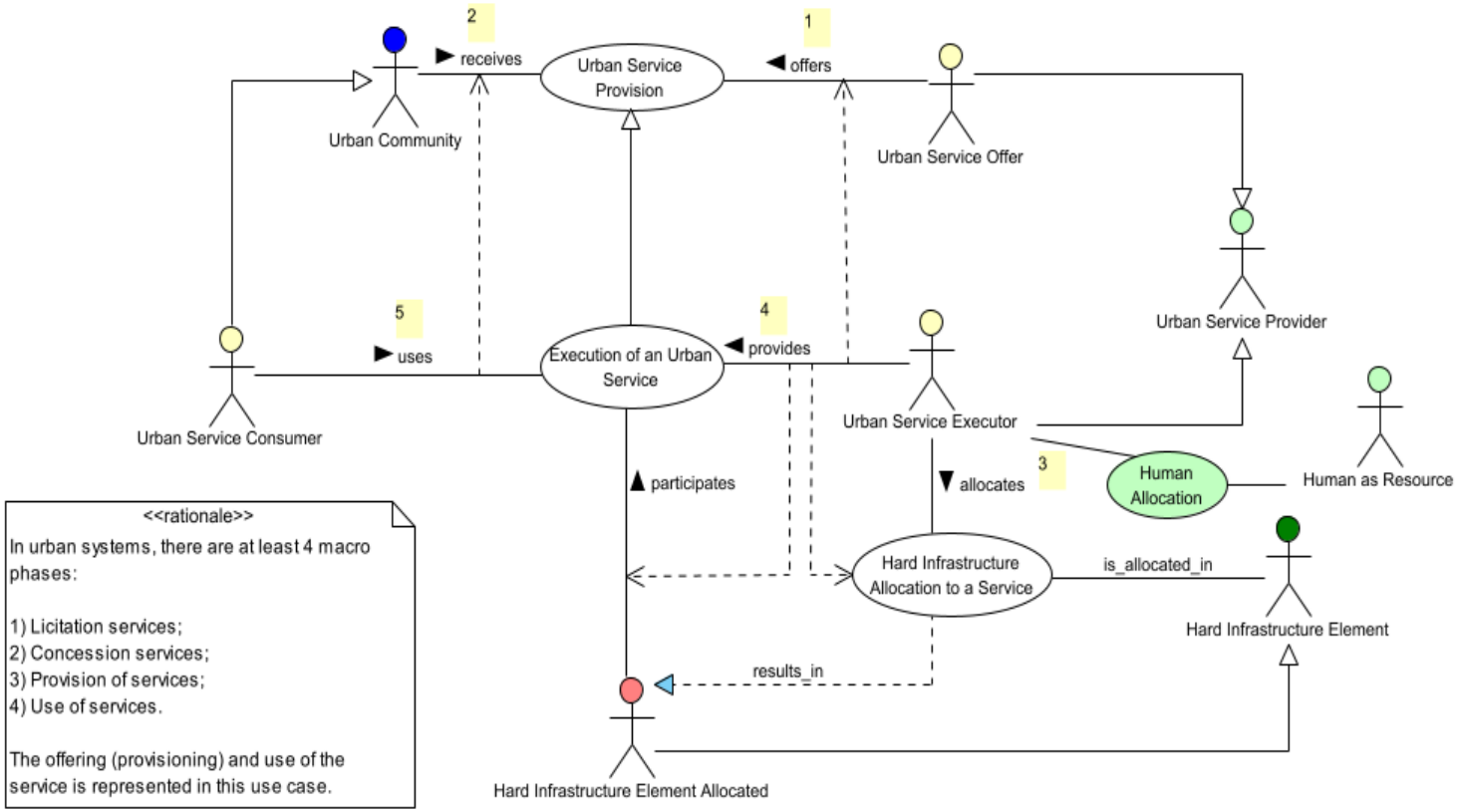
1.4. Ontology of Urban Infrastructure



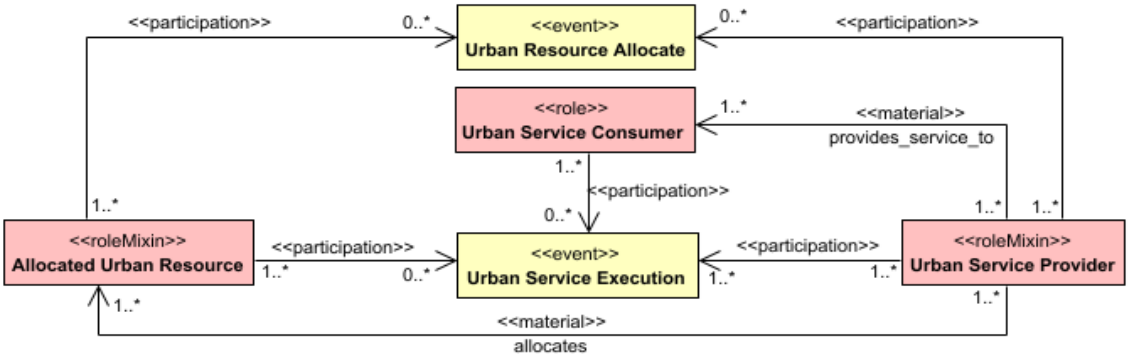
1.5. Ontology of Soft Infrastructure



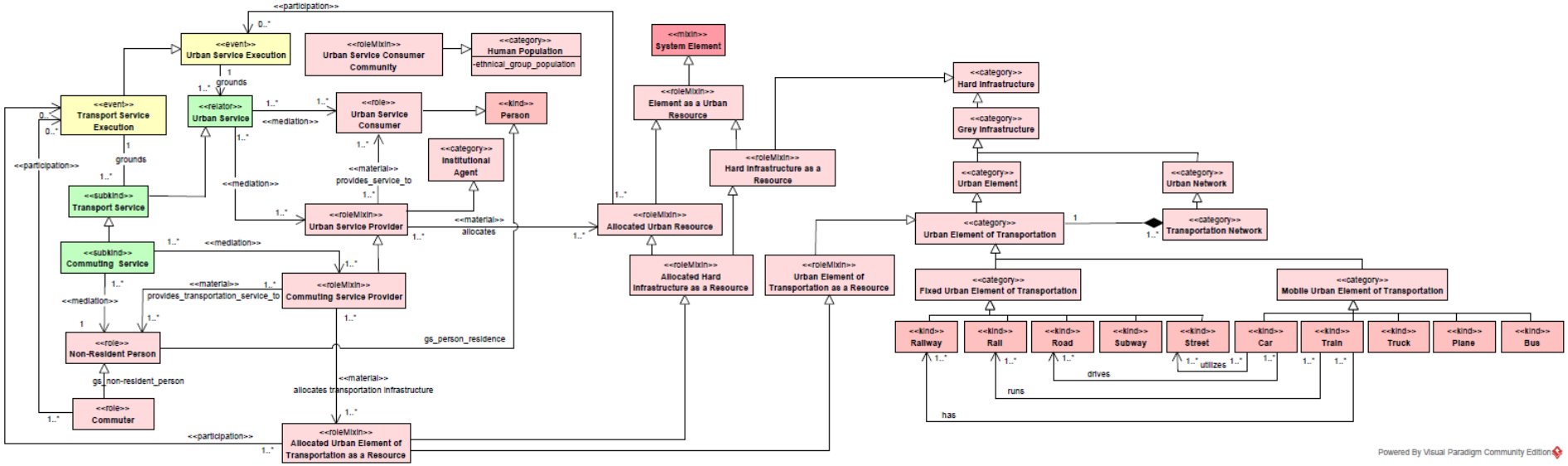
1.6. UC-1-Execution of Urban Services



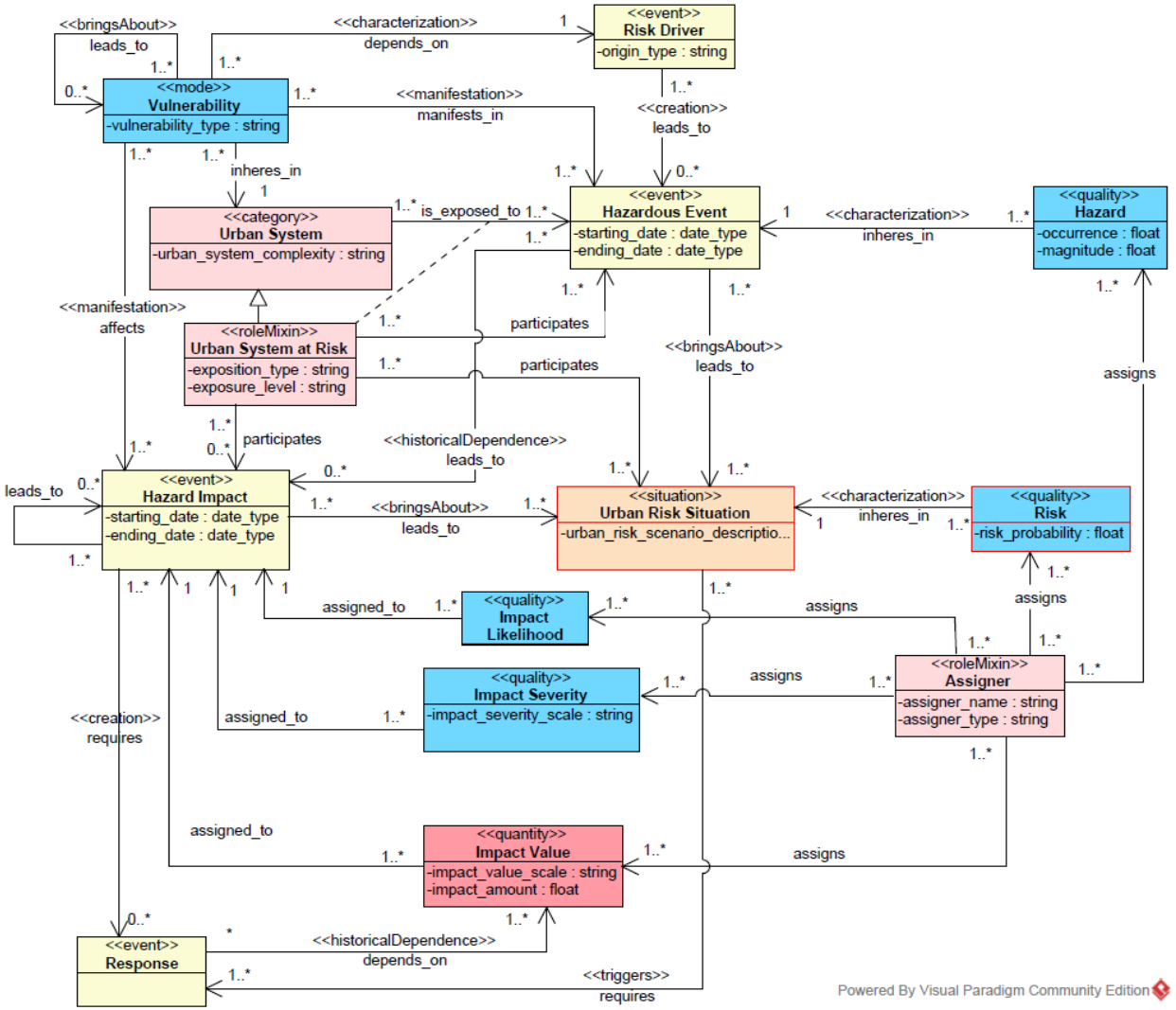
1.7. Urban Service Execution



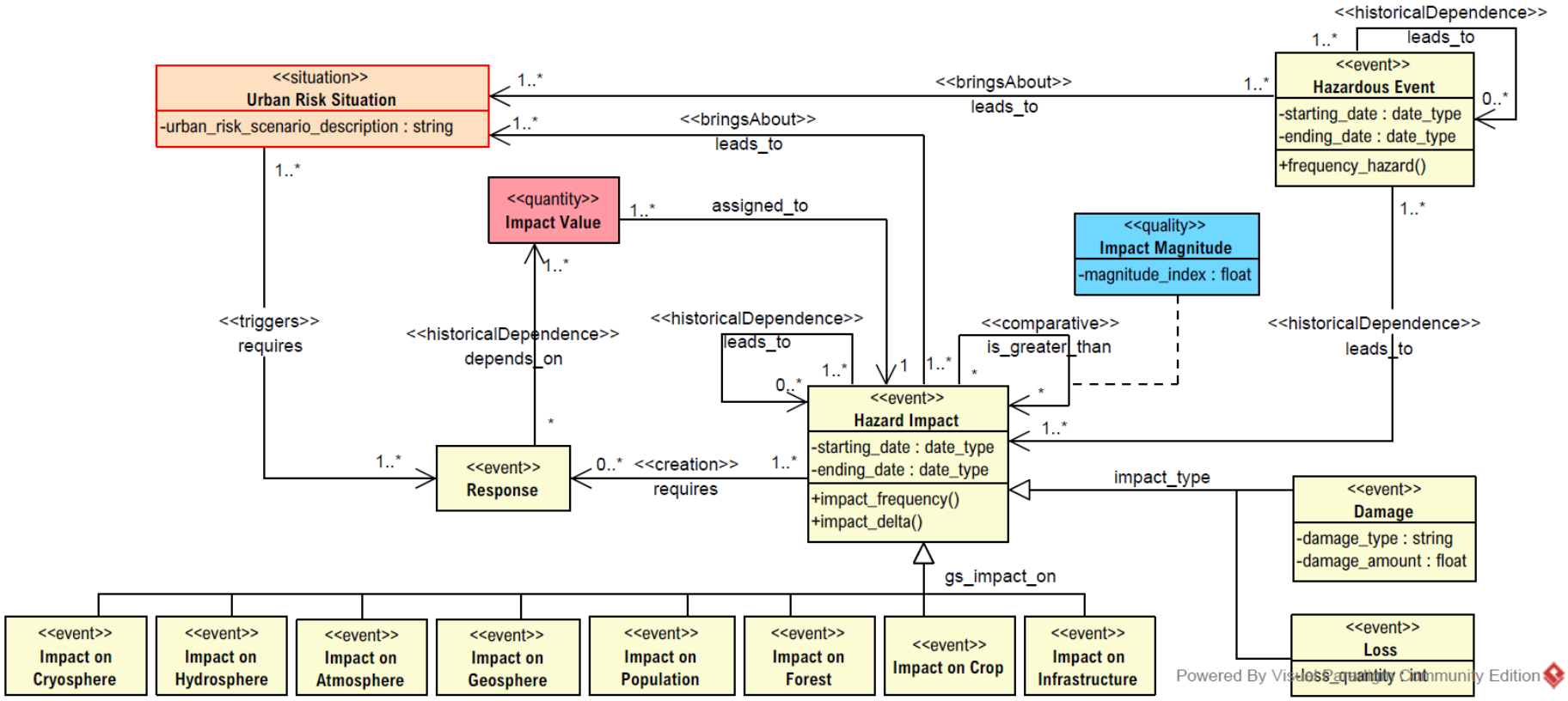
1.8. Ontology Transport Service



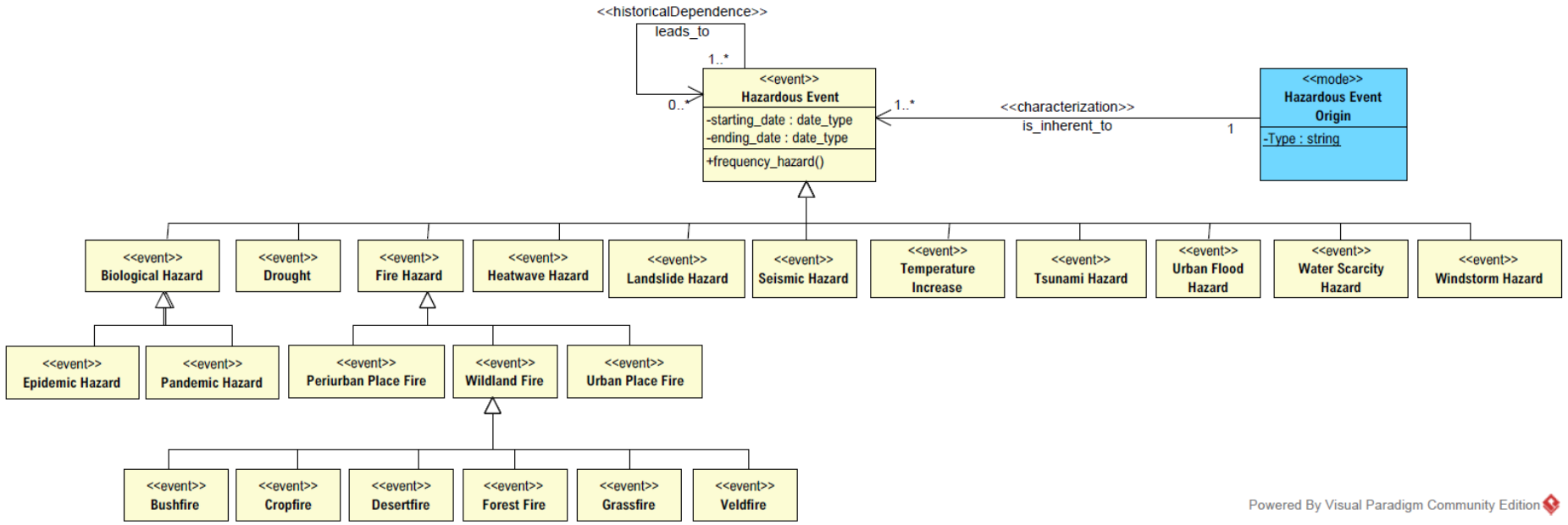
1.9. Risk-driven Ontology of Urban Systems



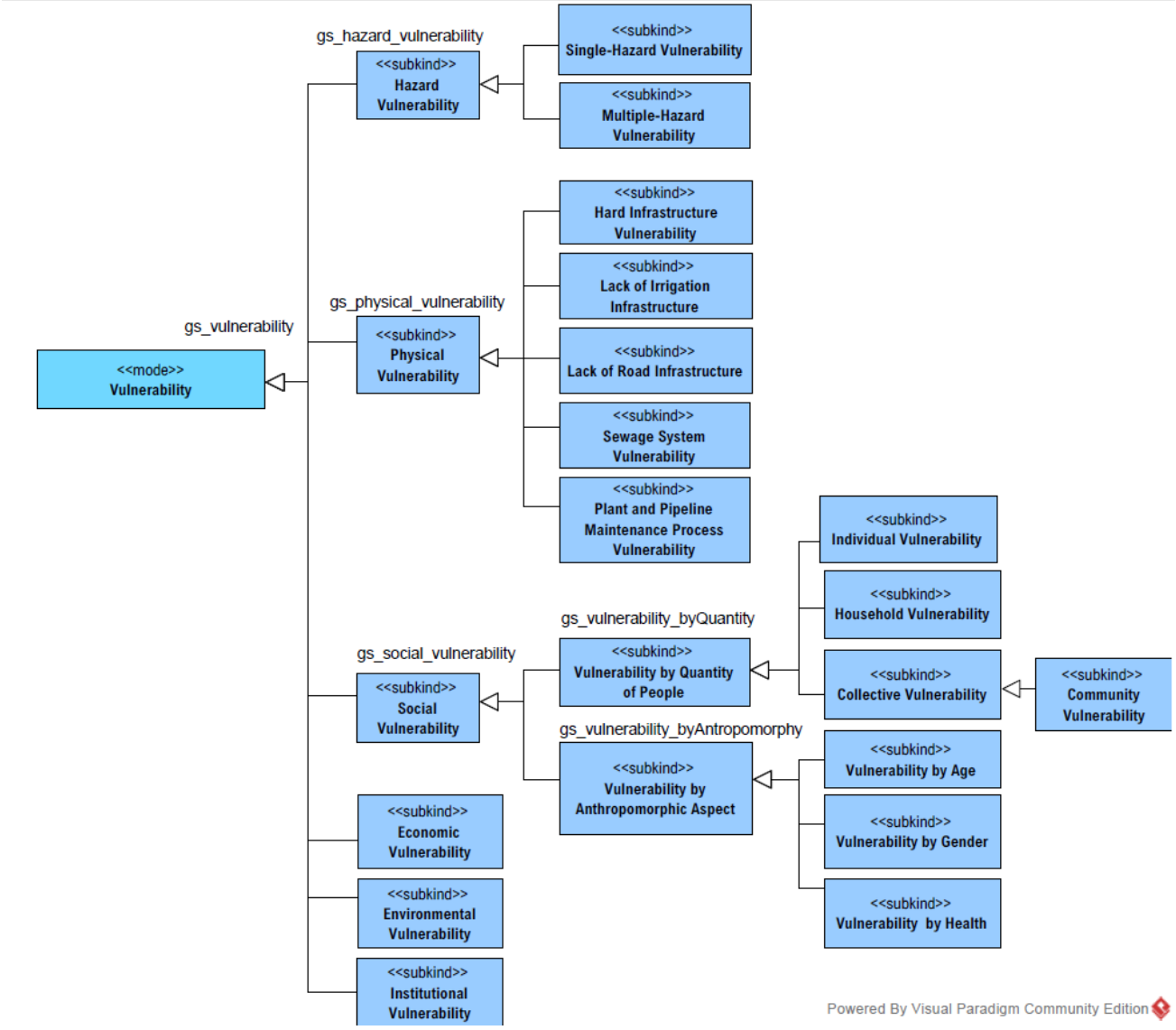
1.10. Ontology of Impact



1.11. Taxonomy of Hazardous Events



1.12. Taxonomy of Vulnerabilities



Vocabulary

Adaptation

Adaptation involves adjusting to the current or future effects and impacts of a hazardous event. For climate change, for example, this could mean building seawalls to protect against rising sea levels or developing drought-resistant crops. For other hazardous events: building of flood-resistant infrastructure in vulnerable areas, changing land use to avoid high-risk zones, or creating emergency shelters.

Adult

It is a *phase* or stage of human development that occurs after the stage of adolescence and puberty. In literature, there are three distinct stages: early (ages 13 to 45), middle (ages 45 to 60), and late (the later years thereafter). There is no consensus about the starting age for these three stages of adulthood.

However, the Italian population statistics by age group are arranged as follows at https://www.statista.com/statistics/789270/population-in-italy-by-age-group/

In RETURN ontologies, we applied the ISTAT groups to define the child phase as a maximum of 12 years; the teenager group as 13 ≤ age ≤ 17; the adult phase as 18 ≤ age ≤ 64, and the elderly phase as minimum 65 years.

Agent

Any agentive Object, whether physical (e.g., a person, a robot, an oak) or social (e.g., a corporation, an institution, a community).

Defined by: https://w3id.org/italia/onto/l0

Airplane

An airplane is a *Mobile Urban Element of Transportation* (i.e., a vehicle) that has wings and one or more engines and is capable of moving through the air. It is designed to transport people and cargo within urban areas as part of an integrated, multimodal transportation system.

AI System

'AI system' means a machine-based system that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment, and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments.

Source: EU Artificial Intelligence Act. https://artificialintelligenceact.eu/article/3/

AI System Population

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Source: https://artificialintelligenceact.eu/article/3/

Allocated Hard Infrastructure as a Resource

It is a hard infrastructure asset (e.g., bridge, road, street) allocated in a service provided in the context of an urban system.

Allocated Urban Element of Transportation as a Resource

It is a transport element allocated to a service provided in the context of an urban system.

Allocated Urban Human Resource

It is a person or a set of people allocated to a service provided in the context of an urban system.

Allocated Urban Natural Resource

It is a natural asset (e.g., river, sea, lake, soil, sky) allocated in a service provided in the context of an urban system.

Allocated Urban Resource

Allocated resources as a Service (RaaS).

Artificial Agent

An Artificial agent is a broad concept that encompasses both technological agents (AI systems, for example, robots, etc.) and agents socially built to act in social reality (e.g., companies, public entities with legal personalities, etc.).

Artificial Population

Artificial Population is all populations that do not encompass natural beings (humans or not) and are designed by human beings. For instance, autonomous systems, institutional agents, intelligent artificial agents, etc.

Assembly Building

These buildings may include any building or part of a building where a group of people gather for recreation, amusement, social, religious, or such types of purposes, such as theaters, assembly halls, exhibition halls, restaurants, museums, club rooms, auditoria, etc.

Assigner

These roles are played by agents (human, group, institutional, or AI) who assign a value or probability to hazardous events, risks, impacts, or elements of the urban system. Using their expertise, quantitative data, and tools such as risk matrices, these professionals determine the likelihood and potential impact of identified risks. This enables informed decision-making for risk mitigation and management within organizations.

Bacterial population

It is the collective of bacteria of a specified gender and species. A bacterial colony may expand geometrically or exponentially.

Biological Agent

A biological agent is a broad category that encompasses all biological agents present or potentially present in an urban system. These agents can have both a component role in the

urban system and a risk driver role, actively participating in risk events initiated by hazardous situations.

Biological Hazard

A biological hazard, also known as a biohazard, is any organic substance or agent that poses a threat to the health of living organisms, primarily humans. Examples of biohazards include viruses, bacteria, fungi, and toxins. Biohazards can cause health problems ranging from minor irritations to severe, even fatal, illnesses. They can be transmitted through blood, bodily fluids, and airborne particles.

Biological Population

A Biological Population is a group of biological organisms living in the same place at the same time.

Blue Infrastructure

Blue Infrastructure integrates blue areas, such as lakes, aquifers, wetlands, floodplains, canals, and coastal areas, into the urban context.

Bridge

It is an urban element carrying a road, path, railway, etc. across a river, road, or other obstacles.

Building Green

Building Green or Green Construction encompasses a set of practices and principles that aim to make the design and use of the built environment as environmentally friendly as possible. These practices minimize the negative impact on the natural environment.

Bus

It is an urban element of transportation, specifically a Mobile Urban Element of Transportation; in general, a large motor vehicle carrying passengers by road, typically serving the public of an urban system or collating urban systems on a fixed route and for a fare.

Bushfire

A fire in scrub or a forest, especially one that spreads rapidly.

Business Building

It is any building type or part of a building that is used for business transactions, keeping records of accounts, town halls, city halls, courthouses, etc.

Car

It is an urban element of transportation, specifically a Mobile Urban Element of Transportation; in general, a four-wheeled road vehicle that is powered by an engine and can carry a small number of people.

Commuter

A commuter is someone who travels a significant distance each day between home and the place of work or study.

Commuter Population

It is a collective of people who regularly travel some distance to work or study.

Commuting Service

Commuting is a periodic, recurring travel between a place of residence and a place of work or study, where the traveler, referred to as a commuter, leaves the boundary of their home community.

Commuting Service Provider

It is an organization (legal person, public or private) that offers transportation to individuals who regularly travel between their homes and workplaces. These services act as intermediaries, connecting commuters with a workforce, a specific worksite, or a broader transportation network. These services may include mass transit, vanpooling, ride-matching programs, or private shuttle services. They often leverage technology to facilitate connections between commuters and employers, or between commuters themselves.

Childhood

It is a human phase between the stages of birth and puberty, or between the developmental period of infancy and puberty. It may also refer to an unborn human being.

For the UNICEF Convention, a child means every human being below the age of eighteen years, unless under the law applicable to the child, the majority is attained earlier.

In the context of urban systems, childhood is a phase that a human being goes through. The following subphases are covered: Early childhood (birth to age 5), middle childhood (ages 6 to 12).

Cropfire

It is a fire that occurs within an agricultural field or related area, such as an orchard or unharvested grain field. It can be the result of crop residue burning, a practice to remove agricultural waste, or it can be a more dangerous, uncontrolled blaze that spreads beyond its intended boundaries.

Damage

Damage is categorized as material damage and immaterial damage. Material damage, also known as property damage, is damage to a person's assets or urban system assets, i.e., the loss of goods or things that have economic value. Material damages include losses actually suffered (emergent damage), as well as amounts that the person has failed to receive (lost profits).

Immaterial damage refers to a decrease in integrity, size, efficiency, or conditions that a community deems detrimental as a result of an adverse event. Depending on the application, damage can be measured in different ways using metrics appropriate for each type of risk analysis. Non-physical damage, in particular, affects the social life of an urban system. This type of damage is understood as a measure of social disruption in terms of the deterioration of social relations and functions that a natural or human-caused event causes a community in the short to medium term (e.g., homelessness) or psychological symptoms in part of the population, such as anxiety and panic disorder, which are correlated with the possibility of the risk events

occurring again.

Deceased Person

It is the phase in which a person is no longer alive. A person cannot be alive and not alive at the same time. Therefore, it is a *disjointed phase* from the Alive phase.

Desert fire

It is a specific type of wildfire that occurs in desert ecosystems, consuming flammable vegetation like grass and shrubs. While historically less common, these fires are becoming more frequent and intense due to climate change and the proliferation of invasive grasses, leading to altered fire regimes and significant impacts on desert ecosystems.

Drought

It is a prolonged period of abnormally low rainfall, leading to a shortage of water.

Educational Building

These buildings include any building used for school, college, or daycare purposes involving assembly for instruction, education, or recreation.

Educational Service

It is a service relation between the consumer of educational services and the agent who provides it. For instance, the public educational service provided by a public entity to people in a city.

Elderly

"Elderly" is a concept that cannot be absolutely defined, as it has different meanings in different societies and historical periods. The United Nations refers to those aged 60 and over as "older people", while ISTAT and the Ministry of Health speak of people aged 65 and over.

In 2018, during the National Congress of the Italian Society of Gerontology and Geriatrics (SIGG - Congresso Nazionale della Società Italiana di Gerontologia e Geriatria), an adjustment to 75 years was proposed. Given the increase in average life expectancy at birth (85 for women, 82 for men in Italy), SIGG argues for a distinction among people over 65 between those in the so-called third age (characterized by good health, social integration, and access to resources) and those in the fourth age (characterized by dependence on others and physical decline).

In this ontology, the elderly are all people over the age of 65.

Electricity Grid

An electricity grid is an interconnected network that supplies electricity from producers to consumers, comprising power generation facilities, high-voltage transmission lines, substations, and lower-voltage distribution systems. Its primary function is to constantly balance the supply and demand for electricity to ensure a stable and reliable energy flow to homes and businesses.

Element as an Urban Resource

It is every element that is used to satisfy human needs in the context of urban systems.

Emergency Service

It is a service relation between the consumer of emergency services and the agent who provides it. For instance, the public emergency service provided by a public entity to people in a city.

Epidemic Hazard

It is an event where an unexpected increase in the number of disease cases occurs in a specific geographical area. Epidemic, pandemic, and biological disasters are caused by hazards of organic origin, including bacteria, viruses, parasites, mosquitoes carrying disease-causing agents, and toxins or bioactive substances that occur naturally or are deliberately or unintentionally released. These hazards can lead to economic and environmental damage and loss of life, affecting people and animals at the population level as well as crops, livestock, and endangered species of flora and fauna.

Family

1. A human community generally formed by people tied together by a relationship of coexistence, of kinship, of affinity, which constitutes the fundamental element of every society, since it is aimed, in its processes and relations, at the perpetuation of the species through reproduction.

2. A family is the basic unit in society, traditionally consisting of two parents rearing their children

("Family." Merriam-Webster.com Dictionary, Merriam-Webster, https://www.merriam-webster.com/dictionary/family.

3. A group of two or more people related by birth, blood, marriage, *de facto* union, or adoption who live together.

4. All the descendants of a common ancestor. (Oxford Language).

Financial Service

It is a service relation between the consumer of the financial system and the agent who provides it. For instance, the financial system (e.g., banks) provided by a public entity to people in a city.

Fire Hazard

It is any condition, event, or situation that increases the likelihood of a fire starting or poses a significant risk in the event of a fire. This includes a wide range of factors such as flammable materials, electrical malfunctions, inadequate fire safety measures, and human negligence.

Firefighting Service

It is a trained, organized unit (like a fire department or brigade) that protects life and property from fire by providing fire prevention, suppression, rescue, and emergency medical services. It involves a range of activities, including detecting, controlling, and extinguishing fires, as well as conducting rescue operations during fires and other emergencies, such as traffic collisions.

Fire Station Building

It is a dedicated structure designed to house firefighting vehicles, equipment, and personnel, serving as a base for emergency response operations. It is a facility equipped with specialized spaces for firefighters to await calls, maintain equipment, and live when on duty, also known as a *firehouse*.

Fire Truck

It is any of various large trucks that carry firemen and equipment to the site of a fire. Synonyms: fire engine. Types: aerial ladder truck, ladder truck.

Fire-Extinguishing Infrastructure

Key Components of Fire-Extinguishing Infrastructure:

Fire Extinguishers:
Portable devices containing extinguishing agents like water, foam, dry powder, or CO2, used for initial fire suppression.

Fire Sprinkler Systems:
Automated systems that release water when heat is detected, typically used in buildings and industrial settings.

Fire Alarm Systems:
Detects smoke or heat, triggering alarms and potentially initiating other fire suppression measures.

Specialized Suppression Systems:
Systems like clean agents or foam-based systems are used in areas where water damage is a concern or for specific fire types.

Emergency Exits and Signage:
Clearly marked exits and signage are crucial for safe evacuation during a fire.

Fire Hydrants:
External water sources connected to a building's water supply, used by firefighters.

Fire Pumps:
Boost the water pressure in sprinkler systems or other fire suppression systems.

Fixed Urban Element of Transportation

The physical support of transport modes, where routes (e.g., rail tracks, canals, or highways) and terminals (e.g., ports or airports).

Forest Fire

A forest fire, also known as a wildfire, is an uncontrolled, destructive combustion of vegetation in a natural setting like a forest, grassland, or brushland. These large, rapidly spreading fires can be ignited by natural causes, such as lightning or human carelessness. They consume natural fuels, with their spread and intensity heavily influenced by environmental factors like wind, topography, and the amount of available vegetation.

Fungus Population

It is a collective of fungi, which is any of about 144.000 known species of organisms of the kingdom Fungi, including yeasts, mildews, molds, and mushrooms.

Green Infrastructure

It is a fusion of natural resources and man-made structures (grey infrastructure) designed to work with nature to provide social, environmental, and economic benefits to urban populations, such as air filtration, temperature regulation, noise reduction, flood control, and recreational areas.

Green Roof

It is a roof partially or completely covered with vegetation planted over a waterproofing system and drainage layers. Also known as a vegetative, living, or eco-roof, it incorporates a combination of a growing medium (soil) and plants on top of a waterproof membrane and other necessary components like a root barrier and drainage layer.

Green Vertical Structure

A green vertical structure, also known as a *green wall* or *living wall*, is a system designed to grow plants on a vertical surface, either an exterior building facade or an interior wall. These structures consist of plants, a substrate or growing medium, a supporting structure, and a system for irrigation. Green vertical structures can provide aesthetic benefits, improve air quality, and offer thermal insulation for buildings.

Grey Building

A Grey Building is one built with a traditional structure with walls and a roof standing more or less permanently in one place. For example, a house or factory. Buildings serve several societal needs – primarily as shelter, living space, privacy & security, to store materials, workspace, etc. In this model, grey buildings are classified by their functionality/occupancy (the use of a structure: for housing, for education, etc.) based on Table 6 of GEM Building Taxonomy, combined with the building taxonomy proposed in NBC 2005.

In addition, Grey Building is classified by its structure based on GEM Building Taxonomy, following the 13 attributes that have been included in the GEM Building Taxonomy Version 2.0: 1. direction, 2. material of the lateral load-resisting system, 3. lateral load-resisting system, 4. height, 5. date of construction or retrofit, 6. Occupancy, 7. building position within a block, 8. shape of the building plan, 9. structural irregularity, 10. exterior walls, 11. Roof, 12. Floor, 13. foundation system.

Source:
https://cloud-storage.globalquakemodel.org/public/wix-new-website/pdf-collections-wix/publications/GEM%20Building%20Taxonomy%20Version%202.0.pdf
https://dailycivil.com/types-of-buildings/

Grey Infrastructure

It is a category of all tangible/physical elements that are (mostly) of atrophic origin (that is, artificial), in other words, engineered assets that provide one or multiple services required by society. This is, in turn, preliminary subdivided into Urban Elements (e.g., buildings, bridges, rails, roads, streets, and public spaces) and Urban Networks (a composition of these urban

elements).

Geosphere

The geosphere is the collection of physical and geological elements that contribute to shaping the Earth's surface. In the urban environment, the geosphere provides the foundation upon which population and infrastructure develop, so that the elements of the geosphere affect them, but the population and infrastructure can also modify the geosphere. For example, urban development and even risk mitigation often involve excavations that interact with and often modify the underlying geology. Therefore, urban development requires an understanding of the local geology, such as soil stability, groundwater conditions, and subsurface characteristics. The geosphere includes the following elements: subsurface, soil, topography, resources, and hydrology.

Geosphere at Risk

The geosphere is at risk when it is vulnerable and exposed to hazardous events, risk situations, and potential adverse impacts.

Grassfire

It is an uncontrolled fire that spreads rapidly through a grassy area or other low-level vegetation, characterized by its speed and intensity, making it a dangerous type of wildland fire.

Grey Infrastructure

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Hard Infrastructure

It is the built environment, the physical connections between places that move people, materials, information, and energy. These "fixed" things include roads, railroads, pipes, buildings, cables, and the networks composed of these constructions. Moreover, encompasses the green infrastructure, which is a category of ecologically oriented designed structures, i.e., a combination of grey and green infrastructures; and the Blue Infrastructure, defined as the blue areas, a mix of natural resources (rivers, sea, beaches, etc.) and human-designed elements.

Hard Infrastructure as a Resource

It is the tangible infrastructure, i.e., the physical infrastructure of roads, bridges, tunnels, railways, ports, etc., that is managed as an asset in the context of an urban system.

Human Population

It is a subtype of the *Biological Population* collective, covering the subtypes of residents, non-resident populations in a given space, and at the same time.

Hard Infrastructure as a Resource

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Hazard

It is a quality carried by a hazardous event. Hazard is a condition or set of circumstances that has the potential to cause or contribute to injury or death" (Sanders and McCormick, 1993, p. 675).

Hazardous Event

[Definition 1] A hazardous event is a circumstance in which people, infrastructure, urban spaces, or the environment are exposed to harm, injury, damage, or adverse impacts arising from a natural or human-induced origin. In the RETURN ontology, a hazard is represented as a hazardous event that possesses the quality of being 'hazardous.' Additionally, every hazardous event has a date on which it occurred within an urban system. This attribute is used to calculate the frequency of event occurrences and their increase. Format: YYYY.MM.DD

Hazard, as an inherent quality, is a type of quality with two attributes: occurrence frequency and magnitude.

Some actions, such as driving a car or traveling by plane, have the potential to cause an adverse event, i.e., an event with a negative impact, such as damage or loss. These activities can trigger a sequence of hazardous events, such as driving on poorly maintained roads. This hazardous situation can activate existing vulnerabilities in the car or driver (e.g., worn tires or a lack of driving experience), leading to exposure to danger and potentially resulting in an adverse event (e.g., a collision or rollover).

Hazardous events lead to urban risks. An urban risk is a situation or scenario where potential damage or loss to the urban system may occur. The impact of a risk can be measured by the value of the elements potentially affected by the hazard impact.

According to the literature, a hazard is "a source of energy or physiological factors and behaviors that, if uncontrolled, will lead to harmful events or occurrences" (Shinar, Gurion, & Flascher, 1991, p. 1095). Grimaldi and Simonds, 1984, p. 236). It is also defined as "a condition or set of circumstances that has the potential to cause or contribute to injury or death" (Sanders & McCormick, 1993, p. 675).

The IPCC defines hazard as "the possibility of a physical event or pattern of events, whether natural or human-caused, that has the capacity to result in loss of life, injury, or other detrimental health effects, as well as damage or loss of property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources."

Hazard Impact

A hazard impact refers to the potential negative effects that a hazardous event can cause. It is the result of a hazard interacting (exposition) with something vulnerable, like people, property, or the environment. The impact can range from minor inconveniences to major catastrophes, depending on the nature of the hazard, its magnitude, and the vulnerability of the affected urban system elements. The taxonomy of hazard impacts in the Return ontology comprehends:

1. Impact on Cryosphere
2. Impact on Hydrosphere
3. Impact on Atmosphere

4. Impact on Geosphere
5. Impact on Population
6. Impact on Forest
7. Impact on Crop
8. Impact on Infrastructure

Hazardous Building

These types of buildings include any building that is used for the storage, handling, manufacturing, or processing of highly combustible explosive materials or products that are liable to burn extremely rapidly, which may produce poisonous fumes.

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Hazardous Event Origin

A *Hazardous Event Origin* is the root cause or the specific situation, process, phenomenon, or human activity that creates, introduces, or worsens a hazard, ultimately leading to potential harm, injury, damage, or adverse impacts on people, property, or the environment. Identifying the hazardous event origin is crucial for understanding how a hazard

manifests and for developing effective control measures and safety strategies to prevent future harm.

Health

It is a *quality* of human beings. Health is defined by the World Health Organization (WHO) as a state of complete physical, mental, and social well-being, not just the absence of disease or infirmity.

Health Building

These buildings include any building or part that is used for medical treatment, etc. Such as Hospitals, nursing homes, orphanages, sanatoria, jails, prisons, mental hospitals, etc.

Health Service

It is a service relation between the consumer of health services and the agent who provides it. For instance, the public health service provided by a public entity to people in a city.

Heatwave Hazard

A heatwave is a period of abnormally hot weather that can last for days or weeks, significantly impacting human health, the environment, and infrastructure. The definition of a heatwave depends on local conditions, as what constitutes "hot" is relative to the normal temperatures for a region. Key characteristics include unusually high maximum and minimum temperatures over several consecutive days, which can lead to risks like increased mortality, drought, wildfires, power shortages, and agricultural losses.

Human-Made System

A system designed by human beings.

Human Population

It is a subtype of the *Biological Population* collective, covering the subtypes of residents, non-resident populations in a given space, and at the same time.

Human Population

It is a subtype of the *Biological Population* collective, covering the subtypes of residents, non-resident populations in a given space, and at the same time.

Impact Likelihood

Impact Likelihood is a combination of two factors in risk assessment: Likelihood, which refers to the probability or chance of an event occurring, and Impact, which refers to the severity or potential harm that the event would cause if it happened. By assessing both the likelihood of a risk and its potential impact, urban systems can better understand, prioritize, and manage risks.

Impact Magnitude

In general, it refers to the size or extent of an impact, or the degree to which something is affected. It can also refer to the severity or intensity of the impact, or the number of people or things affected. In specific contexts, such as earthquake analysis or risk assessments, 'magnitude' may have more precise definitions. Impact magnitude can be measured as high, medium, or low, relating to a percentage index. These indices are established by considering

impact severity (e.g., how large or wide-ranging the impact is, how intense the effect is, and how many individuals, systems, or areas are impacted). Also, the impact measure considers the probability of a hazard occurring within a time interval, such as High, Medium, or Low.

Impact on Atmosphere

An "impact on the atmosphere" is any change to the air that results from a hazardous event. This impact often stems from human activities such as pollution and deforestation, leading to consequences, for instance, altered global temperatures, increased extreme weather events, and air quality degradation.

Impact on Crop

Impact on crop refers to any alteration, whether positive or negative, to the growth, quality, yield, or economic value of cultivated plants, often stemming from hazardous events.

Impact on Cryosphere

Impact on the cryosphere refers to the changes and consequences that occur within Earth's frozen regions, including snow, ice sheets, glaciers, and permafrost, due to factors like rising global temperatures. These impacts manifest as altered physical systems and have widespread ecological, social, and economic repercussions, such as sea level rise, disrupted ecosystems, impacts on water supply, and effects on human well-being and cultural practices in vulnerable areas.

Impact on Forest

An impact on a forest is any significant change to its environment, health, or function, caused by natural events or human activities, such as deforestation, climate change, invasive species, pollution, or infrastructure development.

Impact on Geosphere

Impact on the geosphere refers to changes to the solid Earth, including its rocks, minerals, and landforms, caused by human activities like mining, deforestation, and urban development, or by natural events such as earthquakes and volcanic eruptions.

Impact on Hydrosphere

An impact on the hydrosphere is any alteration to Earth's water systems, including oceans, rivers, lakes, groundwater, and glaciers, caused by natural processes or human activities. These impacts can manifest through water pollution, changes to water flow, disruptions to the water cycle, and alterations to water quality and availability, ultimately affecting ecosystems, biodiversity, and human well-being.

Impact on Infrastructure

"Impact on Urban Infrastructure" refers to the diverse negative effects that hazardous events may have on the hard and soft infrastructure, including transversal changes in resource availability, ecosystem health, land use, public well-being, and economic activity. These impacts are evaluated through direct, indirect, and catalytic effects and involve analyzing how infrastructure influences various aspects of urban life, such as health, job creation, pollution, and overall livability.

Impact on Population

The impact of hazardous events on populations refers to the adverse effects on human systems resulting from risk situations, such as natural disasters or technological failures, encompassing consequences such as death, injuries, illness, displacement, psychological distress, disruption of essential services (e.g., water, electricity, and communication), and damage to infrastructure and the environment. These impacts are intensified by a population's inherent vulnerability to these hazards.

Impact Severity

The impact severity of a hazard impact is a measure of the negative consequences or degree of harm that the event could cause, considering factors such as the number of people affected, amount of capital lost, damage to buildings, infrastructure disruption, or impact on life expectancy. It assesses "how bad things could get" if the risk materializes and is ranked on an ordinal scale (e.g., negligible, minor, moderate, major, severe, catastrophic) to prioritize responses and management efforts.

Impact Value

The impact value of a hazard impact is a measure of its potential consequences on people, property, operations, and the economy, expressed on a scale (e.g., high, medium, low) or numerically, and often incorporates its severity, exposure, and vulnerability to determine an overall risk. It helps prioritize risks by quantifying the potential damage and informing the allocation of resources for mitigation and prevention efforts.

Industrial Building

These types of buildings are mainly used for manufacturing purposes. Here, products or materials of all kinds and properties are fabricated, assembled, or processed, for example, gas plants, refineries, mills, dairies, etc.

Institutional Agent

A juridical person is a legal person who is not a natural person, but an organization recognized by law as a fictitious person, such as a corporation, government agency, non-governmental organization, or international organization (such as the European Union).

Juristic Person. An entity, such as a corporation, that is recognized as having legal personality, i.e., it is capable of enjoying and being subject to legal rights and duties. It is contrasted with a human being, who is referred to as a natural person.

Source:
https://www.oxfordreference.com/display/10.1093/oi/authority.20110803100027393

Institutional Agent Population

It is a collection of fictitious people that exist in the legal system, which are entities such as corporations, firms (business entities), and some government agencies. They are treated in law as if they were people, i.e., they can do the things that a human person can normally do in law - such as make contracts, sue and be sued, own property, and so on. There are no natural people (human beings) in this category.

Landslide Hazard

Landslide hazard is the potential occurrence of damaging slope failures, encompassing any downslope movement of rock, soil, or debris under the influence of gravity. This hazard is determined by factors, such as slope stability, material properties, and triggering events, such as heavy rainfall, earthquakes, or human activities that alter natural slopes. Quantifying landslide hazard involves assessing the magnitude and likelihood of these failures in a specific area over a given time, often represented on hazard maps that show different levels of risk.

Law Enforcement Service

It is a service relation between the consumer of law enforcement services and the agent who provides it. For instance, the legal system (courts, mediation courts, policy, etc.) provided by a public entity to people in a city.

Living Person

It is a phase or stage of being alive, as opposed to being dead, during which your organs work and carry out their functions.

Loss

Loss (resulting from being deprived of something) is a measure (quantified or not) of the damage or destruction caused by a disaster. This includes the loss of human life in hazardous events.

Mercantile Building

These shall include buildings used for soap, markets, stores, wholesale, or retail.

Mitigation

Mitigation is defined as the implementation of actions or activities aimed at limiting the adverse impacts of hazardous events and urban risks that have already occurred.

Mobile Urban Element of Transportation

Mobile elements of transportation or modes represent the conveyances, mostly taking the form of vehicles used to support the mobility of passengers or freight. Some modes are designed to carry only passengers or freight, while others can carry both.

See

https://transportgeography.org/contents/chapter1/what-is-transport-geography/core-components-transportation/

Mold Population

It is a collective of molds, a subtype of fungus that grows indoors.

Natural System

It is a set of elements that arise naturally, without human construction.

Non-Human Agent

It is every non-human being with agentive capacity to influence an urban system. This category is classified as Pet, Plant, Wild Animal, Fungus, MGE, Virus, Mold, and Bacteria.

1) A pet is any domesticated or tamed animal that is kept as a companion and cared for affectionately.

2) A wild animal in an urban system is any non-domesticated animal that has adapted its lifestyle to living in cities or in suburban neighborhoods.

3) A plant is a living and natural organism of the kind exemplified by trees, shrubs, herbs, grasses, ferns, and mosses, typically growing in a permanent site, absorbing water and inorganic substances through its roots, and synthesizing nutrients in its leaves by photosynthesis using the green pigment chlorophyll.

4) Mobile genetic element (MGE), also known as a transposable element (TE), is a type of moving genetic material that can either move around within a genome or jump across different genomes.

5) Viruses may have arisen from mobile genetic elements that gained the ability to move between cells. They may be descendants of previously free-living organisms that adapted a parasitic replication strategy. Viruses can leave the cell and move to other cells and organisms; mobile genetic elements generally just move around the genome within a cell.

6) Fungus is any member of a kingdom of organisms called Fungi that lack chlorophyll, leaves, true stems, and roots, reproduce by spores, and live as saprotrophs or parasites. The group includes molds, mildews, rusts, yeasts, and mushrooms.

7) A mold is a microscopic fungus that grows and lives on plant or animal matter or on non-organic objects. Most molds are made up of filaments and reproduce through the production of spores. Spores spread by air, water, or insects. There are many thousands of species of fungi. Mold is the colloquial term used for indoor fungi. Fungal spores occur naturally outdoors and can easily be transferred inside; they can sit on surfaces. Mold organisms are extremely resilient and have evolved to adapt to survival in sub-optimal conditions. Types of indoor mold differ according to geographical location.

Non-Human Population

Non-Human Being Population is all populations that do not encompass human beings, but it is natural. It is subcategorized as: 2.1) Pet Population, 2.2) Wild Animal Population, 2.3) Plant Population, 2.4) Mobile Genetic Element Population (MGE), 2.5) Fungus Population, 2.6) Protist Population, and 2.7) Bacteria Population. There is a subtype of MGE, which is the Virus Population. Also, there is a subtype of Protist Population, which is the Mold Population.

Non-Resident Person

It is a role played by people who are not registered in the Register of Residents in a given municipality at a given time. It can be a tourist or a person who temporarily lives in a certain place without having the rights and duties of residents.

Non-Resident Population

It is the collective of individuals who are **not** registered with the Registry of the Resident Population in a given municipality at a given time.

It can be a tourist or a person temporarily living in a particular place without the duties and rights of residents.

Pandemic Hazard

Pandemic hazards are the potential for large-scale outbreaks of infectious disease that can greatly increase morbidity and mortality over a wide geographic area.

Park

It is a large public garden or area of land used for recreation.

People Community

A group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings. Community can be defined by a sense of identification with and emotional connection to others through common symbol systems, values, and norms; shared interests; and commitments to meeting mutual needs.

Source:
https://www.evms.edu/education/resources/community-engaged_learning/glossary_of_terms/

Perforate Pipey

A perforated pipe is a pipe with strategically placed holes or slots along its length, designed to collect and redirect water or other liquids from surrounding soil or surfaces into the pipe. Unlike solid pipes, which are for water transport, perforated pipes serve as active collection systems, preventing water accumulation and managing drainage in applications such as foundational, agricultural, and landscape drainage.

Peri-urban Place Fire

A peri-urban place fire is a wildfire occurring in the peri-urban zone, which is a mixed, transitional area at the interface between rural and urban environments. These fires pose a significant threat due to their proximity to homes and infrastructure, high fuel loads from mixed vegetation, multiple ignition sources, and the increasing expansion of urban areas into these vulnerable landscapes.

Peri-urban Zone

A peri-urban zone is the transitional, mixed-use area between a city and the surrounding rural landscape, characterized by both urban and rural land uses, social characteristics, and economic activities. These zones often see significant social and demographic changes, as people move to areas on the urban fringe, and can be defined by their diverse land use, economic ties to the city, and proximity to urban centers.

Permeable Pavement

Permeable pavement is a type of pavement, such as porous asphalt or concrete, designed to allow rainwater and snowmelt to pass through its surface and infiltrate into the ground below, rather than run off into storm drains. This system typically includes a porous surface layer, a bedding course, and an aggregate base that stores and filters the water, eventually recharging groundwater or being directed to a sub-drain system.

Person

It is every human being with the capacity to influence and act on an urban system. A person is categorized by life phases, phases of existence, and whether they are a resident or not.

OCL forms

```
a Person is in Elderly phase if isElderly = true
context Person::isElderly: Boolean
derive: self.age >= 65
The set of Elderly people is given by
context Human Population::elderlyHumanPopulation: Set(Person)
derive: Person.allInstances()->select(p: Person | p.isElderly)
```

Pet Population

It is a collection of any domesticated or tamed animal that is kept as a companion and cared for affectionately.

Plant Population

It is the collection of plants per unit area of land. Plant populations are characterized by their size (or density) and their structure (the number of individuals of different ages and sizes).

Protection Forest

A protection forest is a forest whose main purpose is to shield people, property, and infrastructure from natural hazards like landslides, rockfalls, avalanches, and erosion, rather than for timber production. These forests are typically located between a source of natural hazard and an endangered area, possessing a strong internal structure to provide stability and a powerful protective effect.

Population

It is a collection of *Agents (*biological or artificial) of the same taxonomic class, counted or sampled at a given location or area, over a given time interval. The population density is a measurement of how crowded a place is, calculated by dividing the number of people in an area by its total land area.

Population at Risk

It is a collection of Agents (biological or artificial) of the same taxonomic class, counted or sampled at a given location or area, over a given time interval, that are at risk.

Rail

It is a *Fixed Urban Element of Transportation* that consists of a bar or series of bars fixed on upright supports or attached to a wall or ceiling, serving as part of a barrier or used to hang things on. A rail can be allocated to a transportation train service.

Railway

It is a track made of steel rails along which trains run.

Rain Barrel

A rain barrel is a container that collects rainwater from a building's roof, typically connected to a downspout, to store and reuse the water for non-potable purposes, such as watering gardens and lawns, thus conserving water and reducing stormwater runoff.

Recreational Service

It is a service relation between the consumer of recreational services and the agent who provides it.

Residential Building

A building should be considered a residential building when more than half of the floor area is employed for dwelling purposes. Other buildings should be considered non-residential.

A residential building is designed and accordingly built for inhabitants to measure in and call home. Inhabitants can be either a family, a single person, a couple, roommates, or a group. A residential building has basically:

- A sleeping room(bedroom)/space,
- A living room/space,
- Conveniences (as in toilet and bath),
- Cooking room/area (kitchen).

All of those functions can either be in shared rooms or spaces or have exclusive rooms per function. These types of buildings include one or two private dwellings, apartment houses (flats), bungalows, duplexes, storehouses, terrace buildings, apartment buildings, condominium buildings, hotels, dormitories, semi-detached buildings, etc.

Source: https://dailycivil.com/types-of-buildings/

Resident Person

It is a person who is enlisted with the Resident Population Registry in a particular local authority area at a given time. The classification of a Resident Person as a <<role>> derives from residency being an incidental characteristic of a human being.

Resident Population

It refers to the collection of people enlisted with the Resident Population Registry in a particular local authority area at a given time. The classification of a Resident Person as a <<role>> derives from residency being an incidental characteristic of a human being.

Registered Family

It is a group of people tied together by relationships of marriage, kinship, affinity, adoption, protection, or affection.

Rule: The members must live and be habitually resident in the same municipality (Article 4 of Italian Presidential Decree 30/05/1989, n. 223).

Response

A response to a hazardous event involves the immediate and systematic **actions** taken during and after the hazardous event to minimize its negative effects, save lives, ensure safety, and address basic human needs. It primarily focuses on immediate and short-term needs, employing specialized agencies and community participation to address effects on people, property, urban infrastructure, and the environment until full recovery efforts can begin.

Risk

Risk is defined as the likelihood or probability of a hazard occurring or its impacts. In this sense, it is a relation between the probability of a hazard occurring and its magnitude, the severity of its potential impact, the vulnerability of the object to the hazard, the level of its exposure to the hazard and its impacts, the complexity of the object (considering its size, economic and social importance, population and infrastructure density), and its ability to respond to the hazards and their impacts.

$$\begin{aligned} &Risk\ Probability \\ &\quad = Hazard.occurrence \times Hazard.magnitude \times Impact.severity \\ &\quad \times Vulnerability\ (Urban\ System, Hazard) \\ &\quad \times ExposureLevel(Urban\ System, Hazard) \times Complexity(Urban\ System) \\ &\quad \times RiskResponse.capacity(Urban\ System, Hazard) \\ &\quad \times RiskResponse.capacity(Urban\ System, Impact) \end{aligned}$$

Risk Driver

A risk driver as an event refers to a specific, significant incident or occurrence that directly leads to a hazardous event, creating a risk situation and influencing its likelihood or impact. Risk drivers are events that are uncertain but will result in negative consequences (losses or damages) or positive opportunities (not represented in the Return ontology), and they can stem from underlying factors or conditions such as climate change, natural disaster, or human actions. The event itself is the trigger that creates or increases a risk. For example, a pandemic is a risk driver event that can drive various risks for urban systems.

Other definitions used by stakeholders that converge on the Return definition of risk driver.

1. [Civil Defense] Risk drivers are processes or conditions that influence the level of disaster risk by increasing levels of exposure and vulnerability or reducing capacity. They include climate change, urbanization, environmental degradation, the changing security paradigm, and technological developments.
Source: https://civil-protection-knowledge-network.europa.eu/eu-overview-risks/risk-drivers

2. [IPCC] A climatic impact-driver is a physical climate condition that directly affects society or ecosystems. Climatic impact drivers may represent a long-term average condition (such as the average winter temperatures that affect indoor heating requirements), a common event (such as a frost that kills off warm-season plants), or an extreme event (such as a coastal flood that destroys homes).
Source:
https://www.ipcc.ch/report/ar6/wg1/downloads/faqs/IPCC_AR6_WGI_FAQ_Chapter_12.pdf

3. [Millennium Assessment] Any natural or human-induced factor that directly or indirectly causes a change in a system
Source: https://millenniumassessment.org/documents/document.272.aspx.pdf

Road

It is a wide way leading from one place to another, especially one with a specially prepared surface which vehicles can use.

Seismic Hazard

Seismic hazard is the potential for ground motion from future earthquakes and any secondary effects like landslides or tsunamis in a specific geographic area, based on the probability of earthquakes occurring and their expected intensity. It describes the physical phenomena and the expected severity of the shaking at a particular location and is a

foundational concept for assessing risk and developing mitigation measures to protect human society and infrastructure.

Soft Infrastructure

Soft infrastructure refers to the intangible things needed to maintain or improve the utilities and services, such as financial, health, cultural, and social, in an urban system. The **population** uses the infrastructure of an urban system through services offered by public or private agents.

Storage Building

These buildings are generally used for the storage or sheltering of goods, wares, or merchandise, like warehouses, cold storages, garages, stables, transit sheds, etc.

Street

An urban way or thoroughfare; a road or public way in a city, town, or village, generally paved, and lined or intended to be lined by houses on each side.

Subway

It is a railway system in which electric trains travel through tunnels below ground.

System

A set of things working together as parts of a mechanism or an interconnecting network; a complex whole.

In the Return Project, in the ontological model, a system is categorized as 1) made by humans (artificial systems) and 2) a natural system, which is a set of elements that arise naturally, without human construction. Both types of systems are coupled; that is, human systems interact with natural systems and vice versa on multiple levels and aspects.

There are several kinds of human-made systems (e.g., urban systems, economic systems, judicial systems) and natural systems. An urban system is a human-made system placed in a specific space and exists at a specific time. It is composed of essential parts, which are the Resource and Population. A *Resource* is an essential part of one or more urban systems; for instance, a river can be a resource for different countries and different cities. The resource is subcategorized as Urban Infrastructure and Agent as a Resource.

System Element

According to standard ISO/IEC 15288:2015, a system element is a discrete part of a system. A system element can be hardware, software, data, humans, processes, procedures (e.g., operator instructions), facilities, materials, and naturally occurring entities (e.g., water, organisms, minerals), or any combination.

Teenager

It is the last phase of childhood that a human being goes through $13 \leq \text{age} \leq 17$ years.

Temperature Increase

A Temperature Increase hazard refers to the danger or negative impacts caused by a rise in temperature, which can manifest as extreme heat events like heatwaves that threaten human health, increase risks of wildfires, and strain infrastructure, or as a gradual increase in global

temperatures leading to more severe storms, droughts, and disruptions to ecosystems and economies.

Tourism Building

A tourism building is a physical structure constructed and maintained to support the tourism industry by catering to the needs of tourists, such as hotels, resorts, theme parks, and other amenities that provide lodging, entertainment, and services within a destination. These buildings are essential components of a destination's infrastructure, designed to attract visitors, enhance their experience, and generate economic benefits for the local area by providing a place for tourists to stay and engage in leisure activities.

Tourist

It is a role played by a person who is traveling or visiting a place for pleasure or interest.

Tourist Population

It is a collective of people who are traveling or visiting a place for pleasure or interest.

Train

It is a series of connected railway carriages or wagons moved by a locomotive or by integral motors.

Transfer

Transfer is shifting the financial burden of potential losses and damage to a third party. For example, an insurance policy to cover the costs of damage from a hurricane or other natural disaster, or catastrophe bonds, i.e., financial instruments where investors receive payments in exchange for providing insurance coverage for catastrophic events.

Transport Service

It is a service relation between the consumer of transport services and the agent who provides it. For instance, the public transport service provided by a public entity to people in a city.

Transport Service Execution

Transport Service Execution is the process of carrying out a defined transportation order or request, involving the actual movement of people or goods from one location to another, along with all the supporting logistics and auxiliary services like scheduling, vehicle assignment, cargo handling, and confirmation. It's a complex, multi-party effort in a supply chain that includes selecting carriers, managing routes, and ensuring the safe and timely delivery of cargo according to agreed-upon terms and conditions.

Transportation Network

Transportation Network is a conglomerate of heterogeneous urban elements, such as roads, streets, paths, railways, bridges, etc., used for the mobility or transportation of goods and people.

Truck

It is a large, heavy road vehicle used for carrying goods, materials, or troops; a lorry.

Tsunami Hazard

Tsunami hazard is the danger and potential for destruction that a tsunami poses to a region, defined by the probability of a destructive tsunami wave occurring and the vulnerability of the area to its impacts. It is assessed by analyzing the potential for large waves, understanding the likelihood of their occurrence from events, such as underwater earthquakes, and estimating the physical damage and loss of life they can cause in low-lying coastal areas.

Urban Agricultural Land

It refers to the land within the urban development boundary designated for small-scale farming activities and growing crops for personal use or sale in surrounding markets. This encompasses vertical production, warehouse farms, community gardens, rooftop farms, hydroponics, aeroponics, and aquaponic facilities, as well as other innovative techniques.

Urban Garden

An urban garden is a green space used for growing plants, fruits, and vegetables in a city or town, utilizing various settings like rooftops, balconies, community plots, or vacant lots.

Urban Green Area

Urban green space refers to open areas reserved for parks and natural environments - encompassing plant life. The landscape of urban open spaces typically ranges from playing fields and highly maintained environments to more natural landscapes. It links ecological processes and functions and encompasses protected forests, roadside trees, park trees, garden trees, and nature conservation areas.

In the context of urban land-use growth and its impact on the environment, green spaces offer ecosystem services to promote human health. Green spaces such as parks, public gardens, and roadside trees are vital components of urban planning.

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Urban Infrastructure

Urban infrastructure is a mix of structures built horizontally or vertically by humans, which provide a variety of utilities and services such as housing, transportation, and leisure. The design of these structures serves to ensure accessibility and convenience to meet the needs of the urban dwellers.

Urban Infrastructure at Risk

Urban infrastructure is a mix of structures built horizontally or vertically by humans at risk.

Urban Human Resource

Urban human resources are the set of people who make up the workforce of an urban system.

Urban Natural Resource

Urban natural resources are a set of any biological, mineral, or aesthetic asset afforded by nature without human intervention that can be used for some form of benefit, whether material (economic) or immaterial. What is considered a “resource” (or, for that matter,

"natural") has varied over time and from one society to another. Examples of assets that can be considered natural resources include forests, surface water, and groundwater, and the fertile lands or the soil and minerals within them (rather than the crops that grow on them), as well as energy resources (such as petroleum, natural gas, and heated water [that is, geothermal energy]) contained within layers of rock.

Source: https://www.britannica.com/science/natural-resource

Urban Network

It is an ordered composition of heterogeneous urban structures, arranged according to their application in an urban system, e.g., a transportation network.

Urban Resource Allocate

It is an event that allocates resources (human, natural, or hard infrastructure resources) to provide a service in the context of an urban system. In this event, an agent participates by playing the role of Urban Service Provider, as well as allocating resources. This event creates the historical foundation of a relationship called Urban Resource Allocation between the allocated urban resource and the Urban Service Provider.

Urban Resource Allocation

It is the (reified) relationship between the Allocated Urban Resource and Urban Service Provider grounded by the Urban Resource Allocate event.

Urban Risk Situation

A risk situation is caused by a convergence of hazardous events and the exposure of urban systems (or parts of them) to these events, as well as the vulnerabilities of these systems. 'Threat' is also a synonym for 'negative risk'. In the Return ontology, stakeholders are only interested in the negative impacts of risks.

Each Urban Risk Situation is assigned a risk probability, which determines its classification. The calculus of risk is a comprehensive framework that considers the following elements:

$$Risk\_Probability = Hazard.occurrence \times Hazard.magnitude \times Impact.severity \times Vulnerability(Urban\ System.Hazardous\_Event) \times ExposureLevel(Urban\ System, Hazardous\_Event) \times Complexity(Urban\ System) \times RiskResponse.capacity(UrbanSystem, Hazardous\_Event) \times RiskResponse.capacity(UrbanSystem, Hazard\_Impact)$$

Urban Element

It is a category of constructed items encompassing buildings, bridges, roads, footpaths, streets, rails, and other related infrastructures.

Urban Element of Transportation

Consists of urban elements that are used for the transportation of people and goods, including fixed infrastructure (e.g., bridges, roads, highways) and mobile elements of transportation (e.g., cars, trains, planes, etc.).

Urban Element of Transportation as a Resource

In the context of a service offering, the *Urban Element of Transportation as a Resource* refers to the physical infrastructure, i.e., hard infrastructure, within an urban system that enables the movement of people and goods, serving as an available asset to be utilized to deliver a transportation-related service. This encompasses everything from roads, public transport networks, and vehicles, which will be connected with intelligent systems, real-time data, and specialized personnel (allocated as a resource as well) that manage and optimize these resources to provide mobility solutions.

Urban Flood Hazard

An Urban Flood Hazard is the potential for inundation of densely populated urban systems due to various causes, such as excessive rainfall, overwhelmed urban drainage and stormwater systems, river surges, or other hydrological factors.

Urban Network

It is an ordered composition of heterogeneous urban structures, arranged according to their application in an urban system, e.g., a transportation network.

Urban Place Fire

An Urban Place Fire, or simply an Urban Fire, is any uncontrolled fire that occurs in a highly populated, developed area, such as a city or town, involving structures like residential, commercial, or industrial buildings.

Urban Service

It represents all services provided by a municipality, either directly or by contract, to any of its current residents. For example: sanitation, water, fire protection, parks, open space, recreation, and streets, roads, and mass transit. The Return Project views urban services as a relationship between the service consumer and the service provider in urban systems. This relation is usually formalized in a document (Normative Description) called the Service Contract

Urban Service Consumer

In general, a service consumer can be anything from a system to an application, to an artificial agent, to a person. A service consumer is a user of products and services provided by a service provider, which can be either a company or a person. In the domain represented by urban systems, we restrict the definition of service consumer to people and service provider to companies (Juridical Person). Between a service consumer and a service provider, a contract is signed and establishes a binding service contract based on legal rules for the consumption of services.

Urban Service Consumer Community

It is a group of people connected by their shared interest in a service provided in an urban system.

Urban Service Execution

It is an event that executes a service in the context of the urban system (health, transport, education). In this event participates one or more allocated urban resources and an agent (Juridical Person), playing the role of Urban Service Provider. This event creates the historical foundation of a relationship called Urban Service between the allocated urban resource and the

Urban Service Provider.

Urban Service Offer

It is an event that offers a service in the context of an urban system, such as health, transport, and education (dynamic aspect). In this event participates one Urban Service Consumer Community and one or more agents (Juridical Person), playing the role of Urban Service Offeror. This event creates the historical foundation of a relationship called Urban Service Offering between Urban Service Consumer Community and the Urban Service Offeror.

Urban Service Offering

It represents the relation between the Urban Service Consumer Community and Urban Service Offeror. This relation is usually presented through oral or written publicity that binds the Service Offeror.

Urban Service Offeror

It is a role played by a Juridical Person in a relationship with the Urban Service Consumer Community. In this relation, Juridical Person offers a set of urban services for a group of people in an urban system.

Urban Service Provider

It is a role play by a Juridical Person who is active in relationships with Urban Resources or Urban Service Consumer/Community. In this role, a Service Provider has the scope to offer, provide, and run urban services such as health, transportation, etc.

Urban System

An Urban System is a human-made system placed in a specific space and time. It is composed of essential parts, which are *Infrastructure, Geosphere*, and *Population*. **Population** is a collective of agents who live or use the urban space and the tangible **Infrastructure** (hard infrastructure) through services (soft infrastructure). In turn, the **Urban Space (Geosphere)** is the territory, the place where the population (resident or non-resident) lives or uses the soil, as well as where the infrastructure is located.

Urban System at Risk

An urban system is a set of interconnected parts (population, urban space, and infrastructure). An urban system at risk has one or more parts vulnerable or exposed to certain risk drivers in certain situations. In hazardous events, urban systems at risk participate as objects: living objects, such as people, animals, and non-living objects, urban infrastructure, and urban space.

In the Return ontology, an urban system at risk is an urban system exposed to one or more hazardous events that lead to one or more urban risk situations. Urban systems at risk participate in both hazardous events and urban risk situations, which create a cascading effect.

Veldfire

A veldfire is an unplanned and uncontrolled fire in an area of rural, uncultivated land, such as a veld, forest, or mountain, outside of a city or town's developed areas. The term "veldfire" is specifically used in South Africa, where "veld" refers to the open countryside beyond urban limits.

Virus Population

It is a collective of a kind of virus. It is possible that viruses originated from mobile genetic elements that acquired intercellular migration capabilities. They could be descendants of formerly free-living organisms that adopted a parasite replication strategy.

Vulnerability

Vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Vulnerability expresses the relationship between the intensity of a hazardous event, the features of the elements at risk (assets, community, system, environment) that affect their behavior, and the measure of the impact resulting from the hazardous event.

In literature, vulnerability is defined in different ways depending on the types of risk being assessed. In seismic risks, vulnerability is the probability that an element at risk, belonging to a specific behavioral class (vulnerability class), experiences or exceeds a damage threshold (according to a predetermined scale of damage) upon the occurrence of an event of an assigned intensity. In flood risks, vulnerability expresses the expected damage to the elements at risk, the extent of damage ranging from 0 (no damage) to 1 (destruction).

Water Network

It is a system of engineered hydrologic and hydraulic components that provides a water supply for an urban system.

Water Service

It is a service relation between the consumer of water services and the agent who provides it. For instance, the public water service is provided by a public entity to people in a city.

Wild Animal Population

Urban wildlife animal populations consist of species that utilize human-dominated ecosystems.

Zoological Park

A zoological park, or zoo, is a facility where animals are housed in enclosures for public exhibitions, conservation, education, and often breeding programs for endangered species.

Water Scarcity Hazard

A Water Scarcity Hazard refers to the risk or event of insufficient available clean water to meet human and environmental demands, resulting from the disruption of the balance between water supply and demand.

Wildland Fire

A wildland fire or wildfire is a fire that originates from an unplanned ignition source, such as lightning, volcanoes, or human activity. It burns in areas known as wildlands, which are generally underdeveloped and uninhabited. Wildlands include forests, grasslands, brushlands, and other ecosystems, as well as croplands.

Windstorm Hazard

A Windstorm Hazard is the potential for harm or loss to life and property caused by powerful winds during a windstorm. It is a condition with dangerously high wind speeds (often exceeding 50-60 mph) or strong gusts that can damage buildings, trees, and infrastructure, and create hazardous conditions like flying debris or reduced visibility.