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multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate

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Risk-Oriented Taxonomy and Ontology of Urban Subsystems and Functional Models

DV 5.2.1

UPDATE VERSION CONTAINING THE SECOND SPRINT OF ONTOLOGICAL MODELS

1. 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)**

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Contributing beneficiary/ies	**UNIBO, UNINA, UNIFI, UNIGE**

* PU = Public

PP = Restricted to other program participants

RE = Restricted to a group specified

CO = Confidential, only for members specified

2. Technical References

Version	Date	Lead contributor	Description
1.0	**30/11/2023**	**EURAC**	**First release**
1.0.1	**17/07/2024**	**EURAC**	**Second release of the ontological models Controlled vocabulary – Skosmos platform**

Summary

Introduction

Second Ontology Engineering Cycle of Ontological Models

This report describes the changes and additions conducted in the second ontology engineering cycle. In this cycle, more emphasis was placed on the representation of soft infrastructure and 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. As a result, the ontology engineering was changed to contemplate the vocabulary updating as shown in **Figure 1**.

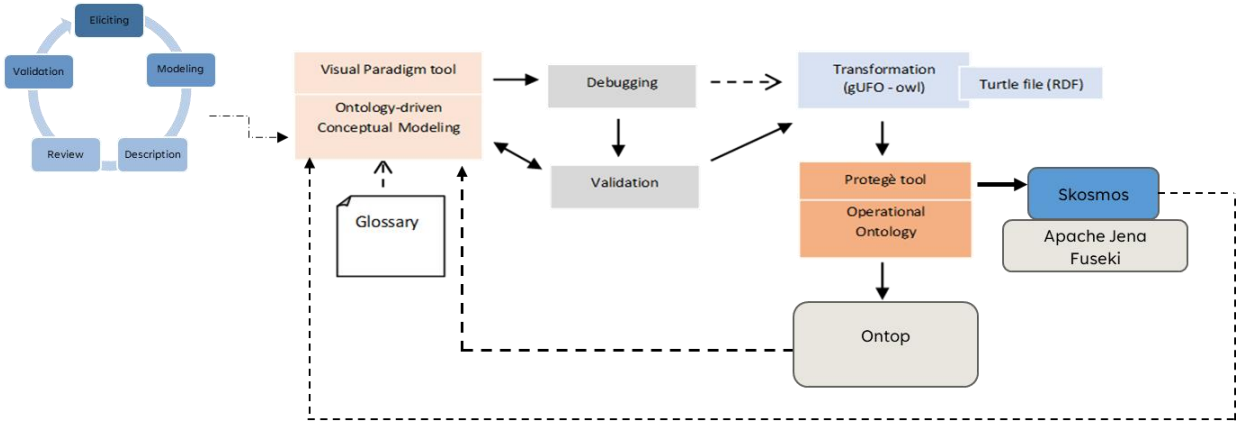

Figure 1 – Method applied for ontology engineering

The first results obtained in the first cycles were described in the paper *Towards a Risk-Driven Ontology of Urban Systems* to be submitted in the *Computers, Environment and Urban Systems* journal.

Ontologies of Urban Systems

Ontology of Populations and Agents in Urban Systems

In the second sprint, we have included the concepts of *Family, Registered Family, Community,* and *Elderly* in the Ontology of Agents in Urban Systems. Regarding the concept of *Individual* discussed with collaborators, we understand that the concept of *Person* in the context of urban systems is synonymous with *Individual*[1]. The semantics applied is that of the Western social dimension, not considering the semantics that exist in the legal dimension, i.e. the human being considered as a subject of rights and obligations. The representation of the legal dimension has already been discussed and will be analyzed in the next sprints. Also, the *phase Elderly* was included in the *generation_set* of life phases (gs_life_phases). The definition adopted was the ISTAT and the Ministry of Health, i.e., people aged 65 and over.

Stereotype	Label	Description
<<category>>	Family	1. A human community generally formed by people tied together by a relationship of coexistence, kinship, and 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 persons related by birth, blood, marriage, *de facto* union, or adoption who live together. 4. All the descendants of a common ancestor. (Oxford Language)
<<kind>>	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)
<<category>>	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.

[1] *"Individual is a single human being as contrasted with a social group or institution".* "Individual." Merriam-Webster.com Dictionary, Merriam-Webster, https://www.merriam-webster.com/dictionary/individual. Accessed 2 Sep. 2024.

		Source:https://www.evms.edu/education/resources/community-engaged_learning/glossary_of_terms/
<<phase>>	Elderly	"Elderly" is a concept that cannot be defined, as it has different meanings in different societies and historical periods. The United Nations refers to those aged 60 and over as "older persons", 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.

In the first sprint, *Population* was categorized into 1) Human Being Population, 2) Non-Human Being Population, and 3) Artificial Population. Human Being Population is categorized as 1.1) Resident Population and 1.2) Non-Resident Population. On the other hand, Non-Human Being Population is categorized 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, and 2.6) Bacteria Population. However, in the second sprint, a higher level was added categorizing the population as Biological Agent Population and Artificial Agent Population (Figure 5).

At a lower level, biological agent populations were categorized as *Human Population* (collective of people) and *Non-Human Population* (collective of fungi, animals, plants, etc.). On the other hand, the artificial populations were sub-categorized as *AI System Population* (e.g., intelligent systems, multi-agent systems, etc.) and *Juridical Person Population* (e.g., legal entities, public entities, companies in general).

The glossary with these terms is in the Technical Documentation – version 2nd sprint.

Figure 2 shows the ontology of Population. Human Population is a subset of a collective of people who may or may not be residents of a city. In turn, *Resident Population* is a collection of people who are residents of a city. Resident Person is categorized as a *role* because being a resident is an accidental property of a human being, i.e. a person can have his/her property of being a resident changed without losing his/her identity as a human being (essential property). Roles are played in the context of relationships. Being a resident means playing a role in a legal relationship (there will be rights, duties, permissions, prohibitions, liberties, powers, and subjections assigned to a resident person).

In addition, **Figure 3** presents the categories of *Agents*: 1) Artificial Agent; and 2) Biological Agent. Biological Agents are subcategorized as Human Beings (i.e., Persons), and Non-Human Beings (e.g., Pets, Wild Animals, Plant, Mobile Genetic Element (MGE), Fungi, and Bacteria). A Person plays different roles Residential Person, Non-Residential Person, or Tourist. Also, he/she passes through distinct phases of life: Child, Teenager, Adult, and Elderly. Also, Person phases are classified as alive and deceased. Additionally, there is a set of artificial agents which encompasses institutional agents (social agents), and computational agents (autonomous systems, and so on).

Finally, we adjusted some labels (e.g., Human Being Population for Human Population; Non-Human Being Population for Non-Human Population; Legal Person for Juridical Person; Commuter Person for Commuter).

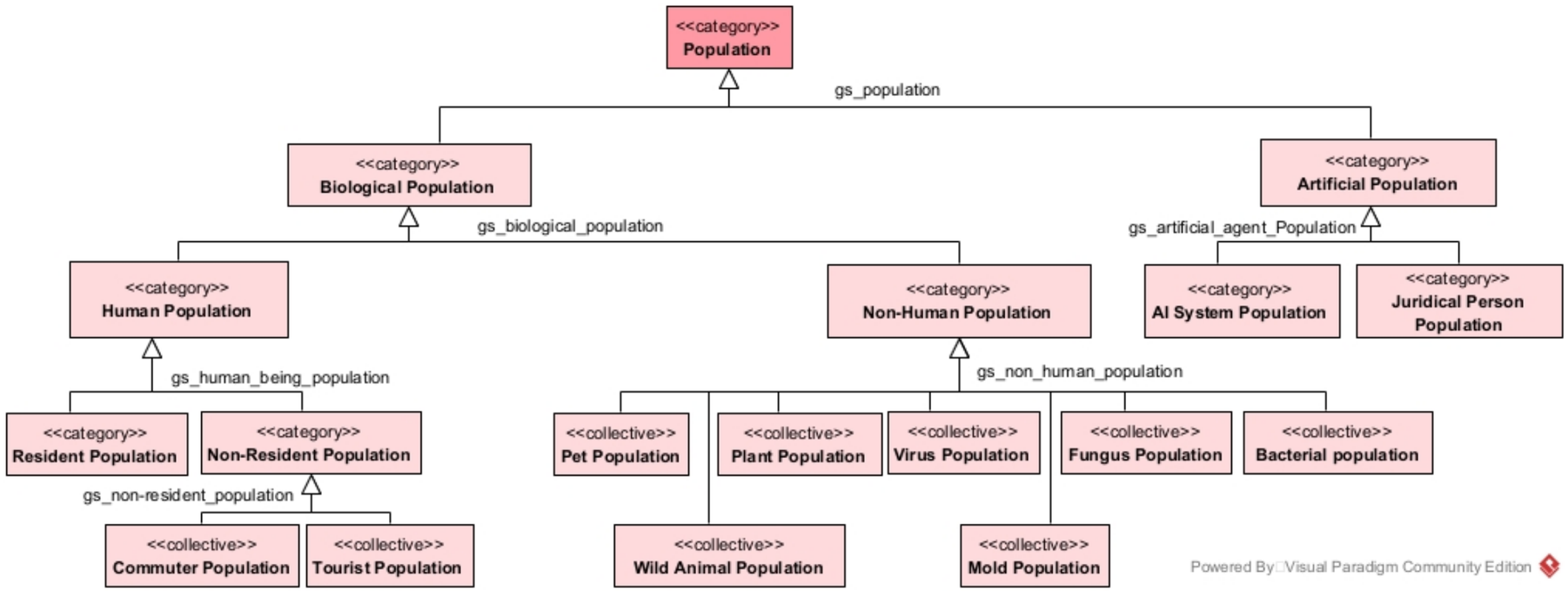

Figure 2 – Ontology of Population

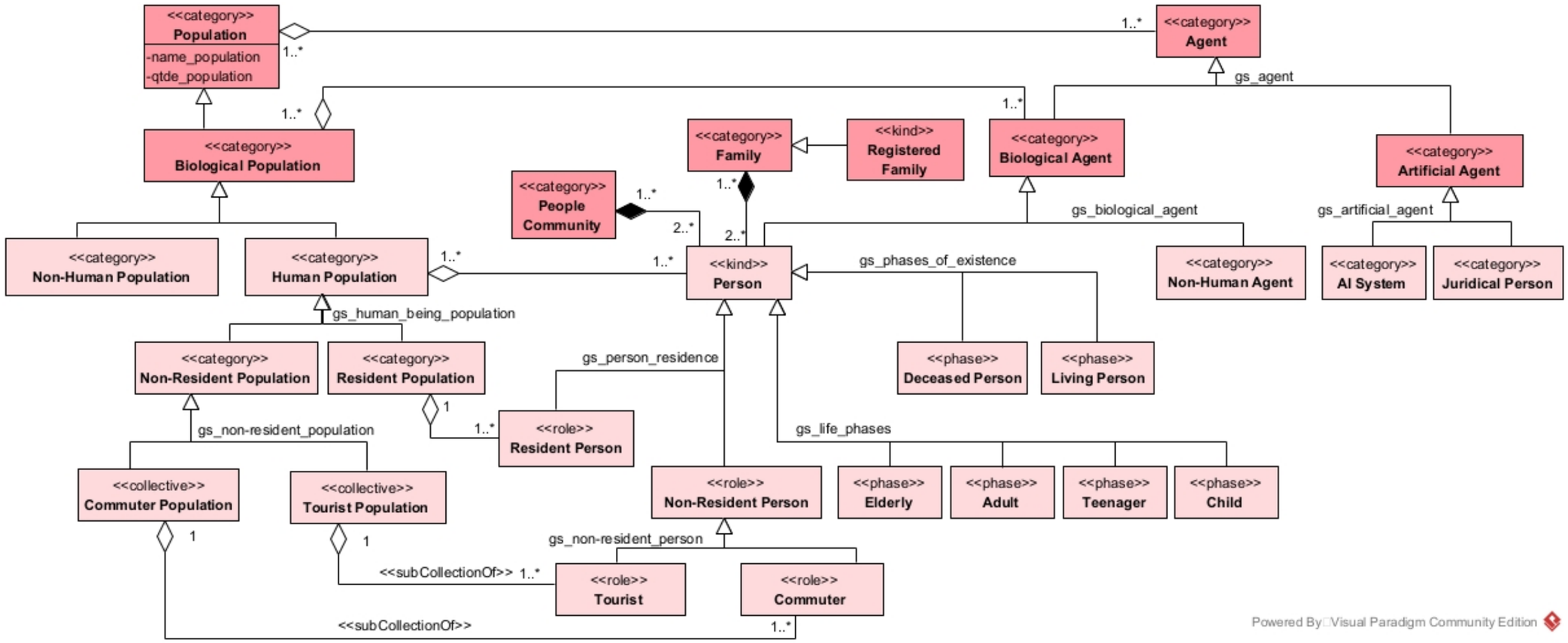

Figure 3 – Ontology of Agents in Urban Systems

Ontology of Urban Infrastructure

The *Ontology of Urban Infrastructure* has been detailed in the *Soft Infrastructure* branch in the second cycle of building. Soft infrastructures include 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 educational and recreational.

In the model (**Figure 6**), soft infrastructures were represented as services (e.g., health services, education services, security, etc.). The concept of service can be understood from different angles. Here, service is represented as the performance of some action or work for one or more people in an urban context. In this sense, the ontological nature of service adopted was that of *relationship* (see **Table 1**). This means that, for example, the health service is a relationship between service providers and service consumers, having as an object the health treatment.

Table 1 Relation types in soft infrastructure (services)

<<relator>>	<<rolemixin>>	<<rolemixin>>	Description
Urban Resource Allocation	*Allocated Urban Resource*	*Urban Service Provider*	Relation between juridical persons, who play the role of service providers, and resources (human resources, hard infrastructure, and natural resources)
Urban Service Offering	*Urban Service Consumer Community*	*Urban Service Offer*	Relation between juridical persons, who play the role of service offers, and a service consumer community
Urban Service	*Urban Service Consumer*	*Urban Service Provider*	Relation between juridical persons, who play the role of service providers, and each service consumer

Each relationship (*relator*) is founded upon a specific event. In turn, for each event, there are a number of participants - agents and objects - who contribute to the event taking place (**Table 2**). For example, in the event *Urban Resource Allocate, there are two* participants: *Juridical Person,* playing the role of *Urban Service Provider,* and the mixin *System Element,* playing the role of *Element as an Urban Resource* (**Figure 5**).

Table 2 Events and participants

<<event>>	<<rolemixin>>	<<rolemixin>>	Description
Urban Resource Allocate	*Allocated Urban Resource*	*Urban Service Provider*	Relation between juridical persons, who play the role of service providers, and resources (human resources, hard infrastructure, and natural resources)
Urban Service Execution	*Urban Service Consumer*	*Urban Service Provider*	Relation between juridical persons, who play the role of service providers, and each service consumer

To better understand the types of services that exist in an urban system, scenarios will be built for each of them (e.g. transport services, health services, etc.). Also, a use case (UC-1) was constructed to illustrate the process of offering, allocating, and executing services in general. In practice, urban systems generally comprise at least four macro phases for the provision of services. The macro phases of service provision can be delineated as follows: 1) tendering of services; 2) concession or authorization of services to public or private companies; 3) provision of services to the population; and 4) use of services by the population. The initial UC-1 model did not provide sufficient detail regarding the first two macro phases.

The following is a description of the UC-1 (**Figure 4**): A *Juridical Person* is a category of agents. It is exclusively the province of juridical persons to assume the role of *Urban Service Provider* (**constraint C1**). The role of the urban service provider is assumed by juridical persons who have been awarded a tender and have received the appropriate concession or authorization to provide services to the population of an urban system. Consequently, the *Urban Service Provider* is also responsible for making the service available to the population, which is referred to as the *Urban Service Offer*. In consequence, the role of *Urban Service Offer* is that which is played by the service provider when offering a service to a community of urban service consumers. This community constitutes a subspecies of the *People Community* category, as defined in the Ontology of Agents. Consumers may decide to utilize a service when it is made available to them. Conversely, for a service provider to be able to offer a service to a community in an optimal manner, it is necessary to allocate resources. These may

include elements of hard infrastructure (trains, buses, ambulances) and agents, i.e., individuals who will carry out the service (e.g., drivers, inspectors, medics, etc.).

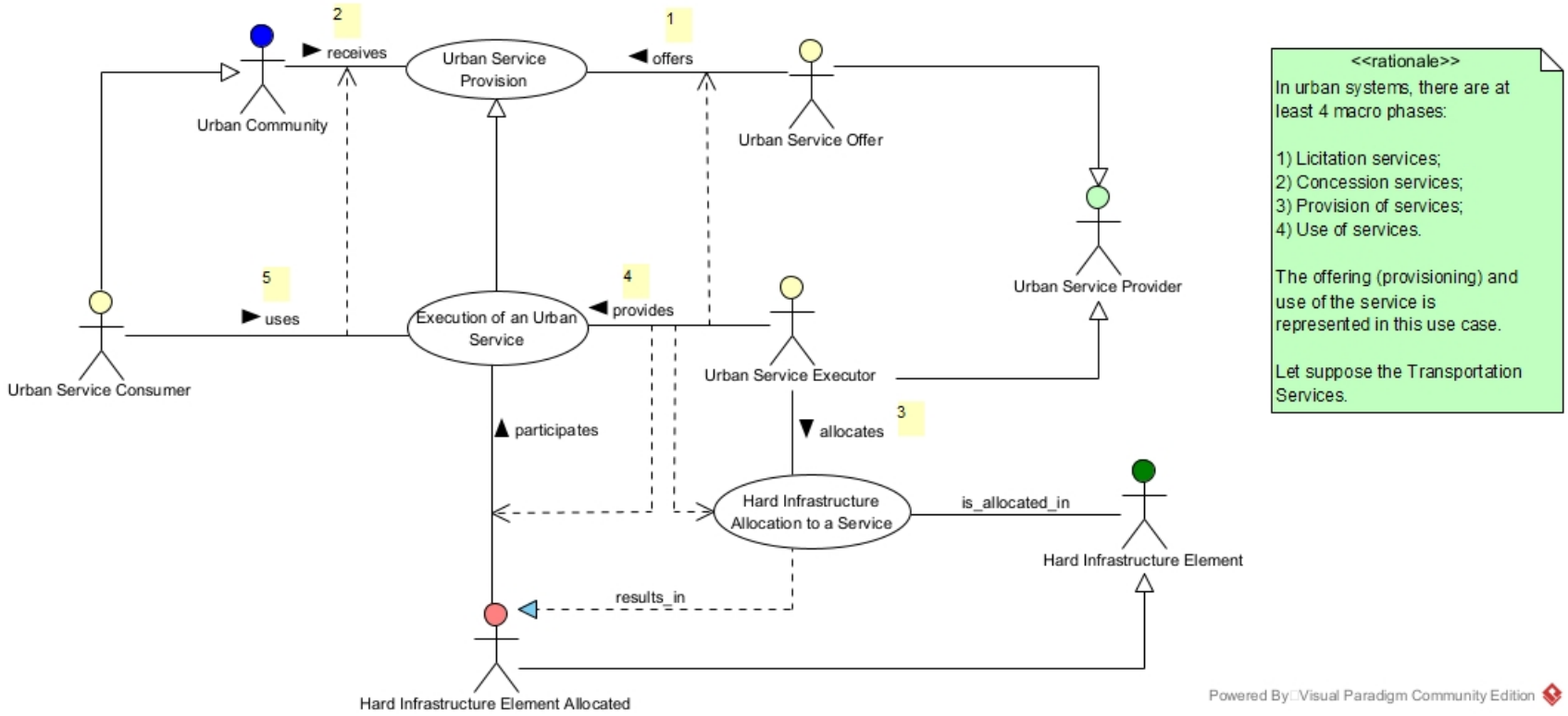

Figure 4 – Use Case – Execution of urban services

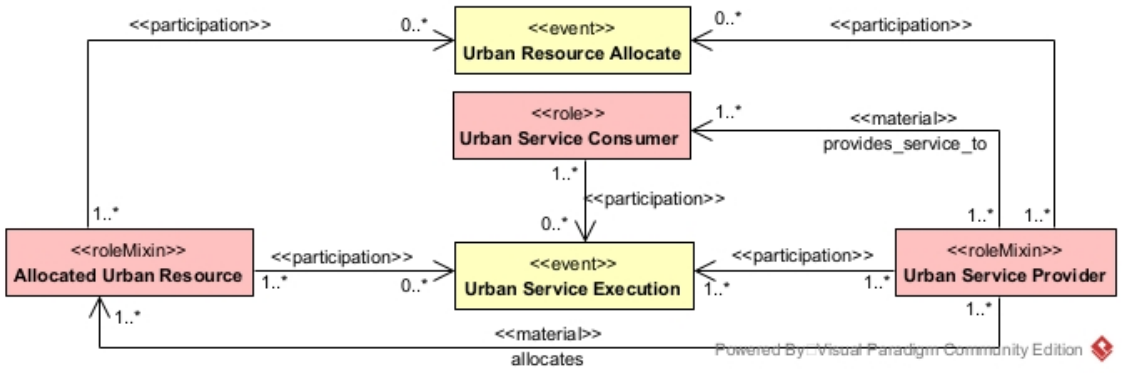

Figure 5 - Resource allocation and service execution events

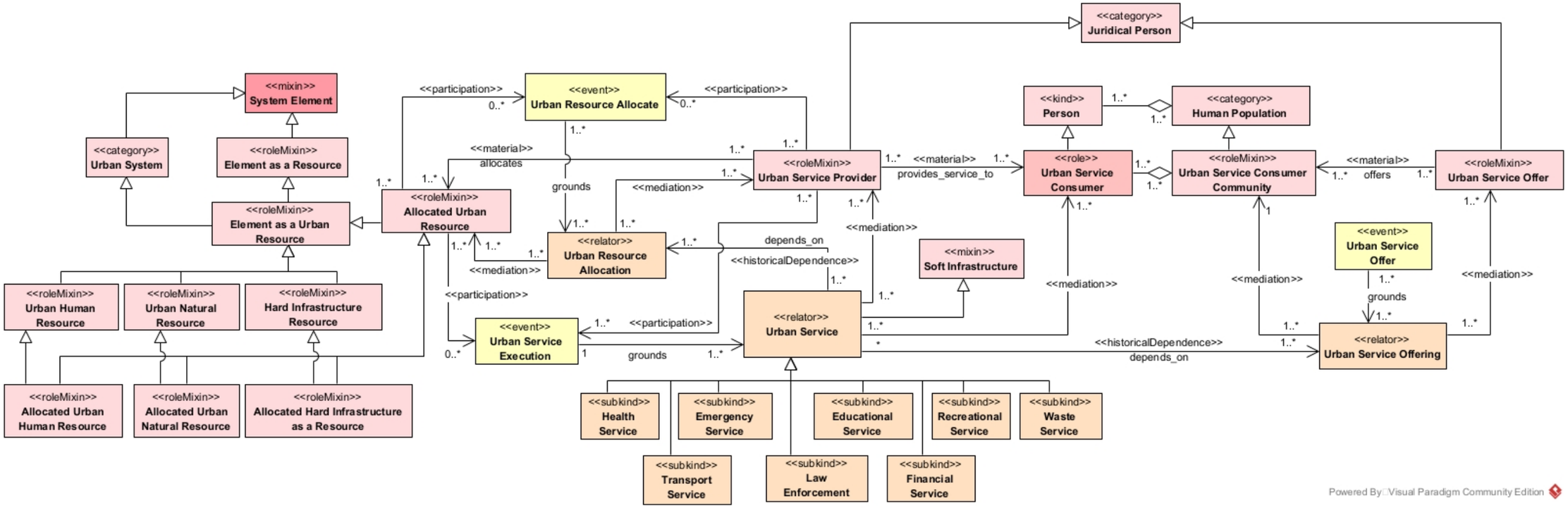

Figure 6 - Ontology of Soft Infrastructure

Ontology of Urban Systems at Risk

The elements of a system can be perceived as resources to be allocated to the soft infrastructure. In this case, they play the role of *Element as a Resource*. In the urban context, this role is specialized in *Element as an Urban Resource* (see the soft infrastructure ontology), which can be: a) *Urban Human Resource*, the portion of human agents that can be allocated to provide services; b) *Urban Natural Resource*, the natural resources available in an urban space. For example, rivers, forests, seas, and land; and c) *Hard Infrastructure Resource*, the artifacts built by humans in an urban context (roads, highways, bridges, road network, port network).

In turn, urban systems can be perceived through a vision of risk. The (role) *Urban System at Risk* perspective is constructed in this case. Similarly, the elements that compose an urban system can be seen from the perspective of risk (*Urban Infrastructure at Risk, Urban Space at Risk, Population at Risk*) (**Figure 8**). From a relational risk perspective, *Urban System at Risk* is a *roleMixin* of an *Object at Risk*, which is directly related to the risk generator (*Risk Driver*).

Risk Driver[2] encompasses both natural and human-induced phenomena, factors, processes, or conditions that result in a direct or indirect alteration of an urban system. Examples include climate change, uncontrolled urbanization, limited emergency response plans, and early warning systems.

Therefore, *Urban Risk* is the mediator element between the *Risk Driver* and the *Urban System at Risk*. Risk can lead to a chain of risks, each of which is historically dependent on the previous risk. In addition, *Urban Risk* is composed of aspects of vulnerabilities and exposures inherent to the *Urban System at Risk* and externally dependent on the *Risk Driver*. This means that the disposition of an *Urban System at Risk* of being vulnerable

[2] **See** https://apps.ipcc.ch/glossary/
https://civil-protection-knowledge-network.europa.eu/eu-overview-risks

and exposed to a *Risk Driver* is manifested in risk events, which in turn grounds *urban risks.*

The vulnerabilities and exposures of an urban system are activated by hazard situations. A situation is said to be hazardous according to the hazard quantifier assigned to it by a risk marker (a human agent or a system). In the proposed model, it is possible to modulate the *Vulnerability* and *Exposure* parameters to verify the set of impacts resulting from potential risk events.

A risk event is the historical foundation of the (urban) risk relation between the *Risk Driver* and the *Urban System at Risk*. This event may have impacts that can be measured as negative consequences (damages and losses). However, it is also possible for risk events to have impacts that do not have significance for the urban system. Thus, depending on the value attributed to the impact, a set of responses will be associated to mitigate the impact that has occurred.

The model presented in **Figure 9Figure 9** is based on the UFO-B pattern (**Figure 7**). By this pattern, events bring about situations that, in turn, trigger new situations. Also, situations activate dispositions manifested in events ("events are manifestations of dispositions"). Furthermore, agentive or non-agentive objects participate in events.

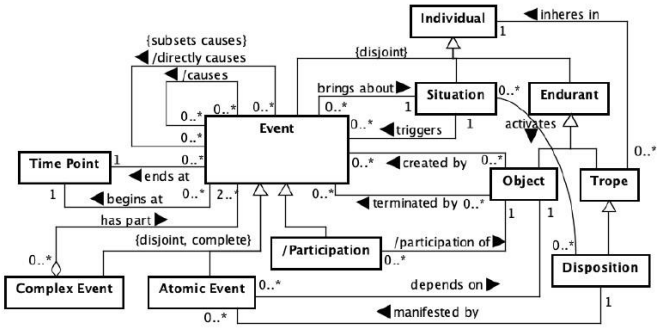

Figure 7 - UFO-B pattern

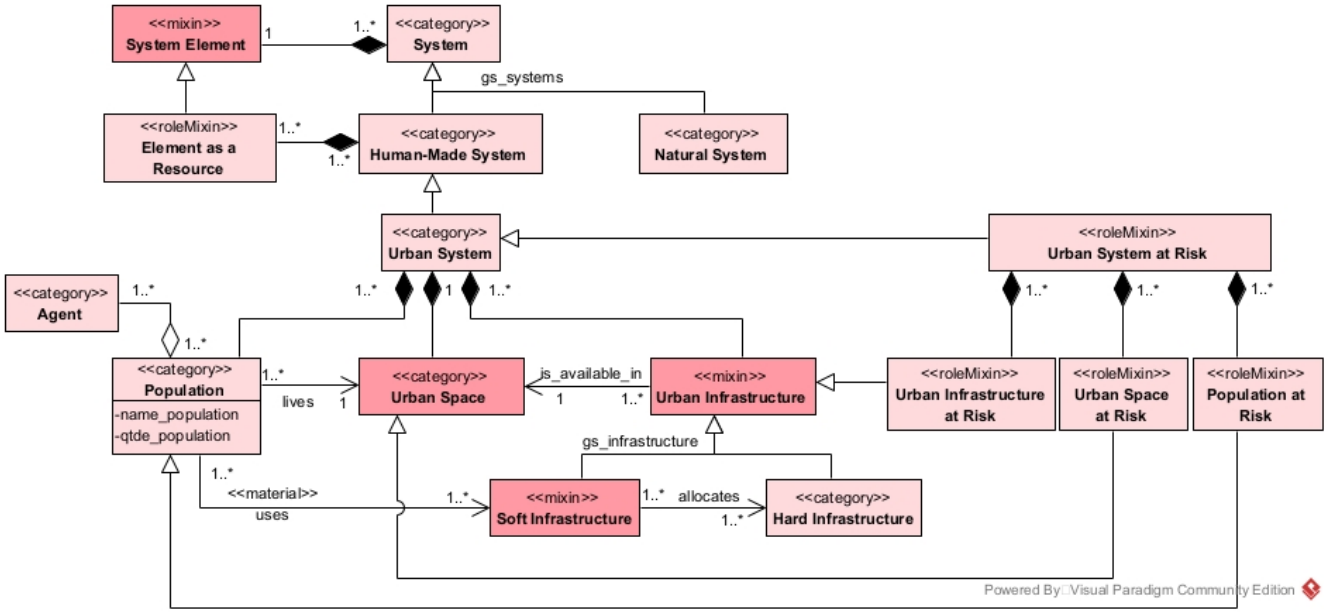

Figure 8 - Ontology of Risk-Driven Urban Systems

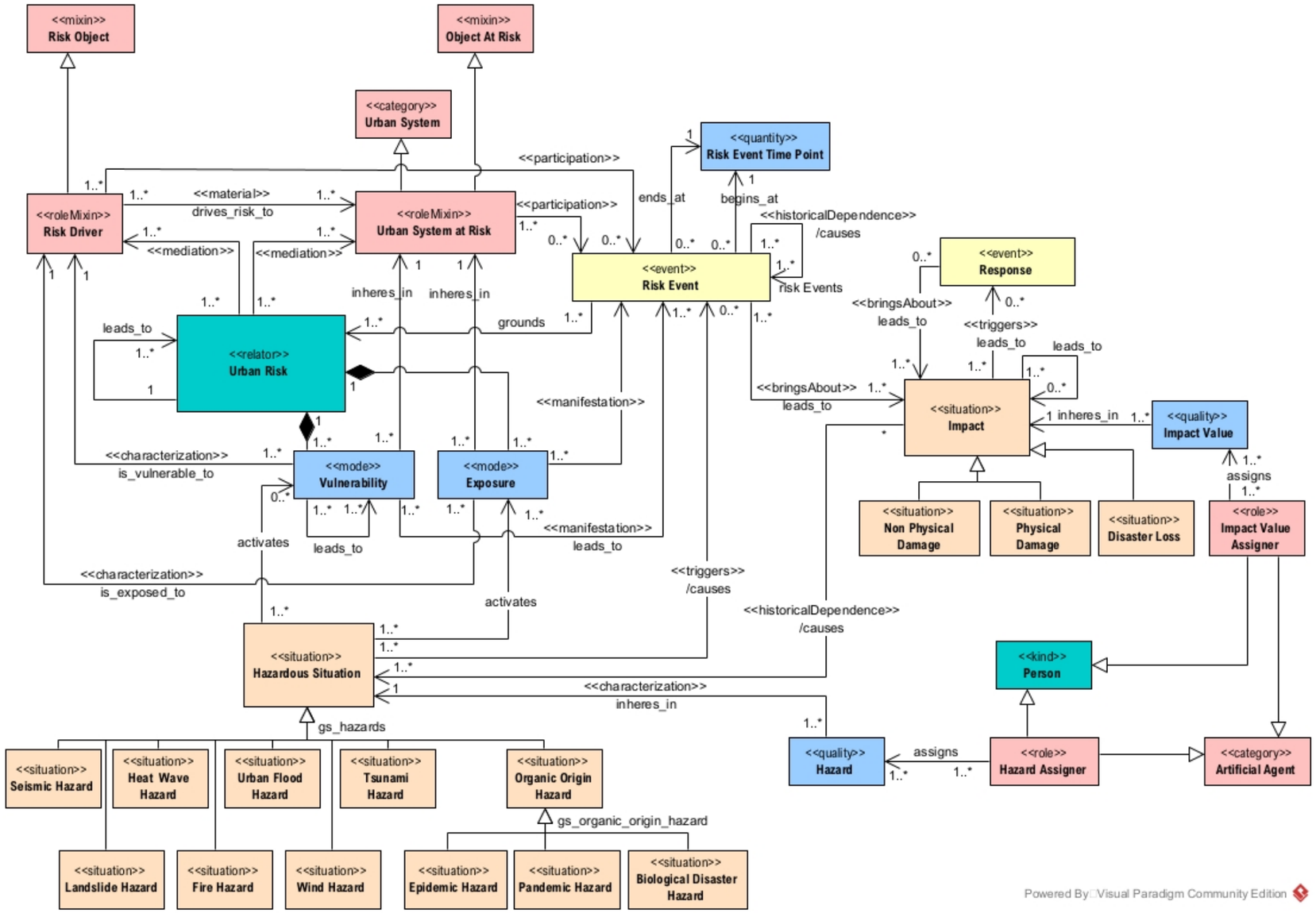

Figure 9 – Ontology of Urban Systems at Risk

Visualization of Controlled Vocabulary

Ontological models are sometimes associated with being complex and difficult for stakeholders to understand when presented directly in the modeling tool. In contrast, taxonomies — typically represented in a hierarchical structure — facilitate precise information retrieval by guiding users to search through the labels of the classes and subclasses present in the hierarchical structure. Nevertheless, taxonomies have not furnished a methodology for portraying the full spectrum of relationships that exist within a specific domain. In other words, the type of relationship represented in taxonomies is only the "*is_a*" relation type.

Another mechanism for structured information visualization is a thesaurus. Thesauri are understood as taxonomies with relationships between classes and subclasses. This allows the user to navigate vertically (following the taxonomic hierarchy) or horizontally, following concepts that are correlated or related in some way. However, thesauri – as taxonomies - does not show the mereological relationships, the dependency relationships, or the intrinsic and extrinsic relationships existing in the real domain.

The taxonomies and thesauri proposed in the Return project offer a relevant controlled vocabulary that facilitates comprehension of the specific domain in question for both experts and laypeople alike. Some tools for building taxonomies and thesauri were studied, including VocBench and Skosmos.

Skosmos is a web-based tool that provides services for accessing controlled vocabularies, used by indexers describing documents and searchers looking for suitable keywords. The advantages are a) can be used to view taxonomies and thesauri; b) easy to use imported TTL files; c) possibility to generate graphs from TTL files; d) the possibility of writing queries on Apache Jena Fuseki; and e) is an open access tool.

Another interesting tool is **Vocbench**, a web-based, multilingual, collaborative development platform for managing owl ontologies, SKOS, thesauri, Ontolex-Lemon lexicons, and generic RDF datasets. The advantages include a) attractive graphical

interface; b) can be used to view taxonomies and thesauri; c) uses standards already established in the community (SKOS, owl); d) availability of codes in JSON-DL, RDF-XML, and Turtle to reuse; e) possibility of writing queries; and f) it is an open access tool.

In addition, the use of Visual Paradigm[3], a CASE tool, allows the creation of a comprehensive **technical documentation webpage**[4] that provides technical information on built ontologies for developers. It should be noted, however, that the generation of queries is not an available functionality. Furthermore, the option to generate technical documentation is only accessible in the paid version of Visual Paradigm. In addition, the user interface is not up to date and is better suited to developers than to laypeople.

In consideration of the shortcomings of the tools under examination, Skosmos presents a considerable learning curve; it is not compatible with ontology viewing; it does not accept all file types in Turtle, which complicates the conversion of models in OntoUML (owl->Turtle) to the Turtle format accepted by the platform; the generation of a readable Skosmos Turtle file necessitates the use of Protegè or a similar tool. On the other hand, Vocbench has an interface not as friendly as the Skosmos interface.

To configure and run the Skosmos environment, it was necessary 1) to install Apache Jena Fuseki; 2) to create and load vocabulary databases at Apache Jena Fuseki installed; 3) to install Skosmos; and 4) to make tests with the Turtle file generated from the operational ontology[5].

[3] Only from the Standard license onwards.
[4] Available at https://gitlab.inf.unibz.it/earth_observation_public/CCT/pnrr-return/ts1/2ndsprint
[5] See https://github.com/NatLibFi/Skosmos/wiki/InstallTutorial