City Knowledge Patterns: A Standard for Smart City Knowledge Management

by

Nooshin Allahyari

A thesis submitted in conformity with the requirements
for the degree of Master of Applied Science

Graduate Department of Mechanical and Industrial Engineering
University of Toronto

City Knowledge Patterns: A Standard for Smart City Knowledge Management

Nooshin Allahyari

Master of Applied Science

Graduate Department of Mechanical and Industrial Engineering

University of Toronto

2014

Abstract

The main focus of this dissertation is to identify the concepts required to represent municipal knowledge. Based on our analysis of Toronto 311 web pages, we were able to identify nine patterns of knowledge: service, permit, organization, infrastructure, public facility, citizen, education, complaint/compliment, and species. We then used these patterns to determine the extent to which four existing reference models and ontologies can represent municipal knowledge, as defined by the Toronto 311 KB. With these patterns, it is now possible to evaluate how well a reference model or ontology meets the need of a municipality. Finally, we provide a formal representation of these patterns using OWL.

Acknowledgments

There are several people that I would like to thank for helping me to write this dissertation.

I would first like to thanks my supervisors, Professor Mark Fox and Professor Michael Gruninger, for thier insight, support, and guidance.

I would also like to thank Professor Mark Chignell for his cogent comments.

Last and most, I would like to thank my parents for always inspiring and supporting me.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

City governments provide the services that are the backbone of modern life. To efficiently and effectively deliver the core services, city government have moved toward data-driven decision making. The first step in this process is creating a semantic model, which enables information sharing with a diverse group of stakeholders such as governmental agencies, individuals (citizens), and businesses.

Due to the inherent complexity and heterogeneity of city information, however, the existing semantic models and government standards are either not general enough to capture the knowledge components of city operations and organizations, or are abstract, vague and hard to implement. Moreover, there does not exist a benchmark to compare and evaluate the necessity or sufficiency of these models.

The focus of this dissertation is to identify patterns of knowledge that recur throughout city knowledge bases, represent these recurring patterns using the OWL semantic web knowledge representation language, and use these patterns to evaluate the conceptual coverage of existing city ontologies and reference models.

We define a Knowledge Pattern (KP) as a description of some structure (i.e., a set of domain specific inter-realted concepts and attributes) that frequently recurs together in the data. Our definition differs from the classical definition of KP, which (Clark et al., 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 in ontology design and other stages of ontology lifecycle (Gangemi & Presutti, 2009).

To develop the City Knowledge Patterns, we explored the Toronto 311 knowledgebase webpages. 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 (through a sampling process) analyze the Knowledgebase 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 knowledge components. The components are selected based on their importance and frequency in the sampled webpages.

To our knowledge, this is the first work that attempts to extract knowledge patterns from data as a tool (formal competency question) in ontology engineering in general, and in the city government domain in particular.

1.1. Summary of Contribution

The three main contribution of this dissertation are:

1. Identifying City Knowledge Patterns from the Toronto 311 knowledgebase as a basis for determining the concepts that must be represented in a reference model or an ontology in the municipal domain. We identify nine different patterns of recurring municipal knowledge.
2. Providing a description logic representation of the patterns, which we implemented using the Ontology Web Language (OWL).
3. Evaluating the conceptual coverage of four existing government ontology/reference models using the City Knowledge Patterns, i.e., each model's

content cover of the concepts and attributes identified in the City Knowledge Patterns.

1.2. Overview of Dissertation

The outline of the thesis is as follows:

Chapter 2 provides background information for the dissertation and looks at the literature relevant to our research. In this chapter, we present a review of government standards and reference models, as well as ontologies and semantic models in the e-government domain. We also provide a brief review of ontology evaluation methods.

In Chapter 3, we introduce the nine City Knowledge Patterns. For each pattern, we present a set of motivating examples to highlight the important characteristics of the pattern. Then, based on these characteristics, we formally introduce the pattern and provide a description logic representation of it.

In Chapter 4, by employing the City Knowledge Patterns, we informally evaluate the conceptual coverage of four established ontologies/reference models in the municipal government domain. For each model, we present a brief overview of the model and provide a comprehensive analysis of their characteristics based on various knowledge components defined in the City Knowledge Patterns. To our knowledge, this is the first data-driven, scenario-based method to evaluate ontologies/reference models in the field of e-government.

Chapter 5 concludes this dissertation by re-stating its main contributions and suggesting some areas for future work.

Chapter 2

Literature Review

As one of the goals of this dissertation is to determine the competency of existing city knowledge representations (both formal and informal), we present a review of government standards and reference models, as well as ontologies and semantic models in the e-government domain. In the first section, existing government standards and reference models are reviewed. Then, an overview of government ontologies is presented. Finally, we review the state of the art in domain ontology evaluation.

2.1. Government Standards and Reference Models

During the past few years, information and communication technologies have been adopted by governments for provision of public services and to improve public administration efficiency (Vassilakis & Lepouras, 2006). However, over time, different government departments and agencies have developed their own way of organizing information technology services, and their own terminology for describing them (Government Strategic Reference Model (GSRM), 2007). To address these issues, governments such as Canada, USA, and UK, have developed reference models and standards to create a common vocabulary among their different entities and organizations.

In general, a Reference Model (RM) describes common concepts and relationships in a specific domain. It is an abstract representation of the entities and relationships involved in a problem space and forms the conceptual basis (not directly tied to any standards, technologies or other concrete implementation details) for the development of more concrete models of the domain (Paschke & Vincent, 2009).

Its main goals are (Hodgson & Allemang, 2006): (i) to eliminate redundant investments in IT capabilities, business processes, or other capital assets; (ii) to increase efficiency by leveraging reusable business processes, data, and IT-components across agencies; and (iii) to identify common business functions across agencies.

We next provide a review of the main government RMs.

Federal Enterprise Architecture Reference Model (FEA-RM) (*Federal Enterprise Architecture*, 2004): FEA-RM was first published in 2004. Its goal is to facilitate cross-agency analysis to identify duplicative investments, gaps, and opportunities for collaboration within and across federal agencies. FEA-RM consists of five interrelated "reference models" (See Figure 2.1). Collectively, the reference models comprise a framework for describing the important elements of the FEA in a common and consistent way. The five reference models are:

a. *Performance Reference Model (PRM):* "The PRM is a reference model for performance measurement, providing common output measurements throughout the federal government" (*Federal Enterprise Architecture*, 2004). This reference model aids federal government agencies to measure the success of their IT investments and its impact on strategic outcomes of the federal government. They achieve this goal by creating a common language (i.e., Enterprise Architecture) in which each agency can describe its outputs and objectives. This is achieved by defining three different categories of the Measurement Area, Measurement Category, and Measurement Indicator hierarchy.

   For instance, the Measurement Area (MA) category consists of different areas such as: Mission and Business Results MA, Customer Results MA, Processes and Activities MA, Technology MA, Human Capital MA, and Other fixed Assets MA. Each of these MAs define a set of Measurement Categories, e.g., Technology MA consists of Technology Costs, Quality Assurance, Efficiency, Information and Data, Reliability and Availability, and Effectiveness Measurement Categories. Finally, for each sub-category the agencies define a set of measurement grouping, e.g., for Technology Cost Measurement Category the

MA defines Overall Costs, Licensing Costs, Support Costs, Operation and Maintenance Costs, and Training and User Costs as the Measurement Grouping, which helps agencies in defining different Measurement Indicators.

b. *Business Reference Model (BRM):* "The BRM provides a framework to facilitate the functional (not organizational) view of the federal government's lines of business, including its internal operations and its services for citizens, independent of the agencies, bureaus and offices performing them" (*Federal Enterprise Architecture*, 2004).

   The BRM structure has a three-layer hierarchy: Business Areas, Lines of Business, and Subfunctions layers. Business Areas segregate the operations of the government into partions that connects the purpose of government (e.g., defense and national security, natural resources, law enforcement, and economic development), the mechanisms used to reach its purpose (e.g., direct service for citizen, knowledge creation and management, credit and insurance, and regulatory compliance and enforcement), and the necessary support functions to perform these operations (e.g., public affairs, revenue collection, legislative relations, and general government). The Business Areas layer is itself broken down into different Lines of Businesses, which includes a set of Sub-functions that represent the lowest level of the BRM.

c. *Service Component Reference Model (SRM):* "The SRM is a functional framework classifying service components according to how they support business and performance objectives. It serves to identify and classify horizontal and vertical service components that support federal agencies and their IT investments and assets" (*Federal Enterprise Architecture*, 2004).

   SRM is comprised of service domains, their types, and components. Service domains have seven high-level service categorizations: customer, process automation, business management, digital asset, business analytical, back office, and support services. Each of theses service domain conatian a set of service types, which provide a categorization of service components related to the service

domain. For example the customer service domain consist of customer relationship management, customer preferences, and customer initiates assistance service types, and each of these types also consist of set of service component, e.g., customer relationship service type consist of call center management, customer analytics, sales and marketing, and product management service components.

d. *Technology Reference Model (TRM):* "The TRM is a component-driven, technical framework categorizing the standards and technologies to support and enable the delivery of Service Components and capabilities. It also unifies existing agency TRMs and E-Gov guidance by providing a foundation to advance the reuse and standardization of technology and Service Components from a government-wide perspective."(*Federal Enterprise Architecture*, 2004).

   The TRM consist of different service areas (Service Access and Delivery, Service Platform and Infrastructure, Component Framework, and Service Interface and Integration), each aggregating the standards and technologies into lower-level functional areas and service categories. For example, the Service Access and Delivery area consists of the following subcategories: (i) The Access Channels category which contains components such as Web Browser, wireless/PDA, collaboration/ communicatins, and other electric channels; (ii) the Delivery Channels category with components such as Internet, Interanet, Extranet, peer to peer (P2P), and Virtual Private Network (VPN); (iii) the Service Requirements category with components such as legislative/ compliance, authentication/single sign-on, hosting; and (iv) the Hardware/ Infrastructure category with components such as assupporting network services and service transport.

e. *Data Reference Model (DRM)* "The DRM is a flexible and standards-based framework to enable information sharing and reuse across the federal government by the standard description and discovery of common data and the promotion of uniform data management practices. It provides a standard means by which data may be described, categorized, and shared." (*Federal Enterprise Architecture*,

2004) .

The DRM has three categories to structure data usage: (i) Data Description which provides a means to describe data; (ii) Data Context which facilitates discovery of data by categorizating data according to taxonomies; and (iii) Data Sharing that supports the access and exchange of data, i.e., by supporting ad-hoc requests and exchange of fixed, re-occurring transactions of data between different parties.

Note that the FEA-RM is developed for the federal government, and thus does not contain some of the main elements of the municipal government.

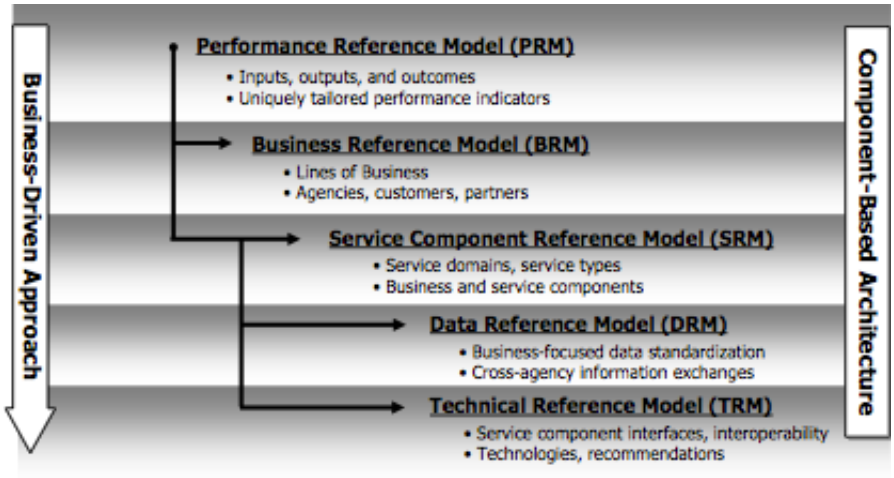


Figure 2.1:FEA Reference Model

Government Enterprise Architecture (GEA) (Peristeras & Tarabanis, 2004b): GEA is a generic government domain model for public administration. It consists of five high-level models: (i) the GEA Mega-Process Model of the Overall Governance System; (ii) the GEA Interaction Model of the Overall Governance System; (iii) the GEA Public Policy Formulation Object Model; (iv) the GEA Service Provision Object Model; and (v) the GEA Object Model for the Overall Governance System.

Since GEA is one of the pioneers RMs in the government domain, and is a model that has been implemented, we select it as one of the models in our comparative study in Chapter 4. Therefore, we defer a comprehensive description of GEA and its models to Section 4.1.

Municipal Reference Model (MRM) (*MRM Model Principles, Definitions, and Rules*, 2011)**:** MRM is a set of core concepts and tools that can help municipalities define and describe their businesses in terms of the programs and services that they provide, i.e., in terms that are most meaningful to municipal clients, residents, taxpayers and stakeholders. These core concepts are: Service, Program, Output, Service Value, Outcome, Need, Target Group, Process, and Organization Unit.

MRM is developed based on the Government Canada Strategic Reference Model (Since 1990), and is compatible with both Service Oriented Architecture (SOA) and the Enterprise Architecture (EA) standards (*Canadian Governments Reference Model (CGRM)*, 2009), (*Government of Ontario IT Standard (GO-ITS)*, 2010).

Since MRM is one of the few RMs designed specifically for the municipal government domain, we select it as one of the models in our comparative study in Chapter 4. Thus, similar to GEA, we postpone a comprehensive description of MRM to Section 4.2.

All the government RMs mentioned above are written in the form of natural language (human- readable document). Such representation has the advantage of being read or modified by domain experts or knowledge engineers. Disadvantages of this form of representation, however, are: (i) it is highly ambiguous, subjective, and is prone to errors; and (ii) an automated agent is not able to understand or interpret the content. To address these issues, researchers have focused on developing a formal representation of different government RMs (i.e., government ontologies). In the next section, we provide a review of some of the main ontologies in the government domain.

2.2. e- Government Ontologies and Semantic Models

As indicated above, researchers have developed government ontologies to provide an unambiguous (or at least less ambiguous) representation of RMs. An ontology is a formal description of a set of objects, concepts, and other entities that are assumed to exist in a domain of interest along with their properties and the relationships that hold among them (Gruber, 1995). It forms a shared terminology for the objects in that domain, along with definitions for the meaning of each of the terms (Fadel, et al., 1994).

Government ontologies can be classified into three categories (Unas, 2000): core ontology, domain ontology, and application ontology. Core ontologies include the concepts common to all domains, e.g., time and process. Domain ontologies define the concepts specific to a domain, e.g., government service and government organization. Finally, application ontologies describe the concepts and their relationships related to solving a particular application.

We next briefly review the main government ontologies in the literature.

Federal Enterprise Architecture Reference Model Ontology (FEA-RMO) (*Federal Enterprise Architecture Reference Model Ontology*, 2004)**.** The disadvantages of RMs in general (see Section 2.1), and FEA-RM in particular, led to the development of FEA-RM ontology. FEA-RMO is a number of ontologies that formalizes FEA Reference Models by using W3C standard language (OWL). Moreover, its architecture is identical to that of FEA-RM, i.e., the Performance Reference Model organizes the overall architecture, making reference to the other models as needed; the Business Reference Model draws upon the Service Reference Model, the Data Reference Model and the Technical Reference Model, where each model is implemented as a series of instance/class patterns. FEA-RMO also contains the FEA Core Ontology, where concepts and properties common to all the reference models are defined (Hodgson & Allemang, 2006). The Table 2.1 indicates some of the concepts used in the FEA-RMO and Figure 2.2 represent a schematic of the upper level concepts of the FEA-RMO ontology and its properties.

Models	Ontology	Example Concepts
Performance Reference Model	PRM	Measurement Area (Customer result, process and activities, etc) Measurement Category (Quality assurance, Financial, service coverage) Generic Indicator (each agency has its own indicators)
Business Reference Model	BRM	Business Area (Homeland security, disaster management, energy, etc.) Line of Business (Knowledge creation and management, Regulation, etc.) Sub-function (Research and development, permit and licensing, etc.)
Service Reference Model	SRM	Service Domains (Customer service, digital asset, support service,etc.) Service Type (visualization, human capital, work force, etc.) Component (license management, remote access control, etc.)
Technology Reference Model	TRM	Service Area (Access channels, hardware/infrastructure, Service Category (database storage, delivery channel, etc.) Service Standard (Security, data intecgange,etc.) Service Specification (integration, interoperability, etc.)
Data Reference Model	DRM	Data sharing, data context, data description, etc.

Table 2.1: FEA-RMO Ontologies

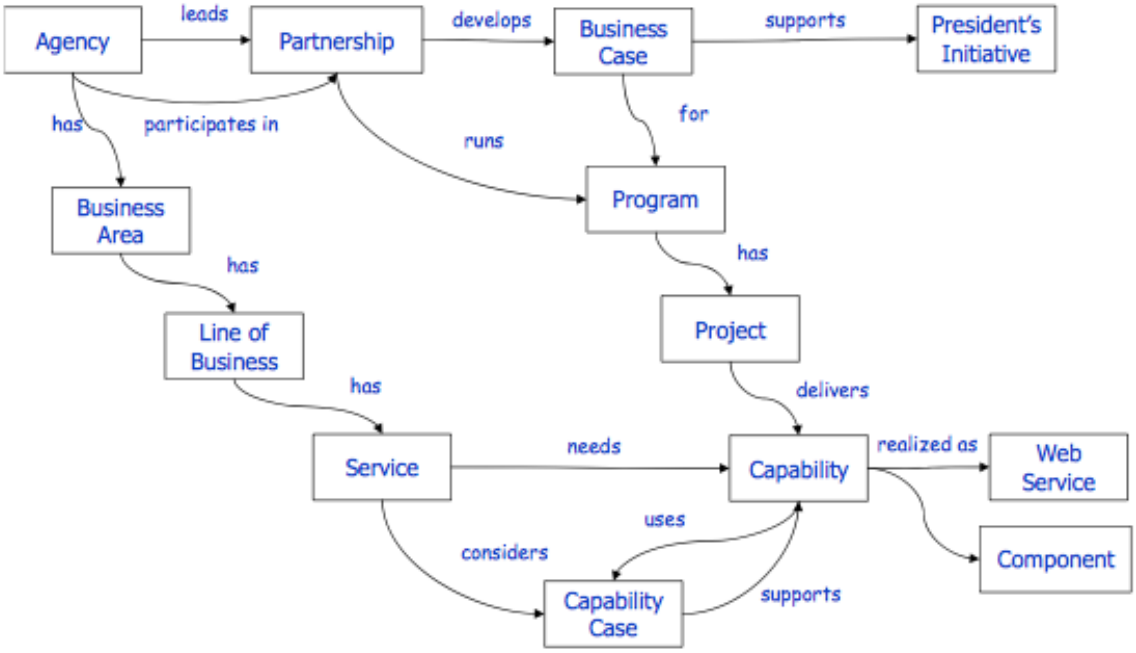


Figure 2.2: FEA-RMO ontology of the Federal Enterprise Architecture

Government Enterprise Architecture Ontologies: Using the GEA reference model, Goudos, Loutas, Peristeras, and Tarabanis develope two different ontologies for public adminstration operation. The first model, employs the Web Service Modeling Ontology (WSMO) to define a formal model for public administration services of the GEA RM(Goudos et al., 2007). In the second model, on the other hand, based on the GEA RM object model, they present a top-level public administration domain ontology using the Web Ontology Language (OWL) (Goudos et al., 2007). Figure 2.2 depicts the upper level concepts and attributes of these ontologies.

Figure 2.3: GEA Upper Level Object Model Ontology

Scribe Ontology (Uceda-Sosa et al., 2011)**.** The Scribe ontology is a sematic model of data in smart cities. The model is designed to provide real time solution for complex situations (in both municipal service delivery and service administration) under large and dynamic data. Since Scribe is the only ontology developed and design to administrate dynamic aspect of city services, and is designed based on real data and scenarios collected from different cities, we have select it as one the models in our comparative evaluation in Chapter 4. Therefore, we defer a comprehensive description of Scribe to Section 4.4.

ontoGov (Tambouris et al., 2004). The ontoGove project is a semantics-based platform for the consistent composition, re-configuration and evolution of e-government services. Based on the analysis of Semantic Web Services (i.e. OWL and WSMO), the model defined a meta-ontology cluster that contains general ontologies that may be used for describing e-Government services and do not change from one deployment to another. It consists of the following ontologies:

- ***Legal Ontology:*** defines the structure of the legal documents, which includes paragraphs, sections, amendments, etc.
- ***Organizational Ontology:*** models an organization by defining its organizational units, roles, persons, resources etc.
- ***Lifecycle Ontology:*** comprises of instances of all decisions relevant for the new service, including instances of the legal and organizational ontologies.
- ***Domain Ontology:*** contains domain specific knowledge.
- ***Service Ontology:*** describes the elements for modeling the service flow. It includes the Domain Ontology for defining inputs and outputs, as well as the Lifecycle Ontology for explaining reasons that motivate the decisions.
- ***LifeEvent Ontology:*** models the categorization of the e-Government services.
- ***Profile Ontology:*** contains metadata about e-Government services and includes all previously mentioned ontologies.

The Profile Ontology and the Service Ontology are defined based on the OWL-S ontologies by taking into account the e-Government specificities (e.g., reference to the laws or legislations that are modeled in the Legal Ontology*)*. The Domain Ontology defines the vocabulary used in the government domain (e.g. type of documents such as passport). The Organization Ontology is defined to model the experiences from the business process modeling and reengineering. The LifeEvent Ontology is specific for the e-Government domain and supports government services inquiries. The Lifecycle Ontology is defined to assist the domain expert with the changes in the service description, as well as to document the reasons for these changes (Apostolou et al. 2005).

The main drawbacks of ontoGov are: (i) it is semi-automated and domain expert dependent (i.e., for every new service created in the system, or every change in one of the current government services, the domain expert must manually perform a set of activities to update the system). Such dependencies can increase the system failures (e.g., human errors), slow the automated process, and increase the judgmental modification of the government services and processes, and (ii) another important drawback of the ontoGov framework is its presumption that comprehensive and well develop ontologies for legal,

domain, organization, and profile exist. However, we could not find such ontologies, their taxonomies, or their lexicon in the ontoGov framework.

TERREGOV (*Terregov Project*, 2011)**.** Terregov is a European integrated project that aims to enhance e-government services. Its main goals are: (i) to provide a simple terminology that allows indexing of the textual documents, and constitute the data, based on local agencies information; and (ii) to facilitate the discovery of web services that are published in different directories. Specifically, the TERREGOV project addresses the issue of inquiring the related information for the local European civil servants in the Social Care domain. It enables the civil servants to access all information sources (e.g., knowledge base, domain expert or others civil servant). The TERREGOV framework proposes a simplified syntax (SOL) allowing development of multilingual centralized ontologies, which aims to address some of the short comes of OWL. It also describes an OWL identifier corresponding to the concepts and properties defined using SOL formalization. Moreover, TERREGOV uses OWL-S for its Semantic Web communication between different civil agents.

While TERREGOV claims to solve the problem of mutilinguality between European countries, and thus the challenges of building a comprehensive ontology for them; it still does suggest development of a local core ontology for each of the local Civil Service providers, without discussing their development methodologies, intended models, or their concepts, attributes and dependencies. (Bettahar, et al., 2009).

SmartGov (Tambouris et al., 2002)**.** The aim of the SmartGov project is to specify, develop, deploy and evaluate a knowledge-based platform to assist public sector employees generate online transaction services. It presents an ontology for transaction services based on the Enterprise Ontology (Uschold et al., 1998). Specifically, it extends the Enterprise Ontology by adding government domain related concepts, attributes, and properties (Adams et al., 2002) (e.g., concepts such as mandate, elect, and transparency). Figure 2.3 depicts a schematic model of the SmartGov framework. Note that while SmartGov has an extensive taxonomy, i.e., defining various entities, relationships, roles, and attributes, it does not provide a formal representation of the taxonomy. Thus, it is not

clear if the ontology is consistent with its intended model.

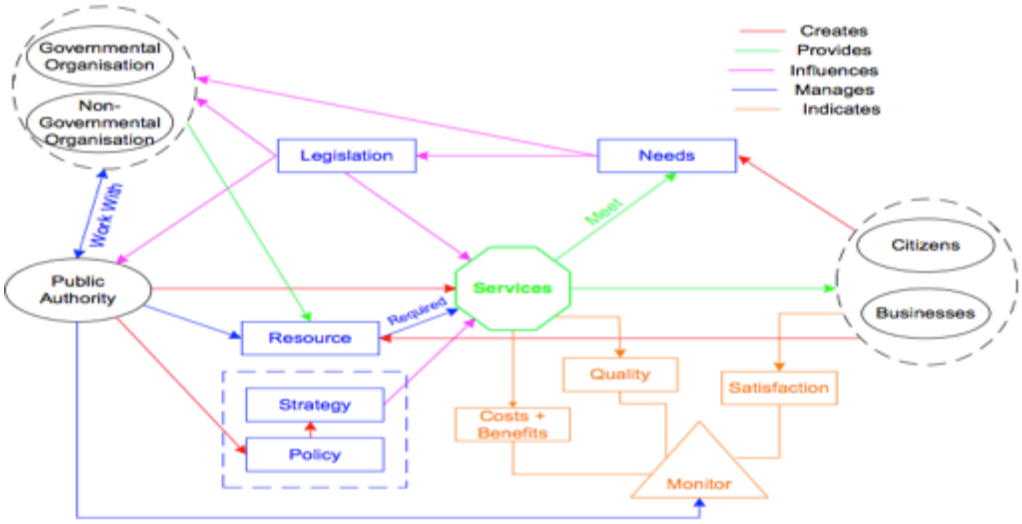


Figure 2.4: SmartGov Framework

e-Government Transformation Project Management (eGTPM) (Sarantis et al., 2010)**:** eGTPM ontology is comprised of the main concepts needed to efficiently manage e-Government project processes. It aims to increase interoperability and knowledge usage between all stakeholders and entities in the implementation of a specific project (Sarantis et al., 2009). By employing a goal orientated and dynamic enterprise modeling principle, eGTPM facilitates communication and collaboration among various parties in order to identify project needs and requirements. The ontology consists of three sub-ontologies, representing the knowledge from three different aspects: (i) knowledge about the e-Government project type, (ii) knowledge about the e-Government management procedure, (iii) and knowledge about the e-Government stakeholders. Figure 2.4 depicts the framework and high-level concepts and relationships of the eGTPM ontology.

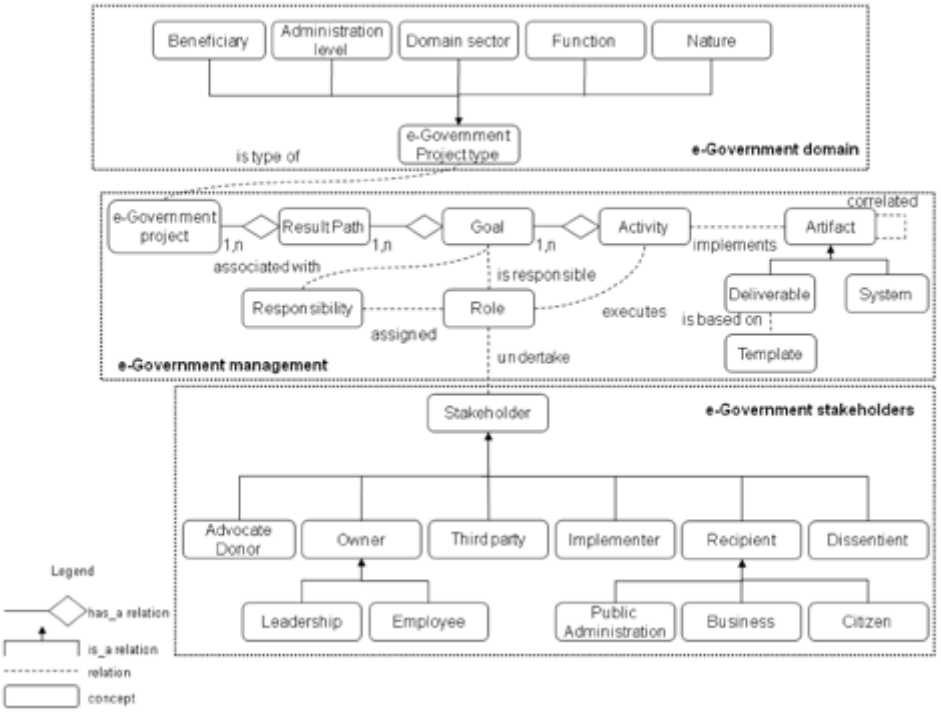


Figure 2.5: E-Government Transformation Project Management (eGTPM) Ontology

QeGS ontology (Magoutas et al. 2007)**.** QeGS ontology formalizes the required knowledge for the realization of a multi-perspective and adaptive evaluation of e-government services. This quality ontology creates a basis for the construction of future public service systems evaluation based on an ontological approach. The QeGS ontology is a three-layer ontology, consisting of 122 concepts, 50 properties and 160 restrictions. It is formalized using OWL. Each layer of this ontology contains different level of abstraction concerning the modeled concepts and relations between them. The purpose of the top layer ontology is to define a minimal set of high-level concepts and relations that are needed to describe the notion of quality of service (shown in Figure 2.5). The middle layer ontology models quality aspects related to e-government services using quality metrics system. Finally, the third is domain-specific, which aims to support the different configurations of e-government portal systems (Magoutas et al., 2007).

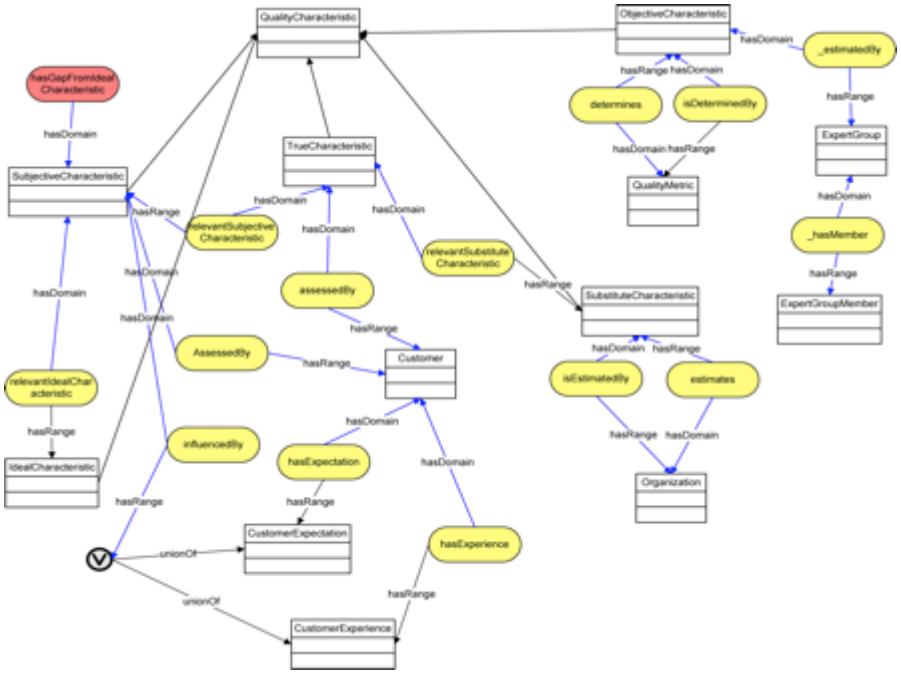


Figure 2.6: QeGS Top Layer Ontology

Note that despite the importance of the domain specific layer (i.e., its role in configuring different services provided in various e-government portals), as well as its role in configuration of its upper level ontology, the framework does not provide a comprehensive discussion of it, thus raising concerns regarding its consistency and incompatibility with the other two layers.

In addition to the models discussed above, other application ontologies for the municipal domain have been developed. These ontologies focus on specific aspect of municipalities. Examples of such ontologies are: Rijeka (Mauher & Smokvina, 2008), which is a municipal asset and property management system for the Web Collaborative Environment; and Towntology (Keita et al., 2004), which is a domain ontology for the Urban Civil Engineering projects.

Except FEA-RMO and Scribe, all the other ontologies mentioned above utilize or extend one or more core ontology (e.g., time, service, and organization ontologies) for their specific framework. Moreover, ontologies such as SmartGov have used a generic enterprise ontology, which is itself comprised of a set of core ontologies, i.e., Enterprise

Ontology (Uschold et al., 1998) is comprised of time, activity, organization and etc. Another established generic enterprise ontologies is TOVE (Fox & Gruninger, 1998). TOVE consist of three different layers (Grunninger, 2003): (i) The Core ontologies that capture the generic characteristics of the enterprise (e.g., activity, organization, and resource ontologies); (ii) The derivative ontologies that are specializations of various classes within some of the Core ontologies (e.g., goal ontology is a specification of the goal class defined in the organization ontology) or a derivative ontology of multiple core ontologies (such as scheduling ontology which is a derivative ontology of both Time/Activity and Resource ontology); and (iii) The Enterprise ontologies, which are used to define classes of enterprises. TOVE is chosen as one of the models in our evaluation in Chapter 4 to assess the usability and extendibility of generic enterprise ontologies for the municipal government domain. Therefore, in Section 4.3, we present a comprehensive description of it.

Note that all the above models and ontologies claim to be able to model all or parts of the government domain with some level of formality. Moreover, as indicated above, many of these models reuse and/or extend existing ontologies. According to Gomez (Gómez-Pérez, 2001): " it is highly recommended that if someone intended to reuse an existing ontology to build a new ontology, or to implement an application that relies on ontologies written by others one should first evaluate and assess it". Thus in the next section we briefly discuss the current ontology evaluation methods that can be used to evaluate government ontologies.

2.3. Ontology Evaluation

To evaluate ontologies, Gomez (Gómez-Pérez, 2004) introduces the following two concepts:

- *Ontology verification* deals with building the ontology correctly, i.e., ensuring that its definitions implement correctly the requirements.

- *Ontology validation* refers to whether the meaning of the definitions really models the real world for which the ontology was created. [1]

There are many different approaches for ontology validation. These approaches include: the alignment with upper level ontologies for evaluation purposes, human assessment, natural language evaluation techniques, using reality as a benchmark, comparing ontology with a golden standard, or an application-based approach (Obrst, Ceusters et al., 2007), (Brank et al., 2005) . However, most validation approaches require the close cooperation of domain and ontology engineering experts, and even in those cases validation often can not be performed automatically (Vrandečić, 2009).

While many evaluation methods are developed and are tested for the evaluation of generic ontologies (Gruninger, 1996), (Porzel & Malaka, 2004), (Brewster et al., 2004), no recommended methodology exist that can specifically evaluate the accuracy, adoptability, clarity, or completeness, of domain specific ontologies (e.g., government, healthcare, or medication) as well as informal representation of these domain. The evaluations in these cases are mostly manual and based on cooperation of domain expert and ontology engineers. This approach is ambiguous, subjective, and time consuming.

One of the few well established and systematic approaches that address the issue of necessity and sufficiency of an ontology for a specific domain is Grüninger & Fox, 1995. This methodology introduces the concept of *Competency* questions in ontology design and evaluation. Grüninger and Fox (1995) propose the following steps to design and evaluate an ontology:

"Motivating Scenario: any proposal for a new ontology or extension to an ontology must describe the motivating scenario and the set of intended solution to the problem;

[1] For a comprehensive review of ontology validation, the readers is refereed to (Obrst, Ceusters, Mani, Ray, & Smith, 2007), and see (Vrandečić, 2009) for a comprehensive review on ontology verification.

Informal Competency Questions: given the motivation scenario, a set of queries will arise which place demands on an underlying ontology;

Specification in First-Order-logic-Terminology: once the informal competency questions have been posed for the proposed new or extended ontology, the terminology of the ontology must be specified using first-order logic;

Formal Competency Question: after the informal competency question have been posed and the terminology of the ontology has been defined, the competency questions are defined formally as an entailment or consistency problem with respect to the axiom in the proposed ontology. The formal ontology questions place restriction on which axiom will be included in the proposed ontology. It is important to understand that the terminology of the ontology must include all terms of a statement for each of the formal competency questions.

Specification in First-Order Logic- Axiom: the axioms in the ontology specify the definition of terms in the ontology and constraints on their interpretation. It is important to understand that axioms specified in first-order logic is the specification of the ontology not its implementation. The process of defining axioms is one of the difficult aspects of defining ontologies. However this process is guided by the formal competency questions. As for informal competency questions, the axioms in the ontology must be necessary and sufficient to express the competency questions and to characterize their solutions; without the axioms we cannot express the question or its solutions. Furthermore, any solution to a competency question must be entailed by or consistent with the axioms in the ontology alone. If the proposed axioms are insufficient to represent the formal competency question or characterize the solutions to the questions, then additional objects and axioms must be added to the ontology until it is sufficient.

Completeness Theorems: Once the competency questions have been formally stated, conditions under which the solutions to the questions are complete must be defined. This forms the basis for completeness theorems for the ontology. Completeness theorems can also provide a means to determine the extendibility of an ontology, by making explicit the role that each axiom plays in proving the theorem." (Grüninger & Fox, 1995)

The Fox and Gruninger methodology provides a framework for evaluating the adequacy of ontologies. Such framework allows a more comprehensive evaluation of different ontologies in a specific domain by determining the competency of each ontology with respect to the set of competency questions that arises from the applications domain.

Despite the existence of such a systematic approach for ontology development, the models in the e-government domain discussed earlier have been developed without any specific methodology or created by someone who is not ontology expert. Furthermore, most of the reference models mentioned above are not formally developed, and the ones which are formalized do not follow any of the well-known ontology development methodologies. Thus, they do not have formal or informal competency questions.

Since competency questions are almost the only existing benchmark in the sense that evaluate the ontology is necessary and sufficient to represent the tasks specified for it, and almost none of the existing models in the government domain have competency questions, for their evaluation we have to identify a set of competency questions (requirements) that specify the basis characterization of the municipal government domain. This issue is one of the main motivations for developing the City Knowledge Patterns for the municipal domain.

2.4. Conclusion

In this chapter, we presented a review of the literature on formal and informal representations of government models, and highlighted their advantages and disadvantages. We also, presented a review on current methodologies in ontology evaluation.

As discussed in this chapter, each government model claims to be able to model all or part of the government. However, there does not exit a benchmark or methodology that can compare these domain specific (government) ontologies/RMs (with different representation languages, and different level of formality). In the next chapter we introduce the City Knowledge Patterns to address this issue, and to create a set of standard patterns of the knowledge components for municipal government.

Chapter 3

City Knowledge Pattern

This chapter presents city knowledge patterns that provide a formal representation of embedded knowledge components in the city of Toronto's 311 knowledgebase. These patterns can be employed to evaluate the applicability of existing ontologies and knowledge representations (both formal and informal) in public administration domain to overcome the issue of incompatibility between real data and government ontologies.

The Toronto 311 knowledgebase is a repository with more than 21,000 webpages containing information about city services, programs, events, bylaws, protocols, standards, and infrastructure. According to 311, these webpages are created either when a new service has been initiated, or when a 311-customer service representative encounters an enquiry that is not addressed in the existing knowledgebase. The major downside is that this information is represented in html, i.e., English, and is not machine readable except for display purpose. Hence this knowledgebase is lacking knowledge structure and cannot be used for semantic reasoning. For example, there are multiple pages addressing the same issue but there is no way to automatically know that they should be linked without having someone read each of the pages; or the incompatibility between page content and page keywords. These obstacles make it impossible for an automated agent to query and infer the hidden knowledge within these webpages.

Therefore, to discover different knowledge patterns in the 311 knowledgebase, we manually explored more than 500 webpages in the knowledgebase. Figure 3.1 depicts the overall percentage of the most important components discovered throughout our exploration of these web pages.

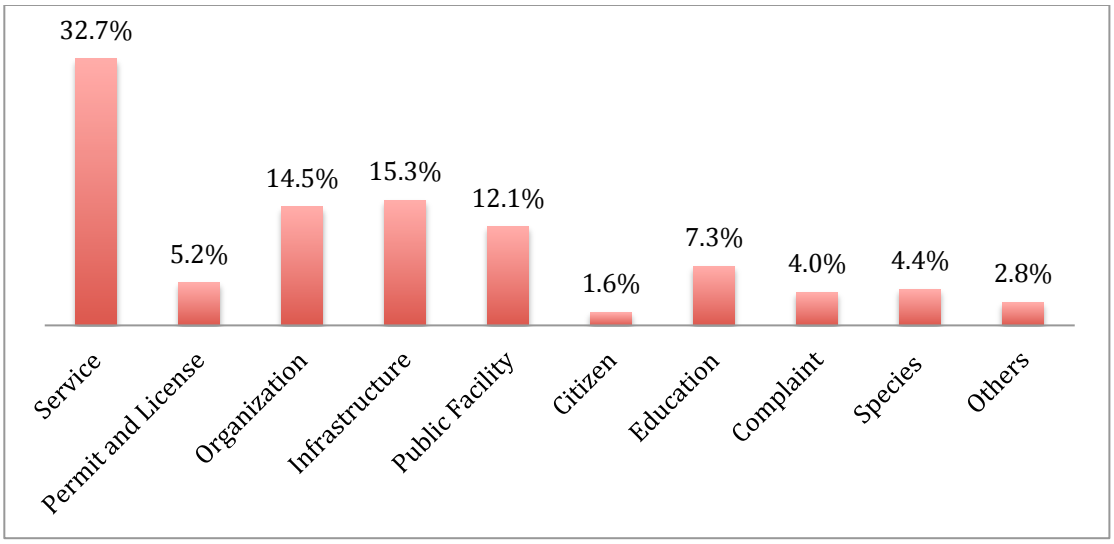


Figure 3.1:Ratio of Different Knowledge Component in Toronto 311 Knowledge base

The above statistics helped us in identifying the main knowledge patterns in the city of Toronto's knowledgebase.

3.1. City Knowledge Pattern

In this section we introduce the city knowledge patterns. For each pattern, we first provide a set of examples to highlight the important characteristics of that pattern; then based on these characteristics we formally introduce the pattern.

The knowledge patterns that we define are:

1. Service knowledge Pattern
2. Permit/License Knowledge Pattern
3. Organization Knowledge Pattern
4. Infrastructure Knowledge Pattern
5. Public Facility Knowledge Pattern
6. Citizen Knowledge Pattern
7. Education Knowledge Pattern
8. Complaint Knowledge Pattern
9. Species Knowledge Pattern

For each knowledge pattern, we explain its constituents by employing real world examples; however, for technical clarity we provide the description logic (DL) representation of each knowledge pattern. Note that we also implemented the DL representation of the knowledge patterns using OWL. For ease of exposition we present the OWL representation of the patterns in Appendix 1.

3.2. Service knowledge Pattern

In this section we define and introduce the service knowledge pattern (SKP). We start by defining the concept of service in public administration domain. Then, through a set of examples we demonstrate the pattern of existing services in the city domain. Finally, we formally introduce the SKP framework.

According to Statistic Canada, local, municipal, or regional public administration is defined, as "subsector comprises establishments of local governments primarily engaged in activities of a governmental nature, such as legislative activities, taxation, public order and safety, and the administration of local government programs"[2]. Furthermore, the Municipal Reference Model (MRM) (see Chapter2) defines government programs, as "a Program is a mandate to achieve outcomes by delivering services"(*MRM Model Principles, Definitions, and Rules*, 2011) (Government Strategic Reference Model (GSRM), 2007). In MRM, service is defined as either a "Public Service", which serves members of the public directly and address needs that are classified by public programs; or an "Enabling Service", which serves organizations that are part of, or agents of, the government and address needs that are classified by **provider** program (*MRM Model Principles, Definitions, and Rules*, 2011) (*Canadian Governments Reference Model (CGRM)*, 2009). Between these two definitions, public service is of utmost importance since it is designed to address public needs and to aid local government in achieving their goals. Moreover, public services and their quality are often used as an evaluation measure for cities in different global and national rankings.[3] [4]

---

[2]http://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVDDetail&db=imdb&dis=2&adm=8&TVD=118464&CVD=118466&CPV=913&CST=01012012&MLV=5&CLV=2&CHVD=118467&D=D

[3]http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=535adce9014df310VgnVCM10000071d60f89RCRD

It is noteworthy that the statistics we provided earlier in this section also highlight the importance of public service in the city domain, i.e., more than 35% of webpages in this knowledgebase are service oriented.

1.2.1 Service in Toronto 311 Knowledgebase

Recall that the Toronto 311 knowledgebase is a cumbersome knowledge repository due to its lack of machine-readable content and huge body of data, which contains information about city services and programs. These services vary in type and are provided by different city divisions or business partners, e.g., waste management, public safety, healthcare, and transportation. To highlight the main elements of service we provide the following examples.[5]

Case1: Residential Bulky Item Collection[6]

The first case we consider is the bulky item collection service. This service is a part of the city of Toronto's waste management program, which deals with collecting oversized items from residential household.

To show the main service components in the bulky item collection service, we have chosen two webpages depicted in Figure 3.2 and Figure 3.3. Figure 3.2 shows a webpage that contains the requirements needed to be eligible to get bulky items removal service, while Figure 3.3 show a webpage that addresses reasons under which bulky item removal service will not be provided. However, while these two webpages where designed for different purposes, the majority of their content overlap.

Such duplication raises question about the efficiency of the knowledgebase, its information structure, and the representation of service component in the knowledgebase.

---

[4]http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=da70dce9014df310VgnVCM10000071d60f89RCRD&vgnextchannel=535adce9014df310VgnVCM10000071d60f89RCRD&vgnextfmt=default

[5] To see the complete list of webpages surveyed in this research see Appendix II

[6] http://www.toronto.ca/311/knowledgebase/89/101000050989.html

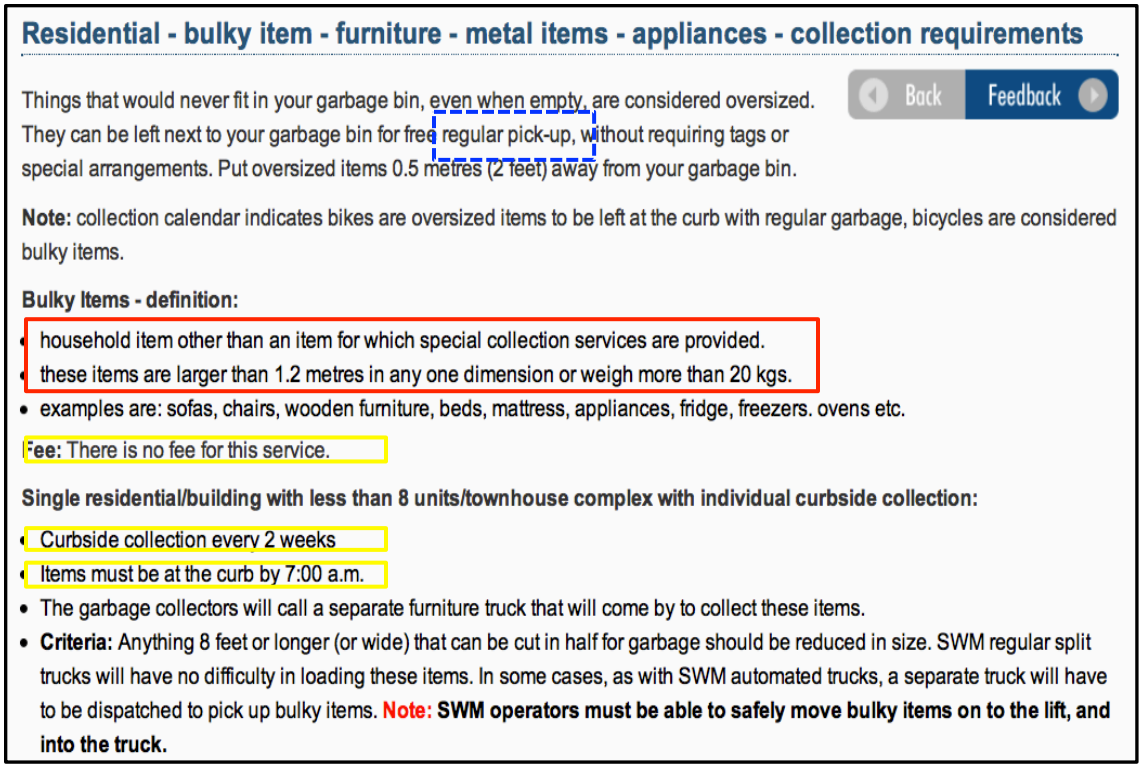
Despite these downsides, these webpages contain valuable information about different service components. In the rest of the section, we will highlight and discuss these components and their importance.

The red boxes in both figures provide similar definitions for bulky items. Like any service, bulky item collection has some constraints (conditions) under which the service will be provided. The yellow boxes in the two figures highlight these constraints, e.g., constraints such as, size, fee, and time interval of the service delivery (every two week), collecting time, and the location to place items.

Once the constraints are fulfilled, the pick up activity takes place. In the figures, this pick up activity is highlighted by the dashed blue boxes. Activities such as pick up are the only interaction between the service provider (city agent) and service requester (resident). Such activities are the core elements of city services. Moreover, their preconditions, characteristics, and outcomes do not change regardless of the context they are used in.

In both figures, the pick up activity occurs on a predefined schedule, and uses some of the city's resources (city agent and vehicle) to deliver the service. If for any reason the pick up activity does not occurred (outcome), depicted by the green box in the Figure 3.3, residents could trigger this activity by either submitting an online request or by contacting 311 customer service representatives to request for the pick up activity recurrence.

Figure 3.3 also contains another interesting component in city services. As can be seen in the black boxes, the resident has the option to choose between two different service alternatives: morning or night collection, where each alternative has its own constraints. Such content has never been considered in any service modeling.



Residential - bulky item - furniture - metal items - appliances - collection requirements

Back Feedback

Things that would never fit in your garbage bin, even when empty, are considered oversized. They can be left next to your garbage bin for free regular pick-up, without requiring tags or special arrangements. Put oversized items 0.5 metres (2 feet) away from your garbage bin.

Note: collection calendar indicates bikes are oversized items to be left at the curb with regular garbage, bicycles are considered bulky items.

Bulky Items - definition:

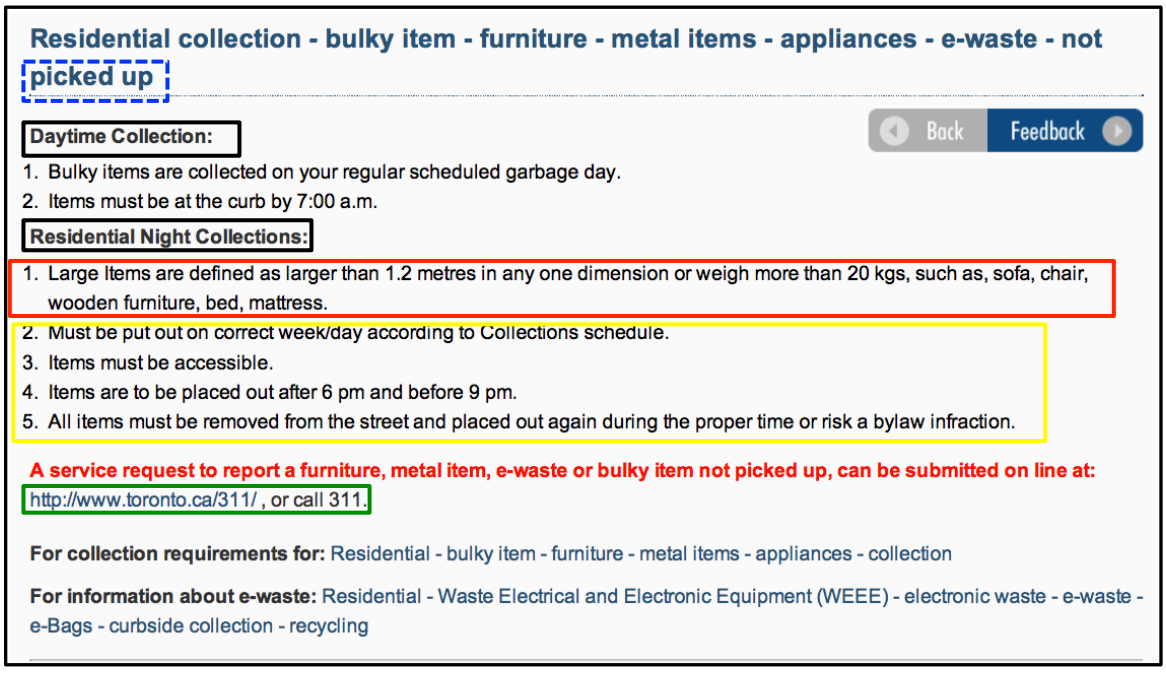
- household item other than an item for which special collection services are provided.
- these items are larger than 1.2 metres in any one dimension or weigh more than 20 kgs.
- examples are: sofas, chairs, wooden furniture, beds, mattress, appliances, fridge, freezers. ovens etc.

Fee: There is no fee for this service.

Single residential/building with less than 8 units/townhouse complex with individual curbside collection:

- Curbside collection every 2 weeks
- Items must be at the curb by 7:00 a.m.
- The garbage collectors will call a separate furniture truck that will come by to collect these items.
- **Criteria:** Anything 8 feet or longer (or wide) that can be cut in half for garbage should be reduced in size. SWM regular split trucks will have no difficulty in loading these items. In some cases, as with SWM automated trucks, a separate truck will have to be dispatched to pick up bulky items. **Note: SWM operators must be able to safely move bulky items on to the lift, and into the truck.**

Figure 3.2:Residential Bulky Item Collection Example1



Residential collection - bulky item - furniture - metal items - appliances - e-waste - not picked up

Back Feedback

Daytime Collection:

1. Bulky items are collected on your regular scheduled garbage day.
2. Items must be at the curb by 7:00 a.m.

Residential Night Collections:

1. Large Items are defined as larger than 1.2 metres in any one dimension or weigh more than 20 kgs, such as, sofa, chair, wooden furniture, bed, mattress.
2. Must be put out on correct week/day according to Collections schedule.
3. Items must be accessible.
4. Items are to be placed out after 6 pm and before 9 pm.
5. All items must be removed from the street and placed out again during the proper time or risk a bylaw infraction.

A service request to report a furniture, metal item, e-waste or bulky item not picked up, can be submitted on line at: http://www.toronto.ca/311/ , or call 311.

For collection requirements for: Residential - bulky item - furniture - metal items - appliances - collection

For information about e-waste: Residential - Waste Electrical and Electronic Equipment (WEEE) - electronic waste - e-waste - e-Bags - curbside collection - recycling

Figure 3.3:Residential Bulky Item Collection Example 2

Case 2: Non-Emergency Ambulance Transfer[7]

In the case 2 we introduce non-emergency ambulance transfer service. City of Toronto's Emergency Medical Services (EMS) division provides the service. This service is designed for transferring patients, who have unstable conditions and need special medical attention during transport, from one care facility or hospital to another.

We have chosen the non-emergency ambulance transfer service web page, as depict in Figure 3.4, to highlight the service components we discussed in case 1 and reemphasize the similarities of knowledge components for city services across all service domains.

The dashed red box in the Figure shows the service provider's division. As in bulky item collection, the non-emergency ambulance transfer is also provided by one of the city of Toronto's divisions, Emergency Medical Services Division.

The activity in this service page is to transfer the patient, the blue dashed box in the Figure depicts the activity. This activity is an instance of complex activities, which are composed of simple activities such as request service, dispatch ambulance, pick up patient, transport patient, and drop off patient at the destination.

We have used yellow colored boxes in the Figure 3.4 to highlight different constraints (conditions) in this example. The conditions are different from ones in the bulky item collection example; however, as was in case 1, for patient transfers activity to be completed all the constraints must be fulfilled. In other words, the pattern under which constraints affect the activity execution is similar for different services.

[7] http://www.toronto.ca/311/knowledgebase/97/101000043097.html

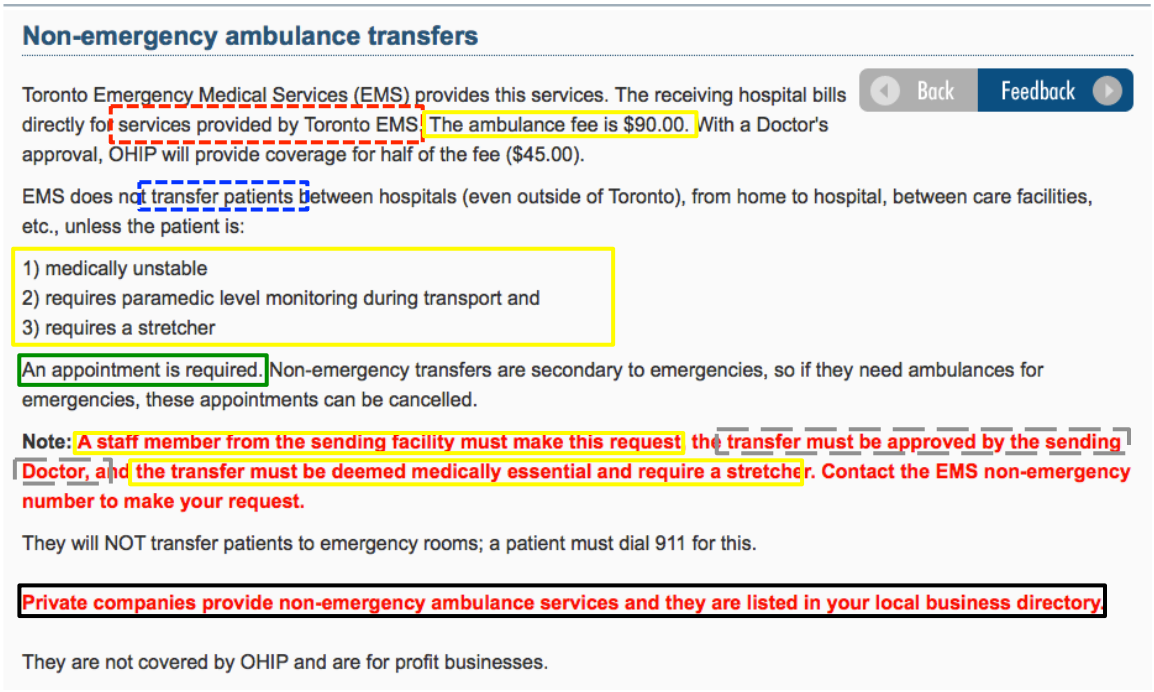


Figure 3.4:Non-Emergency Ambulance Transfer Service

Among all the constraints in non-emergency ambulance transfer service example, there is a specific condition shown in dashed gray box (Figure 3.4) that have different and yet important effect on this service. In order for the ambulance transfer service to be performed; this precondition, approving transfer by the sending facility doctor, should be fulfilled before the actual transfer process starts.

Similar to other conditions in this service the approval precondition is a necessary condition for the service; however, the difference is approval precondition is a separated process by itself and depicts a different constraint pattern from usual service conditions. We will explain the pattern of such constraints and how they affect service processes, as an approval process in the “Permit/License Knowledge Pattern”.

Another noteworthy point of the case 2 is the triggering event element of this service, as depicted in the green box in the Figure 3.4. We explained this element in the second example of case 1. While the first instance of case 1 does not need a triggering event, since picking up bulky item is a prescheduled service event recurring every two week; when one of the pick up services is missed, the resident could request a recurrence of pick up activity by one the two triggering events: call 311, or fill out an online request.

The triggering event for the ambulance request in this case is to call EMS non-emergency.

Finally, as was in case 1, there might be more than one way to perform a specific service, which we called it service alternative. Case 2 also shows a service alternative for non-emergency ambulance transfers service by suggesting private ambulance transfer option instead of EMS ambulance transfers service, shown in the black box in Figure 3.4 Some conditions of service alternative are different from the EMS non-emergency ambulance transfer. For instance, private companies who provide this service are not covered by health insurance, Ontario Health Insurance Policy (OHIP), and the patient should cover the ambulance fees by himself.

Case 3: Multi domain activities

In case 3, we have employed three different webpages from various municipal services and programs to highlight one of the most intriguing feature of city services we have observed in Toronto 311 knowledgebase webpages.

Figure 3.5 shows an emergency service request for animal pick up service. The activities to perform for this service are: submit a request, and pick up an animal; however, for simplification reasons we will only concentrate on one of the activities pick up activity, shown in the dashed blue box.

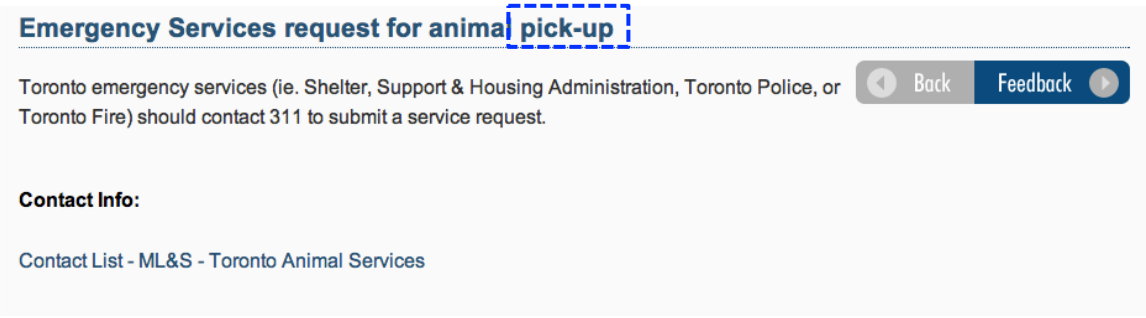


Figure 3.5:Emergency Animal Services

The second instance of this case is the TTC Wheel Trans Service, shown in Figure 3.6. This service is one of many transportation services the Toronto transportation Commotion (TTC) department provides. It is a special service for people with disabilities (Wheel Trans Service).

Figure 3.6:Transportation Disable Services

The webpage outlines locations under which this service is provided. Similar to our first example this service is also consist of a simple activity: pick up.

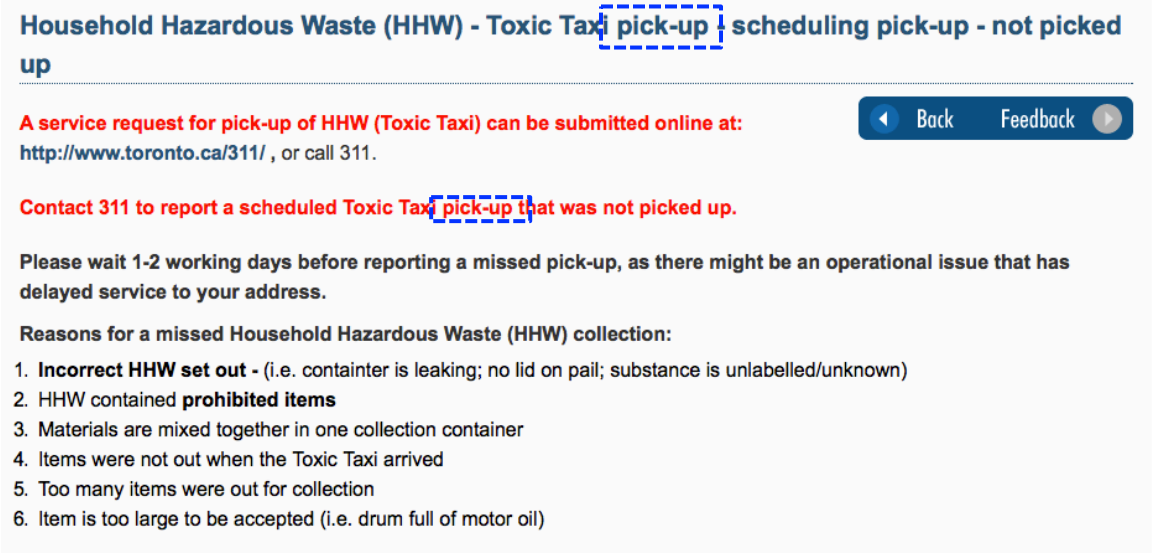


Figure 3.7: Household Hazardous Waste

The third example shows a household hazardous waste collection service webpage, Figure 3.7. The household hazardous items are waste items that contain toxic materials, and due to their toxic and harmful nature need special collection services. Although this webpage also shares components of city services we explained in case 1, and case 2; we are only emphasizing on the simple activity **pick up** for household hazardous collection as shown in dashed blue box in the Figure.

In case 3, we have employed three different examples from three different city programs: public safety, transportation, and solid waste management. As we highlighted

with dashed blue boxes for each service instance, the simple activity to perform for these services is pick up activity.

We have observed that regardless of the type of the service or the city program these services belong, every service instance consists of limited set of simple activities such as request, contact, submit, dispatch, or pick up.

The fact that the numbers of simple activities to perform for city services are much less than the number of services city provides means that there are valuable opportunities to simplify the knowledge structure of city public services while improving their efficiency. We will discuss these opportunities in next section along with our model of Service Knowledge Pattern.

Another noteworthy fact to highlight is that while all service instances used in case 3 contain the same activity pick up, the objects that received these services are different. In the first two instances the objects picked up by service providers are live objects (animate) although from different species; while the last instance is a toxic material object (inanimate). It is important to consider each object's needs and provide appropriate **resource** (vehicle, agent) to accommodate these needs.

In other word, recognition of city services and the elements that are affected by that service are similarly important. In the next section we will introduce our model of city service knowledge pattern considering all elements that affect a city service or can be affected by a city service as we highlighted in case1, case2, and case3.

1.2.2 Service Knowledge Pattern

In this section we will employ knowledge inherent of city services we highlighted in previous section via cases 1, case 2, and case 3 to provide a general and comprehensive model for city Services Knowledge Pattern (SKP).

As we explained through multiple examples in previous section, Toronto 311 knowledgebase webpages show a similar knowledge pattern for most of the city services. Based on these similarities we could create a unique definition of city services.

A municipal service is composed of processes and activities that fulfill citizen, local businesses and organization's needs and achieve municipal goals. This definition is also compatible with the definition of service defined by MRM model we mentioned in the introduction section; however, we consider both "public services" and "enabling services" as subclasses of municipal services.

Based on this definition almost all city services are representable by SKP except services that need permit or license. Such services will be discussed as a different knowledge pattern called "Permit Knowledge Pattern".

The SKP is the root pattern for different service types that city government provides. As we showed in cases 1, 2, and 3 these service types can be distributed in various types such as: internal services (Figure3.5, communicate between Toronto police or Toronto fire, and 311 to request animal pick up) verses public services (Figure 3.7, household hazardous waste collection); online services (paying hydro bills), etc.

City services also can be defined based on the service category they belong to such as Transportation services (Figure3.6, TTC wheel trans service), Safety services (Figure 3.5, animal pick up), and Solid waste services (Figure 3.2 and 3.3, Bulky item collection or household hazardous collection).

The interesting consideration about these service types and categorizations is that regardless of the types or categories the knowledge constituents of the different services remain unchanged. As a result, we suggest that instead of defining city services in different categorizes or based on different types, which is common practice, city services could be defined as a set of processes and activities with general service constituent and be extended to correspond to different city services' characteristics by adding different types (has-service-type) or different categories (has-service-category) as object properties of those services.

The main upside of defining object properties for simple activities instead of defining different service types, service categories, city programs, etc., is that the knowledge representation of city activities will be simplified; and yet it allows expressive definition

of various city services based on simple activities. As we highlighted in case 3, a simple activity such as pick up can be coupled with different service categories, service type, or other object properties to represent different services such as:

- Emergency Service Request for Animal Pick up
  - *has-service-type* (internal service)
  - *has-service-category* (public safety)
  - service-requester (Toronto police or Toronto fire)
  - *service-provider* (Toronto animal services)
  - *Triggering event* (call 311)
  - *has-location* (dynamic locations to pick up animals)
  - *perform* (activity, pick up)

- TTC Wheel trans pick up service
  - *has-service-type* (public service)
  - *has-service-category* (transportation)
  - *has-location* (City Hall, Metro Hall,…)
  - *Service-provider* (Toronto Transportation Commotion)
  - *Service-requester* (city residents with disabilities)
  - *perform* (activity, pick up)

In addition, as we explained in Case 1 and Case 2, in order to perform an activity specific preconditions or constraints (condition) must be satisfied (see Figure 3.2 and Figure 3.3). The has-location property in previous example represents the location condition under which TTC wheel trans service will be provided. In other word, we can employ object properties as a mean to represent different constraints for various services.

As mentioned in Figure 3.3 and Figure 3.4, some services can be delivered in more than one way, which we called it service alternative. These alternative services deliver the same service while using different processes. Figure 3.4 shows two alternatives for non-emergency patient transfer service: EMS ambulance service or private business ambulance services. If these services are defined under different service categories (public services verses private businesses services), it is crucial for city organization to

recognize the similarities between these service alternatives and defined them as a same service with different service types or different service categories.

Neglecting simple definitions such as service alternatives could affect the performance of the city services significantly; the definition of the same service under different categories without recognizing characteristics of the service could decrease the performance of automated agents to infer possible alternatives for customer, or enhance service's queue for a specific service alternative while other alternatives are available.

In order to perform a service, city government uses its resources. These resources will be consumed, used or be hold during service delivery by some organization agent [4]. In Case 1, bulky item pick up vehicle and city agent, who performs the pick up activity, are instances of city resources that are used during the activity occurrence.

Due to scarce nature of city resources and their importance in public service delivery; city resources and their connection to city government organization are concepts we will discus in more details using three different knowledge patterns: "Organization Knowledge Pattern", "Public Facility Knowledge Pattern", and "Infrastructure Knowledge Pattern".

In summary SKP defines every city service as one or more simple or complex activity, which consumes or holds city resources. This activity at least has one triggering event, and there are constraints that should be satisfied for the activity to be performed. There could be other processes or activities that delivers the same service outcome recognized as service alternatives. Finally, simple activity with same inherent characteristics could be coupled with different types, categories, or other properties and represent different city services.

In the following we have provided Service knowledge pattern in prose in Table 3.1 and the Description Logic (DL) representation of SKP in Table 3.2.

Service Knowledge Pattern Example (Hazardous Waste Collection Instance)

Example:

- Kitchen container request
- Household Hazardous Waste (HHW) Collection Service (Design Pattern)
- Issue International Driving License, Taxi Driver License, Mobile Business

Activity = pickup/drop off/collection of resource

Resource = Hazardous Waste

Triggering Event = phone call/web request/ in person request

Constraints that have to be satisfied in order for activity to be performed

- Constraint may apply to the abstract with exceptions for specific resources

- Packaging constraints
  - Sealed container
  - Non leaking container
  - Labeled
- Agent (recipient) constraints
  - Residential vs. corporate
- Capacity (units of measure) constraints
  - Volume (Min and Max)
  - Size
  - Number
- Location
  - Where it is to be placed
- Temporal
  - When it is to be placed out

Service Alternatives

- Given a set of constraints, what is the alternative service
  - If too few liquids, then take it to the depot

Outcomes:

Disposition of hazardous house material (inanimate object)

Table 3.1:Service Knowledge Pattern

MunicipalService ≡ LocalGovernmentService ≡ RegionService ≡ CityService

CityService ≡ ((∀hasServiceCategory. ServiceCategory) ⊓ (∀hasServiceType. ServiceType) ⊓ (∀hasServiceProvider. ServiceProvider) ⊓ (∃hasServiceRequester. ServiceRequester) ⊓ (∃hasCondition. Condition) ⊓ (∃hasServiceAlternative. ServiceAlternative) ⊓ (∃isPerformedBy. CityOrgAgent) ⊓ (∀hasActivity. Activity) ⊓ (∀hasResource. Resource) ⊓ (∀hasStartTimes. TimePoint) ⊓ (∀haEndTime. TimpePoints))

ServiceCategory ⊑ CityService
EducationService ⊑ ServiceCategory
EnergyService ⊑ ServiceCategory
FinanceService ⊑ ServiceCategory
FireAndEmergencyResponse ⊑ ServiceCategory
GovernanceService ⊑ ServiceCategory
HealthService⊑ ServiceCategory
RecearionService ⊑ ServiceCategory
SafetyService ⊑ ServiceCategory
SolidWasteService ⊑ ServiceCategory
TransportationService ⊑ ServiceCategory
UrbanPlanningService ⊑ ServiceCategory
WasteWaterService ⊑ ServiceCategory
WaterService ⊑ ServiceCategory
EducationService ⊓ EnergyService ≡ ⊥
EducationService ⊓ Financial Service ≡ ⊥
EducationService ⊓ FireAndEmergencyResponseService ≡ ⊥
EducationService ⊓ GovernanceService ≡ ⊥
EducationService ⊓ HealthService≡ ⊥
EducationService ⊓ RecreationService≡ ⊥
EducationService ⊓ SafetyService ≡ ⊥
EducationService ⊓ SolidWasteService ≡ ⊥
EducationService ⊓ TransportationService ≡ ⊥
EducationService ⊓ UrbanPlanningService ≡ ⊥
EducationService ⊓ WasteWaterService ≡ ⊥
EducationService ⊓ WaterService ≡ ⊥
EnergyService ⊓ FinancialService ≡ ⊥
EnergyService ⊓ FireAndEmergencyResponseService ≡ ⊥
EnergyService ⊓ GovernanceService ≡ ⊥
EnergyService ⊓ HealthService ≡ ⊥
EnergyService ⊓ RecreationService ≡ ⊥
EnergyService ⊓ SafetyService ≡ ⊥
EnergyService ⊓ SolidWasteService ≡ ⊥
EnergyService ⊓ TransportationService ≡ ⊥
EnergyService ⊓ UrbanPlanningService ≡ ⊥
EnergyService ⊓ WasteWaterService ≡ ⊥
EnergyService ⊓ WaterService ≡ ⊥
FinancialService ⊓ FireAndEmergencyResponseService ≡ ⊥
FinancialService ⊓ GovernanceService ≡ ⊥
FinancialService ⊓ HealthService ≡ ⊥
FinancialService ⊓ RecreationService ≡ ⊥
FinancialService ⊓ SafetyService ≡ ⊥
FinancialService ⊓ SolidWasteService ≡ ⊥
FinancialService ⊓ TransportationService ≡ ⊥
FinancialService ⊓ UrbanPlanningService ≡ ⊥
FinancialService ⊓ WasteWaterService ≡ ⊥

FinancialService ⊓ WaterService ≡ ⊥
FireAndEmergencyResponseService ⊓ GovernanceService ≡ ⊥
FireAndEmergencyResponseService ⊓ HealthService ≡ ⊥
FireAndEmergencyResponseService ⊓ RecreationService ≡ ⊥
FireAndEmergencyResponseService ⊓ SafetyService ≡ ⊥
FireAndEmergencyResponseService ⊓ SolidWasteService ≡ ⊥
FireAndEmergencyResponseService ⊓ TransportationService ≡ ⊥
FireAndEmergencyResponseService ⊓ UrbanPlanningService ≡ ⊥
FireAndEmergencyResponseService ⊓ WasteWaterService ≡ ⊥
FireAndEmergencyResponseService ⊓ WaterService ≡ ⊥
GovernanceService ⊓ HealthService ≡ ⊥
GovernanceService ⊓ RecreationService ≡ ⊥
GovernanceService ⊓ SafetyService ≡ ⊥
GovernanceService ⊓ SolidWasteService ≡ ⊥
GovernanceService ⊓ TransportationService ≡ ⊥
GovernanceService ⊓ UrbanPlanningService ≡ ⊥
GovernanceService ⊓ WasteWaterService ≡ ⊥
GovernanceService ⊓ WaterService ≡ ⊥
HealthService ⊓ RecreationService ≡ ⊥
HealthService ⊓ SafetyService ≡ ⊥
HealthService ⊓ SolidWasteService ≡ ⊥
HealthService ⊓ TransportationService ≡ ⊥
HealthService ⊓ UrbanPlanningService ≡ ⊥
HealthService ⊓ WasteWaterService ≡ ⊥
HealthService ⊓ WaterService ≡ ⊥
RecreationService ⊓ SafetyService≡ ⊥
RecreationService ⊓ SolidWasteService ≡ ⊥
RecreationService ⊓ TransportationService ≡ ⊥
RecreationService ⊓ UrbanPlanningService ≡ ⊥
RecreationService ⊓ WasteWaterService ≡ ⊥
RecreationService ⊓ WaterService ≡ ⊥
SafetyService ⊓ SolidWasteService ≡ ⊥
SafetyService ⊓ TransportationService≡ ⊥
SafetyService ⊓ UrbanPlanningService ≡ ⊥
SafetyService ⊓ WasteWaterService ≡ ⊥
SafetyService ⊓ WaterService ≡ ⊥
SolidWasteService ⊓ TransportationService ≡ ⊥
SolidWasteService ⊓ UrbanPlanningService ≡ ⊥
SolidWasteService ⊓ WasteWaterService ≡ ⊥
SolidWasteService ⊓ WaterService ≡ ⊥
TransportationService ⊓ UrbanPlanningService ≡ ⊥
TransportationService ⊓ WasteWaterService ≡ ⊥
TransportationService ⊓ WaterService ≡ ⊥
UrbanPlanningService ⊓ WasteWaterService ≡ ⊥
UrbanPlanningService ⊓ WaterService ≡ ⊥
WasteWaterService ⊓ WaterService ≡ ⊥
ServiceType ⊑ CityService
EnablingService ⊑ ServiceType
InternalService ⊑ ServiceType
PublicService ⊑ ServiceType
OnlineService ⊑ ServiceType
OnsiteService ⊑ ServiceType
PubicService ⊓ EnablingService ≡ ⊥
PubicService ⊓ OnlineService ≡ ⊥
PubicService ⊓ OnsiteService ≡ ⊥

EnablingService ⊓ OnlineService ≡ ⊥
EnablingService ⊓ OnsiteService ≡ ⊥
OnlineService ⊓ OnsiteService ≡ ⊥
ServiceProvider ⊑ CityService
Division ⊑ ServiceProvider
Contractor ⊑ ServiceProvider
BusinessPartner ⊑ ServiceProvider
LicensedBusinesses ⊑ ServiceProvider
Division ⊓ Contractor ≡ ⊥
Division ⊓ BusinessPartner ≡ ⊥
Division ⊓ LicensedBusinesses ≡ ⊥
Contractor ⊓ BusinessPartner ≡ ⊥
Contractor ⊓ LicensedBusinesse ≡ ⊥
Licensedbusinesses ⊓ BusinessPartner ≡ ⊥
ServiceRequester ⊑ CityService
CityAgent ⊑ ServiceRequester
Resident ⊑ ServiceRequester
CityAgent ⊓ Resident ≡ ⊥
PermenentResident ⊑ Resident
TemporaryResident ⊑ Resident
PermenetResident ⊓ TemporaryResident ≡ ⊥
Tourist ⊑ TemporaryResident
Condition ≡ Constraint
Condition ⊑ CItyService
Size ⊑ Condition
Fee ⊑ Condition
Time ⊑ Condition
Location ⊑ Condition
Volume ⊑ Condition
Fee ⊓ Size ≡ ⊥
Fee ⊓ Time ≡ ⊥
Fee ⊓ Location ≡ ⊥
Fee ⊓ Volume ≡ ⊥
Size ⊓ Time ≡ ⊥
Size ⊓ Location ≡ ⊥
Size ⊓ Volume ≡ ⊥
Time ⊓ Location ≡ ⊥
Time ⊓ Volume ≡ ⊥
Location ⊓ Volume ≡ ⊥
ServiceAlternative ⊑ CityService
Process ⊑ CityService
AtomicProcess ⊑ Process
AtomicProcess ≡ Activity [8]
CompositeProcess ⊑ Process
CompositeProcess ⊑ ≥ 1 consistOf. AtomicProcess
Activity ≡ ((∀corespondToCityService. CityService)
⊓ (∃fullfill. Condition) ⊓ (∃hasCityOrgAgent. CityOrgAgent) ⊓ (∀hasOccurrence. TimePoint))
TimePoint ⊑ Time
TimeInterval ⊑ Time
TimePont ⊓ TimeInterval ≡ ⊥

[8] For the complete activity and activity-state ontology taxonomy please refer to Appendix I

Resource ⊑ CityService Human ⊑ Resource Finance ⊑ Resource Infrastructure ⊑ Resource Human ⊓ Finance ≡ ⊥ Human ⊓ Infrastructure ≡ ⊥ Finance ⊓ Infrastructure ≡ ⊥ Publicfacility ⊑ Infrastructure CityOrgAgent[9] ≡ ((∃hasOrganization.MunicipalOrganization) ⊓ (∀perform. Activity) ⊓ (∀hasSkill. Skill) ⊓ (∀hasRole. Role) ⊓ (∀hasAuthority. Authority) ⊓ (∀hasDivision. Division) ⊓ (∀consume. Resource) ⊓ (∀hasGoal. Goal)) Event ⊑ CityService TriggeringEvent ⊑ Event A Box[10]: Activity (Pick up) Activity (Submit) Activity (Request) Activity(Transfer) Activity(Deliver) Activity(Arrive) Activity(Check) Activity (Report) Activity (Drop off) Activity (Collect) Activity (Dump) Activity (Clean) TimePoint (7: 00) Location (25. St Mary) Volume (20kg) Size(2.4 m) Triggering event (Call) Triggering event (smart phone) Triggering event (email) Triggering event (Fax) Triggering event (OnlineForm) CityService (non-emergency ambulance transfer) CityService (Waste Collection) CityService (Emergency Animal Pick up Service) CityService (TTC Wheel Transit)

Table 3.2:Description Logic Representation of Service knowledge Pattern

[9] The City Organization Agent and its definition will be provided in the Organization Knowledge pattern

[10] Similar to other knowledgebase representations, description logic representation of Toronto 311 knowledgebase could be represented as T-Box and A-Box as shown in Table 3.3.2. In addition, using these A-box and T-box we can represent specific Rules for each city service in this domain. However, due to the large scope of A-box concepts in this domain, and the fact that the emphasis of this research is on representation of a consistence and meaningful T-box containing necessary and crucial city knowledge patterns, we will only concentrate on the T-box aspect of knowledgebase for other knowledge patterns.

3.3. Permit/License Knowledge Pattern

The second knowledge pattern we propose is the permit knowledge pattern (PKP). We will start by defining permits and licenses in public service administration. Then, using an example from Toronto 311 knowledgebase we demonstrate the knowledge constituents for permit and license within city services. Finally, we formally define the PKP in the municipal government domain.

A license gives a person or organization permission to engage in a particular activity. In public administration domain, many activities require a government issued license. These licenses are issued for a various activities, e.g., fishing, hunting, driving a motor vehicle, providing health care services, practicing law, manufacturing, engaging in retail and wholesale commerce, and providing public services such as food and environmental inspection.

Permits are issued by one of the authorized agencies, bureau, or divisions of the local, provincial, or federal government based on existing laws, bylaws, or municipal codes. A license for a certain activity allows the government to closely supervise and control the activity. Moreover, permits synchronize and facilitate internal communication between different sub- organizations, business partners, and departments within the city domain.

Despite the importance of permits and license, government reference models and ontologies have mostly ignored its effect on the overall performance of city services. Furthermore, we also observe a similar lack of attention in practice, i.e., only 6% of our observations of the Toronto 311 knowledgebase webpages contain information related to city permits and licenses. This under report statistic combined with the lack of easily accessible information about various permits and licenses in the city of Toronto knowledgebase will be discusses in the following section.

3.3.1 Permit in Toronto 311 knowledge base

In Toronto, the division of Municipal Licensing and Standards is responsible for bylaw administration and its enforcement throughout the city. The division provides information

about various permits and licenses. The following example, selected from the 311 knowledgebase, highlights the knowledge pattern embedded in permits and licenses.

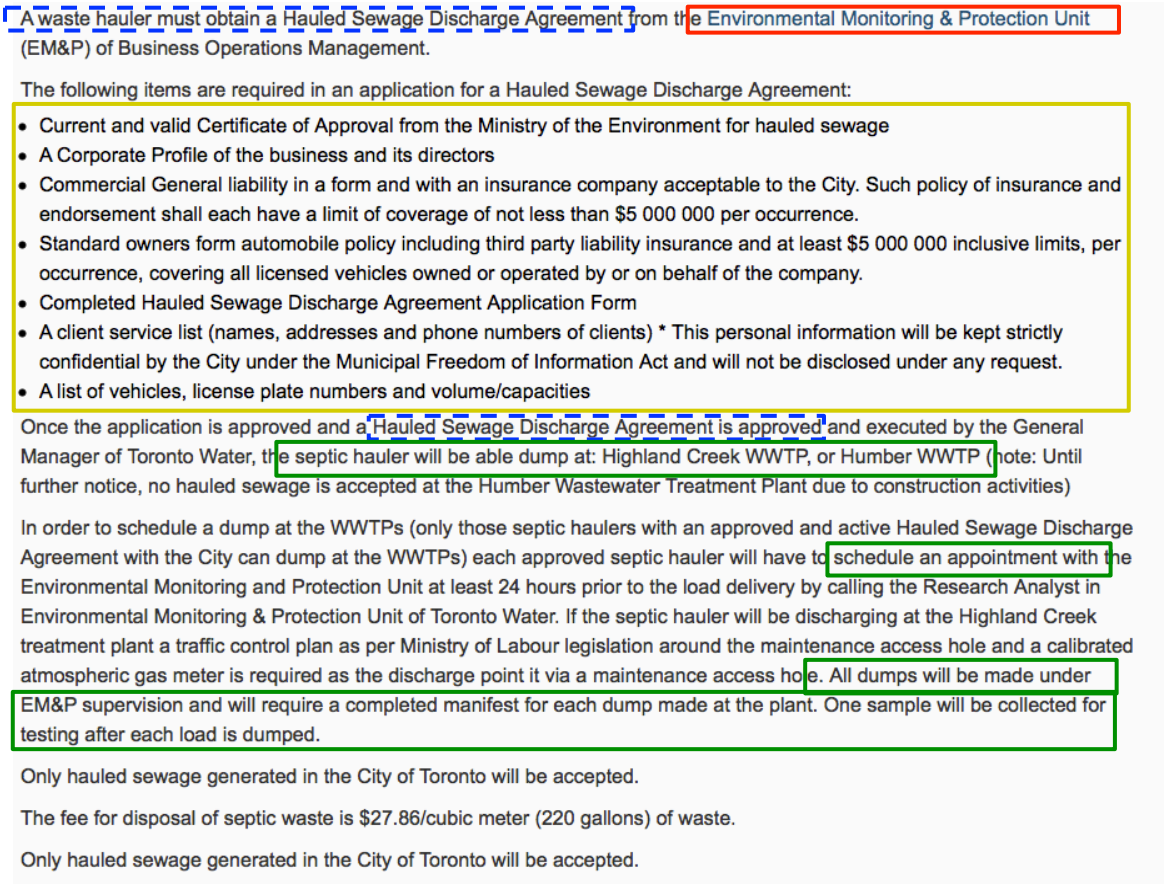
The example we consider is hauled sewage discharge permit (agreement)[11]. This permit gives a hauler the permission to remove, transport, and discharge sewage from cesspools, septic tank systems, privy pits, portable toilets, or sewage holding tank. Note that this permit excludes industrial, commercial or hazardous waste removal.

Figure 3.8 show a webpage containing the elements under which a hauled sewage discharge agreement will be obtained. As illustrated by the dashed blue boxes, to perform the service, a hauler should acquire an approved permit. This permit is issued by the Environment Monitoring and Protection (EM&P) unit – which we denote as the permit provider (show by red box).

Similar to the service knowledge pattern, this example also has an agent who uses resources to perform an activity (blue box); it has a service provider (red box); and a set of constraints to be satisfied for the activity to occur (yellow box).

Despite these similarities, there are fundamental differences that make permit a unique type of activity with its own specific knowledge inherent. Specifically, there are four main differences that make permit unique. First, the activity outcome of the permit acquisition process is either approval or denial. Second, the resource in use for the permit process is the permit or license itself (since the hauler will use the permit as a resource to provide sewage removal services). Third, some permits will require specific certificates or skills as their constraints. Finally, unlike activities in SKP, in every permit acquisition process, there are specific steps and processes that should be followed after performing the permitted activity (e.g., scheduling an appointment with disposal facility, or dumping septic sewage, as shown by the green boxes).

[11]http://www.toronto.ca/311/knowledgebase/88/101000041288.html



A waste hauler must obtain a Hauled Sewage Discharge Agreement from the Environmental Monitoring & Protection Unit (EM&P) of Business Operations Management.

The following items are required in an application for a Hauled Sewage Discharge Agreement:

- Current and valid Certificate of Approval from the Ministry of the Environment for hauled sewage
- A Corporate Profile of the business and its directors
- Commercial General liability in a form and with an insurance company acceptable to the City. Such policy of insurance and endorsement shall each have a limit of coverage of not less than $5 000 000 per occurrence.
- Standard owners form automobile policy including third party liability insurance and at least $5 000 000 inclusive limits, per occurrence, covering all licensed vehicles owned or operated by or on behalf of the company.
- Completed Hauled Sewage Discharge Agreement Application Form
- A client service list (names, addresses and phone numbers of clients) * This personal information will be kept strictly confidential by the City under the Municipal Freedom of Information Act and will not be disclosed under any request.
- A list of vehicles, license plate numbers and volume/capacities

Once the application is approved and a Hauled Sewage Discharge Agreement is approved and executed by the General Manager of Toronto Water, the septic hauler will be able dump at: Highland Creek WWTP, or Humber WWTP (note: Until further notice, no hauled sewage is accepted at the Humber Wastewater Treatment Plant due to construction activities)

In order to schedule a dump at the WWTPs (only those septic haulers with an approved and active Hauled Sewage Discharge Agreement with the City can dump at the WWTPs) each approved septic hauler will have to schedule an appointment with the Environmental Monitoring and Protection Unit at least 24 hours prior to the load delivery by calling the Research Analyst in Environmental Monitoring & Protection Unit of Toronto Water. If the septic hauler will be discharging at the Highland Creek treatment plant a traffic control plan as per Ministry of Labour legislation around the maintenance access hole and a calibrated atmospheric gas meter is required as the discharge point it via a maintenance access hole. All dumps will be made under EM&P supervision and will require a completed manifest for each dump made at the plant. One sample will be collected for testing after each load is dumped.

Only hauled sewage generated in the City of Toronto will be accepted.

The fee for disposal of septic waste is $27.86/cubic meter (220 gallons) of waste.

Only hauled sewage generated in the City of Toronto will be accepted.

Figure 3.8: Agreements-Hauled Sewage Discharge Agreement

To better illustrate the hauled sewage disposal agreement, in Figure 3.9 we provide a business process model diagram of haulage permit approval, its connection with sewage disposal service, and its processes. For simplification we have omitted the hauler-customer interaction sub-process and only emphasize on the interactions between hauler and city government.

Recall from the SKP that a permit is a unique sub-process of a city service, which works as a mandatory precondition for its post-processes. As depicted in Figure 3.9, the process of sewage discharge agreement approval (shown in a separated sub-process) is a mandatory precondition for its post-activities such as scheduling a dump appointment, i.e., the whole process of sewage disposal will be suspended unless the hauler obtains the agreement from city authorities.

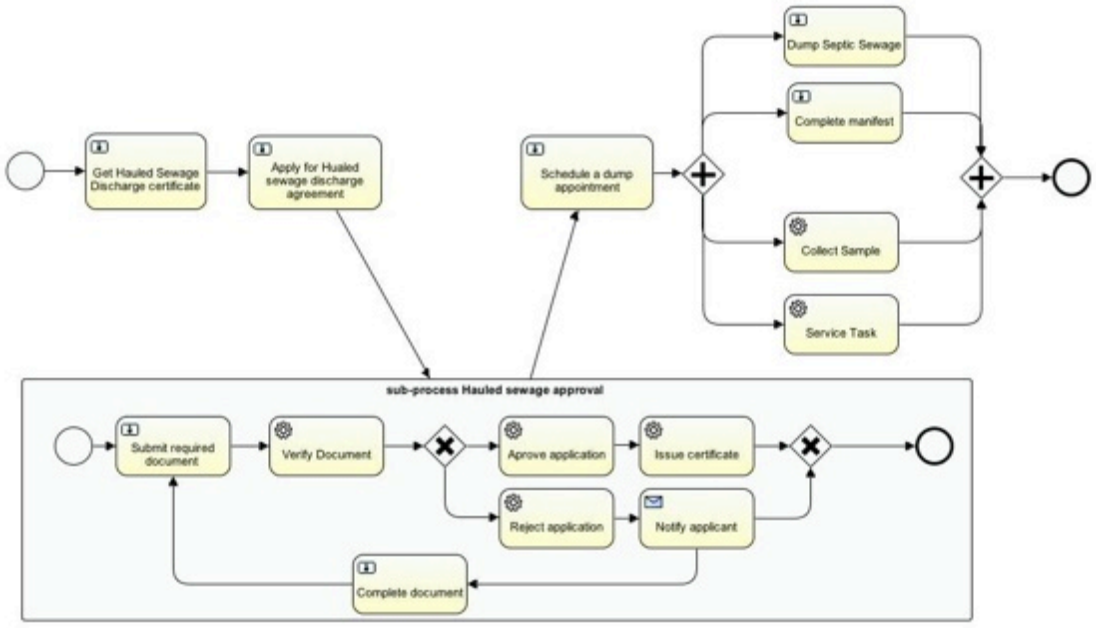


Figure 3.9: BPM Diagram for Hauled Sewage Discharge Agreement

3.3.2 Permit/License Knowledge Pattern

Permits and license have similar knowledge patterns except when it comes to their time span. Specifically, licenses are by definition issued for a longer period of time than permits. If some entity obtains a license, the license authorizes it to provide a service for a specific period of time (usually longer than one year), while permits are usually temporary and are valid for a short period of time. Despite this difference in the **temporal** aspect of the permit and license constraints, we are able to represent them as a single pattern (with similar knowledge constituents) by defining the time constraints as object property (has-start-date, has- expiration-date) for licenses, and defining property restriction cardinalities (max-cardinality for events) for the permit execution. The following examples demonstrate this resolution:

- Hauled Sewage discharge agreement:
  - *has -certificate* (hauled Sewage)
  - *has- start-date* (day of issue license)

  - *has-expiration date* (day the license is expired)
  - *has-fee* (cost of license)
  - *has-service-provider* (municipal licensing and standard)
- Permit for holding an event in city Park:
  - *has-permit (*event in the ark)
  - *has-location*(park's name)
  - *is-valid- for* (>X or <X events)
  - *has-fee*(cost of permit)

As we explained in the SKP, each service consists of set of processes and activities that will be executed as long as their constraints are satisfied. Services that require permit or license also follow the same pattern, but are distinct in that the activities that follow the permit acquisition have a *pre- condition* (***Permit approval***) and before it is satisfied these activities are **suspended (**see Figure 3.9**)**. Furthermore, such services also have a permit ***provider***, which is an organization agent. Most departments within city government have their own ***permit/license unit*** under the supervision of municipal licensing and standards department. We will discuss the service provider and organizational unit components in more details in the organization knowledge pattern.

Note that one of the differences between permit and service in general is the ***resource*** component. Since the procured permit is a pre-requirement for another service, the permit is itself considered as a resource. Moreover, in addition to *SKP* constraints such as time, location, and agent, PKP has some unique constraints such as ***certificates*** or ***skills***, which are needed for the permit approval activity to occur. The activity of permit ***Approval*** or ***Denial*** is the most significant aspect of PKP, since it determines whether its following processes could proceed. The ***Following Processes*** are usually related to services and activities that need an approved permit or license as their pre-condition to be performed, e.g., in our example only after acquiring the waste haulage license, the hauler could make the required accommodation for sewage disposal.

It is note worthy that the knowledge representation of services that are related to the permit knowledge pattern is different from representing of regular service activities.

Table 3.4 shows the description logic representation of knowledge constituents of permit knowledge pattern.

Permits/License Knowledge Pattern

Example

- Waste Haulage license
- Building construction Permit
- Street disclosure Permit for special event

Activity = approving an agent to perform an activity

Resource = permit

Provider = some org agent

- Permit/license unit
    - Specific Organization Permit/License Unit with Authority

Constraints

- Temporal
- The required time to procure permit before an event
- Certification
    - Skill
- Approvals/Denials
- Other requirements, e.g., non-profit,
- Fee, payment constraint

Process to be followed in performing the permitted activity

For waste haulage:

- Location information: permitted dumps
- Source of waste
- Cost: disposal fee
- Analysis of the waste

Table 3.3:Permit Knowledge Pattern

Permit ≡ Agreement ≡ License ≡ Licence
PemittedActivity ⊑ Activity
PermittedActivity ≡ Activity ⊓ ∃ hasResource. Permit
LicensedBusinesse ≡ ServiceProvider ⊓ ∃hasPermit. Permit
PermitProvide ⊑ Division
PermitProvider ≡ Division ⊓ responsibleFor. Permit
PermitProvider(Municipal LicensingAnd Statndard)

Pemit ≡ ((∀ hasStartDate. TimeInterval) ⊓ (∀hasExpirationDate. TimeInterval)
⊓ (∀approvedBy. CityOrgAgent ⊓ (∀haspermitApproval. Boolean)
⊓ (∀canPerform. PermitttedActivity)
⊓ (∀hasPermitProvider. MunicipalLicensingAndStandards) ⊓ (∀issuedBy. Division)
⊓ (∃require. Skill) ⊓ (∃hasSkill. Boolean) ⊓ (∀hasOutcome. Boolean)
⊓ ((∃ ≥ isValidFor. Event) ⊔ (∃ ≤ isValidFor. Event)) ⊓ (∃ hasCondition. Condition)

PostPermitttedActivity ≡ Activity ⊓ (∀hasState. (Suspend)) ⊓ (∀ hasCondition. Precondition)
Precondition ≡ PermittedActivity ⊓ (∀hasState. (Complete))

Skill ⊑ Organization
Certificate ⊑ Skill
TimeInterval ⊑ Time
TimesPoint ⊑ Time
TimePoint ⊓ TimeInterval ≡ ⊥
Time ⊑ Condition
Precondition ⊑ Condition

Table 3.4:Description Logic Representation of Permit Knowledge Pattern

3.4. Organization Knowledge Pattern

In this section we introduce Organization Knowledge Pattern (OKP). First we define the concept of organization in the public services domain. Then using some examples from Toronto 311 knowledgebase we will describe the components of municipal government organization. Finally, we formally introduce organization knowledge pattern.

According to (Fox et.al 1995) “an organization is the set of constraints on the activities performed by agents”[1]. Accordingly, we define municipal government organization as a complex organization in which existing constraints and conditions from its numerous sub-organizations restrict processes and activities of public service

administration provided by its agents. We believe that our model of organization and its components are general enough to be extended to respond to all types of sub-organizations working under or with the city government organization.

The OKP plays a significant role in connecting the other city knowledge patterns, and could demonstrate how the recognition of city knowledge patterns elevates the organizational cooperation in city's day-to-day operation and lead to a smarter communication between municipal government's components.

In the "Infrastructure Knowledge Pattern" [12] and "Public Facility Knowledge Pattern"[13] we define two concepts of infrastructure and public facilities as municipal government's resources at the municipal level, which are used by city government's agents. These agents are the organization agents who work for city government and provide services as explained in in the "Service knowledge Pattern". Recall from service knowledge pattern that SKP defines the skeleton of city operation's general pattern; however, the key pattern that connects these three knowledge pattern with each other and with other knowledge patterns is the "Organization Knowledge Pattern", since it is the connecting piece for all the other knowledge patterns to work together.

3.4.1 Organization in Toronto 311 Knowledgebase

The following examples from Toronto 311 knowledgebase will demonstrate the main characteristics of government organization.

Case 1: City of Toronto Organizational Chart

Similar to any organization, the city of Toronto government organization is also has an **organizational structure**. This organizational structure, depicted in Figure 3.10, determines the upper level **sub-organizations/divisions** of the city of Toronto, the **organization agents** who is **responsible** for specific responsibilities in that sub-organization or divisions driven from a **role** the agent have in the city of Toronto's organizational hierarchy. For example, as shown in the red box, the Municipal Licensing

[12] Refer to Infrastructure Knowledge Pattern, Chapter 3, page 41
[13] Refer to Public Facility Knowledge Pattern, Chapter 3, page 50

and Standards is a division of the City of Toronto, Tracy cook is the organization agent who plays the role of the Executive Director of this division. Similarly, the blue box shows the Emergency Medical Services division; Paul Raftis is the organization agent who plays the role of EMS Chief and General Manager of this division.

As the organizational chart illustrates, these two organization agents are under separated section of the city of Toronto's public administration and part of two different teams (e.g., the medical emergency service division is under the deputy of the city manager Brenda Palterson's management, and Paul Raftis is a member of Brenda Palterson's team). They perform different activities (Municipal licensing and Standard services vs. Medical Emergency Services) and they have different roles (EMS Chief and General Manager vs. Executive manager of Licensing and Standard).

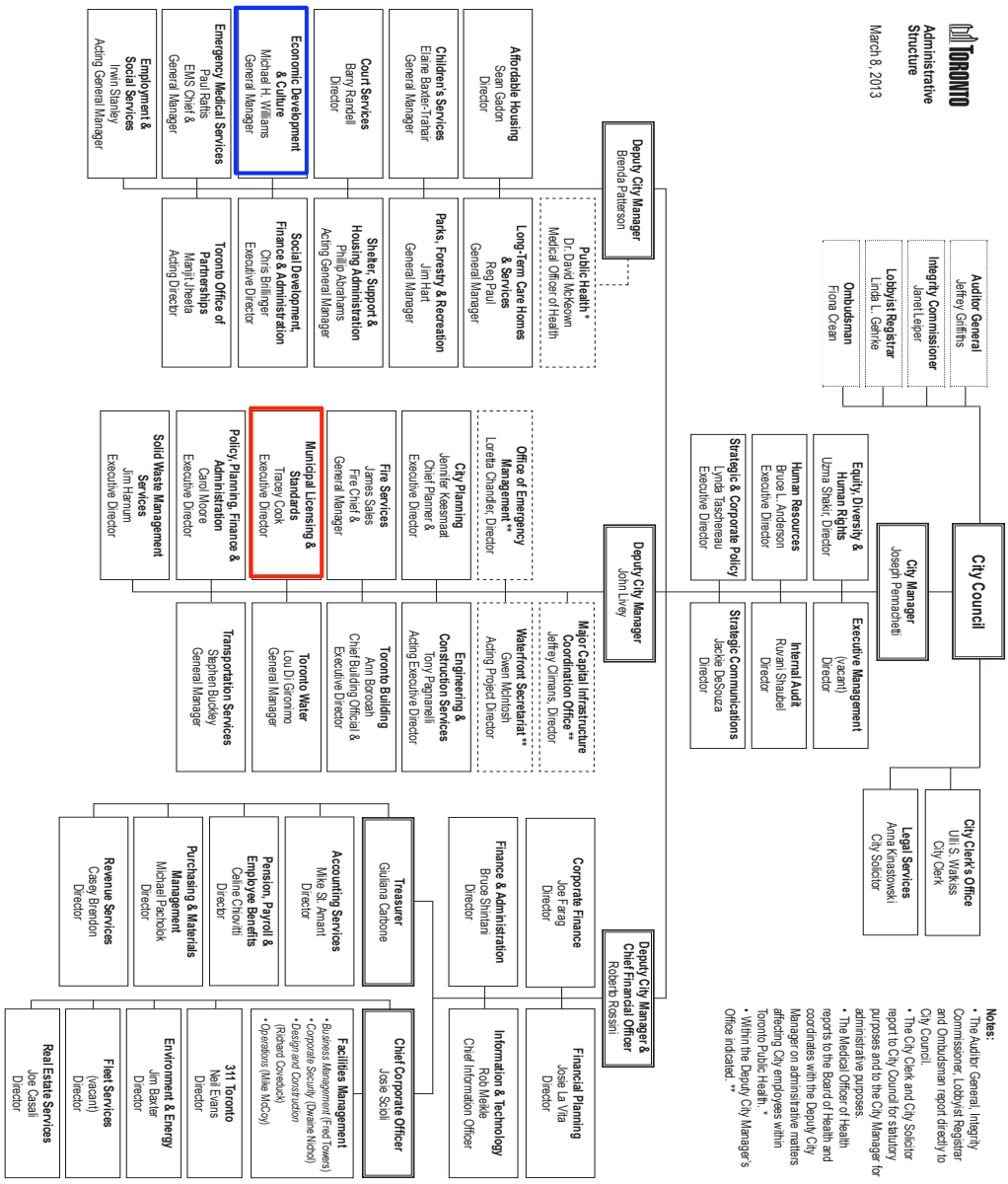


Figure 3.10:City of Toronto Administration Structure

Case 2: Toronto Police

In this example, we employ one of the important sub-organizations of the city of Toronto, Toronto Police, to highlight some of the knowledge components of OKP. The webpage in Figure 3.11 contains information about some of the Police **divisions**, general definition of their **services** (activities), and the activities the police officers (organization-agents) **perform**.

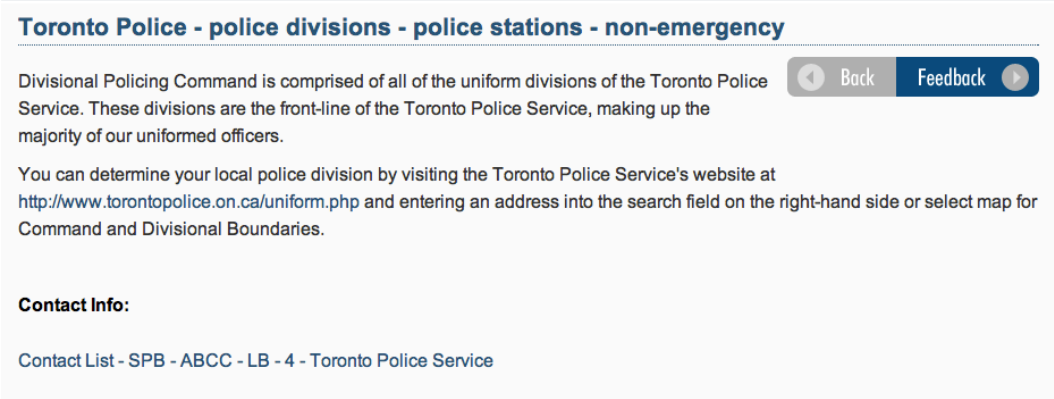


Figure 3.11: Toronto Police -Police Divisions- Police Stations

Figure 3.12 depicts a webpage containing the contact information for various police related services. The first contact information is in case of emergency 911number, shown in the blue box. The webpage also contains information about different organization **units**, and the organization agent who has specific **role** in that unit (e.g., the red box depicts the contact information to contact the Toronto Anti-Violence Intervention Strategy (TAVIS) coordinator, Sergeant Jeff Pearson).

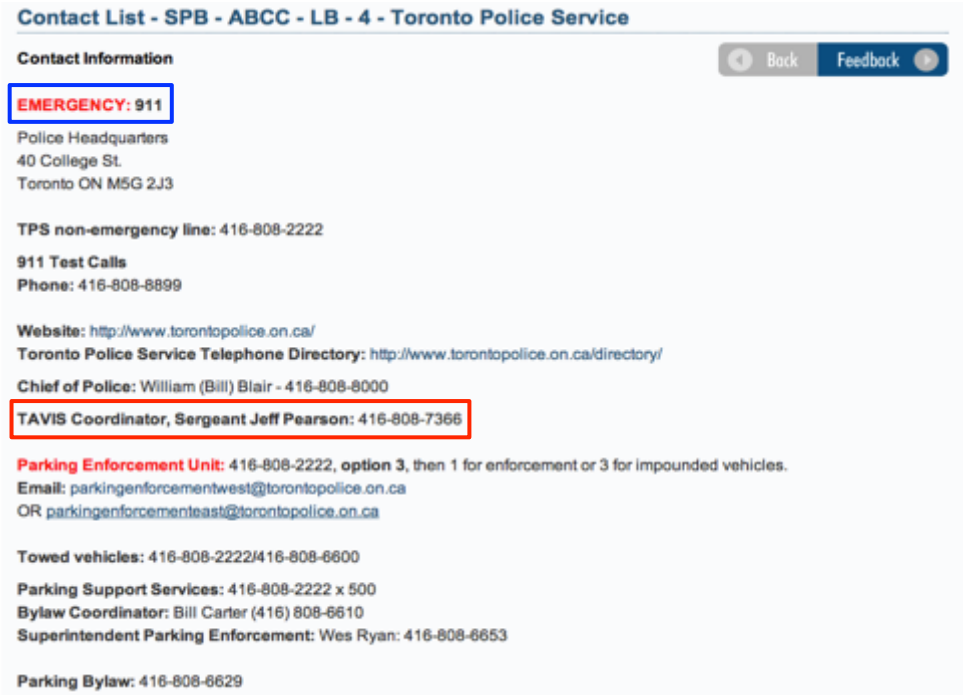


Figure 3.12: Contact Information-SPB-ABCC-LB-4-Toronto Police

Case 3: Strategic Communication

In Toronto 311 knowledgebase many knowledge components of OKP are hidden in simple webpages named as "contact list". In previous example we used one of these webpages to highlight the relationship between one of the city of Toronto organization's division (Police), its units and agents. In Case 3, depicted in Figure 3.13, we employ a different contact list webpage related to strategic communication, planning and research division to highlight another knowledge components of OKP.

As shown in the green box, each division might consist of different organizational **roles**. These roles are occupied by different organization agents who have a set of predefined **responsibilities** for that role and **perform** specific **activities** based on their responsibilities. Note that some roles are occupied with more than one organization agents (e.g., our Toronto newsletter role is occupied by David Clark, and Deborah Brown).

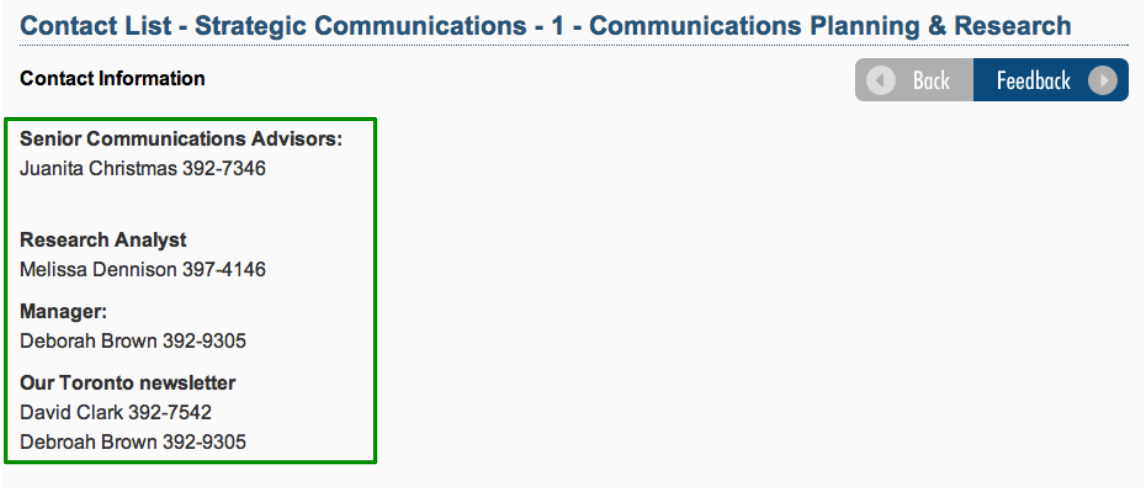


Figure 3.13:Contact List-Strategic Communication-Communication Planning and Research

Case 4: Provincial Organization

In Case 4, we use another contact list webpage to highlight an important characteristic of OKP. The contact list webpage is related to the provincial Ministry of Transportation. The Ministry of Transportation is one of the divisions of Province of Ontario, which we denote as provincial government organization. It is noteworthy that every municipal

government within the juristic territory of provincial government is a sub-organization of that provincial government organization (e.g., The Municipal Government of Toronto is a sub-organization of the Government of Ontario).

Figure 3.14: Contact List- provincial- Ministry of Transportation-Highway Property Management

Case 5: major Emergency-City response

One of the important concerns in every city is how the municipal government corresponds to major emergency situations (e.g., flood, contagious disease, nuclear emergency). Figure 3.15, depicts the city of Toronto's strategic organization transformation in case of critical emergencies. During tan emergency, a new organizational hierarchy will be launched, the Emergency management Committee, (see the green box). The new organization authorizes some of the organization agents to new roles with new responsibilities (we denote this process as empowerment).

Despite new role and responsibilities each organization agent is still a member of his/her previous team. In other word, organization agents such as Chief of the Emergency Medical Services, Toronto Fire Service, and Toronto Police Service are parts of their own team but in case of emergency they are also part of the Emergency Management Committee team.

Figure 3.15: Major Emergency- City Response

3.4.2 Organization Knowledge Pattern

As illustrated through Cases 1, 2, 3, and 4 organizations are the center of city services. The Organization knowledge components are also the key elements in connecting different City Knowledge Pattern together. In this section we use these inherent knowledge components to introduce Organization Knowledge Pattern (OKP).

In the center of every organization are organization agents. These agents perform organization's activities by consuming, or using organization's resources to achieve organization's goals. Moreover, the agents play different roles based on their different responsibilities and communicate with each other through social communication or formal communication links. An organization agent could play more than one role or be a member of more than one team in an organization (see Case 5), which allows the organization to define different roles according to agent's skills and organization's goals.

By defining the agent component in the OKP we allow the municipal government to define individual entities within the city government and determine their different roles, responsibilities, activities, and their authorities to use resources or make interaction with other organizations / organization entities. For example in case 1 by defining two different organization agents, their divisions, and roles we can define different organization entities:

- *Division* (Municipal Licensing and Standards)

- *Role* (Executive Director)
- *City organization Agent* (Tracy Cook)
- *Perform* (Municipal Licensing and Standards services)
- *is-responsible –for* (Senior Management responsibilities)

Or in the other case:

- *Division* (Emergency Medical Service)
- *Role* (EMS Chief)
- *Role* (General Management)
- *City Organization Agent* (Paul Raftis)
- *Perform* (EMS services)
- *is-responsible-for* (managing and directing)

As can be seen in the second example the agent (Paul Raftis) plays more than one **role** in the city of Toronto organization. In addition, the ***organizational structure,*** as shown in Case 1, of the city of Toronto government organization is the component that differentiates and defines various levels of the city government organization such as ***sub-organizations***, ***divisions***, ***sub-divisions***, ***committees***, ***units***, etc. Definition of organization chart is a preliminary requirement to define government bureaucracy, *roles*, *responsibilities*, and *authorities* for the *organization agents*. We believe that definition of concepts such as ***division*** or ***committee***, their properties, and relationships with other organizational entities will improve the overall structure of the city government organization as shown in the previous examples. It will connect ***organizational agents*** to other knowledge patterns with respect to their ***roles*** and the ***authorities*** driven from this ***organizational structure***.

By defining each level of organizational structure automated agents have the ability to collect information and to reason about different level of organizational structure. The automated query and reasoning are particularly useful in providing high-level managerial reports such as monthly reports of divisions under deputy managers or reports for city council (see Case 1).

Moreover, the definition of organizational structure will help city organization to ***empower*** its agents on their different ***roles*** and will ***authorize*** them to ***perform*** specific ***tasks*** and ***activities***.

The notion of ***Empowerment*** is one of the most important elements in the OKP. The empowerment characterizes the municipal government organizations' ability to create a new organization, a virtual or a temporary team, or a new role within an existing organization. It is also enables new authorities for organization agents based on their new roles. Specifically, some agents due to their additional skills might be empowered to play another organization role or to perform other activities in specific situations (see Case 5).

Organization Knowledge Pattern

Example Web Pages

- Toronto Police – police divisions – police stations – non-emergency
- Toronto Public Health
- Toronto EMS

Constituent Knowledge

- Who is responsible for defining
- Organization Agent
  - Goals
  - Perform Activities
  - Responsibilities
  - Skills
  - Authority
  - Membership
    - Team
    - Virtual- Team
    - Project
- Organization Role
- Communication link
  - Contact information for each component of the structure
  - Links to other information about each component
- Organization Goal
    - Vision
    - Mission
    - Values and beliefs
    - Strategies
- Organization Structure
  - Sub-organization
  - Division
    - Subdivision
- Empowerment
  - Continual
  - Temporal
- Services provided
- Information

Table 3.5: Organization Knowledge pattern

FederalOrganization ⊑ Organization
ProvincialOrganization ⊑ Organization
MunicipalOrganization ⊑ Organization
PrivateOrganization ⊑ Organization
FederalOrganization ⊓ ProvincialOrganization ≡⊥
FederalOrganization ⊓ CityOrganization ≡⊥
FederalOrganization ⊓ PrivateOrganization ≡⊥
ProvincialOrganization ⊓ CityOrganization ≡⊥
ProvincialOrganization ⊓ PrivateOrganization ≡⊥
CityOrganization ⊓ PrivateOrganization ≡⊥
CityOrganization ≡ RegionOrganization

CityOrganization ≡
((∀ CityOrgAgent. CityOrgAgent) ⊓ (hasActivity. Activity) ⊓ (∀ hasResource. Resource) ⊓
(∃ hasCondition. COndition) ⊓ (∀ hasAuthority. Authority) ⊓ (∀ hasDividion. Division) ⊓
(∃ hasGoal. Goal) ⊓ (∃achieve. Goal) ⊓ (∀hasCommunicationLink. CommunicationLink) ⊓
(∀hasSkill. Skill) ⊓ (∀hasOrgStructure. OrgStructure) ⊓ (∀hasTeam. Team))

CommunicationLink
≡ ((∀ hasSendingAgent. CityOrgAgent) ⊓ (∀hasSendingRole. Role)
⊓ (∀hasRecievingAgent. CityOrgAgent) ⊓ (∀hasReceivingRole. Role)
⊓ (∀hasInterest. Information) ⊓ (∀willVolunteer. Information))

CityOrgAgent ≡ ((∃hasOrganization.CityOrganization) ⊓ (∀perform. Activity) ⊓ (∀hasSkill. Skill) ⊓
(∀hasRole. Role) ⊓ (∀hasAuthority. Authority) ⊓ (∀hasDivision. Division) ⊓ (∀consume. Resource) ⊓
(∀hasGoal. Goal) ⊓ (∀ isResponsibleFor. Responsibility) ⊓ (∃ memberOf. Team) ⊓
(∀play. Role) ⊓ (≤ 1 hasRole. Role) ⊓ (∀hasCommunicationLink. CommunicationLink))

Role ≡((∀ hasProcess. Process) ⊓ (∀ hasAuthority. Authority) ⊓ (∀ require. Skill)
⊓ ((∃superiorOf. Role) ⊔ (∃ subordinateOf. Role)) ⊓ (∀ hasResource. Resource)
⊓ (∃ hasPolicy. Constraints) ⊓ (≥ 1 hasResponoibility. Responsibility)
⊓ (∃hasSupervisor. CityOrgAgent) ⊓ (∃hasSupervisee. CityOrgAgent)
⊓ (∃hasEmpowerment. Empowerment))

Activity ≡ ((∀corespondToCityService. CityService)
⊓ (∃fullfill. Condition) ⊓ (∃hasCityOrgAgent. CityOrgAgent) ⊓ (∀hasOccurrence. TimePoint))

CommunicationWithAuthority ⊑ Authority
Role ⊑ CityOrganization
hasSupervisor ⊑ hasRole
hasSubordinate ⊑ hasRole
Supervisor ≡ Role ⊓ ∃ hasSubordinate. CityOrgAgent
Subordinate ≡ Role ⊓ ∃ hasSupervisor. CityOrgAgent
hasSupevisor ⊑ hasSubordinate⁻
Goal ⊑ CityOrganization
SubGoal ⊑ Goal
Mission ⊑ Goal
Vision ⊑ Goal

ValuesAndBeliefs ⊑ Goal
Strategies ⊑ Goal
SubGola ⊓ Mission ≡⊥
SubGola ⊓ Vision ≡⊥
SubGola ⊓ ValuesAndBeliefs ≡⊥
SubGola ⊓ Strategies ≡⊥
Misssion ⊓ Vision ≡⊥
Misssion ⊓ ValueAndBeliefs ≡⊥
Misssion ⊓ Strategies ≡⊥
Vision ⊓ ValueAndBeliefs ≡⊥
Vision ⊓ Strategies ≡⊥
ValuesAndBeliefs ⊓ Strategies ≡⊥
CityOrgAgent ⊑ CityOrganization
Division ⊑ CityOrganization
SubDivision ⊑ Division
CommunicationLink ⊑ CityOrganization
Activity ⊑ CityOrganization
Skill ⊑ CityOrganization
Responsibility ⊑ CityOrganization
Authority ⊑ CityOrganization
Team ⊑ CityOrganization
ProjectTeam ⊑ Team
VirtualTeam⊑ Team
ProjectTeam ⊓VirtualTeam≡⊥
Resource ⊑ CityService
hasSupervisor ⊑ hasSupervisee⁻
hasCondition ≡ hasPolicy
hasCondition ⊑ CityOrganization
TemporalEmpowermen ⊑ Empowerment
ContinualEmpowermen ⊑ Empowerment
TemporalEmpowermen ⊓ ContinualEmpowermen ≡⊥

Table 3.6: Description Logic Representation of Organization Knowledge Pattern

3.5. Infrastructure Knowledge Pattern

In this section we introduce Infrastructure Knowledge Pattern (IKP). We first describe a unified definition of municipal infrastructures. Then, employing a set of examples from Toronto 311 knowledgebase we highlight the existing pattern of municipal infrastructures' knowledge components. Finally, we formally introduce the IKP framework.

To be able to introduce the IKP, we must first provide an unambiguous definition of infrastructure and its characteristics. According to Vining and Richard (2001), there is no

universally accepted definition of infrastructure that takes into account public provision, subsidization, or regulation. Furthermore, in a decentralized government system with different layers of authority (e.g., federal, provincial, or municipal) the definition of infrastructure becomes even more complicated (i.e., the ownership of the infrastructure is not clear). In other word, there are infrastructures that are under the authority of the municipal government, while there also exist infrastructures that are not under the governance of that city even though geographically located in it (e.g., national parks).

The Merriam Webster defines infrastructure as "the system of public works of a country, state, or region; or the resources (as personnel, buildings, or equipment) required for an activity". Despite the simplicity, the definition highlights the main characteristics of infrastructures in the government domain. Specifically, in the government domain infrastructure assets are owned by either government (federal, provincial, or municipal), which is specified in the definition as public work or resources of country, state or region, or by the private sectors.

Statistic Canada also suggests a similar definition of infrastructure. According to Statistic Canada infrastructure in general can be classified as follows:

Types of Assets ➡ ⬇	Produced	Non-Produced
Tangible	Physical Structure	Environment
Intangible	Social /Institutional and other	

In this classification, infrastructures are classified into three main categories: physical structure, environment, and social /institutional. Physical infrastructures are those infrastructures that are tangible and manufactured, e.g., bridges, roads, and ports. Environmental infrastructures are tangible but made by nature, e.g., lakes, and gas/oil reserves. Finally, social/institutional infrastructures are intangible, and may or may not be produced.

The only difference in the definition of infrastructure between Webster dictionary and Statistic Canada is that the later definition does not consider the different levels of government. While Statistic Canada does not make such a distinction in its definition, the federal government of Canada recognizes such distinction and has indeed transferred some of its infrastructure assets to local governments in the past few decades. As shown in Figure 3.16, the infrastructure share of local governments has increased in past few decades, while at the same time the shares of federal and provincial government have decreased (Mackenzie, 2013)[14].

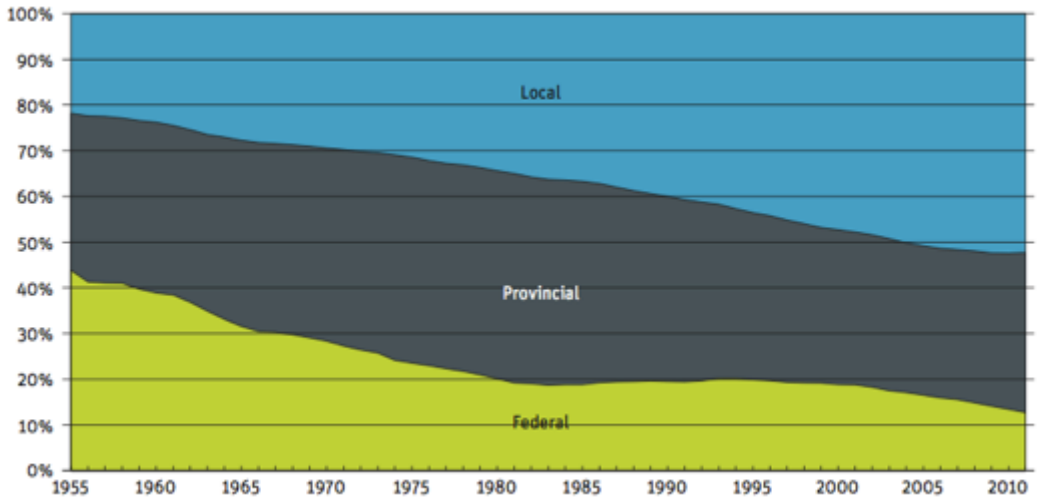


Figure 3.16: Infrastructure Shares by Order of Government,1995-2011

To come up with a unified definition of infrastructure, which overcomes the short falls of the above definitions; we have added a third dimension "Juristic Division" to the Statistic Canada's model. As Figure 3.6.2[15] shows, by adding this new dimension, we separate the infrastructures based on their juristic territories. Accordingly, we define infrastructure as physical structure or environmental asset of municipal government and its private business partners that are consumed as city resources in daily operation of public services and activities.

---

[14] According to Canadian federal government, by 2011, the federal government and local governments had reversed their positions in infrastructure asset shares. The federal government owns only 13% of the stock, the provinces 35%, and municipalities 52%.

[15] This chart is part of Canada's Infrastructure Gap, Page 8, Alternative Federal technical Paper, http://www.policyalternatives.ca/sites/default/files/uploads/publications/National%20Office/2013/01/Canada's%20 Infrastructure%20Gap.pdf

Note that infrastructures can drastically affect the city's daily operation (e.g., a natural disaster or a malfunction of a physical infrastructure can affect or stop the public service delivery). Despite their importance, they are overlooked in the Toronto 311 knowledgebase, i.e., less than 8% of the observed webpages in our study contained information related to infrastructure, and even in those cases the components of infrastructure are unstructured, random, and ambiguous.

In the next section, we provide a set of examples from the 311 knowledgebase to highlight the main knowledge components of government infrastructures.

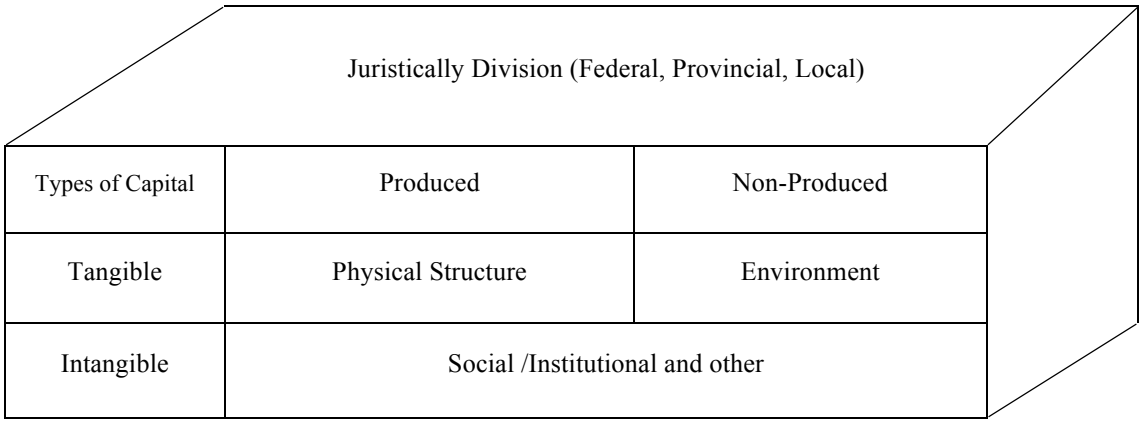


Figure 3.17:Infrastructure Classification based on Jurisdiction

3.5.1 Infrastructure Knowledge in Toronto 311 knowledgebase

The following examples from Toronto 311 knowledgebase webpages will highlight the knowledge constituents of Infrastructure Knowledge Pattern.

Case1: Juristic Division

The first example we consider is Defense Construction Canada[16], an organization responsible for providing infrastructure and environmental services to Canada's Department of National Defense, a federal organization (see Figure 3.18). While this

[16] http://www.toronto.ca/311/knowledgebase/64/101000045964.html

organization only deals with the federal government, i.e., provides construction and maintenance services for the federal government's infrastructure, the Toronto 311 knowledgebase still provide information about it.

Figure 3.18: Defense Construction Canada

This example shows the necessity of defining different **jurisdictions** (federal, provincial, and municipal), and linking different infrastructures to the appropriate jurisdictions. Such a definition provides a more structured representation of infrastructure.

Note that the ownership of an infrastructure can be shared between the different levels of government. For example, as depicted in Figure 3.19, the Toronto Waterfront Corporation, which is responsible for the Toronto's waterfront revitalization, is jointly owned by the Government Canada, the Province of Ontario, and the City of Toronto. For each jurisdiction there is a specific organization with a set of predefined responsibility and roles to perform, e.g., federally Department of Finance Canada is responsible for waterfront revitalization (see the blue box).

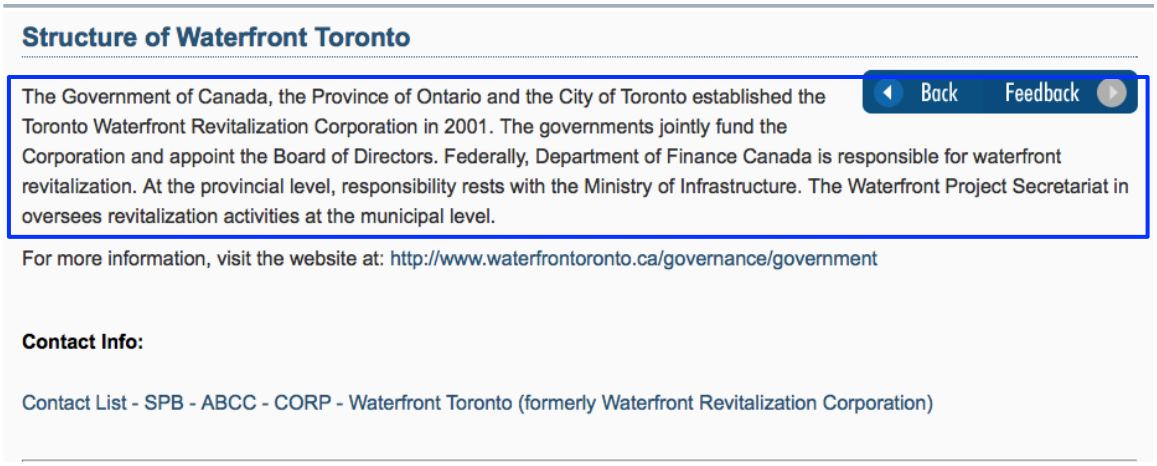


Figure 3.19:Structure of Waterfront Toronto

Case 2: Physical Structure [17]

Our second example is concerned with transportation infrastructures. Specifically, Figure 3.20 depicts a webpage that provides statistics regarding the different road infrastructures in the city of Toronto (shown in the blue box). These infrastructures are instances of **physical structures** of the city.

There are two main concerns in this webpage: (i) the accuracy of webpage in long term, (ii) the necessity of continuous updates due to lack of semantic structure in the Toronto 311 knowledgebase. We can define infrastructures such as road, expressway, main road, etc. as transportation infrastructure; then categorize these transportation infrastructures with object property (type-of) as physical structure, which is a sub-category of infrastructure. The number of roads, expressway, bus shelters, or other infrastructure should be a dynamic feed with the data property (number) from real time data for these facilities.

[17] http://www.toronto.ca/311/knowledgebase/90/101000052090.html

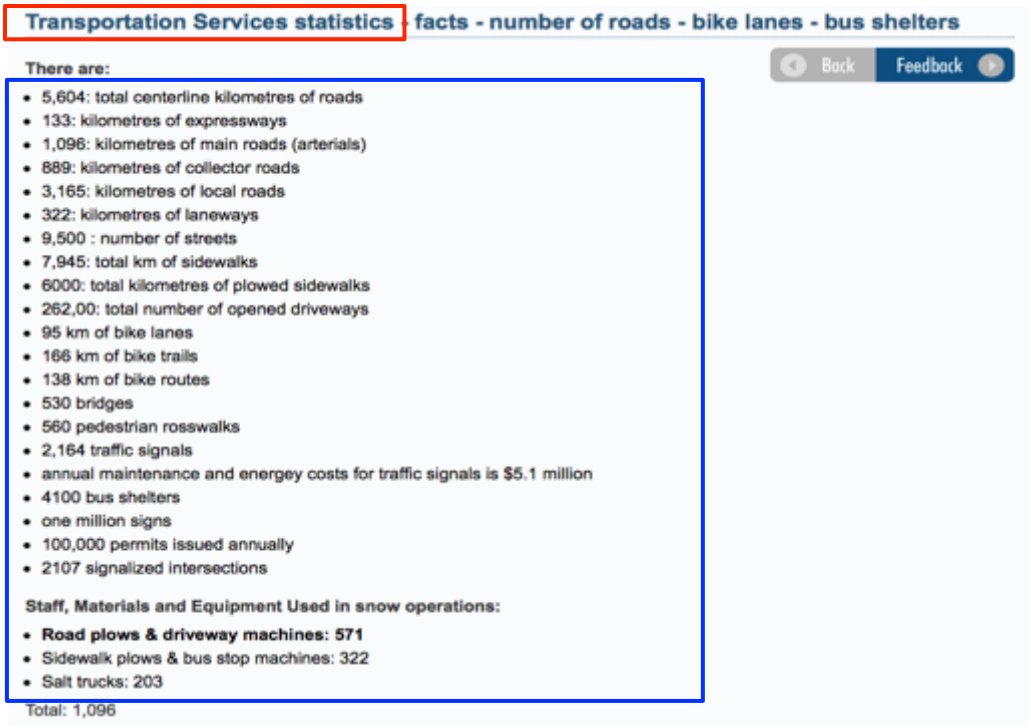


Figure 3.20:Transportation Services Statistics- City of Toronto

To describe the knowledge components of IKP in general, and physical structures in particular, we consider the webpage depicted in Figure 3.21. This webpage provides information about the organization responsible for a specific service (i.e., dead animal removal), given the location of the service. We have chosen this example to highlight three important components: (i) infrastructures are always related to city services i.e., they are **resources** used by the city to deliver a service; (ii) infrastructures within a municipal region could belong to different levels of government, e.g., highways within the city of Toronto could be either **municipal** infrastructure (DVP or highway 27) or **provincial** infrastructure (QEW) (see the two blue boxes); (iii) the municipal infrastructure could have **public** or **private** ownership, e.g., highway 407 is a private infrastructure (see green box) while the highways mentioned earlier are public infrastructure.

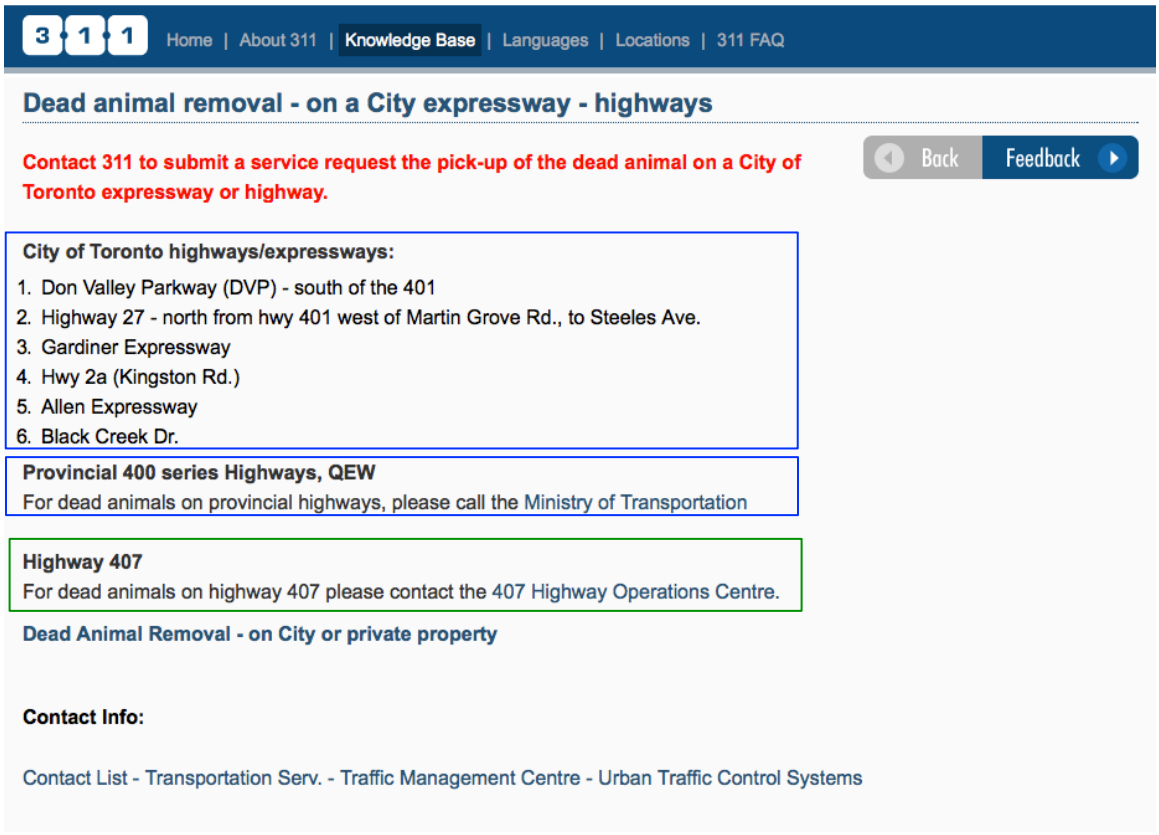


Figure 3.21: Dead Animal Removal- on City Expressway-Highways

3.5.2 Infrastructure Knowledge Pattern

The IKP characterizes the infrastructures (resources) that are essential for the city's daily operation (e.g., roads, water facilities, and electricity). The municipal government is mostly responsible for development, expansion, and update of such infrastructures within its geographical boundaries. Following Statistic Canada's definition of infrastructure, we categorize the city's infrastructures into **physical structure** (see Case 2), or **environmental** resources (e.g., lakes and forests). It is worth noting that in the 311 knowledgebase, environmental resources are not considered as infrastructure assets of the city. As a result, finding the knowledge constituents of such resources is difficult.

For both types of infrastructures mentioned above, the ownership is either **public** or **private**. Moreover, public infrastructures can belong to the federal, provincial, or municipal government (see Case 1).

Because we have no precise definition that describes **intangible** forms of asset, we will not consider them in the IKP. Table 3.7, depicts the main knowledge components of the Infrastructure Knowledge Pattern.

Example

Road

Subway

Water resources

Constituent Knowledge

Tangibility

- Tangible
- Intangible

Production

- Physical (Manmade, Produced, Artifact)
- Environment (Natural, Non-Produced)

Juristic Division

- Federal
- Provincial
- Municipal (Local)

Ownership

- Public
- Private

Type of Resource

- Consumed during activities

Table 3.7: Infrastructure Knowledge Pattern

$\text{Infrastructure} \sqsubseteq \text{Resource}$
$\text{Tangibility} \sqsubseteq \text{Infrastructure}$
$\text{Tangibile} \sqsubseteq \text{Tangibility}$
$\text{Tangibile} \sqsubseteq \text{Tangibility}$
$\text{Tangibile} \sqcap \text{Tangibile} \equiv \bot$
$\text{Producation} \sqsubseteq \text{Infrastructure}$
$\text{PhysicalStructure} \sqsubseteq \text{Producation}$
$\text{Environmental} \sqsubseteq \text{Producation}$
$\text{PhysicalStructure} \sqcap \text{Environmental} \equiv \bot$
$\text{Environmental} \equiv \text{Natural} \equiv \text{nonProduced}$
$\text{PhysicalStructure} \equiv \text{Produced} \equiv \text{Engineered}$
$\text{JuristicDivision} \sqsubseteq \text{Infrastructure}$

$$\text{Federal} \sqsubseteq \text{JuristicDivision}$$
$$\text{Provincial} \sqsubseteq \text{JuristicDivision}$$
$$\text{Municipal} \sqsubseteq \text{JuristicDivision}$$
$$\text{Federal} \sqcap \text{Provincial} \equiv \bot$$
$$\text{Federal} \sqcap \text{Municipal} \equiv \bot$$
$$\text{Provincial} \sqcap \text{Municipal} \equiv \bot$$
$$\text{Ownership} \sqsubseteq \text{Infrastructure}$$
$$\text{PublicOwnership} \sqsubseteq \text{Ownership}$$
$$\text{PrivateOwnership} \sqsubseteq \text{Ownership}$$
$$\text{PublicOwnership} \sqcap \text{PrivateOwnership} \equiv \bot$$
$$\text{PublicInfrastructure} \equiv ((\geq 1\ \text{isOwnedBy.Organization}) \sqcap (\forall\ \text{hasJuristicDivision.JuristicDivision}) \sqcap (\forall\ \text{hasOwnership.Ownership}) \sqcap (\forall \text{hasTangibility.Tangibility} \sqcap (\forall \text{consumedBy.Activity}))$$

Table 3.8: Description Logic Representation of Infrastructure Knowledge Pattern

3.6. Public Facility knowledge Pattern

Recall from the previous section that a major class of city infrastructures is physical structures (e.g., bridges and sewage systems). However, there is a subclass of infrastructures that have all the characteristics of physical structures (they are tangible and made by humans), but have their own unique properties (examples of such infrastructures are museum, pool, and zoo). We denote such infrastructures as public facilities. Specifically, public facilities have their own unique knowledge components (e.g., availability, hours of operation, age limits, or accessibility for disables, thus their relationship with public services is different from the infrastructures in the IKP. Therefore, to capture such a pattern, in this section we introduce the Public Facility Knowledge Pattern (PFKP).

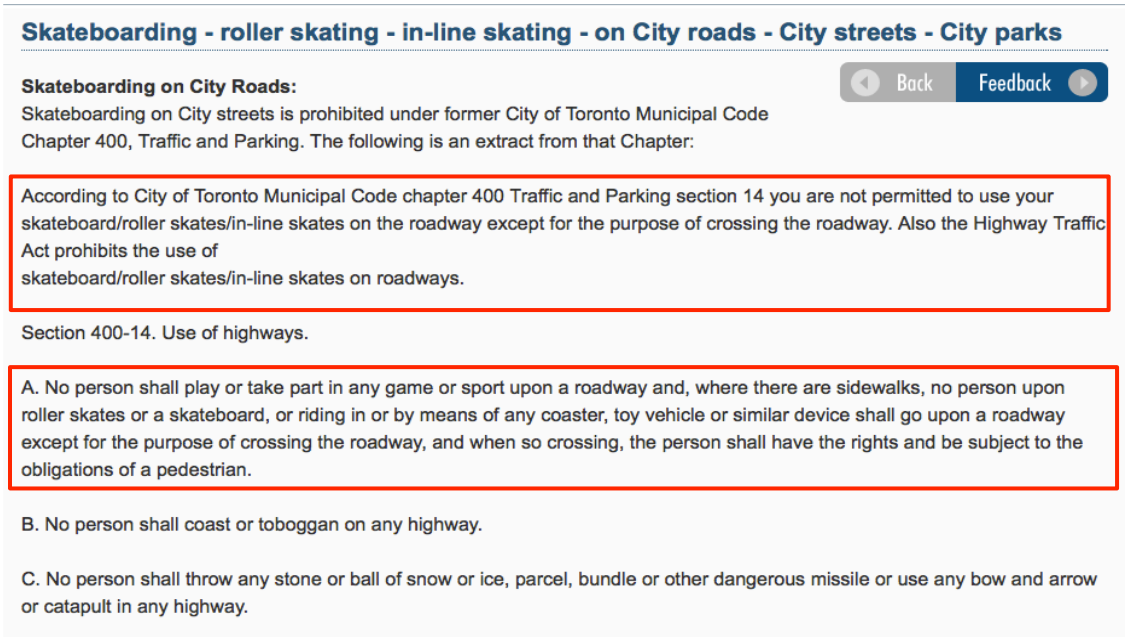
3.6.1 Public Facility in Toronto 311 knowledgebase

In our investigation of the Toronto 311 knowledgebase we observed that 12% of the webpages contain a components related to public facilities. Moreover, public facilities were the third most common subject in this survey (behind service and organization). The following set of examples illustrates the main components of public facilities.

Case 1: Skateboarding-roller skating -inline skating on City road and parks[18]

Figure 3.22 depicts a webpage containing information about city policies on skateboarding in public facilities such as streets and parks. These policies dictate the rules, which the citizens must following when using a facility. For example, the red boxes in Figure 3.22 shows instances where skateboarding is prohibited on a public facility.

In general, the example highlights that public facilities have policies (constraints) that dictate a set of activities are allowed or prohibited in each facility.



Skateboarding - roller skating - in-line skating - on City roads - City streets - City parks

Back Feedback

Skateboarding on City Roads:
Skateboarding on City streets is prohibited under former City of Toronto Municipal Code Chapter 400, Traffic and Parking. The following is an extract from that Chapter:

According to City of Toronto Municipal Code chapter 400 Traffic and Parking section 14 you are not permitted to use your skateboard/roller skates/in-line skates on the roadway except for the purpose of crossing the roadway. Also the Highway Traffic Act prohibits the use of
skateboard/roller skates/in-line skates on roadways.

Section 400-14. Use of highways.

A. No person shall play or take part in any game or sport upon a roadway and, where there are sidewalks, no person upon roller skates or a skateboard, or riding in or by means of any coaster, toy vehicle or similar device shall go upon a roadway except for the purpose of crossing the roadway, and when so crossing, the person shall have the rights and be subject to the obligations of a pedestrian.

B. No person shall coast or toboggan on any highway.

C. No person shall throw any stone or ball of snow or ice, parcel, bundle or other dangerous missile or use any bow and arrow or catapult in any highway.

Figure 3.22: Prohibited Activities on Public Facilities(Streets, Highways, Parks)

Case 2: Prescribed Burn in High Park[19]

In this example, we use the Prescribed Burn in High Park webpage to illustrate two important aspects of the PFKP: **provider** and **availability.**

---

[18] http://www.toronto.ca/311/knowledgebase/70/101000040270.html
[19] http://www.toronto.ca/311/knowledgebase/61/101000921761.html

In our example, the **provider** is the City of Toronto Parks, Forestry and Recreation division, which performs the prescribe burn activity, a maintenance activity for parks and forests (see the blue box in Figure 3.23). Moreover, the red box highlights the **availability** of the park during the prescribe burn activity. The availability component of a public facility indicates the times a public facility is available for public use.

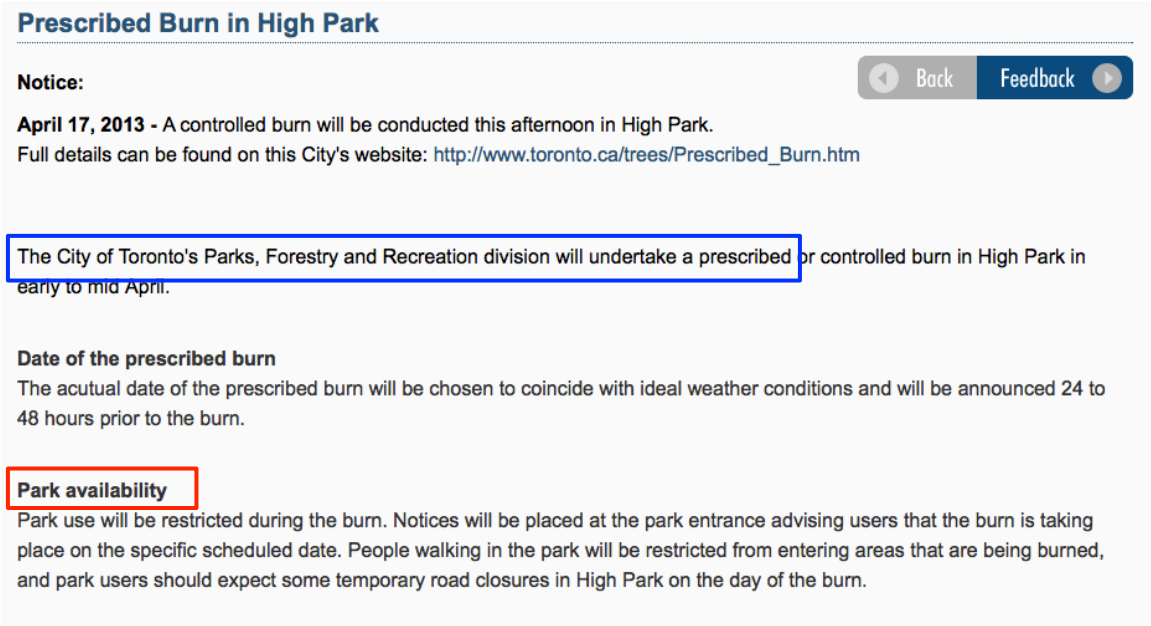


Figure 3.23: Prescribed Burn in Park High

Case3: Holding Events in Public Facilities

Figure 3.24 depicts a webpage containing information about holding meetings or receptions events in the Campbell House (a museum in the city of Toronto). We have chosen this webpage since it highlights an important component of public facilities: **reserve/rent.** Specifically, this example shows that some public facilities allow citizen to **reserve** that facility to hold events.

Figure 3.24: Campbell House-Meeting or Reception

Case 4: Spadina Museum

Another example of public facilities is the Spadina Museum. As in Case 2, the webpage contains information about the availability of the museum (see the red box). It also provides links and contact information. An important component not provided in the previous cases is **accessibility.** Specifically, in this example the webpage indicates that the museum has wheelchair accessibility (see the red box). In general, since the public uses public facilities, it is crucial that such facilities provide information about their special services for disable visitors.

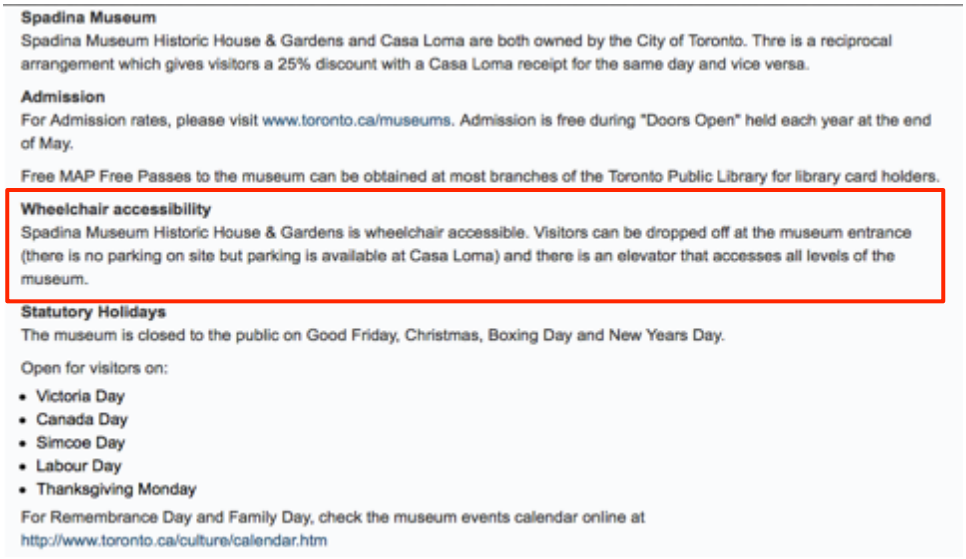


Figure 3.25: Spadina Museum

Case 5: Swimming Pool

Our final example is the swimming pool facilities. These facilities could have **public** or **private** ownership. Moreover, as shown in Figure 3.26 swimming pools have **availability** (closure) component (shown in the green box). In addition to availability, public facilities contain other characteristics such as **opening day** (blue box), **operation hour**, and **extended hours** (yellow box).

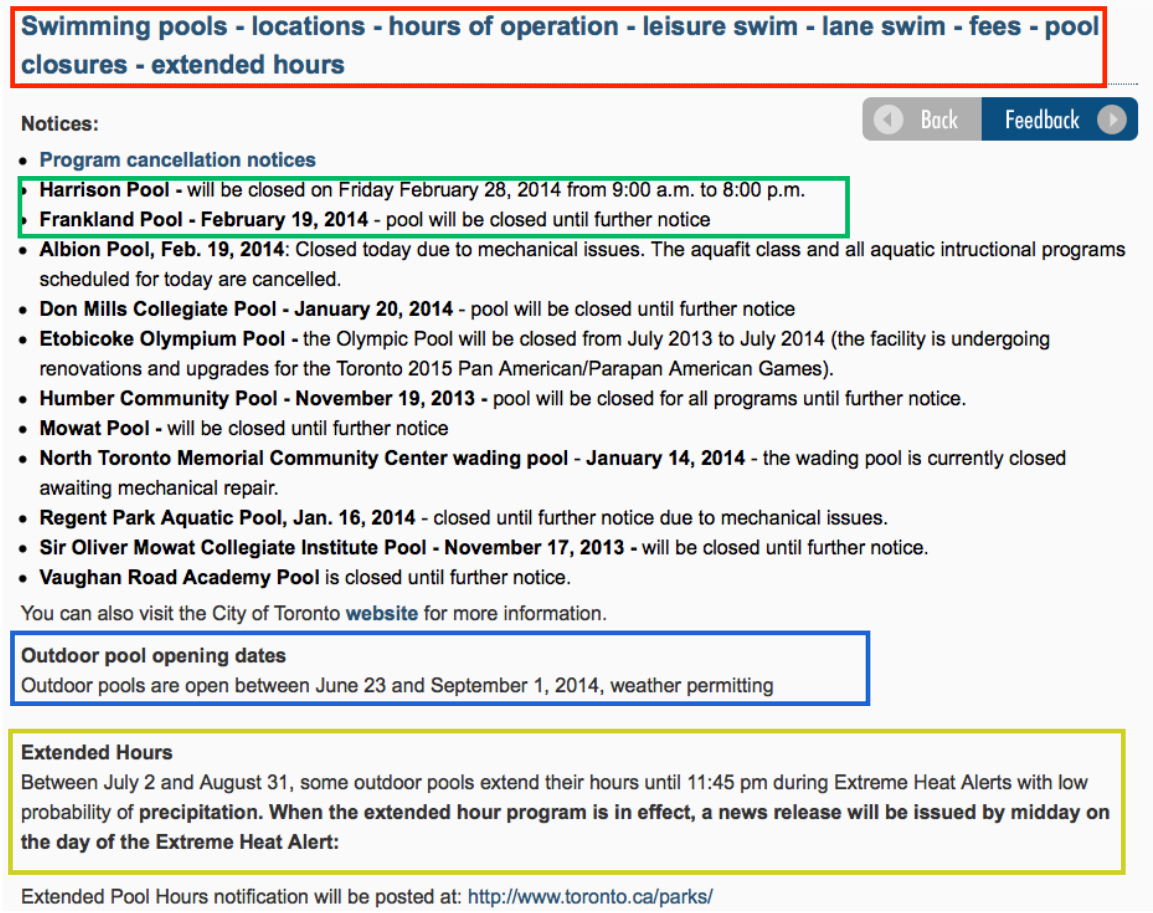


Figure 3.26: Swimming Pools- Location- Hours of Operation-Fees

Figure 3.27 depicts age restriction for using swimming pools. According to this webpage infants and toddlers cannot use regular swimming pools. We denote this component as **age limitation**, which is a constraint on the permitted activities in public facilities. Moreover, some of these facilities could have cost constraints on their activities such as swimming pools tickets and fees.

Figure 3.27: Swimming Pools- Toddler- Tots- Infants

3.6.2 Public Facility Knowledge Pattern

Public facilities are a subclass of infrastructures, with a unique set of characteristics. Due to this subclass relation, public facilities inherit all the characteristics of the Infrastructure Knowledge Patter (IKP), while having an addition set of characteristics that distinguishes them from other infrastructures. In the rest of this section, we characterize the additional knowledge components of public facilities.

One of the inherent characteristics of public facilities is the ownership component, which means that every facility has an owner that could be either public or private. Regardless of the ownership of the public facilities, city must provide information about the services that they provide, and about the organization **division** (**agent**) that delivers the service. Note that Organization Knowledge Pattern elements such as ***agent*** and ***division*** play a significant role in connecting Service Knowledge Pattern components to public facility resources. The ***division*** is responsible to communicate ***availability*** of the public facility, and provide information about facilities' new programs, **hours of operation**, **fees**, **age limitation,** and **accessibility** for disables. It also is responsible for continuous communication between citizens and facility by providing its ***contact information*** (the information can be directly acquired from the provider or through the city's nonemergency service center (311)).

Finally, each public facility has a set of ***permissible***/**non-permissible** (prohibited) activities, which can and/or cannot be done on their premises. Note that under specific conditions, a permit can be procured for a non-permissible activity to take place (e.g., while photography in museums is prohibited, under specific conditions a citizen can acquire a photography permit for a limited time).

Example

- Museums
- Pools
- Zoo

Constituent Knowledge

- Activity
  - Permissible Activities (Permitted)
  - Non-Permissible Activities (Prohibited)
- Provider = some organization agent (Division)
- Availability
  - Operation Hour
  - Operation Date
- Restriction (Age limitation)
- Fees
- Reserve option
- Rent Option
- Accessibility
  - Inability Access
- Contact Info
  - Website
  - Email
  - Phone
  - Address

Table 3. 9: Public facility Knowledge Pattern

Activity $\sqsubseteq$ CityService
Division $\sqsubseteq$ CityService
Condition $\sqsubseteq$ Organization
Fee $\sqsubseteq$ Condition
Restriction $\sqsubseteq$ Condition
AgeLimitation$\sqsubseteq$ Restriction
Fee $\sqcap$ Restriction $\equiv \bot$
Publicfacility $\sqsubseteq$ Infrastructure
PermittedActivity $\sqsubseteq$ Avtivity
ProhibittedActivity $\sqsubseteq$ Activity
$\neg$ isPemitted $\equiv$ isProhibited
Permitted$Activity \equiv$ PremissibleActivity
NonPermittedActivity $\equiv$ NonPremissible $\equiv$ ProhibitedActivity

PermittedActivity ⊓ ProhibitedActivity ≡ ⊥
hasPublicFacilityProvider ⊑ Organization
Availability ⊑ PublicFacility
OperationHour ⊑ Time
OperationDate ⊑ Date
OperationHour ⊓ OperationDate ≡ ⊥
RentOption⊑ PublicFacility
ReserveOption⊑ PublicFacility
Accesibility ⊑ PublicFacility
InabilityAccess ⊑ Accesibiliy
ContactInfo ⊑ PublicFacility
PublicFacilityWebsite ⊑ ContactInfo
PublicFacilityEmail ⊑ ContactInfo
PublicFacilityPhone ⊑ ContactInfo
PublicFacilityAddress ⊑ ContactInfo
PublicFacilityWebsite ⊓ PublicFacilityEmail ≡ ⊥
PublicFacilityWebsite ⊓ PublicFacilityPhone ≡ ⊥
PublicFacilityWebsite ⊓ PublicFacilityAddress ≡ ⊥
PublicFacilityEmail ⊓ PublicFacilityPhone ≡ ⊥
PublicFacilityEmail ⊓ PublicFacilityAddress ≡ ⊥
PublicFacilityPhone ⊓ PublicFacilityAddress ≡ ⊥
PublicFacility ≡
((∀ hasActivity. Activity) ⊓ (∃isProhibited. Activity) ⊓ (isPermitted. Activity) ⊓
(∃ hasCondition. Condition) ⊓ (∀ hasResource. PublicFacility) ⊓
((∃ reserve. ReserveOption) ⊔ (∃ rent. RentOption) ⊓ (∃ Provideservice. CityService) ⊓
(∀ hasPublicFacilityProvider. Organization) ⊓ (∀ isAvailable. Boolean) ⊓
(∃isAccessible. Accessibility) ⊓ (∃ hasContactInfo. ContactInfo) ⊓
(∃ hasOperationHours. TimeInterval) ⊓ (∃ hasOperationDate. Date) ⊓
(∃hasRestriction. Restriction))

Table 3.10: Description Logic Representation of Public Facility Knowledge Pattern

3.7. Citizen Knowledge Pattern

In its day-to-day operation, a city acquires information from its citizens in the course of delivering the service. Since the 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 Citizen Knowledge Pattern that provides a unified view of the totality of the citizen related information.

3.7.1 Citizen Knowledge in Toronto311 Knowledgebase

The following examples from the Toronto 311 knowledgebase illustrate the various types of citizens' knowledge used by the city of Toronto:

Case 1: Personal Information

To illustrate one type of information regarding citizens gathered by the city, we have chosen two different services: the parking permit and the pet license application forms. These forms show one of the most common types of information that citizens should provide to request service, namely personal information.

As depicted in Figure 3.28, the application form for obtaining a parking permit requires that the applicant (citizen) provide information in two sections: personal and priority information (depicted in red boxes). We only focus on the personal, since most city service providers request such information to initiate a service. The personal information section of the parking permit form requires the following information from the service requester: *plate number* of the automobile, *name*, *address*, and *contact numbers* (*home*, *business*, or *cell*) of the automobile owner (shown in the blue box).

Similar to the parking permit example, the pet license application (depicted by Figure 3.29) also requires that the requester provide personal information such as name, address, and phone number (the first section of the form).

TORONTO Transportation Services Division
Right of Way Management

Application for
Permit Parking

City Hall, Main Floor, West Tower
100 Queen Street West
Toronto, ON M5H 2N2

Personal Information

Name of Applicant | **Plate Number**

Address | Unit | City | Prov. | Postal Code

Applicant Telephone
Home Area Number **Business** Area Number **Cell / Other** Area Number

Permit Term Options: Dec 1 - May 31 ☐ Jun 1 - Nov 30 ☐

Are you a previous permit holder? Yes ☐ No ☐

If applying by mail, contact the Permit Parking office at 416-392-7873 to confirm permit fee before sending a cheque

Priority Information

Is there parking on the property? Yes ☐ No ☐

If Yes, do you have access to that parking? Yes ☐ No ☐

Is this the first vehicle for which you have obtained a permit? Yes ☐ No ☐

Additional information that may affect your permit priority:

Personal information on this application is collected under the authority of the City of Toronto Act, 2006, s.136(c), By-law No. 680-2006, and the City of Toronto Municipal Code, Chapter 925, Permit Parking. It will be used for administrative purposes in connection with your application and enforcement purposes of Municipal Code Chapter 925.

Your name, the address of the proposed parking and number of vehicles to be parked will be treated as public information and may be included in reports to the Community Council.

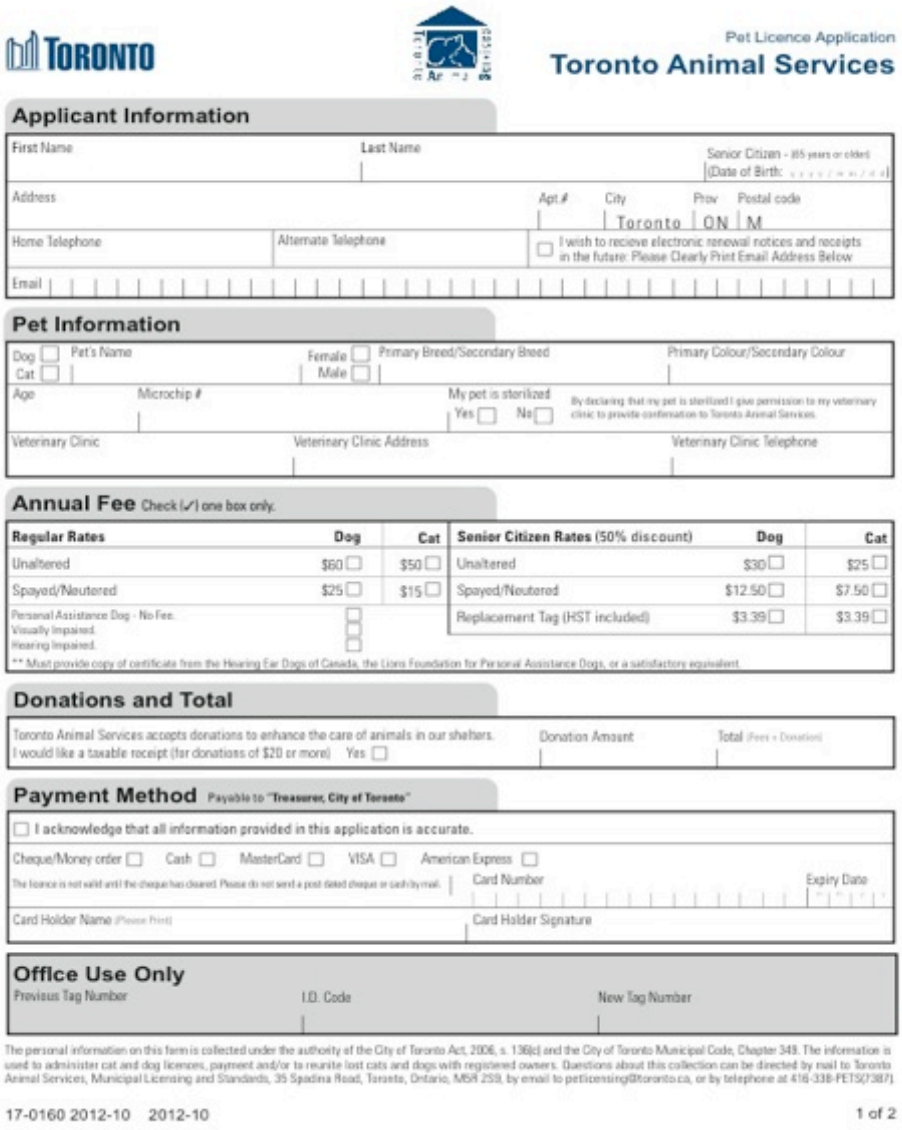
Any questions about the collection or use of this information can be addressed to the Supervisor of Permit Parking.

Applicant's Signature: _____ Date: _____

This application must be accompanied by your payment and the appropriate documentation as outlined on our website at www.toronto.ca/transportation

W002032A 04/10

Figure 3.28: Parking Permit Application



TORONTO

Pet Licence Application

Toronto Animal Services

Applicant Information

First Name | Last Name | Senior Citizen - 65 years or older (Date of Birth:)

Address | Apt # | City: Toronto | Prov: ON | Postal code: M

Home Telephone | Alternate Telephone | ☐ I wish to recieve electronic renewal notices and receipts in the future. Please Clearly Print Email Address Below

Email

Pet Information

Dog ☐ Cat ☐ | Pet's Name | Female ☐ Male ☐ | Primary Breed/Secondary Breed | Primary Colour/Secondary Colour

Age | Microchip # | My pet is sterilized Yes ☐ No ☐ | By declaring that my pet is sterilized I give permission to my veterinary clinic to provide confirmation to Toronto Animal Services.

Veterinary Clinic | Veterinary Clinic Address | Veterinary Clinic Telephone

Annual Fee Check (✓) one box only.

Regular Rates	Dog	Cat	Senior Citizen Rates (50% discount)	Dog	Cat
Unaltered	$60 ☐	$50 ☐	Unaltered	$30 ☐	$25 ☐
Spayed/Neutered	$25 ☐	$15 ☐	Spayed/Neutered	$12.50 ☐	$7.50 ☐
Personal Assistance Dog - No Fee. Visually Impaired. Hearing Impaired.	☐ ☐ ☐		Replacement Tag (HST included)	$3.39 ☐	$3.39 ☐

** Must provide copy of certificate from the Hearing Ear Dogs of Canada, the Lions Foundation for Personal Assistance Dogs, or a satisfactory equivalent

Donations and Total

Toronto Animal Services accepts donations to enhance the care of animals in our shelters. I would like a taxable receipt (for donations of $20 or more) Yes ☐ | Donation Amount | Total (Fees + Donation)

Payment Method Payable to "Treasurer, City of Toronto"

☐ I acknowledge that all information provided in this application is accurate.

Cheque/Money order ☐ Cash ☐ MasterCard ☐ VISA ☐ American Express ☐

The licence is not valid until the cheque has cleared. Please do not send a post dated cheque or cash by mail. | Card Number | Expiry Date

Card Holder Name (Please Print) | Card Holder Signature

Office Use Only

Previous Tag Number | I.D. Code | New Tag Number

The personal information on this form is collected under the authority of the City of Toronto Act, 2006, s. 136(c) and the City of Toronto Municipal Code, Chapter 349. The information is used to administer cat and dog licences, payment and/or to reunite lost cats and dogs with registered owners. Questions about this collection can be directed by mail to Toronto Animal Services, Municipal Licensing and Standards, 35 Spadina Road, Toronto, Ontario, M5R 2S9, by email to petlicensing@toronto.ca, or by telephone at 416-338-PETS(7387).

17-0160 2012-10 2012-10 1 of 2

Figure 3.29: Pet license Application

Case 2: Automobile Information[20]

In this example we look at a different type of information related to citizen that is gathered by the municipal government. Specifically, we consider the test center for vehicle inspection web page in the city of Toronto 311 knowledgebase. The test center conducts inspection on various vehicles such as taxicabs, limousines, and driving schools (highlighted by the red box in Figure 3.30).

[20] http://www.toronto.ca/311/knowledgebase/81/1010000037981.html

In order to get the vehicle inspection service (which is mandatory), the owner must satisfy predetermined requirements (as shown in the blue box) before the licensing office is able to proceed with the service. One of these requirements is the Used Vehicle Information Package (UVIP). This package includes:

- The vehicle details
    - Vehicle Identification Number (VIN)
    - Plate Number
    - Year, Make
    - Model
    - Color
    - Body Type
    - Cylinders
    - Power
    - Status
- Ontario vehicle registration history
- Odometer information
- Outstanding debts (link to liens) on the vehicle
- Retail sales tax requirements
- Bill of sale
- Tips on vehicle safety standards inspections

While the automobile information has knowledge components different from that of the personal information (see the previous example), they are both information related to an individual (owner of the automobile). This highlights the fact that the citizen's information can take many forms.

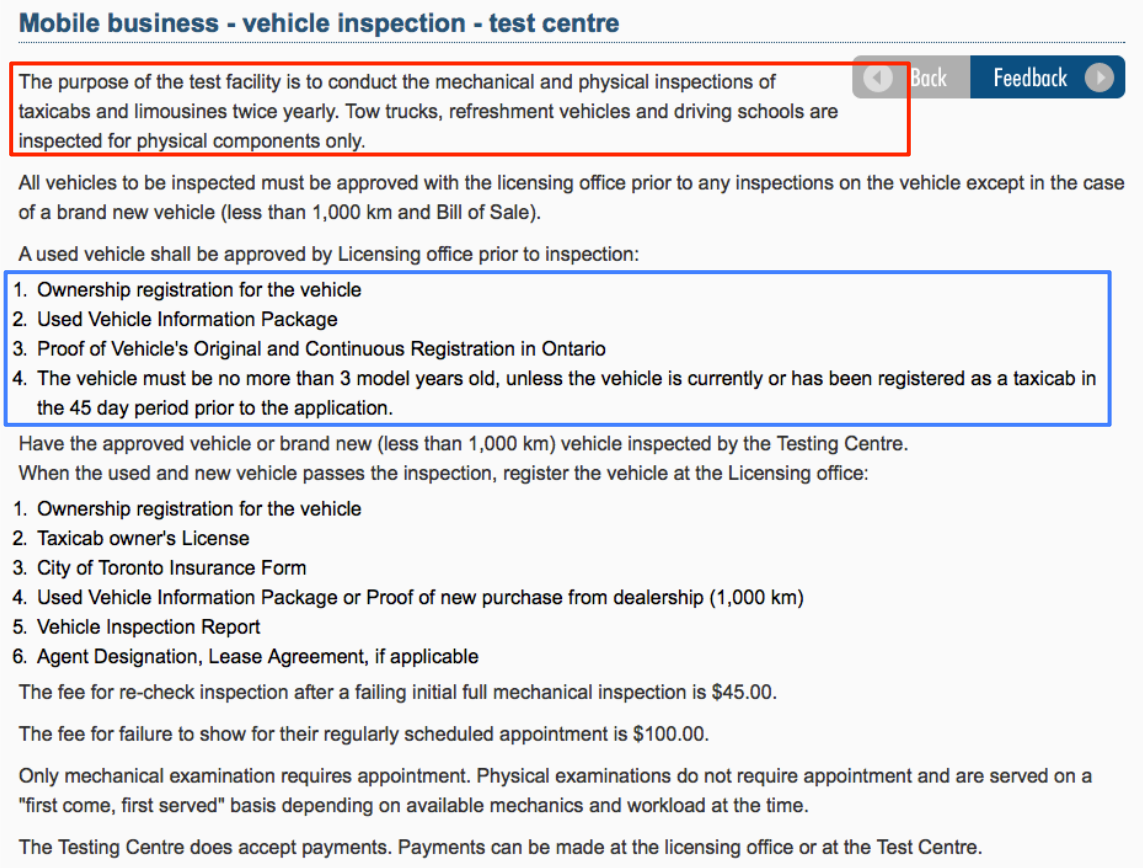


Figure 3.30: Mobile Business- Vehicle Inspection

Case 3: Medical Information

The third type of citizen information is medical information. Specifically, we discuss the "In Case of Emergency" (ICE) program, which is one of the recent initiatives in the city of Toronto emergency services. The program is designed to aid emergency medical service providers in situations where the patient is unconscious or when the ability to communicate between the patient and provider is not possible (e.g. when the patient can't speak English, or is has a heart attack). Note that the scope of the program is quite large: more than two hundred thousand elderly across the city of Toronto are already covered; moreover, it is strongly recommended that other age groups join the program.

Participants in the program should fill out (and carry with them at all times) a specific

form (shown in Figure 3.31) that contains the following information:

- Personal information including name, address, home number, cell number, work number
- Family doctor information such as name, address, and phone number
- Emergency contact list including two people, along side their addresses, and contact numbers
- Health information, which includes information regarding the person's existing medical problems, current medication usage, and allergies to medications.

As can be seen this form also has a personal information section very similar to that discussed in the previous cases. On top of the personal information this form requires extensive information from the citizen regarding their medical history. This history can play a significant role for public safety and wellbeing.

It is noteworthy that currently some citizens have an Electronic Medical Record (EMR), or Electronic Health Record (EHR). This electronic health information provides a person's health history, MRI, CT Scan, or X ray results in case of emergency; however, since these information services are not accessible for all citizens, and most of them are provided by private organization at a costs, we will not discuss the direct effect of them on city governance and city emergency services regulations. They will eventually be categorized under either personal or emergency information in the future.

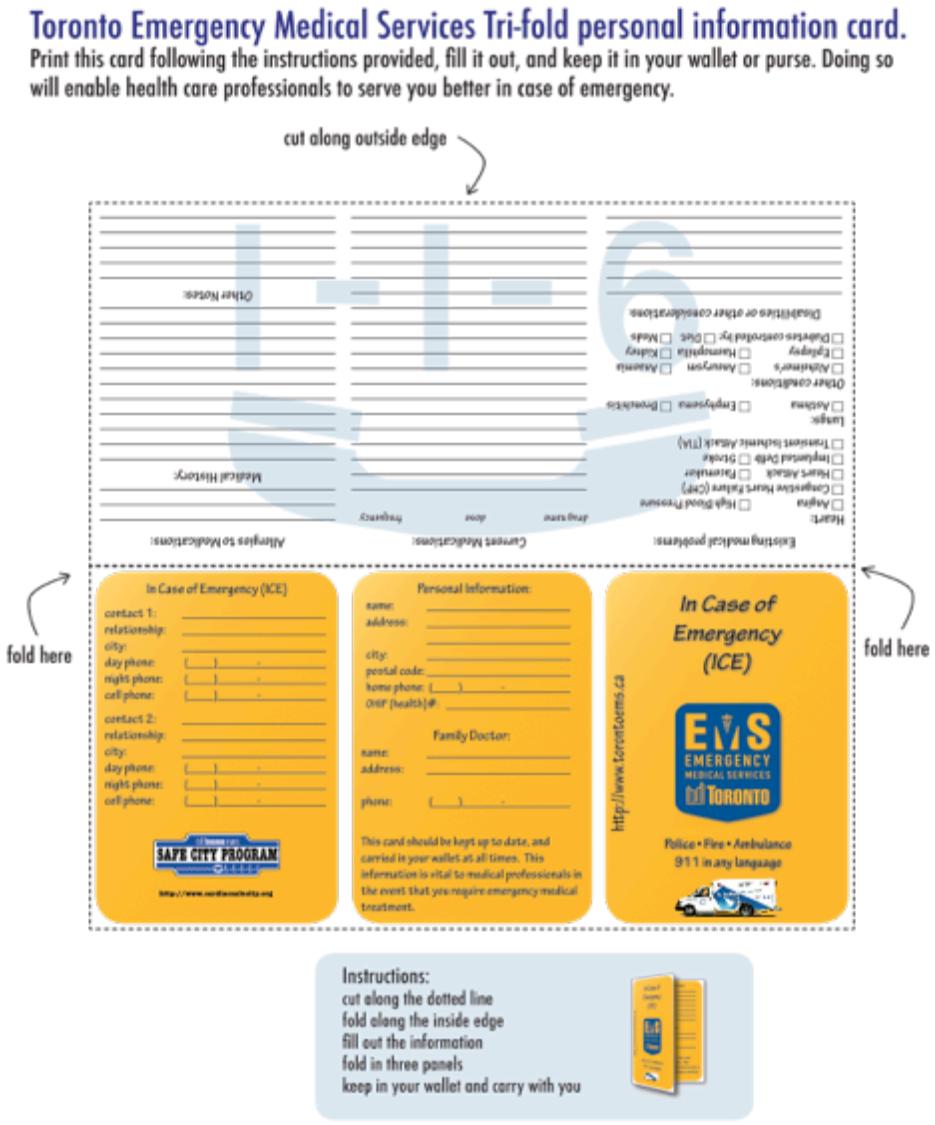
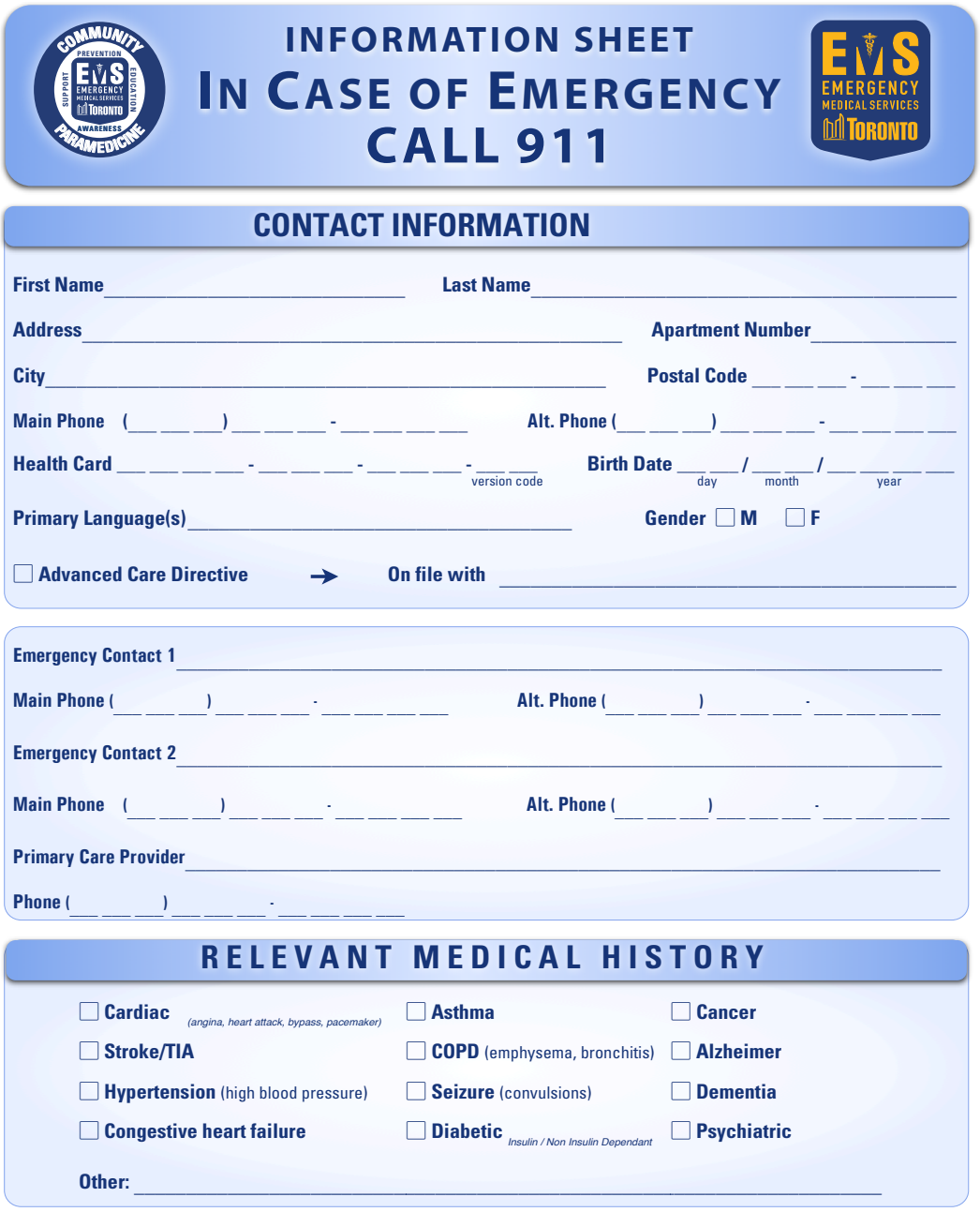


Figure 3.31: Ice Program Form (Old Version)

Note that Figure 3.32 and Figure 3.33 depict the new version of ICE form. It is important to understand that despite the differences in representation, the components of both forms are still the same.



INFORMATION SHEET

IN CASE OF EMERGENCY CALL 911

CONTACT INFORMATION

First Name _____ Last Name _____

Address _____ Apartment Number _____

City _____ Postal Code ___ ___ ___ - ___ ___ ___

Main Phone (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___ Alt. Phone (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___

Health Card ___ ___ ___ ___ - ___ ___ ___ - ___ ___ ___ - ___ ___ (version code) Birth Date ___ ___ / ___ ___ / ___ ___ ___ ___ (day / month / year)

Primary Language(s) _____ Gender ☐ M ☐ F

☐ Advanced Care Directive → On file with _____

Emergency Contact 1 _____

Main Phone (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___ Alt. Phone (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___

Emergency Contact 2 _____

Main Phone (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___ Alt. Phone (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___

Primary Care Provider _____

Phone (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___

RELEVANT MEDICAL HISTORY

☐ Cardiac *(angina, heart attack, bypass, pacemaker)*	☐ Asthma	☐ Cancer
☐ Stroke/TIA	☐ COPD (emphysema, bronchitis)	☐ Alzheimer
☐ Hypertension (high blood pressure)	☐ Seizure (convulsions)	☐ Dementia
☐ Congestive heart failure	☐ Diabetic *Insulin / Non Insulin Dependant*	☐ Psychiatric

Other: _____

Figure 3.32: Ice Program Form Page 1 of 2 (New Version)

Figure 3.33: ICE Program For Page 2 of 2 (New version)

3.7.2 Citizen Knowledge Pattern

As demonstrated through Cases 1, 2, and 3 citizen information spans many city services. Several pieces of information are acquired and used by different public service divisions every day. As a result, it is crucial for future analyses, reuse, and management of city

services to provide a standard categorization of citizen information and to present an unambiguous and meaningful representation of this information. Therefore, such a semantic integration can be the key component to a more dynamic and smarter city services in the future.

By recommending the Citizen Knowledge Pattern (CKP), we suggest a means to organize citizens' information in a structured manner. Such recognition of overlapped information in city services can lead to the development of a structured and shared knowledge about citizens.

In CKP, we divide the municipal government's information of its citizens into three categories:

- Personal Information
- Medical Information
- Automobile Information

As shown in Table 3.11 personal information consist of but is not limited to citizen's name, age, gender, address, phone, cell number, website, etc. The medical category consists of information that can assist emergency medical service provision, e.g., emergency contact list, family doctor contact information, health insurance, and health record (see case 3). Finally, automobile information categorizes information regarding citizen's vehicle, e.g., manufacturer, year, plate number, license, and traffic tickets. Note that we presented these three categories based on our analysis of the 311 knowledgebase. Specifically, in our analysis we only encountered citizens' information that fell into one of these three broad categorizations. However, we do not rule out other possible categories for citizen information.

Due to the importance of private information, we have to address privacy and accessibility of citizen information in CKP. Information privacy considers two correlated aspects: ***authority*** and ***accessibility***. Recall that we discussed the concept of "Authority" in the Organization Knowledge Pattern. In that pattern, we also discussed the properties

of authority, and elaborated on the correlation between authority and two organizational concepts: responsibility and organization role.

In the CKP, on the other hand, we concentrate on the relationship between the concepts of authority and accessibility. These two concepts are the most important characteristic of CKP, since they determine the level of access to the citizen's information based on ones authority, which is driven from his/her organization role and responsibility. We suggest that the level of accessibility to citizens' information should be categorized as:

- Public
- Permitted
- Private

Specifically, citizen information is the proprietary information of either the Toronto government or the Ontario Public Service. Therefore, to secure the privacy of information, these two organizations must determine the level of accessibility for different city agents based on their organizational roles and responsibilities. Under specific circumstances, an unauthorized agent could request permission to access restricted information for a limited time.

Note that we consider information with private level of accessibility in cases where the information is not considered completely private but the citizen does not wish for it to be made public.

Example Web Pages

- Parking Permit Application
- Used Vehicle Information Package (UVIP)
- In Case of Emergency (ICE) program

Constituent Knowledge

- Personal information
    - Name
    - Gender
    - Age
    - Address
    - Phone
    - Email
    - Cell
    - Website
- Medical Information
    - Emergency contact list
    - Health insurance
    - Medications or Medical problems
    - Family doctor contact information
    - Health record history (ICE, EMR, EHR)
- Automobile information
    - VIN
    - Plate number
    - Make, year
    - Model
    - Brand
    - Traffic tickets
    - Ontario vehicle registration history

Citizen Information Privacy

- Authority: who can have access to citizens information on what level
    - Authority level
- Accessibility:
    - Public
    - Permitted (limited Access)
    - Private

Table 3.11: Citizen Knowledge Pattern

CitizenInformation ≡ ResidentInformation
CitizenInformation
≡ ((∀ hasPersonalInfo. PersonalInformationInfo)
⊓ (∃hasMedicalInfo. MedicalInfor) ⊓ (∃hasAuthomobileInfo. AutomobileInfo)
⊓ ((∀ hasCityOrgAgent. CityOrgAgent)
⊓ (∃ hasAuthority. Authority)(∃ hasAccess. InfoAccess))

PersonalInfo ≡ ((∀ hasName. Name) ⊓ (∀ hasGeneder. Gender) ⊓ (∃ hasAddress. Address)
⊓ (∃ hasEmail. Email) ⊓ (∃ hasPhoneNumber. PhoneNumber)
⊓ (∃ hasWebsite. Website))

MedicalInfo ≡ ((∀ hasEmergencyContactList. EmergencyContactList)
⊓ (∀ hasHealthInsurance. HealthInsurance)
⊓ (∀hasMedicalProblem. MedicalProblem)
⊓ (∃ hasFamilydoctor. PhysicanContactList)
⊓ (∃ hasHealthRecordHistory. HealthRecordHistory))

AutomobileInfo ≡ ((∃ hasVIN. VIN) ⊓ (∀ hasPlatenumber. PlateNumber) ⊓ (∃ makeIn. Year)
⊓ (∃ hasModel. Model) ⊓ (∀ hasBrand. Brand) ⊓ (∃ hasTrafficticket. TraficTicket)
⊓ (∃ hasPVRH. PVRH[21]))

PersonalInfo ⊑ CitizenInfo
MedicalInfo ⊑ CitizenInfo
AutomobileInfo ⊑ CitizenInfo
PersonalInfo⊓ MedicalInfo ≡⊥
PersonalInfo⊓ AutomobileInfo ≡⊥
MedicalInfo ⊓ AutomobileInfo ≡⊥
CityOrgAgent ⊑ Organization
Authority ⊑ Organization
InfoAccess ⊑ CitizenInfo
Name ⊑ PersonalInfo
Gender ⊑ PersonalInfo
Address ⊑ PersonalInfo
Email ⊑ PersonalInfo
PhoneNumber ⊑ PersonalInfo
Website ⊑ PersonalInfo
Name⊓ Gender ≡⊥
Name⊓ Address ≡⊥
Name⊓ Email ≡⊥
Name⊓ PhoneNumber ≡⊥
Name⊓ Website ≡⊥
Gender ⊓ Address ≡⊥
Gender ⊓ Email ≡⊥

[21] PVRH stand for province vehicle registration history

Gender ⊓ PhoneNumber ≡⊥
Gender ⊓ Website ≡⊥
Address ⊓ Email ≡⊥
Address ⊓ PhoneNumber ≡⊥
Address ⊓ Website ≡⊥
Email ⊓ PhoneNumber ≡⊥
Email ⊓ Website ≡⊥
PhoneNumber ⊓ Website ≡⊥
EmergencyContactList ⊑ MedicalInfo
HealthInsurance ⊑ MedicalInfo
MedicalProblem ⊑ MedicalInfo
PhysicanContactList ⊑ MedicalInfo
HealthRecordHistory ⊑ MedicalInfo
ICE ⊑ HealthRecordHistory
EMR ⊑ HealthRecordHistory
EHR ⊑ HealthRecordHistory
ICE ⊓ EMR ≡⊥
ICE ⊓ EHR ≡⊥
EHR ⊓ EMR ≡⊥
EmergencyContactList ⊓ HealthInsurance ≡⊥
EmergencyContactList ⊓ MedicalProblem ≡⊥
EmergencyContactList ⊓ PhysicanContactList ≡⊥
EmergencyContactList ⊓ HealthRecordHistory ≡⊥
HealthInsurance ⊓ MedicalProblem ≡⊥
HealthInsurance ⊓ PhysicanContactList ≡⊥
HealthInsurance ⊓ HealthRecordHistory ≡⊥
MedicalProblem ⊓ PhysicanContactList ≡⊥
MedicalProblem ⊓ HealthRecordHistory ≡⊥
PhysicanContactList ⊓ HealthRecordHistory ≡⊥
VIN ⊑ AutomobileInfo
PlateNumber ⊑ AutomobileInfo
Model ⊑ AutomobileInfo
Brand ⊑ AutomobileInfo
Trafficticket ⊑ AutomobileInfo
PVRH ⊑ AutomobileInfo
VIN ⊓ PlateNumber ≡⊥
VIN ⊓ Model ≡⊥
VIN ⊓ Brand ≡⊥
VIN ⊓ TrafficTicket ≡⊥
VIN ⊓ PVRH ≡⊥
PlateNumber ⊓ Model ≡⊥
PlateNumber ⊓ Brand ≡⊥
PlateNumber ⊓ TrafficTicket ≡⊥
PlateNumber ⊓ PVRH ≡⊥
Model ⊓ Brand ≡⊥
Model ⊓ TrafficTicket ≡⊥
Model ⊓ PVRH ≡⊥

Brand ⊓ TrafficTicket ≡⊥
Brand ⊓ PVRH ≡⊥
TrafficTicket ⊓ PVRH ≡⊥
Year ⊑ Time

Table 3.12: Description Logic Representation of Citizen Knowledge Pattern

3.8. Education Knowledge Pattern

In this section we define the Education Knowledge Pattern (EKP). First through a set of examples we demonstrate the knowledge components of education in the Toronto 311 knowledgebase. Then using these components we formally introduce education knowledge pattern.

3.8.1 Education in Toronto311 Knowledgebase

The following examples from the Toronto 311 knowledgebase illustrate the various types of educational knowledge components embedded or used in the city of Toronto's 311 webpages:

Case 1: Municipal Education Program

The first case we consider is the municipal education program, shown in Figure 3.34. This program is an educational service provided by the city of Toronto. The program is a typical service with characteristics we discussed in the service knowledge pattern such as service provider agent (Archive staff as shown in the green box), time and location constraints (Tuesday and Thursday and at City Hall , Wednesday and Friday at the Archives as shown in the yellow box). As a result we can represent this service by using object properties and knowledge components introduced in the service knowledge pattern.

Note that again the issue of ambiguity between two concepts of "Program" and "Service" is presented in this service webpage. As we discussed in the SKP there is a distinct difference between a program and a service. A *Program* is a combination of different services and their processes and activities (both internal and external) to achieve

specific municipal, provincial, or federal goals (*Canadian Governments Reference Model (CGRM)*, 2009).

Despite the similarities between educational services and other services, the educational services contain some important characteristics that should be discussed separately. First, these services have a **target group** (5 grade, 10 grade, and ESL students as shown in the red box). Second, educational services also have a **triggering event** component; however, in most cases in the education services the triggering events is initiated with the **registration** of the **service requester** (see the black box).

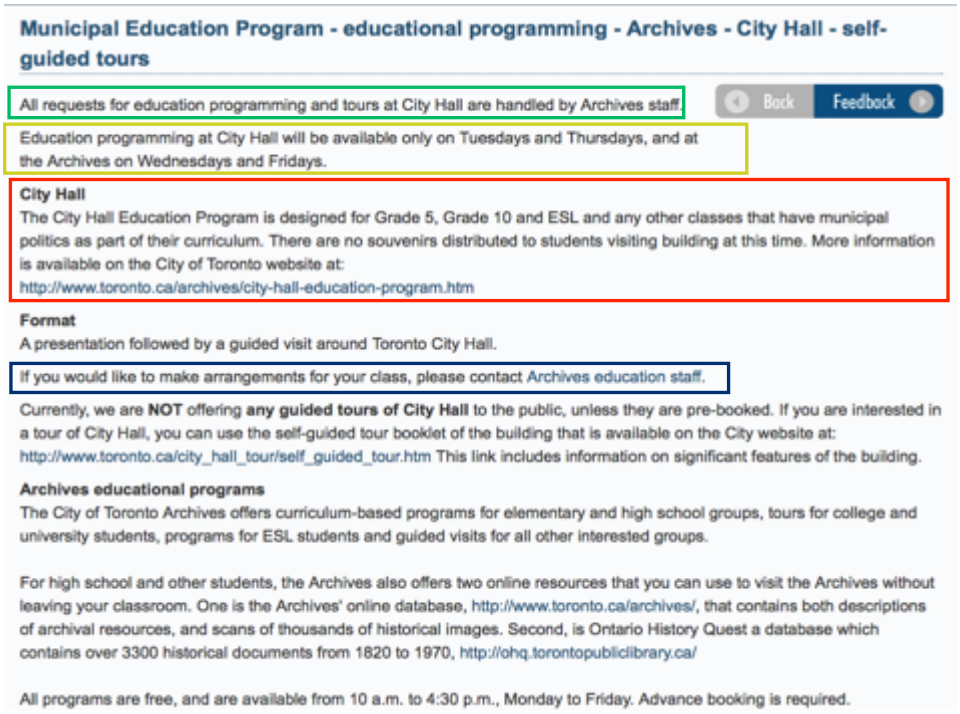


Figure 3.34: Municipal Education Program

Figure 3.35 represents another example of educational services. In this program the **target group** is adults who have not finished high school. The program gives the opportunity to acquire the knowledge and skills associated with high school diploma, and offers Ontario High School Equivalent Certificate for people who complete the program (see the red box).

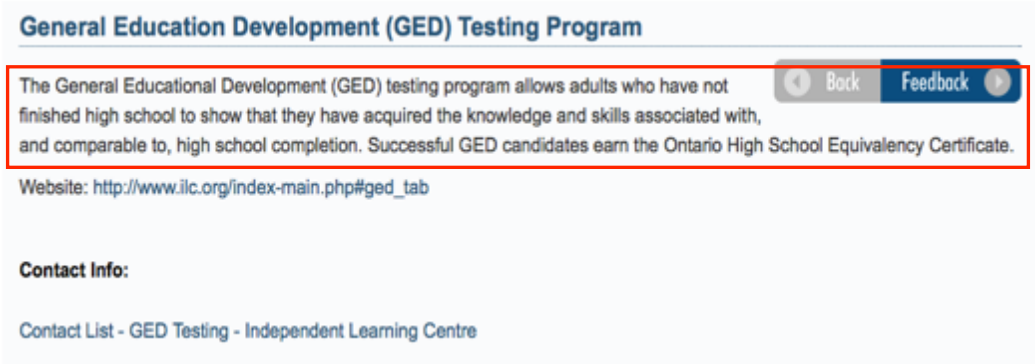


Figure 3.35: General Education Development(GED)

Case 2: Reason for Green Leaves

Another type of educational component in Toronto 311 knowledgebase is webpages containing **educational context**. Figure 3.36 is an example of such webpages. Unlike this webpage usually these educational contexts are implicitly embedded in other webpages, which makes categorizing, structuring or retrieving this information challenging.

We suggest using object property *has-educational-context* for such webpages to connect them to related service categories. Similarly for educational contexts we suggest using object property *impact-service* to relate educational webpages to the service webpages.

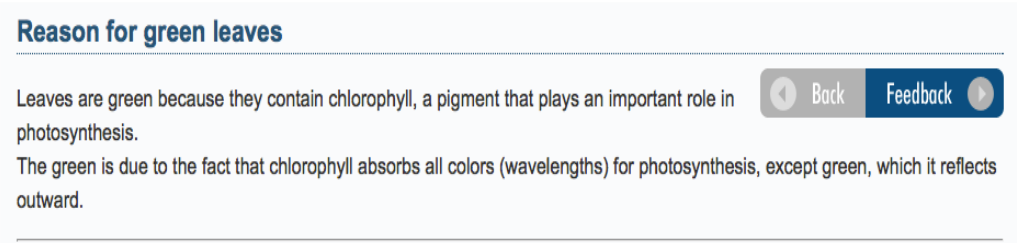


Figure 3.36: Reason For Green Leaves

3.8.2 Education Knowledge Pattern

As described through Case 1 education services is one type of city services with many similarities to other services discussed in service knowledge pattern. However, due to some important characteristics educational services are discussed separately in this section. Another reason to introduce the Education Knowledge Pattern (EKP) is existence of webpages containing educational context in Toronto 311 knowledgebase as discussed in Case 2.

Among Toronto 311 web pages that are related to education, the concept of ***Target Audiences*** or ***Target Group*** is always present. Each educational service has been designed for specific group of citizens. Based on the target group the education service and its content could change. The target group might be explicitly mentioned in the webpage, such as adult who have not finish high school (See Figure 3.35).

As mentioned educational programs consist of several educational services and as a result could target more than one target group. As a result, it could be executed through different divisions and sub-organization of municipal government with same goals but different approaches. Defining the ***responsible organizations*** or **organization division** (Service provider) for any particular educational program could help city government to prevent multiple execution of the same program with same objectives. It can facilitate future combination of services for the same target group, and can inspire creation of virtual or temporary inter-organization (division) teams to plan joint programs in order to reduced costs of city government educational programs.

Similar to other services, educational services have **conditions** and constraints such as days and times the educational services are offered. Educational services also need a **triggering event** for service initiation (registration).

Another important aspect of EKP is to recognize **educational context** in the city services (such as embedded educational information in the Toronto 311 knowledgebase webpages or verbal educational information provided by 311 customer representatives). As mentioned in Case 2, we denote this educational information as educational context

and use object properties such as *has-educational-context* and *impact-service* to connect this information to related city services**.** Note that despite its importance of measuring the ***impact*** of educational context on other services, the impact is not a quantitative or measurable variable.

Education Knowledge Pattern
Example Web Pages
Reason For Green Leaves
Waste management
General Education Development
Constituent Knowledge

• Educational Program vs. Educational service
• Triggering event
• Target Audience/Group
  o Who the targeted audience is
• Organization in charge
  o Which organization entity is running the program
• Constraints on participation
• Times/dates if appropriate
• Educational context
• Services impacted by the education

Table 3.13: Education Knowledge pattern

$$\text{TargetGroup} \equiv \text{TargetAudience}$$
$$\text{EducationService} \sqsubseteq \text{CityService}$$
$$\text{EducationContext} \sqsubseteq \text{Education}$$
$$\text{TargetGroup} \sqsubseteq \text{ServiceRequester}$$
$$\text{ServiceProvider} \sqsubseteq \text{organization}$$
$$\text{ServiceRequester} \sqsubseteq \text{CityService}$$
$$\text{TriggeringEvent} \sqsubseteq \text{CityService}$$
$$\text{Registration} \sqsubseteq \text{EducationService}$$
$$\text{EducationProgram} \equiv (\text{Education} \sqcap \geq 1\ \text{composedOf.}\ \text{EducationService})$$

$$\text{EducationService} \equiv ((\forall\ \text{decompositionOf.}\ \text{EducationProgram}) \sqcap (\forall\ \text{hasTargetgroup.}\ \text{TargetGroup}) \sqcap ((\exists\ \text{hasCondition.}\ \text{Condition}) \sqcap (\forall \text{hasDate.}\ \text{TimeInterval}) \sqcap (\forall\ \text{hasTime.}\ \text{TimePoint}) \sqcap (\forall\ \text{hasServiceRequester.}\ \text{ServiceRequester}) \sqcap \big((\exists\ \text{hasTriggerintevent.}\ \text{TriggeringEvent}) \sqcap (\exists\ \text{isInitiated.}\ \text{Registration})\big) \sqcap (\forall\ \text{hasServiceProvider.}\ \text{ServiceProvider}) \sqcap (\exists\ \text{impactCityService.}\ \text{CityService}))$$

$$\text{EducationalContext} \equiv ((\exists\ \text{impactService.}\ \text{CityService}) \sqcap (\exists\ \text{hasEducationcontext.}\ \text{URI}) \sqcap (\exists\ \text{hasServiceCategory.}\ \text{EducationService}))$$

Table 3.14: Description Logic Representation of Education Knowledge Pattern

3.9. Complaint/Compliment Knowledge Pattern

Public administration in every municipality aims to provide the best quality of city services for its citizens. Since policies, priorities, geographical needs, population, and culture vary from one city to another, each city may follow a different strategy to provide a high quality of service.

Municipal government similar to any other live system requires feedback to evolve, progress, or improve. Feedback is a simple, effective, and inexpensive method to improve service quality. In the city administration context, feedback is in the form of complaints/ compliments, which are used to evaluate the city's service quality. Moreover, these complaints/compliments reflect the citizen's level of satisfaction for the service he/she receives from the service provider.

3.9.1 Complaints in Toronto 311 knowledgebase

The following examples collected from Toronto 311 knowledgebase will illustrate different knowledge components related to complaints or compliments:

Case 1: Solid Waste Management- Complaint- Compliment[22] [23] [24]

One of the service categories that have the most interactions with citizens is the Solid Waste Management service. Due to this constant interaction, and since the service is outsourced to a third party; it is crucial for the city of Toronto to get feedback on the quality of the service. To this end, city must provide information about the procedure a resident should follow to file a complaint/compliment (see Figure 3.37).

Figure 3.37: Solid Waste Management Complaint

Note that the city also provides information about situations where the city agent is not responsible for the unsatisfactory situation. For instance, Figure 3.38 shows a webpage containing information about situation under which the city does not accept complaint about leakage from garbage trucks.

[22] http://www.toronto.ca/311/knowledgebase/17/101000508617.html
[23] http://www.toronto.ca/311/knowledgebase/34/101000202334.html
[24] http://www.toronto.ca/311/knowledgebase/33/101000039333.html

Figure 3.38: Garbage Trucks Leaking Juice on The Road Complaint

In Figure 3.39, we have selected another webpage related to solid waste management services complaint. The only difference between this web page and the one in Figure 3.37 is that this webpage specifies the complaint subject, operator throwing bins complaint, which is also implied under the category of operation/operator complaints in the first example. This duplication in the knowledgebase without properly defining the relationship between the webpages is inefficient and redundant (note that we saw similar duplication problems in the Service Knowledge Pattern).

Figure 3.39: Solid Waste Management -Operator Throwing Bins

Case2: City of Toronto Vehicles and Drivers Complaints [25]

In this example we consider a webpage about the city of Toronto's vehicle and drivers complaints (e.g., fire service or EMS drivers or vehicles). This webpage, depicted in Figure 3.40, provides a comprehensive reference for different complaint **events** (such as filling complaint about Fire Services driver or vehicle, or filling complaint about Emergency Medical Services driver or vehicle). In order to submit a complaint/compliment about city of Toronto's vehicle or driver, citizens should

[25] http://www.toronto.ca/311/knowledgebase/67/101000046667.html

contacting 311 and file a complaint/compliment (which we denote as **initiate the event)**, as shown in the blue box. Moreover, the webpage provides a list of necessary information that the citizen must provide to initiate the complaint, e.g., the vehicle license number or serial number (see the black box). This information is collected to specify the **organization entity** that is the subject of the complaint/compliment.

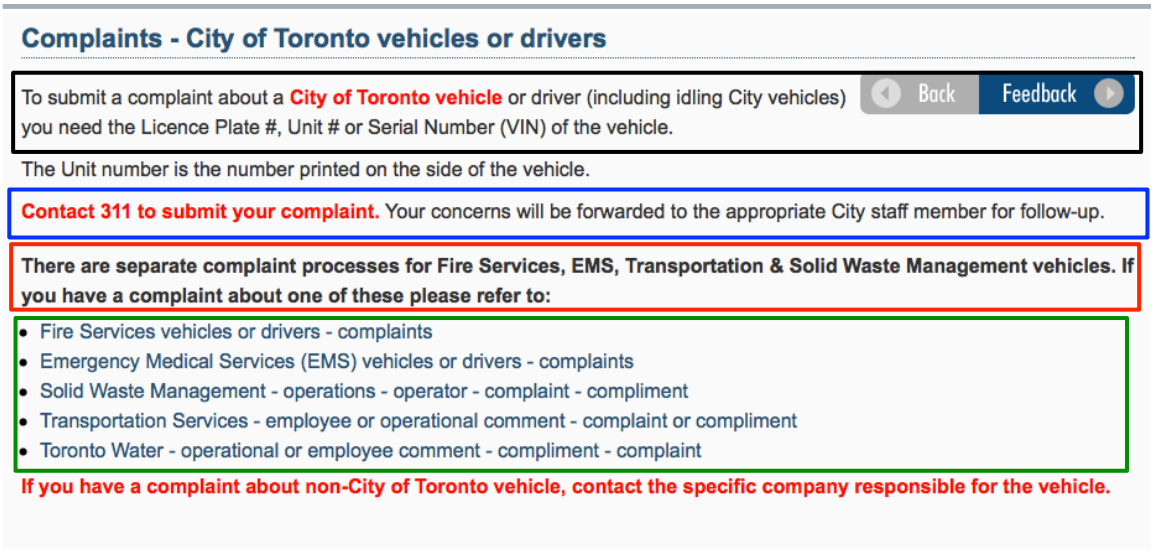


Figure 3.40:City of Toronto Vehicle or Driver Complaints

Note that different divisions have different complaint processes (see the red box). For example, as depicted in Figure 3.41, to submit a complaint about the Toronto Fire Service vehicles or drivers, the citizen must contact the District Fire chief in the Mechanical Division (which we denote as the **responsible organization**).

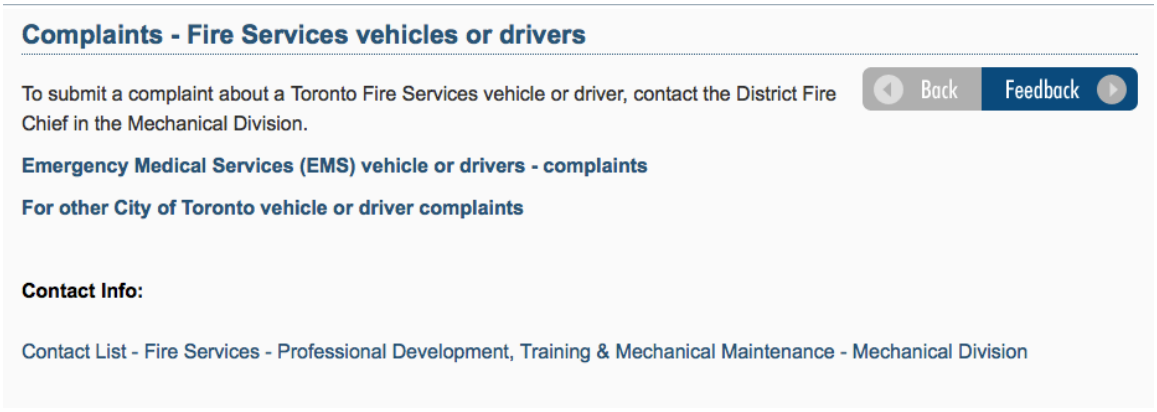


Figure 3.41: Fire Services Vehicle or Driver Complaints

3.10.2 Complaint/Compliment Knowledge Pattern

In this section, we employ the knowledge inherent of complaints we highlighted in previous section (Case 1 and 2) to provide a comprehensive model for Complaint Knowledge Pattern (COKP).

In order to file a complaint/compliment (the **initiating event**) about an **organization entity (**subject of a complaint**)**, the citizen should communicate with the **organization responsible** for receiving the complaint/ compliment (we denote this communication as the **action**). Many divisions have their own unit or agent in charge of responding to a complaint (see Case 2). For those organizations that do not have such a unit/agent, the nonemergency center of the city (311) is the responsible organization for the complaint (see Case 1).

Note that citizens should provide detailed information about the event they want to complain about. This information must contain the personal information of the complainer, date, time, and organization entity being complained about (e.g., vehicle license number or serial number in Case 2).

Despite the simplicity of the COKP, it is an important pattern since it addresses the following concerns: (i) in the Toronto 311 knowledgebase, there is no standard procedure in submitting a complaint (i.e., each complaint can have a different procedure from other complaints based on the type of the service and the **division** that provides that service); (ii) in many cases the city will not relay the result of a specific complaint to the complainer. Table 3.15 depicts the main component of the Complaint Knowledge Pattern.

Complaint Knowledge Pattern

Example Web Pages

- Submitting a compliment/complaint about 9-1-1
- Compliant-Fire services Vehicle or Driver
- Transportation Services - employee or operational comment - complaint or compliment
- Complaint about Solid Waste Management (collections, operations, operator, property damaged)

Constituent Knowledge

- Initiating Event
  - E.g., complaint or compliment
- Who is complaining/complimenting
- Date/Time
- Event being complained about
- Organization Entity being complimented/complained about
  - E.g., Police
- Organization Entity to whom the complaint/compliment is to be sent
  - E.g., Police review board
- Action
  - Communicate to the police review board

Table 3.15: Complaint/Compliment Knowledge Pattern

$$\begin{aligned}
\text{Complaint} \equiv\ & ((\forall \text{hasCityService. CityService}) \sqcap (\exists\ \text{ProvidesFeedback. CityService}) \\
& \sqcap (\exists\ \text{hasTriggeringevent. Triggeringevent}) \sqcap (\exists\ \text{initiateEvent. Complaint}) \\
& \sqcap (\exists\ \text{hasResponsibleOrganization. Organization}) \\
& \sqcap (\exists\ \text{hasInformation. CitizenInfo}) \\
& \sqcap \big((\exists\ \text{hasSubject. CityOrgAgent}) \sqcap (\exists \text{hasDate. Date}) \sqcap (\exists\ \text{hasTime. Time})\big)
\end{aligned}$$

$$\begin{aligned}
\text{Compliment} \equiv\ & ((\forall \text{hasCityService. CityService}) \sqcap (\exists\ \text{ProvidesFeedback. CityService}) \\
& \sqcap (\exists\ \text{hasTriggeringevent. Triggeringevent}) \\
& \sqcap (\exists\ \text{initiateEvent. Compliment}) \\
& \sqcap (\exists\ \text{hasResponsibleOrganization. Organization}) \\
& \sqcap (\exists\ \text{hasInformation. CitizenInfo}) \\
& \sqcap ((\exists\ \text{hasCompliment. Compliment}) \sqcap (\exists\ \text{hasSubject. CityOrgAgent}) \\
& \sqcap (\exists \text{hasDate. Date}) \sqcap (\exists\ \text{hasTime. Time}))
\end{aligned}$$

$$\text{Complaint} \sqcap \text{Compliment} \equiv \bot$$

Table 3.16: Description Logic Representation of Complaint/Compliment Knowledge Pattern

3.10.Species Knowledge pattern

Among the different types of information a city provides, there are many cases that the stipulated information relates to different types of species such as animal and insects. This species related information could be found in city bylaws, guidelines, and regulations. Despite the importance of such information in public services (they may have a significant health or safety impact), in our exploration of the 311 knowledgebase, we have observed that finding the correct, relevant, and comprehensive information about a specific topic or problem related to species could be a challenging task. For example, it is difficult to find a concrete answer to the following questions:

- What are different species that live in a specific region?
- When is an animal a threat to a citizen?
- What are the regulations about trapping a wild animal?
- How can a citizen deal with pests?
- Where is the nearest animal center?
- What can a citizen do when a wild animal damages his/her private property?

In order to overcome such difficulties, and to present specie-related information in a structured manner, we introduce the Species Knowledge Pattern (SKP).

3.10.1 Species Knowledge in Toronto 311 Knowledgebase

The information regarding different species varies from one city to another based on the variety of wild life and animal species that exist in its metropolitan area or suburban regions. The following examples from the Toronto 311 knowledgebase illustrate the different components of SKP.

Case 1: Pests (Bee, Wasp or Hornet Nest)

In this case we employ several examples from the Toronto 311 knowledgebase. The examples are related to the issue of removing bee, wasp, or hornet nests from different type of properties. Based on the **location** of the nest, the condition under which the nest poses **danger** to citizens' safety, and the ownership of the property, different regulations

must be followed for the nest **removal action** to take place**,** as shown in the blue boxes in Figures 3.42, 3.43, 3.44, and 3.45.

Figure 3.42 depicts a situation in which the bee, wasp, or the hornet nest is located on a tree on the city properties. The page provides **ecological** and **life cycle** information about these species (shown in the red box). This information is provided so citizens understand the benefits of these insects' in the ecosystem. Another important aspect is the **conditions** under which these species are considered a danger to humans (shown in the green box). These conditions could be divided into three categories: **human interaction** (in this example as long as the nest is not disturbed by humans the insects could tolerate human approach), the **location condition** (if the nest's altitude is higher than 3 meters it will typically not be removed; otherwise, the urban Forestry will inspect it to see if it is a threat to the public safety and thus decide whether or not to removal it), and the **seasonal condition** (nest removal inspection can be requested in summer, while nest removal is not necessary in the fall since wasps do not survive the winter season).

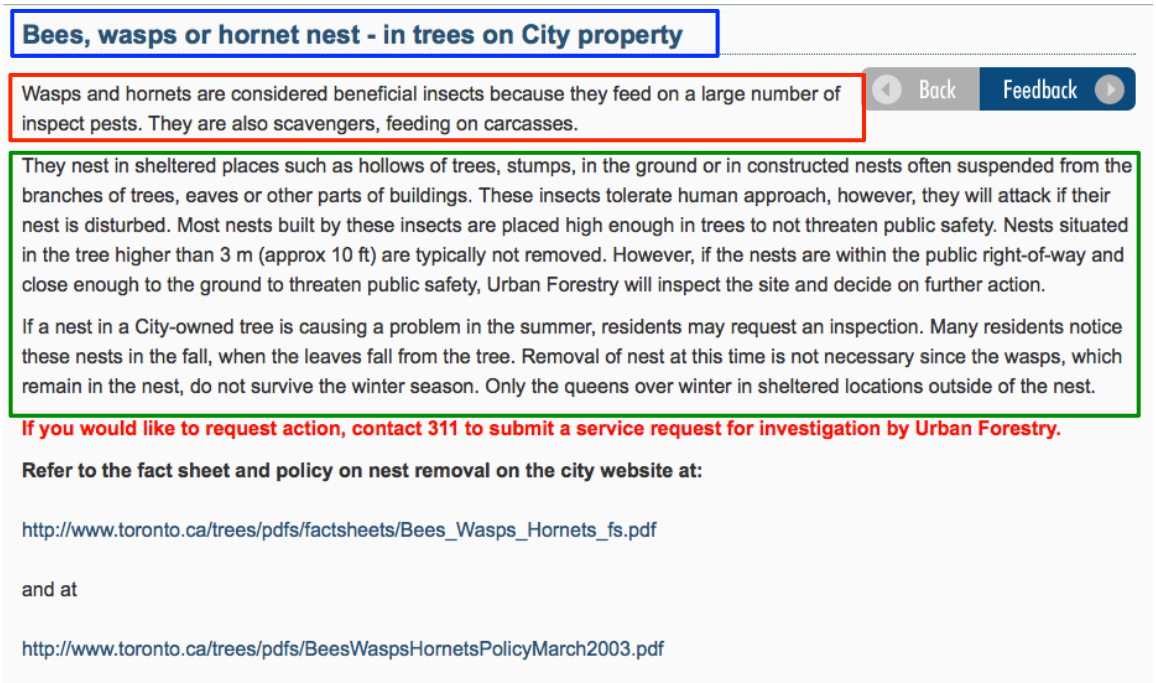


Figure 3.42: Bees, Wasps, or Hornet Nest- In Tree on City Property

Figure 3.43 depicts a similar situation as the one described in the previous example, with one distinction: the bee, wasp, or hornet nest is located on a private property. In this case, the resident can take one of the following two actions based on the whether the nest is located on his/her own property or on the neighbor's property. If the nest is on their own property, they could employ a private pest control companies to remove it. If it is on their neighbor's property on the other hand, they can submit a complaint to Municipal Licensing and Standards and request an investigation (see the red boxes).

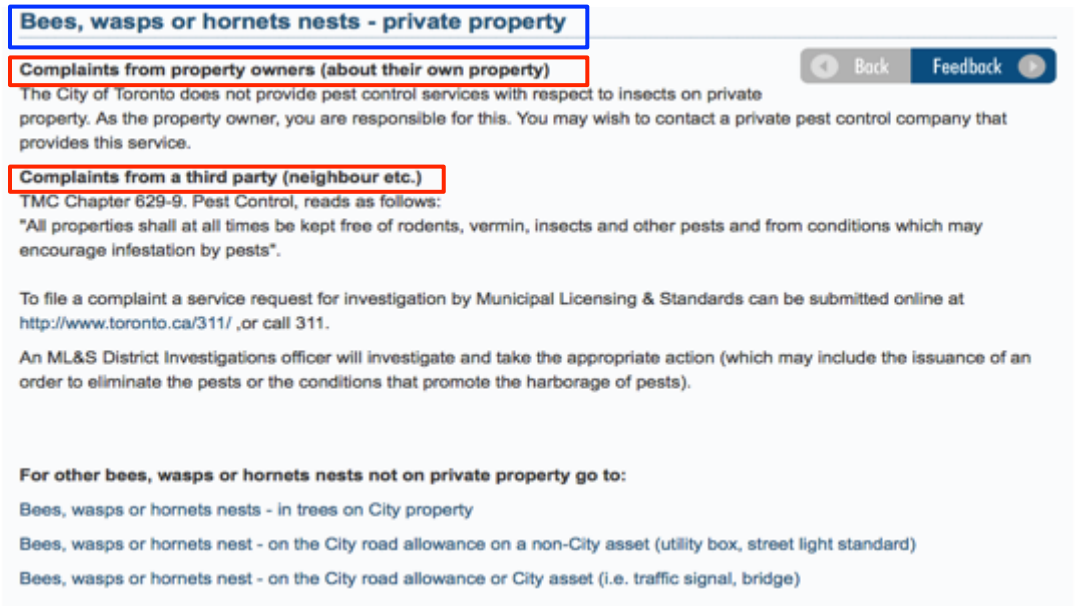


Figure 3.43: Bees, Wasps, or Horn Nest -Private Property

Figures 3.44 and Figure 3.45 show a similar situation (bee, wasp, or hornet nest on the city road allowance) with one distinction: whether it is a city asset or not. This distinction determines which organization entity is responsible for the insect investigation and/or removal. Table 3.17 lists the non-city assets and the organization responsible for them (in terms of the nest removal activity).

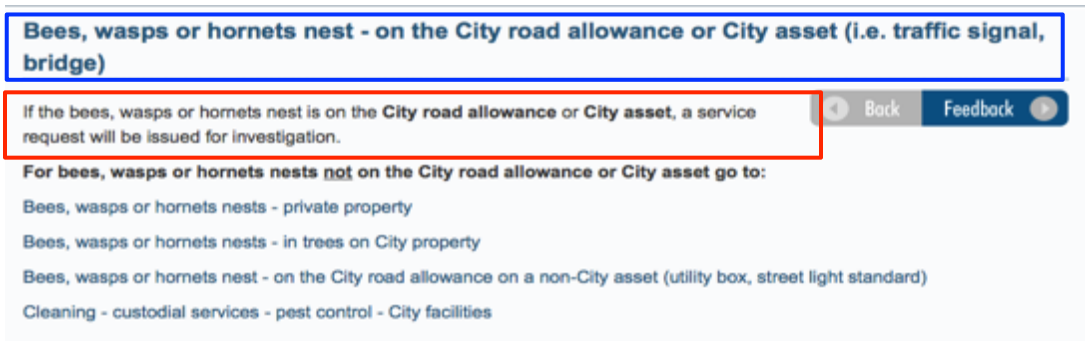


Figure 3.44: Bees, Wasps, Hornet Nest-On the City Road Allowance or City Asset

Figure 3.45: Bees, Wasps, or Hornet Nest- On the City Road Allowance on the Non-city Assets

Organization	Assets and Properties
Toronto Hydro	Hydro boxes, street lights
Bell Canada	Bell telephone boxes
Canada Post	Canada post box
Urban forestry	Trees on City property
311 online services, City license & standard	City road allowance or City asset (i.e. traffic signal, bridge)
Private pest control company	Private properties

Table 3.17: Assets of the City of Toronto-Responsible Organization for Insect Nest Removal

Case 2: Wild Animal (Coyote, Bear, Fox, Raccoons, Deer)

In addition to pests, the city of Toronto provides information about other types of animals. In this case we focus on the wildlife residing in the metropolitan area of the city of Toronto.

Figure 3.46 provides information about situations in which the wildlife does not represent a health risk to the public. In such cases, the Toronto Wildlife Centre is the **organization** responsible to deal with wildlife issues and inquiries (shown in the red box). Citizen can contact this center to request information about a wild animal or to report an injured animal.

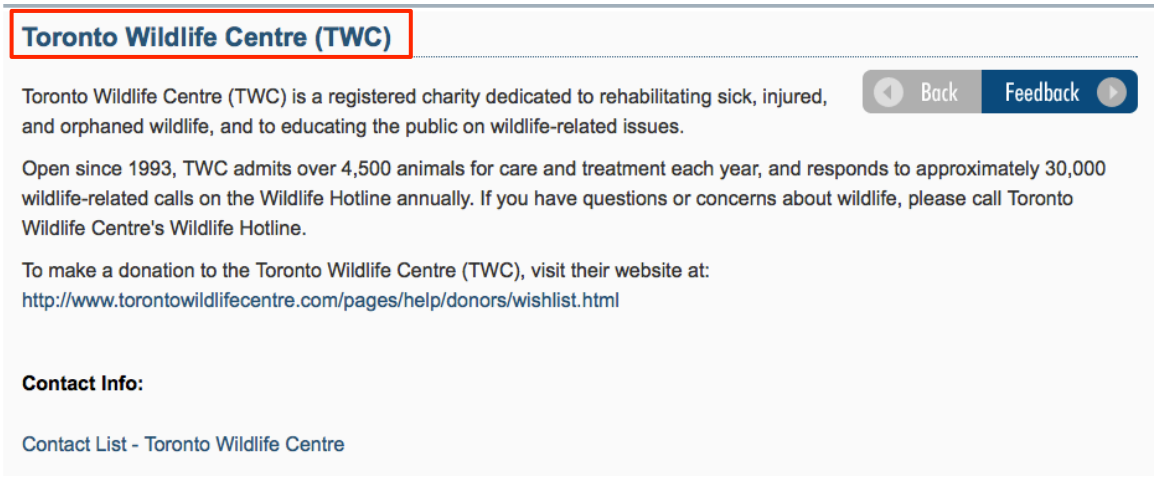


Figure 3.46: Toronto Wildlife Center

If the wildlife could potentially threaten public health, on the other hand, other **organizations** such as the Toronto Public Health or the Infection Control Unit will get involved (see Figure 3.47). For example, as can be seen in the green box, Toronto Public Health will provide the general information about the health risk of exposure to raccoons.

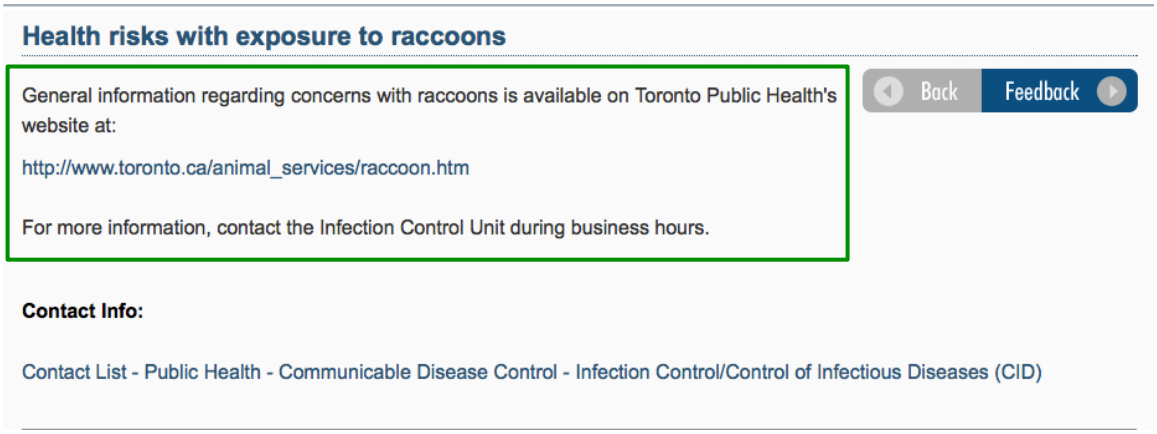


Figure 3.47: Health Risk With Exposure to Raccoons

Another example regarding wildlife information provided by the city is the webpage explaining the city's policy on coyotes. The first interesting point when one skims this webpage is the disparity between the title and the content of the webpage (despite the title of the webpage, it does not contain any information about bears, nor does it provide a link to the relevant information resource for a bear related issue). Another inconsistent component, which arises from the comparison of this webpage with the previous two examples, is that the webpage introduces yet another **organization** responsible for dealing with wildlife related issues (Animal Services). Such references to multiple organization agencies dealing with the same problem without properly explaining their relationships, roles, responsibilities, and communication links will make the use of the information in the knowledgebase random, hard to understand, and inefficient.

As discussed in the pest examples, we also see seasonal conditions here. Specifically, the green box in Figure 3.48 shows that wild animals also have seasonal behavior (appearance of more coyotes in the winter). Moreover, the city provides extra clarification about why such seasonal behavior exists and how to deal with the wildlife (shown in the yellow box).

Figure 3.48: City Policy on Coyotes- Wildlife Sighting -Bears

Case 3: Pets (Dog, Cat, Parrot, hamster)

The final example concerns pets. In almost every city there are guidelines regarding pets and pet protection services. Unlike the species categories described in the previous cases, the information and services related to pets are more structured. For example, the information about pet adoption, veterinarian services, animal shelters are easily accessible.

Figure 3.49 depicts the set of requirements for pet adoption. It contains the components of Service Knowledge Pattern such as activity (adoption), condition (requirement, and fees), and service provider (Toronto animal services). The only difference between an animal service and other types of service is its properties and relationships. Recall from Service Knowledge Pattern that every service has an object and that these objects were either an animate or inanimate. The animal species are an instance of animate objects.

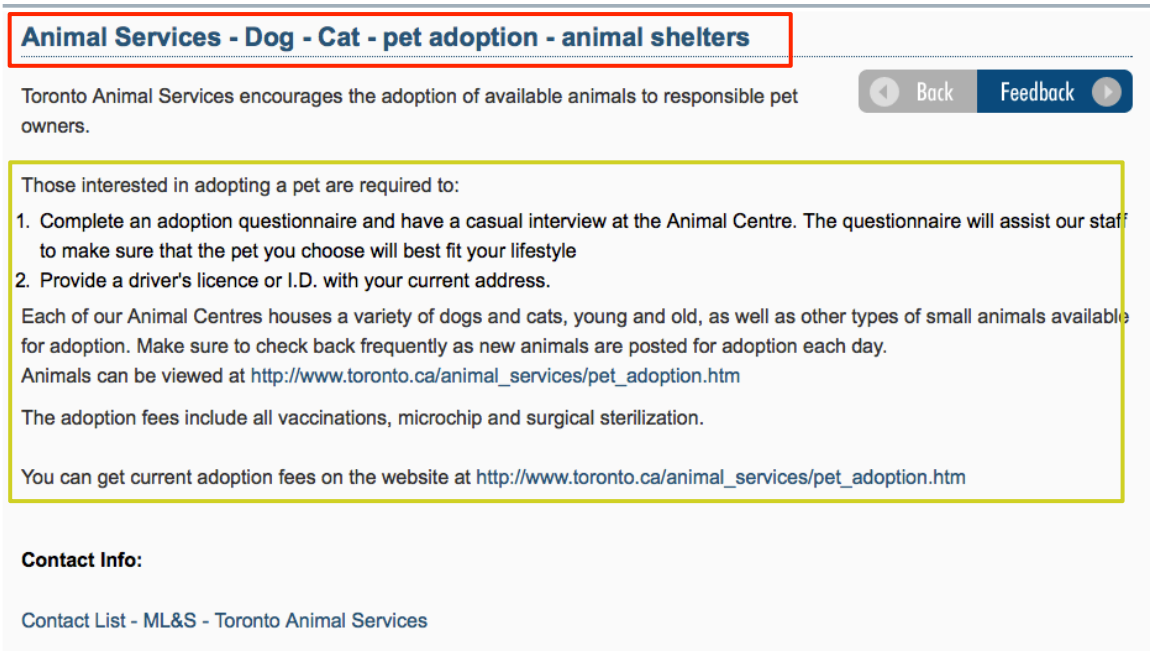


Figure 3.49: Animal Services- Dog - Cat- Pet Adoption

3.10.2 Species Knowledge Pattern

In Species Knowledge Pattern (SeKP), we divide all species into two distinct categories: **insects** and **animals**. Accordingly we categorize animals in to two groups of pets and non-pets (wild animals). This categorization is general enough to encompass all species that coexist or interact with city residents. Moreover, the categorization will help in grouping related information to standardize the characteristics of each category. The Pets category is by far the most observed category in the 311 knowledgebase. For instance, there are many services related to pet veterinarian, animal centers, and pet adoptions. Despite the lack of attention to the other categories, it is crucial to define a comprehensive knowledge patter that encompasses their characteristics due to their impact on public health and safety.

The SeKP is shown in Table 3.18. The first consideration is the **nature of danger** that the species poses. If a species is considered a danger to citizens, its related information should be public and easily accessible. The second component is the **location** of the

species (e.g., in Case 1, based on the location of pest nest the corresponding action could be drastically different).

Another important aspect is the species' **ecological impact**. They can have both positive and negative impact on the ecology of urban areas (e.g., recall from Case 1 that some pests could eat other pests, or scavengers feeding on carcasses).

It is also important to highlight the **life cycle** information of species such as their life span (see Case 1), or the mating and recreation information (see Case 3). This information can inform the citizens on how they should handle species under different **conditions**. Even if coexistence with species could have ecological benefits, they could potentially threat human safety. In such conditions (**human interaction**, or **seasonal**) it is important for both citizens and environment protection organizations to have information on how to deal with such potential danger.

Finally, the city should publicize information about the **removal** or the **preventative actions** in case any specie or wild animal disturbs day-to-day life. Using this information, citizens could request or take actions to resolve their problems (e.g., preventing action such as not leavening fallen fruit and food debris lying around yard, or covering garbage bins could prevent unwanted wildlife nesting in the residence).

Species Knowledge Pattern

- Nature of the Danger
    - E.g., sting, or concern to people who are hypersensitive
- Location information – where do they nest, roam
    - E.g., hollows of trees, stumps, ground, constructed nests in trees or buildings
- Ecological information – how does it positively or negatively impact the ecology
    - E.g., eat other insect pests, scavengers feeding on carcasses
    - Pollinate and honey producers
- Life Cycle information – how long do they live
- Conditions under which they are dangerous
    - Human interaction
        - Will attack if nest disturbed
    - Location
        - If nest higher than 3m, they are typically not removed
        - If within public right-of-way or close to ground to threaten public safety the Urban Forestry will inspect and decide further action
- Removal Action
    - If Conditions satisfied, then resident may request inspection
    - No need to remove once leaves fall since wasps do not survive the winter
- Preventative Action
    - Do not leave fallen fruit and food debris lying around
    - Make sure garbage bins are covered
    - Do no keep uneaten pet food outside
    - Remove water from ponds, puddles, birdbaths and any other source of standing water.
- Category:
    - Insect
        - Pest
    - Animal
        - Pet
        - Non-pet

Table 3.18: Species Knowledge pattern

$Animal \sqsubseteq Species$
$Insect \sqsubseteq Species$
Animal $\sqcap Insect \equiv \bot$
$Pet \sqsubseteq Animal$
$\neg Pet \sqsubseteq Animal$
Pet $\sqcap \neg Pet \equiv \bot$
LifeCycleInfo $\sqsubseteq SpeciesInfo$
MatingleInfo $\sqsubseteq SpeciesInfo$
$LifeCycleInfo \sqcap MatingInfoc \equiv \bot$
RemovalActivity $\sqsubseteq$ Activity
PreventivelActivity $\sqsubseteq$ Activity
$RemovalActivity \sqcap PreventiveActivity \equiv \bot$
$PetAdoptationService \sqsubseteq AnimalService$
$VeterinarianServiceService \sqsubseteq AnimalService$
$AnimalShelterService \sqsubseteq AnimalService$
$PetAdoptationService \sqcap VeterinarianService \equiv \bot$
$PetAdoptationService \sqcap AnimalShelterService \equiv \bot$
$VeterinarianService \sqcap AnimalShelterService \equiv \bot$

Species $\equiv$ (($\exists$ has$Ecologicalimpact.Boolean$)
$\sqcap$ ($\forall hasInformation.SpeciesInfo$)
$\sqcap$ ($\exists hasActivity.Activity$) $\sqcap$ ($\forall hasLocation.Location$)
$\sqcap$ ($\exists hasHumaninteraction.Boolean$) $\sqcap \exists hasCondition.(Season)$

$InsectRemoval$
$\equiv$ ((($\forall isTypeOf.Species$) $\sqcap$ ($\exists hasLocation.CityProperty$)
$\sqcap$ ($\exists hasHumaninteraction.(True)$ $\sqcap$ $\big(\exists impose.(Danger)\big)$
$\sqcap$ $\big(hasActivity.(Remove)\big)$
$\sqcup$ $\Big($($\exists hasLocation.PrivateProperty$) $\sqcap$ ($\exists hasComplaint.Complaint$)
$\sqcap$ ($\exists hasTriggeringevent.Triggeringevent$) $\sqcap$ ($\exists initiateEvent.Complaint$)
$\sqcap$ ($\exists hasInformation.CitizenInformation$) $\sqcap$ $\big(hasActivity.(Remove)\big)\Big)$)

$(\neg Pet\ Removal)$
$\equiv$ (($\forall isTypeOf.Species$) $\sqcap$ ($\exists hasLocation.Location$)
$\sqcap$ ($\exists hasHumanInteraction.(True)$) $\sqcap$ $\big(\exists impose.(danger)\big)$
$\sqcap$ $\big(\exists hasActivity.(Remove)\big)$ $\sqcap$ ($\exists hasDivision.Division$)
$\sqcap$ ($\exists hasCondition.(Season)$))

$Pet \equiv$ (($\forall isTypeOf.Species$) $\sqcap$ ($\exists hasCitysSrvice.AnimalService$))

Table 3.19: Description Logic Representation of Species Knowledge pattern

3.11.Evaluation of the City Knowledge Patterns

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. Since the URL of each of the 311 webpages ends with a unique five digit number, we use the following random sampling methodology:

1. We first randomly generate a five digit number,
2. We check the existence of the URL ending with the number generated in step 1,
3. If the webpage in step 2 exists, we save it as one of the validation samples,
4. If the webpage does not exist, we discard the number and go to step 1,
5. We repeat steps 1-4 until we have 100 different random webpages.

After the random sampling, we analyzed their content to see if their knowledge is covered by our CKPs. Figure 3.50 depicts the frequency of the knowledge patterns observed in these 100 webpages.

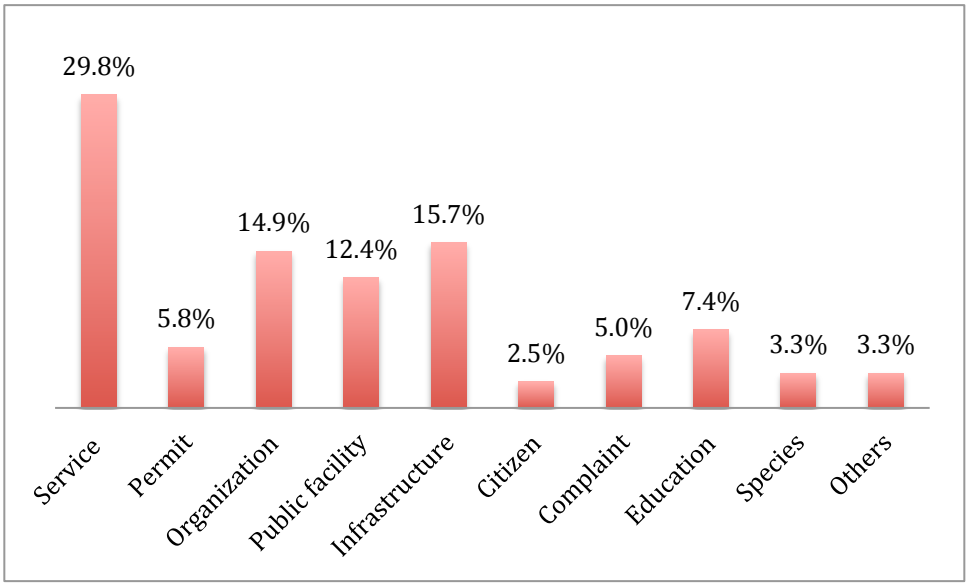


Figure 3.50: Validation of the Patterns

As can be seen, the frequency of the knowledge patterns in the validation sample is very similar to the ones in Figure 3.1. Specifically, as before, the Service, Infrastructure,

Organization, and Public facility Knowledge Patterns are the most frequent ones. The 3.3% webpages under the "others" frequency shown in Figure 3.50 represent webpages we have not identified in the CKPs. For example, a webpage explaining the legal name description of the city (City of Toronto), a webpage providing information about the result of some study (loading space standards across the city), and a webpage providing external link for a specific topic (healthy measures campaign). This validation indicates that the 500+ sample webpages used to extract the CKPs is a good representation of the 21000 webpages of the 311 knowledgebase.

3.12.Formalization of the City Knowledge Patterns

We use the Ontology Web Language (OWL) to represent the City Knowledge Patterns. The current representation of the CKPs contains more than 170 classes and 100 object properties.

To represent the CKPs, we import and the TOVE Organization ontology, and the OWL-S service ontology. The latter is used to represent the relationship between city services (processes) and the activities city organization agents perform on daily basis. Appendix I contains the full representation of the CKPs.

To check the consistency of the CKPs we used different reasoners provided by Protégé, i.e., Pellet, HermiT 1.3.8, FaCT++. The consistency check indicates that the inferred model is consistence with respect to all of the three reasoners.

To further investigate the consistency of the model, we used the DL Query tab in the Protégé to check the CKP inferred model's ability in returning simple DL queries. For example, Figure 3.51 depicts the ability of the model in querying about its properties and individuals. For example, the query in Figure 3.51 shows the ability of the model in returning individuals who are type of PublicFacility, and are either reservable or rentable.

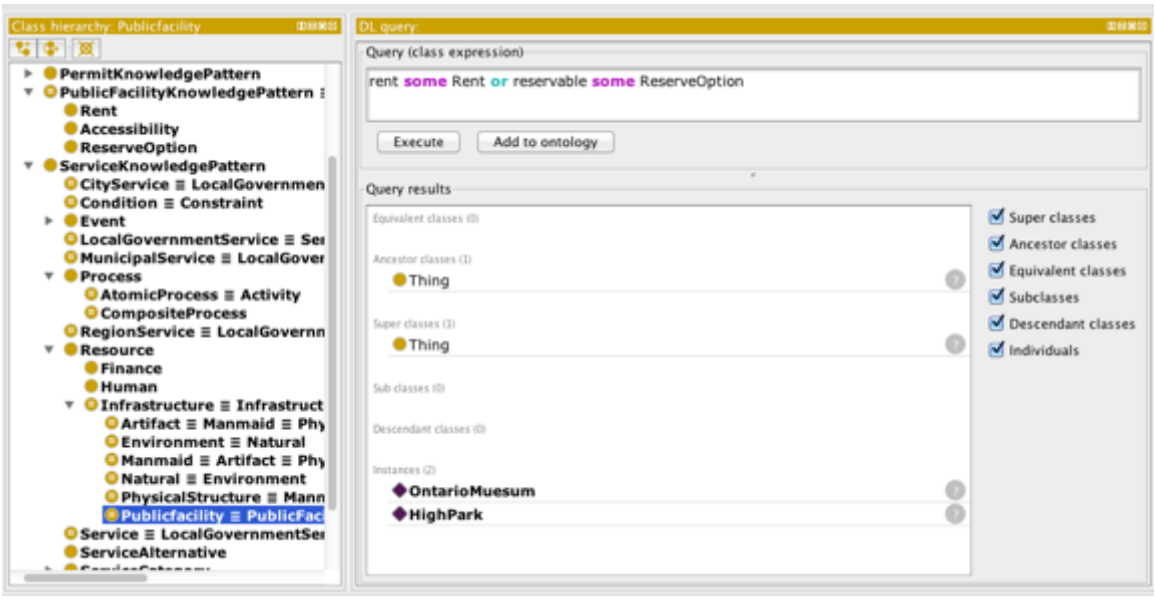


Figure 3.51: City Knowledge Patterns Sample Inference DL Query

Chapter 4

Comparative Evaluation

In this chapter we employ the City Knowledge Pattern to evaluate the coverage, i.e., the models' content cover of the knowledge defined in the CKPs, of four ontologies and reference models in the municipal government domain.

The models that we consider in our evaluation are:

1. Government Enterprise Architecture
2. Municipal Reference Model
3. TOronto Virtual Enterprise Ontology
4. Scribe Ontology

These four models were selected for their unique aspects (i.e., domain specific, generic model of enterprise, and etc.). For each of these models, we first provide a brief overview. Then, we present a comprehensive analysis of their characteristics based on the knowledge components of the City Knowledge Patterns.

4.1. Government Enterprise Architecture (GEA)

In this section we compare the City Knowledge Patterns with the Government Enterprise Architecture (GEA), introduced in Chapter 2. The reasons we choose this model in our comparison is that GEA is one of the few domain specific ontologies developed for government (Peristeras & Tarabanis, 2004b), (Sotirios K Goudos et al., 2007). We first provide a brief description of GEA along with its components. Then, to specify its

usability for municipal government domain we compare its elements with the City Knowledge Patterns.

GEA is a generic government domain model for public administration. GEA aims at introducing a consistent set of models that constitute the basis for reference government domain ontology. Specifically, GEA consists of the following five high-level models (Peristeras & Tarabanis, 2004b):

1. The GEA Mega-Process Model of the Overall Governance System: this model consists of three layers that formulate the overall domain of the governance system: (i) Formulate Public Policy; (ii) Provide Service; and (iii) Support Operations (shown in Figure 4.1[26]).

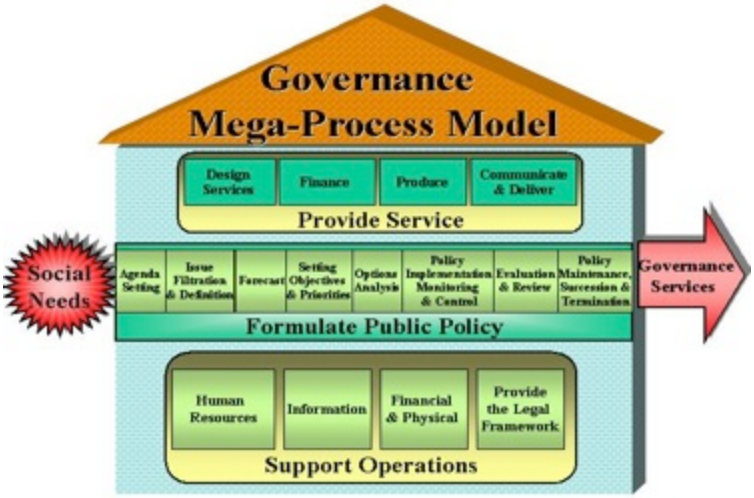


Figure 4.1: GEA Mega- Process Model

2. The GEA Interaction Model of the Overall Governance System: this model builds a high-level interaction diagram between the overall governance process of the Mega-Process Model and the basic governance actors (society, administration system, political system).
3. The GEA Public Policy Formulation Object Model (strategic planning): the model generates a customized data model of the most influential strategic concepts of the government system for the Formulate Public Policy layer of the Mega-Process

[26] This Figure is copied from (Peristeras & Tarabanis, 2004b)

Model. This model consists of six main components: Culture, Environment, Knowledge, Organization, Resource, and Functions.

4. The GEA Service Provision Object Model: this model builds an object model for the Provide Service layer of the Mega-Process model. It consists of two separated levels: the Operation (transaction) and the Knowledge (planning) layers.
5. The GEA Object Model for the Overall Governance System: this model builds a top-level object representation for the governance system by aggregating the Public Policy Formulation and the Service Provision domains of the Mega-Process Model.

Note that GEA is a generic model of government public administration and it has been implemented using semantic web service ontologies such as WSMO (Sotirios K Goudos et al., 2007) and OWL-S. Moreover, Goudos et al., (S.K. Goudos et al., 2007) propose an OWL-base ontology for the GEA Service Provision Object Model.

We next compare the City Knowledge Patterns with GEA (and its implementations).

4.1.1.Service in GEA

Both the Service Knowledge Pattern (SKP) and GEA contain the following service knowledge components:

- Both SKP and GEA break down their services into simple *activities*. (S.K. Goudos et al., 2007),
- Both models have an *outcome* knowledge component for their activities.
- Both models have *service requester* and *service provider* entities.
- Both models impose *constraints* on their services (including pre-conditions).
- The GEA has a *Corrective Action Program* component that is similar to *activity recurrence* knowledge component in the SKP.
- Both models use *resources* to *perform* their activities.

The main difference, on the other hand, is the lack of the *Triggering Event* and the *Service Alternative* knowledge components of SKP in GEA.

4.1.2. Permit, Education, and Species in GEA

The Permit, Education, and Species Knowledge Pattern constituents are not considered in GEA. Note that GEA considers permit and education as types of public services.

4.1.3. Organization in GEA

Recall that the GEA Public Policy Formulation Object Model consisted of six main components, which define its data model. This object model contains knowledge components such *organization agent*, *role*, *mission*, *vision*, *needs*, *values*, etc. that are similar to the knowledge components of the Organization Knowledge Pattern (OKP). Moreover, similar to OKP, the GEA defines the relationship between activities, resources, and the organization agent (Peristeras & Tarabanis, 2004b).

On the other hand, unlike OKP, GEA does not consider the *skill*, *responsibility*, and *authority* knowledge components for its organization agent. It also ignores the different roles an agent can *play* as a *member* of different *teams*. Furthermore, the organization structure (e.g., *division, unit*, and *committee*) and *empowerment* knowledge components are not considered in GEA.

4.1.4 Infrastructure and Public Facility in GEA

The GEA completely ignores the infrastructure and public facility knowledge components. In GEA, these concepts and their inheritance knowledge are not considered as government resources or government assets.

4.1.5. Citizen in GEA

Both GEA and the Citizen Knowledge Pattern (CKP) take into account citizen knowledge components. Specifically, in GEA, the class “ProfileDescription” contains various citizen knowledge components (e.g., age category, gender, citizenship, health status, etc.). Note that despite the lack of some of the knowledge components of the CKP in GEA (e.g., Medical information and Automobile information), we observe that these classes can be defined as subclasses of the “ProfileDescription” class (S.K. Goudos et al., 2007).

The main difference between CKP and GEA, on the other hand, is that the *authority* and *accessibility* components of CKP (for information privacy purposes) are not considered in GEA.

4.1.6. Complaints/Compliments in GEA

Despite the importance of the complaint/compliment knowledge components in the quality of the government service delivery, GEA ignores the complaint knowledge constituents.

Note that in GEA, all public services produce an outcome with a consequence (the consequence is define as the by-product of service execution in form of information related to the service). While GEA imposes a condition that clients (service requester) are not interested in the service consequence, by removing this condition it has the potential to incorporate the Complaint knowledge components (Peristeras & Tarabanis, 2004a).

4.2. Municipal Reference Model

Municipal Reference Model (MRM) is one of the few reference models designed specifically for the municipal government domain. This is the main reason we selected it as one of the models in our comparative study. Before we formally compare the city knowledge patterns with MRM, we first provide a brief description of MRM and its architecture.

The MRM is a set of core concepts and tools that can help municipalities define and describe their businesses in terms of the programs and services that they provide, i.e., in terms that are most meaningful to municipal clients, residents, taxpayers and stakeholders. It is based on the Government Canada Strategic Reference Model (1990), and is compatible with both Service Oriented Architecture (SOA) and the Enterprise Architecture (EA) standards (*Canadian Governments Reference Model (CGRM)*, 2009), (*MRM Model Principles, Definitions, and Rules*, 2011).

Since MRM contains a small set of core terms or elements that are broadly used, it can be adopted as a reference model by any municipality (see Figure 4.2[27]). These core components along with their formal definitions are:

- **Program:** a mandate to achieve *Outcomes* by delivering *Service*.
- **Service:** a commitment to deliver *Output* that contributes to *Outcomes*.
- **Need:** a condition wanting or requiring relief.
- **Organization Unit:** a point of authority, accountability or responsibility commanding resources commensurate with its obligations.
- **Outcome:** a desirable change in the level of a *Target Group Need* resulted from Service delivery.
- **Output:** a unit of *value* produced by a *Service* and conveyed to a service recipient.
- **Service Value:** the expectations of parties receiving the *Service's Output* directly or indirectly, and ensures their alignment with associated *Service* objectives and *Outcomes.*
- **Target Group:** A set of parties that share intrinsic or extrinsic characteristics, causing a *Program* to identify (target) them (*MRM Model Principles, Definitions, and Rules*, 2011).

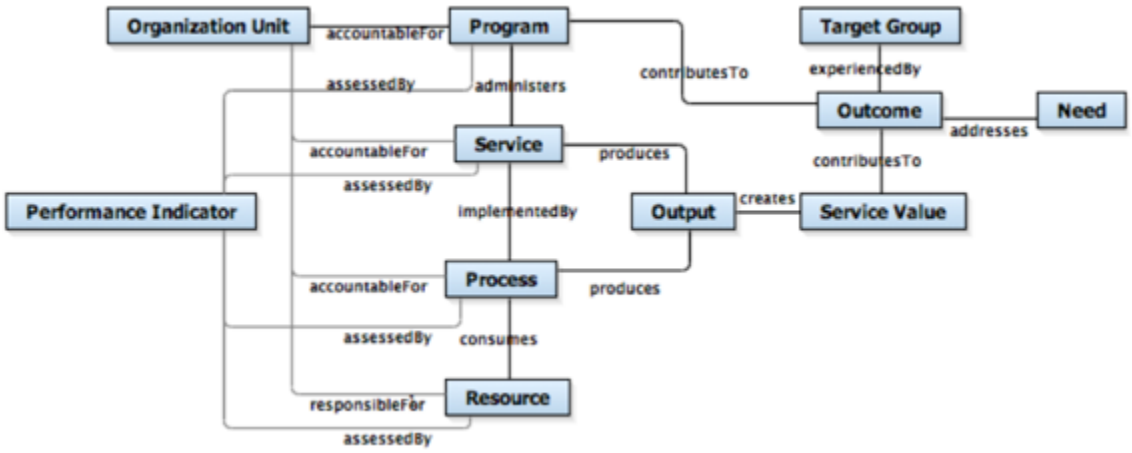


Figure 4.2: Municipal Reference Model Core Concepts

[27] This Figue is copied from (*MRM Model Principles, Definitions, and Rules*, 2011)

As shown in Figure 4.3[28], MRM shares these core concepts with the Canadian Provincial Reference models (e.g., Public Service Reference Models (PSRM) by province of Ontario), and the Canadian Government Reference Model (CGRM). The usage of a common lexicon increases the interoperability between different levels of government.

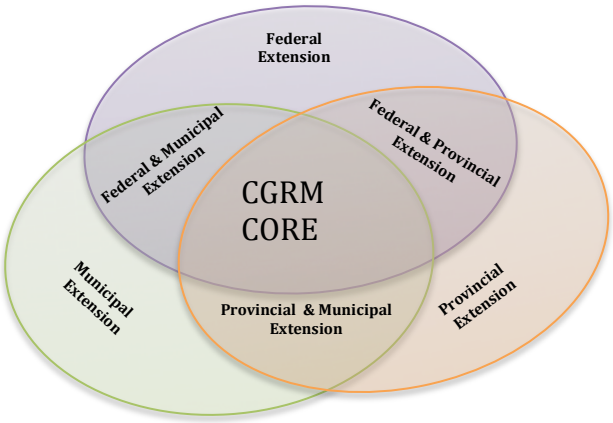


Figure 4.3: Canadian Government Reference Model-Core Elements

Despite its comprehensive documentation and promising aspects, MRM is an informal representation of the municipal government domain. Therefore, while some pioneer cities (e.g., city of Toronto, region of Peel) have implemented MRM, the implementation technologies (i.e., semantic web technology, ontologies, etc.), applied tools and methodologies to extend the core concepts for each jurisdiction, or the efficiency of the extended core model may differ from one city to another.

We next compare the City Knowledge Patterns with the knowledge components of MRM.

4.2.1. Service in MRM

Similar to the SKP, MRM also considers the following knowledge components: service, its processes and their relationship with city resource resources, service provider organization, client organization/entity, and service outcomes.

There are four major differences between SKP and MRM:

---

[28] This Figure is copied from Canadian Government Reference Model (CGRM)-Version 1.0-Final, http://www.iccs-isac.org/library/2013/01/Canadian-Governments-Reference-Model-Version-1.0-Final.pdf

1. Unlike SKP in which all services are broken down into activities, MRM only provides a general understanding of city services and their processes. This representation does not specify how these processes are executed.
2. MRM does not consider the *Service Alternative* and the *Triggering Event* knowledge components of SKP.
3. Unlike MRM, which distinguishes between city *Program* and city *Service* knowledge components, SKP doe not have a *Program* knowledge component. This is due to the fact that despite the use of MRM principles by the city of Toronto, in our investigation of the Toronto 311 knowledgebase, program and service knowledge components were used synonymously (see Case 3 in Section 3.8.1 and Case 1 Section 3.9.1), thus increasing the ambiguity of these concepts.
4. Unlike SKP, MRM does not consider constraint for its municipal services (e.g., agent constraints, capacity constraints, location constraints, temporal constraints). However, the MRM has a general understanding of resource constraints in which the municipal government has the authority to limit the usage of the resources.

4.2.2. Permit, Complaint, and Species in MRM

MRM is the only municipal model that explicitly specifies a separated service category for permission. It categorizes different permit/license services in its different programs. For example, the Economic Development program (shown in Figure 4.4) is a program in MRM that contains permit/license services (business Licensing or Film/Motion Picture Permission).

Program Name: Economic Development

Business Licensing	New Business Recruiting
Film/Motion Picture Permission	Tour Coordination
International Marketing	Tourism Information
Job Training	

Figure 4.4: Permit Related Program in MRM

Note that unlike the PKP, MRM does not specifically recognize the knowledge components of permit/license. Note that the knowledge component “Program” coupled

with the "Permission" service category allows it to define different permit/license services, and to link services and processes to a specific permit/license service.

Similar to permits/licenses, MRM does not explicitly recognize the knowledge components of the Complaint and the Species Knowledge Patterns. However, as discussed above, by coupling different service categories it can represent services related to complaint and species.

4.2.3. Organization in MRM

Figure 4.5[29] depicts a schematic model of the MRM organization structure. As can be seen the class *Organization Unit* is the core of the organization structure. According to MRM an Organization Unit is defied as: "a point of authority, accountability or responsibility commanding resources commensurate with its obligations". It consists of different Organization Unit Types (e.g., Department, Division, Section, Agency, etc.), is accountable for different Program, is responsible for Processes based on organization Role, and has authority for organization Resources.

Given the definition above, both OKP and MRM consider the following knowledge components: Organization Structure, Service and Process, Resource, Goal, Role, Mission, Vision, Authority, and Responsibility.

The main difference between the two is that while MRM considers an Organization Unit as its core, in OKP the organization agent is the central component. The reason why we consider the organization agent as the core component is that every organization unit itself consists of different agents who play the organization role. Moreover, in reality, organization agents can play multiple roles or be members of different Organization Units. Therefore, it is essential to break down an Organization Unit to its components (its agents). Another difference between OKP and MRM is that unlike OKP, MRM does not have the Empowerment knowledge component. As discussed in Section 3.5.2, considering this component provides the flexibility to create new organization units,

[29] This Figure is copied from (*MRM Model Principles, Definitions, and Rules*, 2011)

virtual or a temporary teams, and new authority for organization agents based on their new roles.

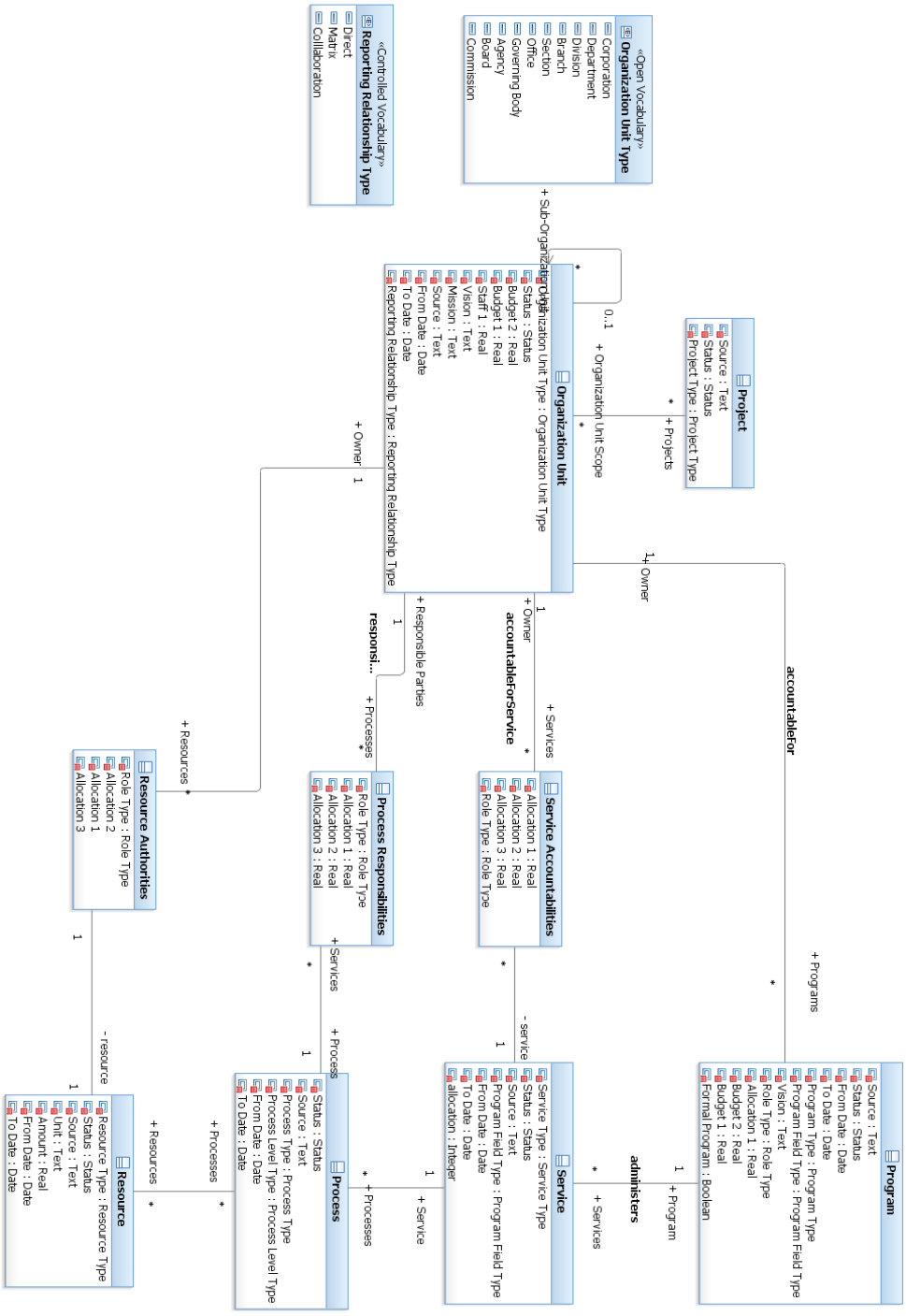


Figure 4.5: Municipal Reference Model Organization Structure

4.2.3. Infrastructure and Public Facility in MRM

The general meta-model of MRM recognizes public facility and infrastructure as city assets (i.e., as depicted in Figure 4.6[30], it considers them as a Resource Type). However, since they are not defined, as core components of MRM, they are not discussed in detail. As a result, due to this lack of documentation on infrastructure and public facility, we are not able to provide a comparison between MRM, IKP and PFKP.

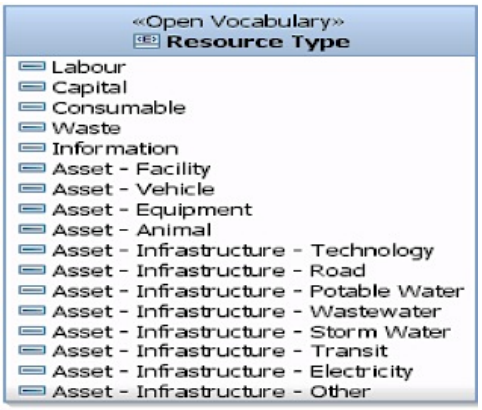


Figure 4.6: Infrastructure and Public Facility in MRM

4.2.4. Citizen in MRM

Although MRM contains concepts such as client organization and individual client, detailed specification of the knowledge components of clients (individual or organization) are not considered in MRM.

4.2.5. Education in MRM

Education knowledge component in MRM shows the following similarities with the EKP:

- Both MRM and EKP contain a service category "Education" for education services.
- Both models allow education services to belong to different municipal programs (e.g., Basic and Advanced Life Support Training service in the Health Program).

[30] This Figure is copied from (*MRM Model Principles, Definitions, and Rules*, 2011)

- Both models have an organization *entity* (unit/agent), which runs the education program.
- Both models have *Target Group* knowledge component(s).
- *Service Impact* knowledge component in EKP has similar knowledge inheritance as *Service Outcomes* in MRM.

The main differences between EKP and MRM, on the other hand, are: MRM does not consider the *Triggering Event*, *Constraints* (Participants, Date, Time, etc.), and *Educational Context* knowledge components.

4.3. TOronto Virtual Enterprise Project

In this section we compare the city knowledge patters with the TOronto Virtual Enterprise (TOVE) project. The reason why TOVE was chosen as one of the models in our evaluation is that despite its generic domain, it contains many of the fundamental concepts, attributes, and relationships that exist in the municipal government domain. Thus, by comparing our knowledge patterns with TOVE we can assess the usability and extendibility of such generic ontologies for the municipal government domain. We first provide a brief description of TOVE. Then, we compare its core ontologies with the city knowledge patterns.

As Figure 4.7[31] depicts, the overall structure of TOVE consist of different layers: (i) The core ontologies that capture the generic characteristics of the enterprise (e.g., activity, organization, and resource ontologies), (ii) The derivative ontologies that are specializations of various classes within some of the core ontologies (e.g., goal ontology is a specification of the goal class defined in the organization ontology) or a derivative ontology of multiple core ontologies (such as scheduling ontology which is a derivative ontology of both Time/Activity and Resource ontology), (iii) The Enterprise ontologies, which are used to define classes of enterprises (Grunninger, 2003).[32]

[31] This Figure is copied from: (Grunninger, 2003)

[32] The Enterprise ontologies are designed to increase the reusability and extendibility aspects of TOVE

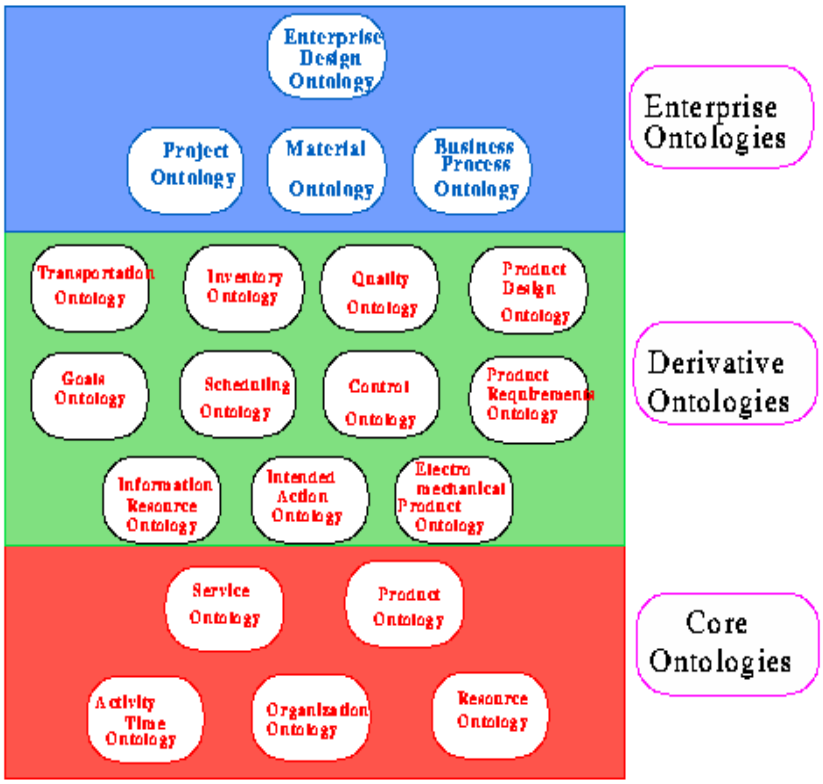


Figure 4.7: TOVE Ontology

The core ontologies of TOVE were developed as part of the Toronto Virtual Enterprise project (Fox & Gruninger, 1998). TOVE currently includes knowledge representation of activity, time, and causality (Gruninger & Fox, 1994), organization (Fox et al., 1995), resources (Fadel et al., 1994), quality (Kim, Fox, & Gruninger, 1995), cost (Tham et al., 1994), product requirement (Lin et al., 1996), trust (Huang & Fox, 2006), and agility (Grüninger et al., 2000). Since Activity, Organization, and Resource ontologies are most related to the municipal government domain we briefly describe them.

---

ontologies for different type of enterprises: the Enterprise Design Ontology to define a template used for modeling any enterprise. The Project ontology captures the constraints of one-of-a-kind manufacturers, and the Business Process ontology addresses service-based enterprises.

The Activity Ontology

In TOVE, an activity is the basic transformational action primitive with which processes and operations can be represented. An enabling state defines what has to be true of the world in order for the activity to be performed. A caused state defines what will be true of the world once the activity has been completed. An activity along with its enabling and caused states is called an activity cluster, which is used to represent an action (see Figure 4.8[33]).

Figure 4.8: Activity -State Model

States in TOVE define what holds to be true before and after an activity is performed. There are terminal and non-terminal states. Terminal states associate resources with activities through the four types of states. These four states reflect how a resource is related to an activity (use, consume, release, and produce). On the other hand, non-terminal states enable the boolean combination of states (Conjunction, Disjunction, Exclusive, and Not). Moreover, the status of a state, and any activity, depends on the status of the resources that the activity uses or consumes, and all states are assigned a status with respect to a point in time (i.e., status can have one of the following values: committed, enabled, disenabled, reenabled, and completed).

An activity specifies a transformation on the world. Its status is reflected in an attribute called status. The domain of an activity status is a set of linguistic constants: dormant, executing, suspended, reExecuting, and completed. The status of an activity is defined by the status of its enabling and caused states.

In TOVE, activity clusters may be aggregated to form multiple levels of abstraction to define new activities. The predicate hassub-activity is used to denote that an activity is a

[33] This Figure is copied from: (Gruninger & Fox, 1994).

subactivity of an aggregate activity (Gruninger & Fox, 1994), (Fox et al., 1995).

The Organization Ontology

TOVE views an organization as a set of constraints on the activities performed by agents. An Organization consists of a set of divisions and subdivisions, a set of agents who consumes organization resources in order to perform organization activities, a set of roles that the members play in the organization and have authorities with respect to their roles, and a set of goals that the members (agents) try to achieve (Fox et al., 1995).

The Resource Ontology

TOVE defines a resource's properties as derived from the role an object plays with respect to an activity, e.g., raw material, machinery, and information. This ontology is able to answer competency questions regarding divisibility, quantity, location, consumption, commitment, structure, and capacity. As mentioned earlier, states associate resources with activities through use, consume, release, and produce terminal states (Fadel et al., 1994).

In order to compare the City Knowledge with TOVE, we partition the patterns into 2 categories: (i) Knowledge Patterns that are considered in TOVE: the Service, Organization, Infrastructure, Public Facility, and Permit Knowledge Patterns; and (ii) Knowledge Patterns that currently do not exist in TOVE, but could be incorporated into the extensions of TOVE for the municipal government domain: Citizen, Species, Education and Complaint Knowledge Patterns. We next discussed each of these categories.

4.3.1.Knowledge Patterns that are considered in TOVE

Since TOVE is a general domain free model of an enterprise, it does not contain domain specific concepts. Therefore, the core ontologies in TOVE must be extended to be compatible with the domain under consideration (municipal government domain). As indicated above, the SKP, OKP, IKP, PFKP, and PKP are partially embedded in TOVE. We will discuss each of these knowledge patterns separately.

4.3.1.1. Service Knowledge Pattern

The activity ontology of TOVE shows similarities with SKP. The main similarities are listed as follows:

- Both SKP and TOVE emphasizes on breaking down services into simple activities.
- Both models define the relationship between activities and resources.
- Both models define the relationship between activities, organization, and organization agent.
- Both models control resource access through defining constraints.
- Both models define various states and state status for their activities.

On the other hand, the main differences between SKP and TOVE are:

- While TOVE is represented in FOL, we have used OWL to implement the patterns.
- The following knowledge components are not considered but can be represented in TOVE: Triggering Event, Service Alternative, and Service Outcome.

4.3.1.2. Permit Knowledge Pattern

While permit knowledge patter is not explicitly considered in TOVE, it can be incorporated through TOVE's Activity ontology (Gruninger & Fox, 1994). Specifically, in the Activity ontology, permit can be represented as a process that affects its proceeding processes/activities, i.e., in the Activity ontology the status of the proceeding activities is suspended until the status of the Permit activity changes.

4.3.1.3. Organization Knowledge Pattern

Since we use the TOVE Organization ontology as a reference model in proposing the OKP, these two models are almost identical with an exception that in OKP we have further defined strategic planning concept such as vision, mission, value and beliefs as subclass of organization goals.

4.3.1.4. Infrastructure and Public Facility Knowledge Patterns

TOVE's Resource ontology is a general ontology for representing resources and assets within an organization. This ontology provides a general understanding of resources, their quantity, location, capacity, and etc. It also contains attributes that connect resources to organization and its agents, who perform an activity. As we discussed in the previous chapter, such attributes are also present in the IKP and PFKP. However, many of the concepts, attributes, and knowledge components of these two knowledge patterns are not represented in TOVE Resource ontology. In particular, attributes such as ownership, juristic division, physical vs. environmental assets, availability, and accessibility are not represented in the Resource ontology.

4.3.2. Knowledge Patterns that Currently Do Not Exits in TOVE

Since TOVE is a generic ontology, it does not have domain specific concepts. As a result, municipal government related knowledge components such as species, compliant, education, and citizen knowledge patterns are not represented in TOVE. Therefore, to represent such knowledge components in TOVE, a new set of derivative ontologies must be developed. Once such ontologies are developed, the relationship between them and the core ontologies must also be defined.

4.4. SCRIBE Ontology

In this section we evaluate the Scribe ontology (Uceda-Sosa et al., 2011) and its components using the City Knowledge Patterns. The model is part of the ongoing research on smart cities by IBM research. Despite its lack of a comprehensive documentation, we select it as one of the ontologies/reference models in our comparison for the following reasons: (i) Scribe is the only ontology developed and design to administrate dynamic aspect of city services, (ii) it is designed based on real data and scenarios collected from different cities.

The Scribe ontology is a sematic model of data in smart cities. The model is designed to provide real time solution for complex situations, in both municipal service delivery and service administration, under large and dynamic data. The goal of the Scribe ontology is to acquire data through physical instruments, recognize and integrate similar pattern from multiple sources, and analyze gathered data for intelligent solutions. The ontology is represented in OWL knowledge representation language and utilizes other tools and technologies in order to perform its tasks (Uceda-Sosa et al., 2011).

Figure 4.9 [34]depicts a schematic representation of the Scribe's upper level ontology (Scribe Core Base), which includes the common building blocks (e.g., TimeBase, GeospatialAndGeopoliticalBase) and the customization ability for each city based on its specific requirements. The core base ontologies are comprised of various fundamental ontologies such as time ontology, measurement ontology, and geospatial ontology (shown in red boxes), which are all modified for the Scribe model. Unfortunately, apart from the abstract visualization, we could not find the specific details of these modified ontologies and their inter connection to other core bases.

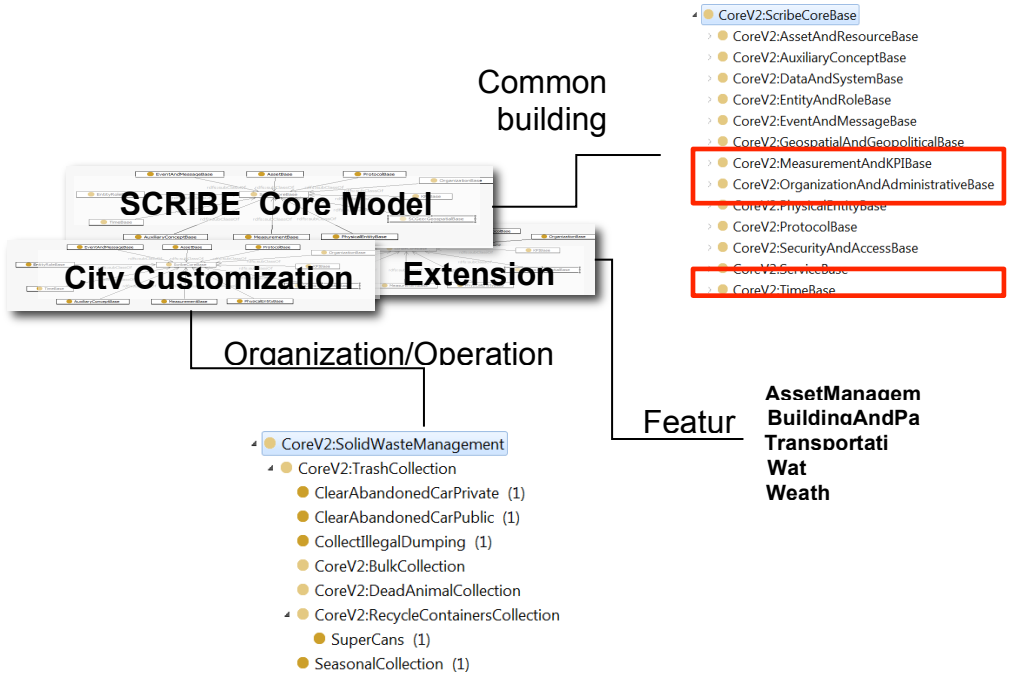


Figure 4.9: Scribe Core Model

[34] This Figure is extracted from "Using Ontologies to make Smart Cities Smarter" slides, Useda et al., Semantic Technologies (SemTech) conference, June 2012

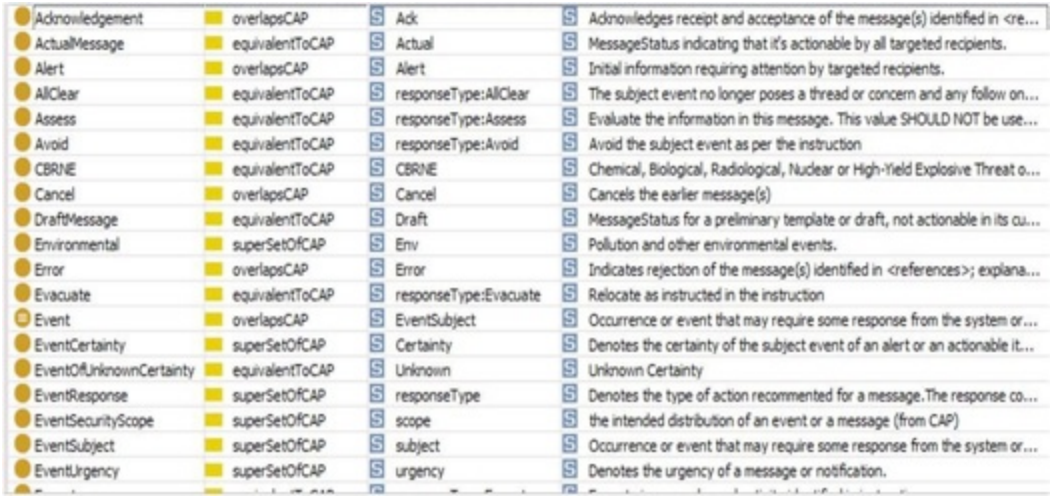
Recently, Scribe CoreBaseV2 was developed to addresses some of the main short comeings of its first version, i.e., many core bases have been added or extended from V1 to V2 (see Figure 4.10[35]). As an example, the "SCGEO: GeospatialBase" in V1 is changed to " CoreV2:GeoSpatialAndGeopoliticalBase" that adds a geo-political component to the former core base (Uceda-Sosa et al., 2011). However, it is not clear whether this change address the essential relationships between federal, provincial, and municipal governments or is referring to political territory of each municipality by using an extended version of Geospatial ontology. In reality, many federal or provincial governments are involved in city services and posses some of the resources that are used to perform these services.

Figure 4.10: Different Version of Scribe Core Base
(Left) Scribe Core Base V1,(Right) Scribe Core Base V2

One of the unique aspects of Scribe is that it models city operations as the flow of events and messages. Every event is a work item that has stakeholders, is a subject of a message, uses city assets, and relates to one of the service areas through a city organization or entity. While such definition of city operation seems simple, comprehensive and precise details of the model are not provided. Specifically, the relationship between different core bases and how they are interconnected is ambiguous.

[35] This Figure is copied from:(Uceda-Sosa et al., 2011)

Another unique aspect of Scribe is that it addresses the compatibility issue between government ontologies and government standards. Specifically, it captures some of the core entities of standards that are related to smart cities such as CAP, UCore, NIEM, and MISA/MRM (see Figure 4.11[36]). Using an integrated message-based model, Scribe links city data with these standards. However, the main concern of such approach is its extendibility with respect to each city's needs (this is a main concern with all government standards and reference models, since it is a time consuming and cumbersome task).



Acknowledgement	overlapsCAP	Ack	Acknowledges receipt and acceptance of the message(s) identified in <re...
ActualMessage	equivalentToCAP	Actual	MessageStatus indicating that it's actionable by all targeted recipients.
Alert	overlapsCAP	Alert	Initial information requiring attention by targeted recipients.
AllClear	equivalentToCAP	responseType:AllClear	The subject event no longer poses a thread or concern and any follow on...
Assess	equivalentToCAP	responseType:Assess	Evaluate the information in this message. This value SHOULD NOT be use...
Avoid	equivalentToCAP	responseType:Avoid	Avoid the subject event as per the instruction
CBRNE	equivalentToCAP	CBRNE	Chemical, Biological, Radiological, Nuclear or High-Yield Explosive Threat o...
Cancel	overlapsCAP	Cancel	Cancels the earlier message(s)
DraftMessage	equivalentToCAP	Draft	MessageStatus for a preliminary template or draft, not actionable in its cu...
Environmental	superSetOfCAP	Env	Pollution and other environmental events.
Error	overlapsCAP	Error	Indicates rejection of the message(s) identified in <references>; explana...
Evacuate	equivalentToCAP	responseType:Evacuate	Relocate as instructed in the instruction
Event	overlapsCAP	EventSubject	Occurrence or event that may require some response from the system or...
EventCertainty	superSetOfCAP	Certainty	Denotes the certainty of the subject event of an alert or an actionable it...
EventOfUnknownCertainty	equivalentToCAP	Unknown	Unknown Certainty
EventResponse	superSetOfCAP	responseType	Denotes the type of action recommented for a message.The response co...
EventSecurityScope	superSetOfCAP	scope	the intended distribution of an event or a message (from CAP)
EventSubject	superSetOfCAP	subject	Occurrence or event that may require some response from the system or...
EventUrgency	superSetOfCAP	urgency	Denotes the urgency of a message or notification.

Figure 4.11: Scribe and Government Standards Compatibility (CAP)

Moreover, the level of interoperability and inference reasoning abilities of the ontology, which are one of the main concerns in ontology design, are not discussed. In summary, despite the expressive representative language and description logic support of OWL, it seems that the Scribe ontology only uses some of the basic aspects of OWL, e.g., class hierarchy, subsumption class, and instance inferencing.

Using the City Knowledge Patterns, we next compare and test the various aspect of the Scribe ontology.

---

[36] This Figure is copied from:(Uceda-Sosa et al., 2011)

4.4.1. Service in SCRIBE

One of the main objectives of the Scribe ontology is to structure and reason about data related to city services. The CityServiceArea module (shown in Figure 4.12[37]) is a simplified and abstract model of municipal services in this ontology.

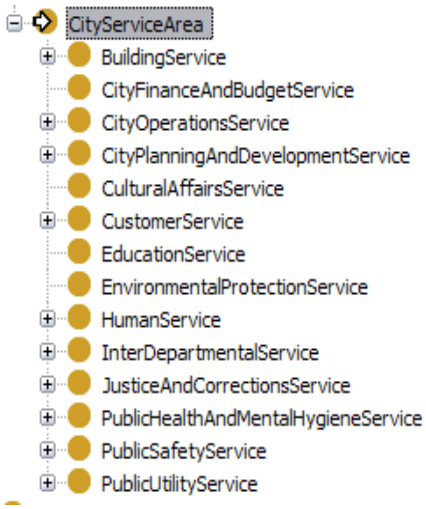


Figure 4.12: Organization of City Services in Scribe Ontology

As can be seen, this categorization is general enough to capture all aspect of city services for both public services and internal services purposes. Moreover, it is general enough to accommodate the fundamental concepts of government standards (such as MRM). However, some of the main issues in this module are:

- Despite its emphases on the core bases and their importance, the relationship between ScribeCoreBase and CityServiceArea is not provided. For example, consider the CityOperationServices (depicted in Figure 4.13[38]), which is one of the important sub classes of CityServiceArea. For this subclass, except for some symmetric object properties such as *associatedtoevent* and *eventassociatedto*, which attributes different service classes to the event class, the specification of

[37] This Figure is copied from:(Uceda-Sosa et al., 2011)

[38] The Figure 4.13 is extracted from "Using Ontologies to make Smart Cities Smarter" slides, Useda et al., Semantic Technologies (SemTech) conference, June 2012

how operation services are related to EventAndMessageBase (see Figure 4.9) is not clear.

- It seems that the CityServicesArea implicitly captures the concepts of city organization (this will be discussed in details in the organization section).

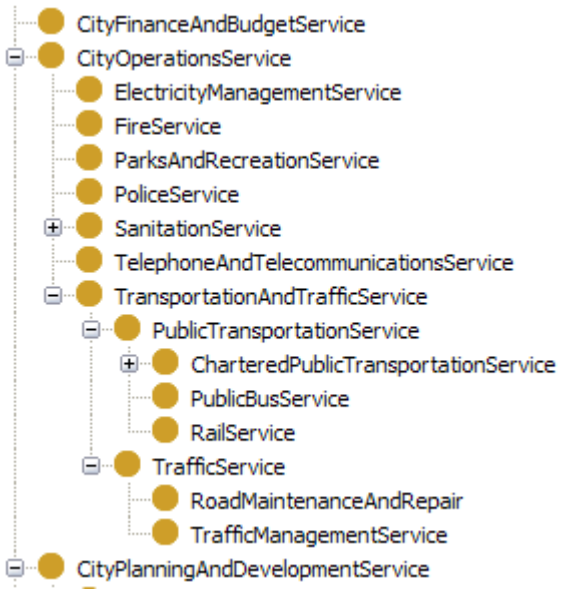


Figure 4.13: City Services in Scribe Ontology

We next list the main differences between SKP and the Scribe ontology:

1. The main difference between the knowledge components of service presented in SKP and Scribe is their different view of city service and its processes and activities, i.e., SKP is activity based whereas Scribe is event base. Specifically, Scribe emphasizes reasoning based on instances of city services, while the emphasis of SKP is on showing the high degree of similarity between activities in different services.
2. It seems that Scribe ignores the entire concept of service constraints and their effects on city services. Specifically, service *constraints* are not considered as one of the main components of city services.
3. As discussed in Section 3.3.1, an important aspect of city services in SKP is *Service Alternative*. While the knowledge component can potentially increase service delivery efficiency, Scribe does not include it as an attribute.

Note that due to lack of documentation, we cannot analyze and compare the resource aspect of city services discussed in SKP with that of Scribe.

4.4.2. Permit in SCRIBE

As discussed in section 3.3, permit is a type of city services. More accurately, it is one of the processes or activities required for service occurrence. While such processes could effect or suspend city service delivery, we found no indication that Scribe considers the knowledge components of permit.

4.4.3. Organization in SCRIBE

The concept of municipal organization as we define in OKP is not applied in Scribe. Specifically, while the main components of OKP are service activities, city organizations, and city resources that are linked with one another through the city organization agent component, the Scribe links it stakeholders, resources, organization, and entities separately to its EventAndMessageBase.

Moreover, while the OrganizationAndAdministrativeBase class in the ScribeCoreBase may be related to some of the OKP components, we are unable to make a comparison due to a lack of sufficient documentation. Furthermore, we also observed some evidence that Scribe defines relationship between concepts of agency and city departments, and their connection with city services. However, it is not clear whether these concepts are part of CityOperationServices, CityOrganizationAndAdministration core, or belong to another part of Scribe.

Both OKP and Scribe assume that cities own their data, and that the city data is not necessarily connected. However, unlike Scribe, OKP accommodates data sharing between different cities, their province, and/or their federal government.

4.4.4. Infrastructure and Public Facility in SCRIBE

As depicted in Figure 4.10, Scribe has a core class “AssetAndResourceBase”, which defines city resources and assets. Due to the lack of documentation, it is not clear whether these resources are described as simple resource or specified as infrastructures and public

facilities, whether they are distinguished as public or private asset, have jurisdiction ownership, or if they represent other knowledge components of IKP and PFKP.

Moreover, the ontology does not explain the ability of inference reasoning for its AssetAndResourceBase. As a result we cannot discuss the inference reasoning aspect of this core as we did in the TOVE resource ontology.

4.4.5. Citizen in SCRIBE

The components of the Citizen Knowledge Pattern are not discussed in the Scribe ontology. Moreover, the concept of entity or person considered in Scribe, which could be a stakeholder, is very general and ambiguous to characterize knowledge components and attributes of the CKP.

4.4.6. Education in SCRIBE

Scribe defines education as a type of city services. However, the knowledge components described in the EKP such as: *Triggering Event* and *Educational Context* in the city services (As discussed in Section 3.9.2) are not considered in the Scribe ontology.

4.4.7. Complaints/Compliments in SCRIBE

There are similarities between CoKP components and the knowledge inheritance of complaint in the Scribe ontology. In both Scribe and the CoKP complaint has a service category, topic (object or entity), location, date, time, receiving division, and an agent who is in charge of following the complaint/compliment. However, due to the lack of citizen knowledge representation in Scribe, it does not represent the information of the complainer.

4.4.8.Species in SCRIBE

In Scribe, species, its categorization, or its knowledge components as we observe and discuss them in the SeKP or in any other form (i.e., different categorization, specific or separated service categorization, additional data about animal related city services) is completely ignored.

4.5. Conclusion

In this chapter, we presented a comprehensive evaluation of the coverage of four established ontologies and reference models using the City Knowledge Patterns. The following table summarizes our evaluation:

	GEA	MRM	TOVE	Scribe[39]
Service KP	Similar knowledge components, except for Service Alternative, and Triggering Event	Doesn't have Service Alternative, and Triggering Event**,** also misses in depth explanation of activities, and constraints.	Similar knowledge components, except Triggering Event, Service Alternative, and Outcome knowledge components.	Different knowledge components. Event base instead of activity base. Does not discuss service constraints, and Service Alternative.
Permit KP	Not Considered	Partially considered	Can be extended	Not Considered
Organization KP	Partially Similar. Skills, authority, goal , responsibility, team, member, organization structure, and empowerment are not considered.	Similar knowledge components,except in stead of organization agent the organization unit is the core component of organization, and the empowerment knowledge component is not considered.	Same Knowledge components, except for strategic concepts (Vision, Mission, Values, etc.)	N.A (no solid documentation regarding the structure of municipal government organization)
Infrastructure KP	Not Considered	N.A (General entity is defined)	Not Considered but can be extended. (Unknown consistency)	N.A (may exist in the AssetsAndResource Base).
Public Facility KP	Not Considered	N.A (General entity is defined)	Not Considered but can be extended. (Unknown consistency)	N.A (may exist in the AssetsAndResource Base)
Citizen KP	Similar Personal Information, but Medical, and Automobile components are not considered. Moreover the personal information privacy (Authority/Accessibility) is not considered	Not Considered	Not Considered	Not Considered
Education KP	Not considered	Similar knowledge components except for Educational Context, Triggering Event, and Constraints(Participants, Time, Date, etc.)	Not Considered	Not Considered
Complaint / Compliment KP	Not considered, but has the potential to extend	Partially Considered	Not Considered	Similar Knowledge Components, except for the complainer info.
Species KP	Not Considered	Partially Considered	Not Considered	Not Considered
Representation	OWL/OWL-S/WSMO	Informal	FOL	OWL

Table 4.1: Comparative Evaluation of Existing Reference Models/Ontologies based on City Knowledge Patterns for City Domain

[39] Note that the documentation regarding the specification of the Scribe Ontology was limited and some of its characteristics might not be considered in this comparison.

Chapter 5

Conclusion

In this final chapter, we summarize the work presented in previous chapters, re-state the major contributions of this dissertation, and present some possible directions for future work.

5.1. Summary and Contributions

Identifying City Knowledge Patterns to represent the embedded knowledge components in the city domain: In Chapter 3, we use the Toronto 311 knowledgebase webpages as a basis for determining the concepts that must be represented in a reference model or an ontology if it is to be used for representing municipal knowledge. We identify nine different patterns of recurring municipal knowledge and presented a formal representation of them using description logic, which we implemented using the Ontology Web Language (OWL).

Evaluating the conceptual coverage of four existing government ontology/reference models: In Chapter 4, using the City Knowledge Patterns, we evaluate the coverage (the models' content cover of the knowledge defined in the CKPs) of four ontologies and reference models in the municipal government domain. This chapter illustrates how the City Knowledge Patterns can be used as a tool for informal conceptual comparison of city government ontologies/reference models represented in different representation languages.

We believe the CKPs can be used to identify the knowledge coverage of other government ontologies and reference models.

5.2. Future Work

Four important future research directions on City Knowledge Patterns (CKPs) are:

1. Recall from Chapter 3 that the presented CKPs are the main knowledge patterns extracted from the 311 knowledgebase. However, there may exist other knowledge patterns not recognized in our framework. Therefore, by further investigating the existence of other potential knowledge patterns, it may be possible to define new patterns, thus increasing the scope of the CKP. For example, it would be interesting to investigate the existence of knowledge patterns that represent the relationship between the municipal government with its business partners and the provincial and federal governments.
2. Using the CKPs to represent the Toronto 311 knowledgebase webpages to increase the level of semantics and improve automated reasoning ability of the knowledgebase.
3. In Chapter 4, we evaluated four established models in the city domain. It would be interesting to evaluation other city models/ontologies, using the CKP framework.
4. Further work can be done on completing the axiomatization of the CKP ontology and extending it to capture additional knowledge patterns and their concepts.

5.3. Conclusion

The main focus of this research is to identify the concepts required to represent municipal knowledge. Based on our analysis of Toronto 311 web pages, we were able to identify nine patterns of knowledge: service, permit, organization, infrastructure, public facility, citizen, education, complaint/compliment, and species. We then used these patterns to determine the extent to which four existing reference models and ontologies can represent municipal knowledge, as defined by the Toronto 311 KB. With these patterns, it is now possible to evaluate how well a reference model or ontology meets the need of a municipality. Finally, we provide a formal representation of these patterns using OWL.

Bibliography

Adams, N., Fraser, J., Macintosh, A., & McKay-Hubbard, A. (2002). Towards an ontology for electronic transaction services. *Intelligent Systems in Accounting, Finance and Management*, *11*(3), 173–181.

Bettahar, F., Moulin, C., & Barthès, J.-P. (2009). Towards a Semantic Interoperability in an e-Government Application. *Electronic Journal of E-Government*, *7*(3).

Brank, J., Grobelnik, M., & Mladenić, D. (2005). A survey of ontology evaluation techniques.

Brewster, C., Alani, H., Dasmahapatra, S., & Wilks, Y. (2004). Data driven ontology evaluation.

Canadian Governments Reference Model (CGRM). (2009). Retrieved from www.iccs-isa.org/

Clark, P., Thompson, J., & Porter, B. (2004). Knowledge patterns. In *Handbook on Ontologies* (pp. 191–207). Springer.

Fadel, F. G., Fox, M. S., & Gruninger, M. (1994). A generic enterprise resource ontology. In *Enabling Technologies: Infrastructure for Collaborative Enterprises, 1994. Proceedings., Third Workshop on* (pp. 117–128). IEEE.

Federal Enterprise Architecture. (2004). Retrieved from www.feapmo.gov

Federal Enterprise Architecture Reference Model Ontology. (2004). Retrieved from www.osra.gov

Fox, M. S., Barbuceanu, M., & Gruninger, M. (1995). An organisation ontology for enterprise modelling: preliminary concepts for linking structure and behaviour. In *Enabling Technologies: Infrastructure for Collaborative Enterprises, 1995., Proceedings of the Fourth Workshop on* (pp. 71–81). IEEE.

Fox, M. S., & Gruninger, M. (1998). Enterprise modeling. *AI Magazine*, *19*(3), 109.

Gangemi, A., & Presutti, V. (2009). Ontology design patterns. In *Handbook on Ontologies* (pp. 221–243). Springer.

Gómez-Pérez, A. (2001). Evaluation of ontologies. *International Journal of Intelligent Systems*, *16*(3), 391–409.

Gómez-Pérez, A. (2004). Ontology evaluation. In *Handbook on ontologies* (pp. 251–273). Springer.

Goudos, S. K., Loutas, N., Peristeras, V., & Tarabanis, K. (2007). Public administration domain ontology for a semantic web services EGovernment framework. In *Services Computing, 2007. SCC 2007. IEEE International Conference on* (pp. 270–277). IEEE.

Goudos, S. K., Peristeras, V., Loutas, N., & Tarabanis, K. (2007). A public administration domain ontology for semantic discovery of eGovernment services. In *Digital Information Management, 2007. ICDIM '07. 2nd International Conference on* (Vol. 1, pp. 260–265). doi:10.1109/ICDIM.2007.4444233

Government of Ontarion IT Standard (GO-ITS). (2010). Retrieved from www.ontario.ca/governement/

Government Strategic Reference Model (GSRM). (2007). *Government Strategic Reference Model (GSRM)*. Retrieved from www.tbs-sct.gc.ca

Gruber, T. R. (1995). Toward principles for the design of ontologies used for knowledge sharing? *International Journal of Human-Computer Studies*, *43*(5), 907–928.

Gruninger, M. (1996). Designing and evaluating generic ontologies. In *Proceedings of the 12th European Conference of Artificial Intelligence* (pp. 53–65).

Grüninger, M., Atefi, K., & Fox, M. S. (2000). Ontologies to support process integration in enterprise engineering. *Computational & Mathematical Organization Theory*, *6*(4), 381–394.

Gruninger, M., & Fox, M. S. (1994). An activity ontology for enterprise modelling. *Department of Industrial Engineering, University of Toronto*.

Grüninger, M., & Fox, M. S. (1995). Methodology for the Design and Evaluation of Ontologies.

Grunninger, M. (2003). Enterprise modelling. In *Handbook on Enterprise Architecture* (pp. 515–541). Springer.

Hodgson, R., & Allemang, D. (2006). Semantic Technology for E-Government. In *Semantic Web Services, Processes and Applications* (pp. 283–303). Springer.

Huang, J., & Fox, M. S. (2006). An ontology of trust: formal semantics and transitivity. In *Proceedings of the 8th international conference on Electronic commerce: The new e-commerce: innovations for conquering current barriers, obstacles and limitations to conducting successful business on the internet* (pp. 259–270). ACM.

Keita, A., Laurini, R., Roussey, C., & Zimmerman, M. (2004). Towards an ontology for urban planning: The towntology project. In *CD-ROM Proceedings of the 24th UDMS Symposium, Chioggia* (Vol. 12).

Kim, H. M., Fox, M. S., & Gruninger, M. (1995). An ontology of quality for enterprise modelling. In *Enabling Technologies: Infrastructure for Collaborative Enterprises, 1995., Proceedings of the Fourth Workshop on* (pp. 105–116). IEEE.

Lin, J., Fox, M. S., & Bilgic, T. (1996). A requirement ontology for engineering design. *Concurrent Engineering*, *4*(3), 279–291.

Mackenzie, H. (2013). *Canada's Infrastructure gap where It Came From, and Why It Will Cost So Much To Close* (Technical Report). Canadain Center for Policy Alternative(CCPA). Retrieved from Government finance Municipalities and urban development Public services and privatization https://www.policyalternatives.ca/publications/reports/canadas-infrastructure-gap#sthash.xBHNEPSW.dpuf

Magoutas, B., Halaris, C., & Mentzas, G. (2007). An ontology for the multi-perspective evaluation of quality in e-Government services. In *Electronic Government* (pp. 318–329). Springer.

Mauher, M., & Smokvina, V. (2008). Municipal asset and property management system for the Web collaborative environment. In *31st International Convention on Information and Communication Technology, Electronics and Microelectronics*.

MRM Model Principles, Definitions, and Rules. (2011). Retrieved from www.missa-asim.ca

Obrst, L., Ceusters, W., Mani, I., Ray, S., & Smith, B. (2007). The evaluation of ontologies. In *Semantic Web* (pp. 139–158). Springer.

Paschke, A., & Vincent, P. (2009). A Reference Architecture for Event Processing. In *Proceedings of the Third ACM International Conference on Distributed Event-Based Systems* (pp. 25:1–25:4). Nashville, Tennessee: ACM. doi:10.1145/1619258.1619291

Peristeras, V., & Tarabanis, K. (2004a). Advancing the government enterprise architecture–GEA: the service execution object model. In *Electronic Government* (pp. 476–482). Springer.

Peristeras, V., & Tarabanis, K. (2004b). Governance Enterprise Architecture (GEA): Domain Models for e-Governance. In *Proceedings of the 6th International Conference on Electronic Commerce* (pp. 471–479). Delft, The Netherlands: ACM. doi:10.1145/1052220.1052280

Porzel, R., & Malaka, R. (2004). A task-based approach for ontology evaluation. In *ECAI Workshop on Ontology Learning and Population, Valencia, Spain*. Citeseer.

Sarantis, D., Charalabidis, Y., & Askounis, D. (2009). An ontology for stakeholder collaboration and knowledge exploitation in e-government project management. In *Proceedings of the 3rd international conference on Theory and practice of electronic governance* (pp. 61–67). ACM.

Sarantis, D., Charalabidis, Y., & Askounis, D. (2010). A Goal Oriented and Knowledge Based e-Government Project Management Platform. In *System Sciences (HICSS), 2010 43rd Hawaii International Conference on* (pp. 1–13). IEEE.

Tambouris, E., Boukis, G., Vassilakis, C., Lepouras, G., Rouvas, S., Canadas, R., … Usero, J. L. (2002). SMARTGOV: a governmental knowledge-based platform for public sector online services. In *Proceedings of the KMGov2002 Workshop* (pp. 23–24).

Tambouris, E., Gorilas, S., Kavadias, G., Apostolou, D., Abecker, A., Stojanovic, L., & Mentzas, G. (2004). Ontology-enabled e-Gov service configuration: an overview of the OntoGov project. In *Knowledge Management in Electronic Government* (pp. 122–127). Springer.

Terregov Project. (2011). Retrieved from www.terregov.eupm.net

Tham, K. D., Fox, M. S., & Gruninger, M. (1994). A cost ontology for enterprise modelling. In *Enabling Technologies: Infrastructure for Collaborative Enterprises, 1994. Proceedings., Third Workshop on* (pp. 197–210). IEEE.

Uceda-Sosa, R., Srivastava, B., & Schloss, R. J. (2011). Building a highly consumable semantic model for smarter cities. In *Proceedings of the AI for an Intelligent Planet* (p. 3). ACM.

Unas, S. M. (2000). Ontological engineering: common approaches and visualisation capabilities. *Informatica*, *11*(1), 41–48.

Uschold, M., King, M., Moralee, S., & Zorgios, Y. (1998). The enterprise ontology. *The Knowledge Engineering Review*, *13*(01), 31–89.

Vassilakis, C., & Lepouras, G. (2006). An ontology for e-government public services. *Encyclopedia of E-Commerce, E-Government and Mobile Commerce*, 865–870.

Vrandečić, D. (2009). *Ontology evaluation*. Springer.