City Resilience Tool - Documentation

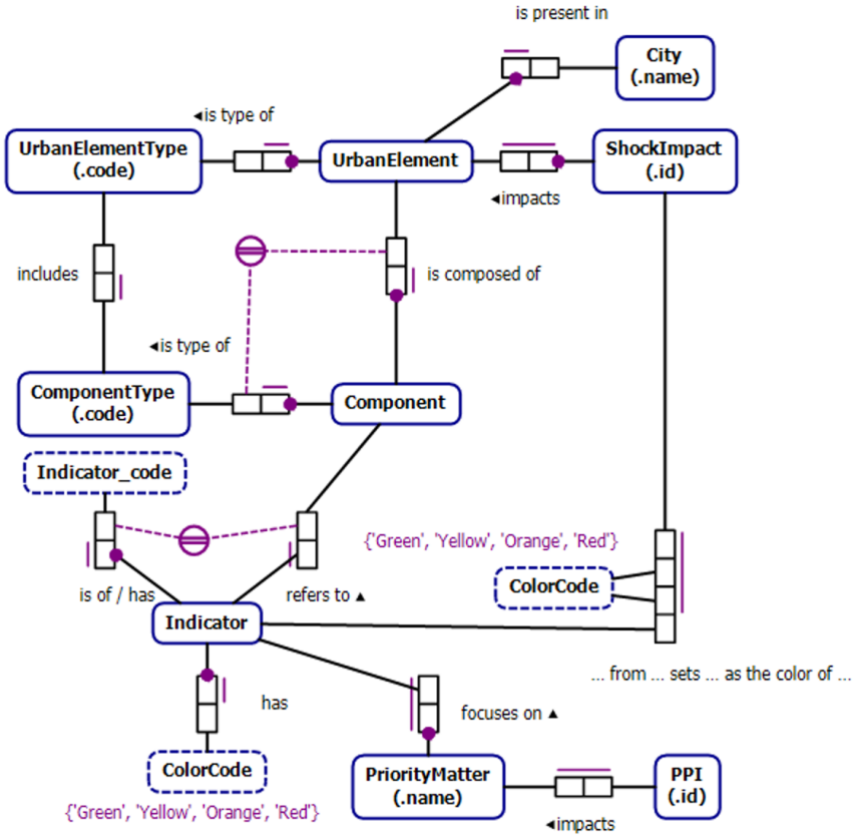
Annex 1: The Conceptual Model

Modeling approach

This document presents the ontology of the CRPT domain using ORM v2.0 modeling language. In short, this conceptual modeling language allows the modeler to capture *entity types* which represent classifiers of real-world objects and *fact types* to model relationships between entities without physical data format (e.g., CSV files, database tables) specification. Besides, one important feature of the language is its very expressive and well-defined constraint toolset that can be applied to elements in the model to make the description of objects and relationships more realistic. For a short summary of ORM v2.0 visual language features, please see this summary document.

Domain overview

The ORM diagram, which provides a view of the complete ORM ontology, shows the most important relationships from our initial analysis point of view: it presents the following core concepts: ShockImpact, Indicator, Component, UrbanElement, PriorityMatter, PPI, and City. A ShockImpact represents occurrences of shocks that may change the ColorCode of an Indicator from one color to another. This information is captured via the 4-ary relationship shown in the lower right corner of the figure. With this information and the relationship between an Indicator and UrbanElement via the Components of an UrbanElement, we can query the impact of a certain shock in the past on an UrbanElement present in a City.

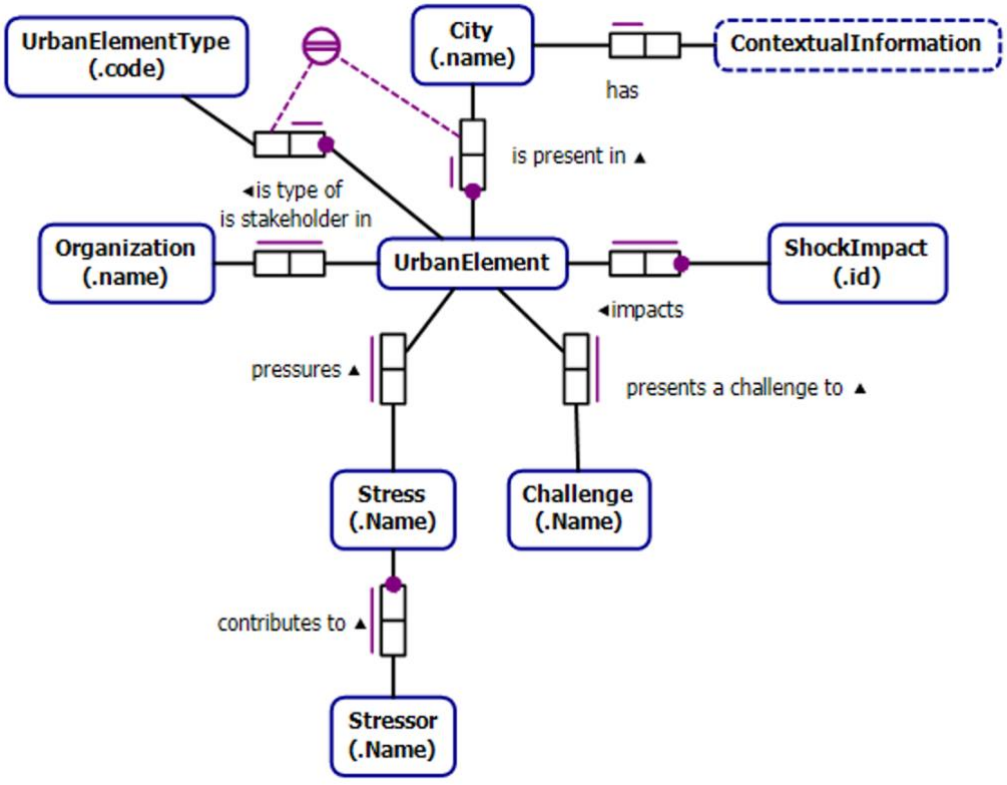


Additionally, cities define various PriorityMatters to help focus on important aspects regarding the development of a city. A PriorityMatter in the domain focuses on a certain set of Indicators which reflect the state of important Components and UrbanElements in a city relevant to the PriorityMatter. This relationship helps domain experts understand the consequences of shocks wrt. PriorityMatters and can highlight where a city needs to take action by implementing additional plans or policies (PPI in the diagram above – see more details on these later in this document).

Furthermore, we can also see in the diagram the classification of Components and UrbanElements via their respective ComponentType and UrbanElementType classifiers. This is important in the domain as there are common features of UrbanElements and Components which we do not want to store redundantly. Also, we do not know in advance all possible classifiers of these entities, so we cannot capture them in such an ontology upfront but we wish to allow domain experts to register these types themselves. Below, we discuss the concepts presented in this overview diagram above as well as add additional information about these.

The rest of this document dedicates a section to each of the core concepts of the CRPT domain to discuss them in more detail.

Urban element

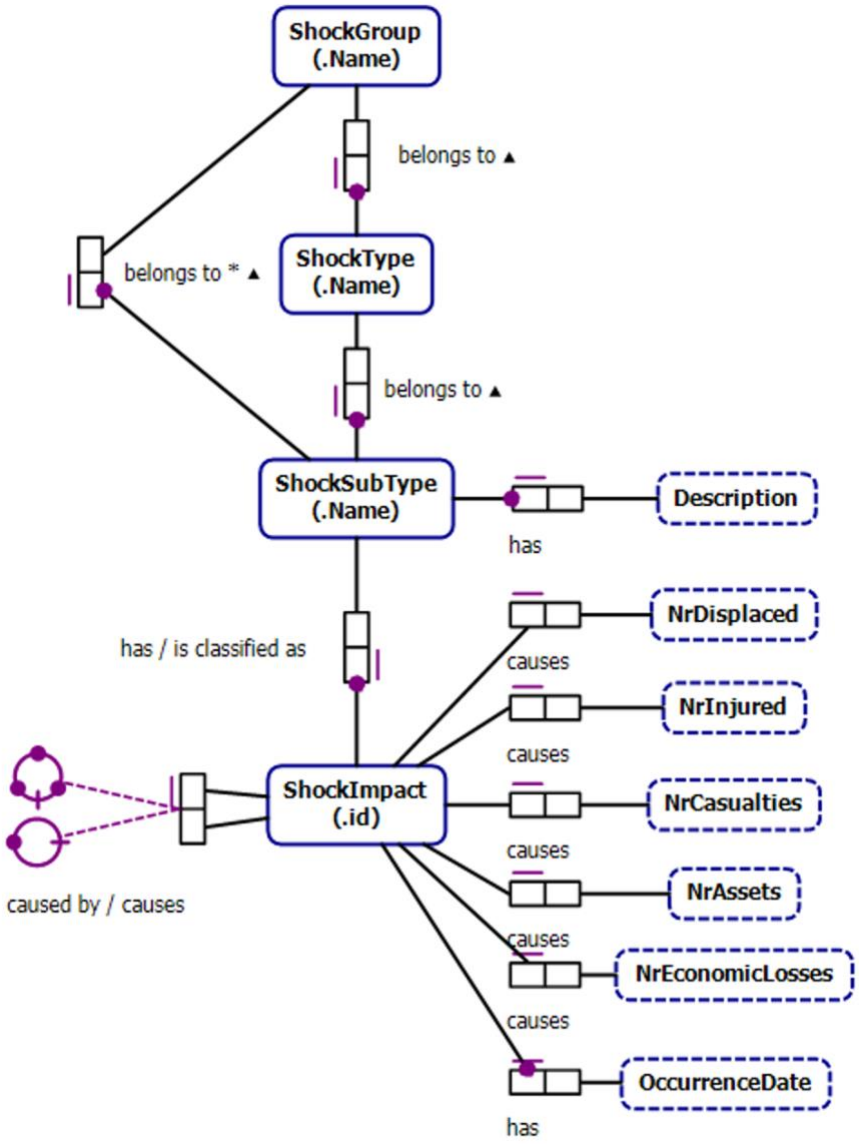


UrbanElements provide an in-depth examination of the urban system's performance by categories. An UrbanElement includes all aspects essential in enabling life in the city, from the built environment to the broader scale of ecology, and from different types of services provided for the inhabitants to characterizing the city's economic state. These are further distinguished into Components that comprise each UrbanElement (or Element for short).

An UrbanElement is identified by its type (UrbanElementType with a code value) and a City in which the UrbanElement is located in. This is expressed in the diagram by the external uniqueness constraint (purple circle at the top of the figure with two horizontal lines in it). An UrbanElement can have an arbitrary number of stakeholders. Besides, ShockImpacts, Stresses, and Challenges may all have an effect on an UrbanElement.

Components of each UrbanElement (e.g. water supply, land tenure, health services, etc.) have their own set of specific indicators dedicated to assessing and characterizing the system's performance (e.g., coverage as physical and spatial dimensions, continuity of operations as functional dimension, etc.), as well as identifying key Stakeholders active in the Component and Policies, Plans, and Initiatives currently under development and/or in place.

Shock impact



An occurrence of a shock is named ShockImpact to help avoiding the overloaded usage of the term "shock", but it essentially captures the hierarchical classification of a shock (subtype, type and group), and currently has a number of attributes related to it, such as the number of casualties (NrCasualties) or occurrence date (OccurrenceDate). A shock may cause and thus be caused by another shock, this is modeled with the fact type caused by / causes

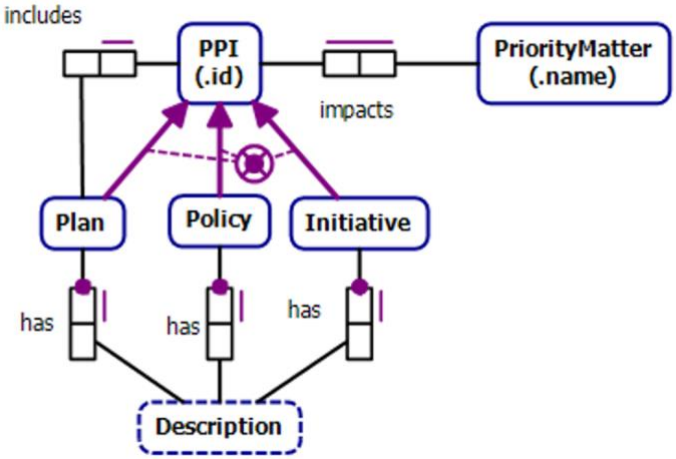
bidirectional fact type. Note that this relationship cannot be cyclic nor reflexive, which is indicated by the two purple constraints next to it.

Having this separate ShockImpact concept in the model already allows us to do aggregations of certain types of shocks happening in a given area and assess the damage caused by these. This sort of analysis is still independent of the indicator color codes at this point, but can already provide insights to city representatives.

Priority matter

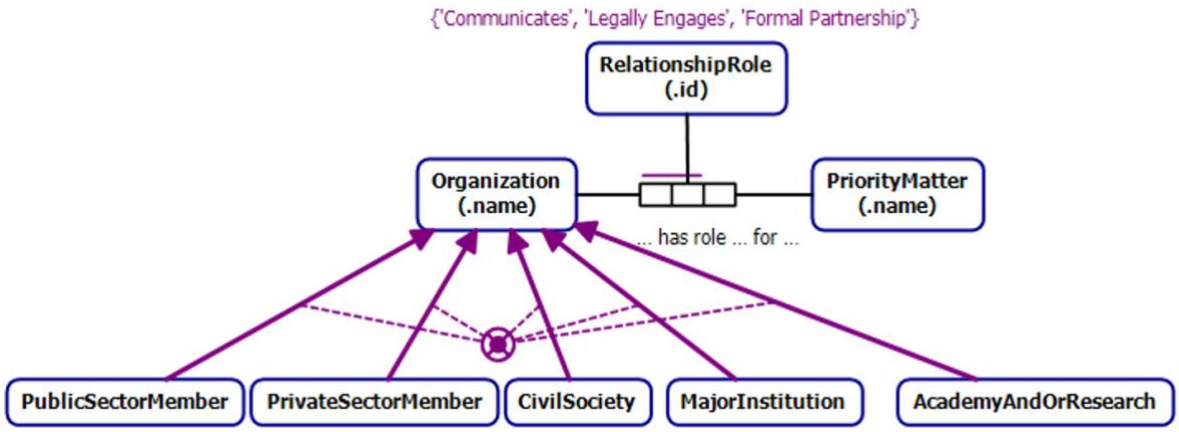
As we have mentioned in the overview, PriorityMatters are linked to Indicators which are in its focus. Besides that, a PriorityMatter may have a description. Priority matters in practice cannot have a clear "boolean" distinction between indicator values classified as "OK/Not OK" as these indicator values are often subjective, and are specific to a certain city/location. Instead, Indicator readings can be used to prioritize PriorityMatters focusing on a certain area.

Plans, policies and initiatives



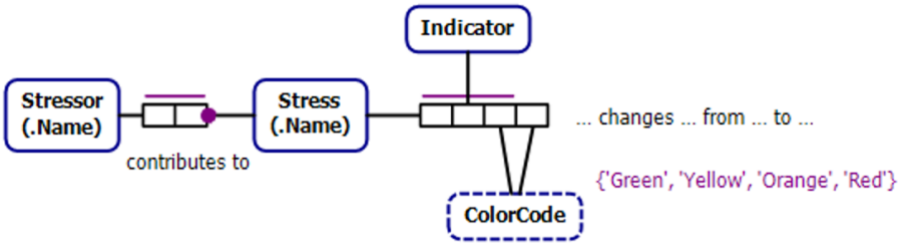
A PPI must be either a Plan, Policy, or Initiative. They all need to have descriptions. Besides, a Plan may include other PPIs, thus may create a hierarchical structure. One example for a plan would be “evacuation plan”.

Organization



Possible types of Organizations are depicted in the diagram above. An organization can be in a relationship with a PriorityMatter, where the type of the relationship must be from the set of {'Communicates', 'Legally Engages', 'Formal Partnership'}.

Stress



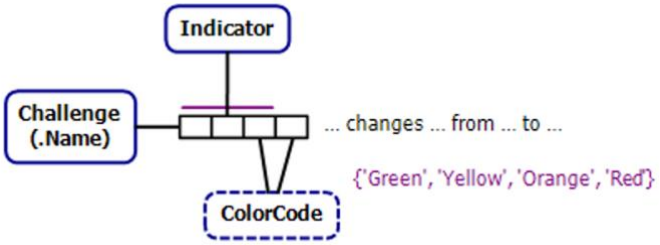
Chronic and ongoing dynamic pressures originated within an urban system with potential for cumulative impacts on the ability and capacity of the system to achieve its objectives.
Examples (Teresina):

- Environmental pollution
- Vegetation loss
- Urban Heat Islands
- Weak economic diversity
- Informal economy

Stressors are the negative factors, processes, or activities that contribute to the generation of stresses.
Examples (Teresina):

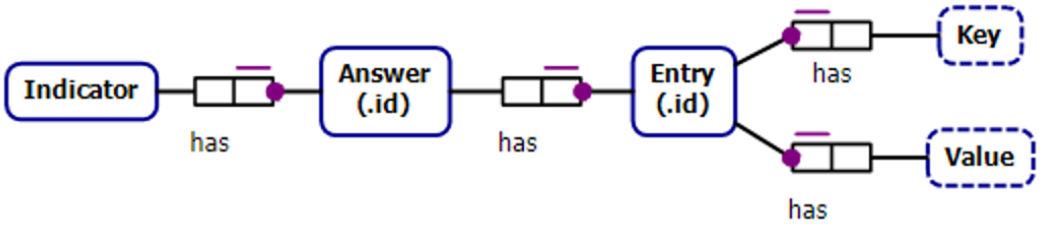
- Soil degradation (for Environmental Pollution stress)
- Deforestation (for Vegetation Loss)
- Inadequate green cover (for Urban Heat Islands)
- Market disconnectivity (for Weak economic diversity)
- National rules and regulations (for Informal Economy)

Challenge



- Challenges, long-term contextual changes and pressures originated outside of the urban system, also undermine the city's capacity for sustainability and resilience
- Examples (Teresina):
- Intergovernmental Coordination
- Climate Change Effects
- Security and Crime
- Note: unfortunately in the case of Teresina we did not link challenges with indicators.

Indicator



To support arbitrary kinds of questions for indicators, we have decided to model each response to a question as Answer, that contains an Entry with a key-value pair for each value provided in that answer.

Annex 2: Using the Model

We can ask our model questions in the interactive notebook connected to our Graph. For instance, how many working days have been lost to floods (based on the historical data we entered for Teresina, Brazil).

```
query
1  sum[shock_type_name_to_shock_and_loss_of_working_days["FLOOD"]]
```

answer:

1	51

We can also ask for the possible impacts of a flood on a city:

```
query
1 shock_type_name_to_affected_urban_element["FLOOD"]
```

#	STRING
1	Basic Infrastructure
2	Built Environment
3	Economy
4	Municipal Public Services

What shocks are triggered directly by floods (1):

#	String
1	Bacterial Epidemic & Pandemic Disease
2	Built Infrastructure Breakdown
3	Pluvial Flood

What are the cascading effects of floods (2):

```
query
1 def output = floodings . shock_trigger_transitively_other_shock . shock_impact_subtype . (transpose[from_shock_subtype_name])
```

#	String
1	Bacterial Epidemic & Pandemic Disease
2	Built Infrastructure Breakdown
3	Fluvial Flood
4	Pluvial Flood
5	Public Services Breakdown

As you can see the knowledge graph indicates that a flood may lead to infrastructure breakdown, which may lead to Epidemics or other health crises.

Finally, we can ask which indicators to focus on to increase resilience against flooding while also increasing resilience against long-lasting impacts (called stresses). This will give us an idea of the most effective (most value-for-money) strategies to build city resilience.

```
query
1 shock_to_stress_indicators_impacted["FLOOD"]
```

#	String	String	String	String
1	Mismanagement of urban metabolism	3.2.3.3.1	Percentage of dwellings damaged by intense flooding (10 years)	Not applicable
2	Mismanagement of urban metabolism	3.2.3.3.2	What level of disruptions on road traffic due to water logging does the service face?	Yellow
3	Mismanagement of urban metabolism	3.2.3.3.3	What level of disruption of access to public services due to water logging does the service face? [+]	Green