

# City Knowledge Patterns: A Standard for Smart City Knowledge Management

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## Abstract

In this paper, we describe our efforts in recognizing knowledge requirements of city governments. This model, which we denote as City Knowledge Patterns, is a set of standard Knowledge Patterns identifying the concepts required to represent municipal knowledge.

## Introduction

Toronto 311 provides 24x7 access to non-emergency services and information. As part of its service, it maintains an online Knowledge Base composed of 21,000 web pages. The web pages are entirely text based, manually maintained, unstructured, and are not machine-readable. In its current form, the content is costly to maintain and difficult to re-purpose, for example to support financial analysis. To address these shortcomings, we investigate whether there is an underlying structure to the content that lends itself to a more structured representation. Specifically, we manually analyze the Knowledge-base to extract the inherent knowledge (Patterns) embedded in it. Each pattern represent a specific knowledge category of the city government, and is comprised of a set of inter-relate concepts and attributes. The concepts and attributes are selected based on their importance and frequency in the sampled web pages. The patterns can be used to evaluating the conceptual coverage (content coverage of the concepts and attributes identified in the patterns) of existing government ontology/reference models.

## City Knowledge Patterns

We define a Knowledge Pattern (KP) as a description of some structure (i.e., a set of domain specific interrelated concepts and attributes) that frequently recurs in the data. Our definition differs from the classical definition of KP, which (Clark, Thompson, and Porter 2004) define as a First Order theory whose axioms are not part of the target knowledge base but can be incorporated via renaming of their non-logical symbols. Moreover, our KP also differs from Ontology Patterns in that unlike our definition of pattern, Ontology Patterns aim to reuse the encoded experiences and good practices of existing ontologies to address common issues

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in ontology design and other stages of ontology lifecycle (Gangemi and Presutti 2009).

As discussed in the introduction, we explored 500+ Toronto 311 web pages in order to extract the KPs, which we denote as the City Knowledge Patterns (CKP). Our investigation resulted in identifying nine KP (based on importance and frequency of their concepts). Figure 1 depicts the overall percentage of the most important patterns discovered throughout our exploration of the web pages. We next briefly describe each KP.

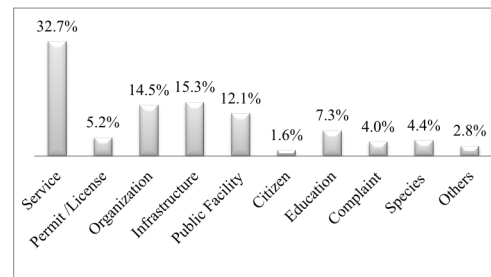


Figure 1: Knowledge Component in Toronto311 Database

**Service Knowledge Pattern (SKP).** SKP encompasses concepts and attributes that are common between different city services, regardless of the service type. Specifically, every city service can be viewed as a set of processes and activities, performed by a service provider (city or private employee), who consumes city resources to deliver the service. These activities must be initiated by a triggering event (e.g., a citizen calling 311), and must satisfy a set constraints in order to be performed (e.g., time or fee constraints).

**Permit/ Knowledge Pattern.** In the city domain, many services require a government issued license, e.g., providing health care services and food inspection. In our framework, a permit is a unique sub-process of a city service, which works as a mandatory precondition for its post-processes. The reason why we considered permit as a separate KP and not as an instance of SKP are: (i) the resource in use for the permit process is the permit/license itself (e.g., acquiring the hauling license, the hauler will use the permit as a resource to provide sewage removal services), and (ii) some permits will require specific certificates or skills as their constraints.

**Organization Knowledge Pattern (OKP).** In OKP, we describe the general characteristics of city organizations by capturing their components and relationships. We assume that organization agents are the center of every city organization. These agents perform organization activities by consuming resources to achieve organizations goals. Moreover, the agents play different roles (or are a member of more than one team) based on their skills. They communicate with each other through social communication or formal communication links.

**Infrastructure Knowledge Pattern.** This KP considers city infrastructure as physical structure or environmental asset of the municipal government and its private business partners, which are used (i.e., type of city resources) in the daily operation of the city. Physical infrastructures are those infrastructures that are tangible and manufactured, e.g., bridges, roads, and ports, where as environmental infrastructures are tangible but made by nature, e.g., lakes, and gas/oil reserves.

**Public Facility Knowledge Pattern (PFKP).** There is a subclass of infrastructures that have all the characteristics of the previous KP, but have their own unique properties such as availability, prohibited activities, accessibility, and age limits. Thus, the PFKP is created to capture these additional knowledge components.

**Education Knowledge Pattern (EKP).** EKP represents the concepts and attributes related to education. We divide such components into two categories: (i) Educational Services: while educational services are a particular type of service, they have a set of characteristics (such as target group - the group that the education service is designed for) that convinced us to place them under EKP; and (ii) Educational Context that provides scientific fact or general information about different subjects.

**Citizen Knowledge Pattern (CiKP).** In its day-to-day operation, a city acquires information from its citizens in the course of delivering the service. Since service is conducted by different organizations, the information is distributed across various databases and is represented in different formats, thus making it difficult to retrieve and/or reuse. To overcome this issue, we introduce the CiKP that provides a unified view of the totality of the citizen related information, which can be divided into three categories: (i) Personal Information (e.g., name, age, and address), (ii) Medical Information (e.g., doctor contact info, emergency contacts, and medication information), and (iii) Automobile Information (e.g., Vehicle Identification Number and Plate Number). Moreover, this pattern categorizes the level of accessibility to citizens' information as: public, private, or permitted (authorized access).

**Complaint/Compliment Knowledge Pattern.** Complaint/Compliment Knowledge Pattern is introduced as a mean to capture the knowledge components related to citizens' response to city services. Specifically, this KP captures information about the agent and activity that is the subject of the complaint, and the information about the

person submitting the complaint (to relay the result of a specific complaint to the complainer).

**Species Knowledge Pattern.** This pattern is created to present species related information in a structured manner. It captures information such as species types, their ecological impact, and the danger they pose to humans. In this pattern, species are divided into two distinct categories: insects and animals (which is itself divided into pets and wild animals). This categorization is general enough to encompass all species that coexist or interact with city residents.

## Validation, Evaluation, and Implementation

**Validation of the CKPs:** To verify that the CKPs derived from the 500+ web pages chosen in our analysis are sufficient to represent the remainder of the knowledge in the 21,000 Toronto 311 web pages, we randomly sampled an additional 100 web pages and determined whether the existing CKPs cover their content (see (Allahyari 2014) for the random sampling procedure). Figure 2 depicts the frequency of the CKPs observed in these 100 webpages, which is very similar to Figure 1. This indicates that the initial sampled webpages used to extract the CKPs is a good representation of the 21000 webpages of the 311 Knowledge Base.

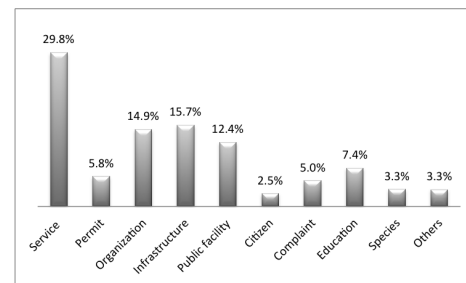


Figure 2: Validation Sampling Result

**Evaluation of City Ontologies:** As mentioned in the introduction, one of the goals of identifying the CKPs is to verify the conceptual coverage of existing government ontology/reference models (the models content coverage of the knowledge defined in the CKPs). In (Allahyari 2014) we use the CKPs to evaluate the coverage of four ontologies and reference models in the municipal government domain. For a comprehensive discussion of the above evaluation the reader is referred to (Allahyari 2014).

**Representation of the CKPs :** In (Allahyari 2014), we have presented a description logic (DL) representation of the CKPs, and implemented them using the Ontology Web Language (OWL). The reader is referred to the latter reference for the DL/OWL representations.

## References

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