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An Ontology-Based Approach to Supporting Knowledge Management in Government Agencies: A Case Study of the Thai Excise Department

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SUMMARY Knowledge management is important for government agencies in improving service delivery to their customers and data inter-operation within and across organizations. Building organizational knowledge repository for government agency has unique challenges. In this paper, we propose that enterprise ontology can provide support for government agencies in capturing organizational taxonomy, best practices and global data schema. A case study of a large-scale adoption for the Thailand's Excise Department is elaborated. A modular design approach of the enterprise ontology for the excise tax domain is discussed. Two forms of organizational knowledge: global schema and standard practices were captured in form of ontology and rule-based knowledge. The organizational knowledge was deployed to support two KM systems: excise recommender service and linked open data. Finally, we discuss some lessons learned in adopting the framework in the government agency.

key words: *government information system, organizational knowledge repository, enterprise ontology*

1. Introduction

Some major roles of government agencies typically include collecting data, sharing the data to the public and providing services to the citizens [1]. However, there are several major problems in terms of data management in government agencies. There is often redundancy and inconsistency of data and processing functions [1]. In a large government agency, many systems were autonomously developed to fulfil the requirements of different departments or projects. This often results in heterogeneous database schema, forms and systems that are difficult to interoperate. The redundancy of data and processing functions make it difficult to integrate data and processing functions within and across organizations.

In providing services to the citizens, government agencies aim to improve the efficiency and effectiveness of the services provided to the citizens. The services provided by government agencies are often repetitive and must follow some standard procedures. However, in practice, the service operations frequently rely on tacit knowledge and expertise of the practitioners [2], [3]. This can sometimes lead to inconsistency in practice and possible human judgment errors. Thus, it is important that there must be common understanding of standard practices within the government agencies to improve reliability and quality of the services.

In this paper, we advocate that knowledge management (KM) in government agencies is necessary for improved data inter-operation within and across organizations and improved services to the public. Organizational knowledge or organizational memory [4] is a subject of KM that is typically referred to taxonomy, content management and standard practices. Organizational knowledge can provide common understanding of its data, systems and procedures for the organization's employees and the external entities [5]. This paper proposes an ontology-based framework in building organizational knowledge repository. The ontological model can provide a support for data and system inter-operation at the semantic level. It can also be used to support construction and maintenance of knowledge base that captures knowledge of best practices in government agency.

A case study of adopting the ontology-based KM framework for the Excise Department*—the national government agency that administers excise tax revenue collection is presented. There are several challenges for the Excise Department in organizational knowledge management. First, there is a lack of global schema for the organization. With the heterogeneity of information systems within the organization, it is not easy for data sharing and inter-operation between different systems within and across organizations. Second, there is a lack of explicit knowledge on excise product classification. Thus, determining tax payment of a product sometimes relies on human judgement for assessing duty class of the product. Enterprise ontology for the Excise Department was developed as organizational knowledge and was used to support two ontology-based KM systems: excise duty recommender system and linked open data portal. We describe some key design issues of the enterprise ontology and the KM systems and discuss some lessons learned based on the case study.

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*http://www.excise.go.th/

2. Background

2.1 Organizational Knowledge

Organizational knowledge or organizational memory or knowledge repository is a component of KM that focuses on the accumulated body of data, information, and knowledge created in the course of an organization's existence [4], [6]. Creating organizational knowledge repository has several advantages for an organization. The content in the repository, which stores historical and current events can be used to support decision making, operation improvement and policy planning [4]. Organizational knowledge also helps to create the common understanding among employees about the formalized rules and procedures within an organization and to provide evidence-based practice [7].

The content of knowledge repository may be classified into two forms: formal records, i.e. artifacts of cooperation, and embedded knowledge in organization's culture and process [4]. Organization memory puts more emphasis on the knowledge codification strategy to promote knowledge access and reuse. Typical knowledge organization techniques include converting extracted knowledge into databases and capturing skills and expertise in form of best practices [8].

In an organization, knowledge is often embedded not only in documents or repositories but also in organizational routines, processes, practices and norms [9]. Practices are commonly associated with routines and rules, which can be seen as governing structures that define practices. One of the organization challenges is in capturing these practices as shared knowledge base for solving practical organizational problems.

2.2 KM Challenges for Government Agency

Although both government and private sectors produce and use data, there are some major differences in their objectives as shown in Table 1. The differences may be summarized in at least two aspects: success indicator and expected openness [5], [10], [11]. The success of private sector is primarily measured by a profit, while that of the public sector is rather measured by the quality of service perceived by the public. In addition, one expectation of the public sector is openness in sharing the data to the public [1], [11], which is in contrast with the private sector, which typically produces proprietary data and closed systems. The openness of data of government agency can improve transparency, and inter-operation with the external entities.

KM is recognized as one key component for increasing productiveness and service quality of government agencies [5], [12]. Work in government agencies is expert work that usually depends on knowledge [13]. The knowledge usually involves legal rules, standards, knowledge work related to sophisticated process, legal norms and administrative domain knowledge. In addition, KM is important for the government agencies in preparing for retirement and transfer of knowledge workers [3]. Thus, capturing tacit knowledge and building knowledge repository that facilitates knowledge creating, sharing and using knowledge are among the most important activities of government agencies [3].

In addition, data involved in an administrative decision are often dispersed over many locations and resided on several systems [13]. Thus, one of the KM challenges for government agencies is content integration that deals with handling of heterogeneous data repositories from different sources. The open government data is a global initiative that aims to improve transparency, citizen participation and inter-operation of a government agency with other organizations [13].

Table 1 Main differences between government and private sectors.

	Private sector	**Government sector**
Success indicator	Based on profit	Based on service quality
Expected openness	Low	High

3. An Ontology-Based Knowledge Management Framework for Government Agency

3.1 Roles of Ontology in Knowledge Management

Government focuses on service delivery and knowledge sharing to public. Thus, there is a need to develop a generic KM framework for the government sector [14]. The semantic technologies have been applied in different e-government projects in various aspects including formal domain models, service ontologies, semantic enhancements of business process models, semantic Service Oriented Architectures (SOAs), and ontology-based knowledge management [15].

Domain ontology is considered a key component for knowledge management in government agencies [13]. Ontology can represent concepts and domain knowledge of government agencies to provide a common reference to interrelate IT-based informational resources [16]. For example, ontology can support organizing and sharing of information resources in citizen-centric web portal [17]. Ontology can be used for mapping data for the purpose of data and system interoperability at the semantic level across government agencies [18], [19]. Ontology can also be used to support semantic description of Web services to support automated service integration [20].

Our framework emphasizes the importance of constructing enterprise ontology [21]–[23]. The roles of enterprise ontology in government KM are described as follows:

- **Providing organizational data taxonomy for content organization**. Ontology designed in terms of data taxonomy can be used for organizing information resources in the content repository. This would allow the information resources in the repository to be classified and retrieved based on concept-based browsing, i.e., faceted search [24].

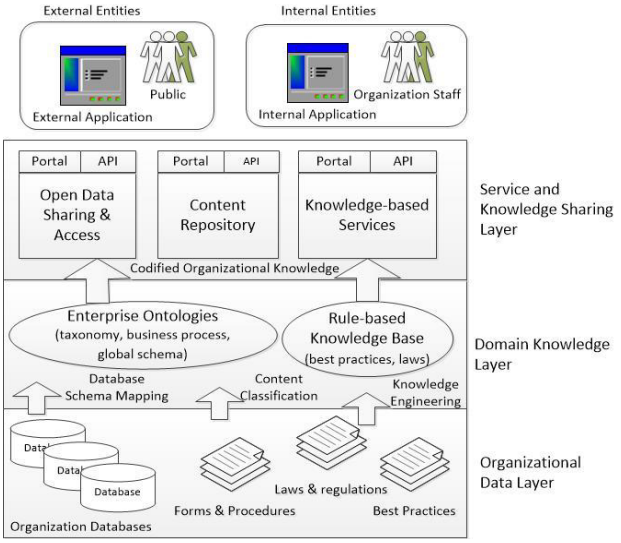


Fig. 1 Layered architecture of ontology-based organizational knowledge repository for government agency.

- **Representing unified organizational schema**. Ontology can be used to represent a global schema for an enterprise that is important for data interoperability between systems within and across organizations. Ontological model is more suitable for capturing an enterprise schema because it can provide better support for semantic interoperability [22], [23].
- **Supporting construction of knowledge base for intelligent systems**. Ontology can be used to represent legal and administrative work knowledge. The formalized legal domain knowledge [13] that captures the knowledge about legal rules and administrative work best practices can be encoded in form of rule-based knowledge. Some intelligent systems that can benefit from the ontology-based knowledge base include legal knowledge-based systems [25]–[28].

3.2 Conceptual Architecture

A conceptual layered architecture of ontology-based organizational knowledge repository for government agencies is shown in Fig. 1.

The organizational data layer consists of database from different information systems within a government agency. It also involves the documents and information resources related to forms, standard procedures, laws, regulations, and best practices.

The domain knowledge layer is the organizational knowledge captured in the form of taxonomy, formalized business process and global schema, i.e. enterprise ontology [22], [23]. The formalized legal and best practice domain knowledge can be captured in the form of rule-based knowledge. For the database sources, the existing database schema must be mapped with the enterprise ontology so that the data from different data sources can be transformed to the same schema for the purpose of data sharing. The embedded knowledge such as legal, standard procedures and best practices, should be encoded in form of formalized rule-based knowledge that can be used by knowledge-based systems.

The service and knowledge sharing layer consists of three forms of service including open data sharing, content repository and knowledge-based services. These services can be consumed and used by both the internal and the external entities and should also be provided for machine consumption via APIs.

4. A Case Study of Ontology-Based KM for the Thailand's Excise Department

4.1 Domain Problem Description

Excise duty is a type of tax charged on certain products and services. It usually targets at products and services that are considered unnecessary or luxurious. Some common products that excise duty are applied to include petroleum, beverage, liquor, and tobacco products, etc. Classification of excise product is necessary to determine the rate of excise duty on a product.

There are several challenges for the Excise Department related to the service operations. First, there is a lack of global schema for the organization. Different information systems and databases have been developed for different projects. This has resulted in redundancy and inconsistency of data schema. Second, there is a lack of explicit knowledge on excise product classification. Thus, determining tax payment of a product sometimes must rely on human experts' judgement for assessing duty classes of products.

In our project, an enterprise ontology was created to represent global schema and standard practices of the organization. The ontology was used to improve data-interoperation and support excise duty recommender service.

4.2 Enterprise Ontology Development

4.2.1 Roles of the Enterprise Ontology

Enterprise ontology, which is a unified representation of the organizational data schema and taxonomy could help in reducing ambiguity and inconsistency in data management in the organization. Some potential applications of the enterprise ontology for the excise tax domain are described as follows:

- *Form consolidation.* The standard structure of the related entities can reduce inconsistency in form fields design. Form consolidation helps to prevent inconsistency in user's input data caused by inconsistent form fields.
- *Content repository organization.* The classes and properties of the related service entities constitute a data

taxonomy that can be used for organizing the information resources in the content repository.

- *Excise Duty Recommender System.* The ontology can provide support for reasoning services about user products and their recommended excise duty classes based on product-to-duty mapping rules.
- *Linked Open Data Portal.* The data from different databases within the agency can be mapped with the ontological data schema. The data can be shared over an open data portal in the RDF (Resource Description Framework) format. An SPARQL endpoint can be provided for querying the RDF data to facilitate the data reuse and integration within and across organizations.

4.2.2 Ontology Development Process

Three knowledge sources were identified: fill-in forms, legal references and domain experts. The customer's forms and form fields were thoroughly analyzed to generalize about classes and properties that are related to the service entities. This "bottom-up" analysis approach allowed some general concepts to be identified and further refined in the next steps.

Another knowledge source was legal documents, i.e. law and regulations on excise tax collection. Key concepts related to each excise product were identified based on the regulations on the product duty. This "top-down" analysis approach allowed some product-specific concepts to be additionally identified. Domain experts were also consulted for resolving ambiguities and inconsistencies found in the reference documents. In the final step, the experts were consulted for verification and approval of the ontology.

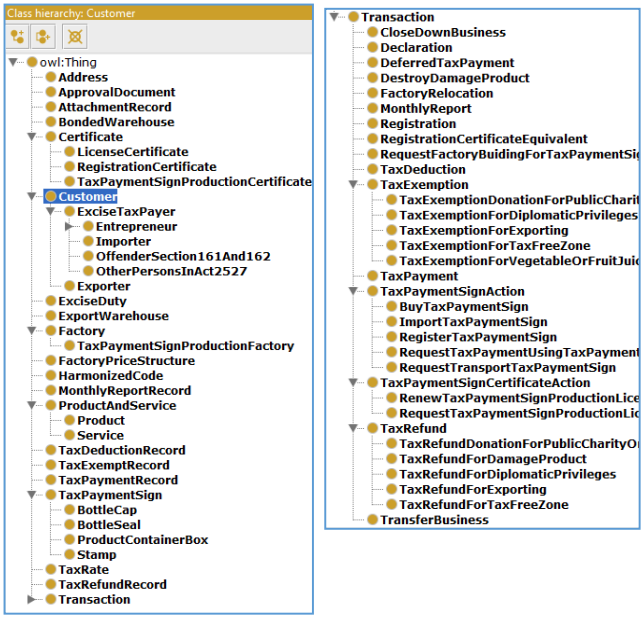
A modular ontology design approach was used to facilitate ontology maintenance and extension. Two types of ontology were created: core and product-specific ontology. The core ontology contains the classes and properties shared by all product types. The product-specific ontologies extend the core ontology and contain the classes and properties related to each product type.

4.2.3 Core Ontology Design

The design of the core ontology is shown in Fig. 2 a). The design of core ontology mainly focuses on the entities related to the customer services. Some main classes include Product, ExciseDuty, Customer, Transaction, Factory, Warehouse, TaxRate, Certificate, and Address etc., as shown in Fig. 2 b). The total numbers of classes, subclass-of relations, subproperty-of relations, object properties and data properties are 71, 51, 15, 51 and 122 respectively.

4.2.4 Product-Specific Ontology Design

Each excise product is defined as a subclass of the Product class. Product properties for excise products were defined in four dimensions: physical, compound, usage or purpose, and identification dimensions. Properties in physical



a) Main class hierarchy b) Transaction class hierarchy

Fig. 2 Class hierarchy of the core ontology of the Excise Department.

Table 2 Product properties for the beverage and petroleum products.

	Beverage Products	**Petroleum Products**
Physical	Package type, Volume	Color
Compound	Sweetener, Flavored, Carbonated, Fruit-or-Vegetable ingredients, Stimulant, Caffeine	Ethanol, Lead, Methyl Ester of Fatty Acid, Sulfur, Pureness
Usage/ Purpose	Drink making machine, Exported product, Donation	Purpose, Place of sale, Buyer, Exported product
Identification	Product name, Brand	Product name, Brand

dimension included those related to external appearance of the product, such as volume, packaging, color, etc. These properties may be used to determine excise duty class. For example, a beverage product sold in a higher-volume container must pay higher tax rate. Properties in the compound dimension include those related to ingredients or elements of the product. For petroleum product, they include chemical components and their proportions such as Ethanol, Lead, Methyl Ester of Fatty Acid, Sulfur, pureness, etc. Properties for specifying usage or purpose of product are also important in determining excise duty class. For example, petroleum or beverage products that are produced and sold for charity or export purposes belong to different classes of tax rates. Properties in identification dimension include product name, and brand, etc. These properties are typically not used in determining product duty class. Table 2 shows dimensions of product properties for two excise products: beverage and petroleum products. Figure 3 shows portions of the petroleum product ontologies.

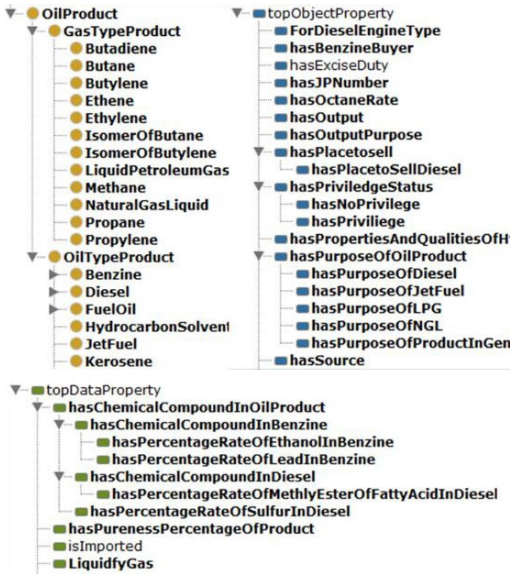


Fig. 3 Portions of the petroleum product ontology.

4.3 Excise Duty Recommender System

Excise duty recommender system can be considered a form of legal intelligent system [25]–[28]. Such an application can help the users in reducing cost of tax advisors, reducing time and effort, and reducing errors [29]. Customers and officers can use the system to support decision making in determining tax payment for a product.

Product-duty mapping rules specify conditions of product properties and their concluded duty classes. A rule management framework using spreadsheets was adopted to simplify management of recommendation rules for different excise products [30]. There are over 250 mapping rules defined in total, which involved over 70 product properties of 22 excise products. The rules for each product were created in a decision table form. Example of a decision table for the petroleum products is shown in Fig. 4 a). In this example, the duty class of a petroleum product is determined by the type, origin, purpose, proportion of Lead and Ethanol of the product. Figure 4 b) shows an example of some output rules in the Jena's syntax [31] translated from the decision table.

The excise duty recommender system[†] was built using the OAM framework [32]. Information about the user' products was obtained from the Web-based input form. The framework adopted the D2RQ system [33] in creating RDF data from the product database. The RDF data were stored in the Jena's TDB triple store and were processed by Jena inference engine based on the product-to-duty mapping rules. The recommendation results were stored in the triple store and retrieved using OAM API.

[†]http://etrs.excise.go.th

F	G	H	I	J	K	L
Proportion of Lead		Proportion of Ethanol				
<= 0.15	> 0.15	>= 10% < 20%	>= 20% <75%	>= 75%	< 10%	Duty Class
X						01.01(3)
	X					01.01(2)
X		X				01.01(4)
X			X			01.01(5)
X				X		01.01(6)

a) product-duty mapping rules in the decision table form

```
[ LinkingRule-2: (?instance rdf:type ns:Benzine) (?instance
ns:has_Percentage_Rate_of_Lead_in_Benzine ?v2c0) le(?v2c0
'0.15'^^http://www.w3.org/2001/XMLSchema#float) (?instance
ns:has_Priviledge_Status_of_Leadfree_Benzine_Buyer ?v3c0) (?v3c0 rdf:type ns:Non-
Privilege_Leadfree_Benzine) (?instance ns:has_Percentage_Rate_of_Ethanol_in_Benzine ?v4c0)
ge(?v4c0 '10.0'^^http://www.w3.org/2001/XMLSchema#float) lessThan(?v4c0
'20.0'^^http://www.w3.org/2001/XMLSchema#float) -> (?instance ns:has_suggested_tax_class
ns:RecInstance-id-2) ]
[ RecInstance-id-2: (?instance rdf:type ns:tax_class) (?instance ns:has_tax_class_value ?v0c0)
regex(?v0c0 '01.01[(]4[)]'^^http://www.w3.org/2001/XMLSchema#string) -> (ns:RecInstance-id-2
rdf:type ns:tax_class_recommendation) (ns:RecInstance-id-2 ns:has_rec_tax_class ?instance) ]
```

b) product-duty mapping rules in the Jena's rule syntax

Fig. 4 Product-to-duty mapping rules for petroleum products.

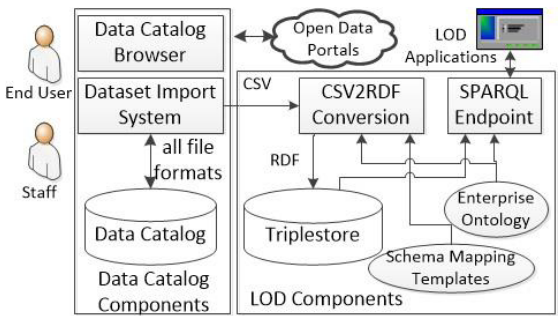


Fig. 5 System architecture of the Excise LOD portal.

4.4 Excise Linked Open Data Portal

The Excise Linked Open Data (LOD) portal[††] supports publishing and consumption of organizational data based on the linked open government data concept [34], [35]. It extends the functions typically found in open government data portals, e.g. Data.gov, by enriching the data for convenient access and reference by applications. Linked open government data portals [36], [37] typically use the Linked data technology in transforming table-based datasets in the CSV format into the RDF format. Access to the published RDF data in the portal is normally provided via a SPARQL endpoint, which supports data integration by URI referencing mechanism.

The system architecture of the portal is shown in Fig. 5. The system consists of the Data Catalog and LOD components. The data management process consists of data publishing, enrichment and access.

Data Publishing. Staff can publish machine-readable data files, e.g. xls, csv, etc., via the dataset import system. The files and their metadata are stored in the data catalog.

Data Enrichment. The files in CSV format will be verified

[††]http://opendata.excise.go.th

```
PREFIX base: <http://opendata.excise.go.th/ontology/core#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT ?x ?y ?z WHERE {
   ?x rdf:type base:Excise_office .
   ?x base:name ?y .
   ?x base:address ?z .}
```

a) Example of an SPARQL query

```
<result>
 <binding name="x">
  <uri>http://opendata.excise.go.th/def/excise_office/040304</uri>
 </binding>
 <binding name="y">
  <literal>สำนักงานสรรพสามิตพื้นที่เชียงแก่น สาขาบ้านไผ่</literal>
 </binding>
 <binding name="z">
  <uri>http://opendata.excise.go.th/def/addresses/excise_office_040304</uri>
 </binding>
</result>
```

b) Example of a query result in XML format

Fig. 6 Example query for listing branch offices via SPARQL endpoint.

Table 3 Summary of the RDF data available in the Excise LOD portal.

Class names	# Prop.	# Inst.	# Triples
Address	16	38,313	613,008
Customer	12	28,973	347,676
Declaration	3	11,125	33,375
Excise_office	4	213	852
Factory	11	35,600	391,600
License	12	46,081	552,972
Product	14	11,125	155,750
Product_unit	3	67	201
Registration	9	6,622	59,598
Total	**84**	**178,119**	**2,155,032**

whether their structure, i.e., column names, is matched with the schema mapping templates. If matched, the data will be transformed to the RDF format based on the classes and properties defined in the enterprise ontology. The RDF data is stored in a triplestore.

Data Access. The published data catalog on the portal can be used by staff, citizens, and developers. The data catalog can also be retrieved and indexed by other data catalogs. LOD applications that utilize government data from different sources can retrieve the data via the SPARQL endpoint. Figure 6 shows an example of SPARQL query to retrieve the list of all branch offices and their addresses and example result in XML format.

As of September 2016, over 110 datasets have been published on the portal. The datasets are mostly statistical and location data. The schema mapping templates were defined for nine ontology classes. The list of classes, number of its property, instances and triples are summarized in Table 3.

5. Discussion and Conclusion

5.1 Related Work

Some design approaches for ontologies in corporate and personal income tax domain were proposed for the U.S. [38], Chinese [39], Italian [40] and Taiwanese [41] tax laws. In [39], [41], the formal concept analysis (FCA) tools were used to support construction of the ontologies. In [38], [40], logical reasoning about application processes was applied. These ontologies primarily focus on modelling concepts related to corporates, persons and their wealth manifestation properties. Our project focuses on the excise tax domain, whose challenges were mainly involved defining properties and rules of various product types and their respective excise duty classes. To the best of our knowledge, our work is the first initiative that discusses ontology design approaches for the excise tax domain.

The scope of ontology-based KM system in our project focuses on applying ontology to support intelligent services and to publish open government data. Some research work with similar applications include content repository annotation and search of cases and documents [42], [43], legal-related knowledge-based system [38], and linked open government data [44], [45]. Our KM system is unique in that it proposes a framework that integrates these applications by means of enterprise ontology.

5.2 Lessons Learned

Based on our experience in adopting the framework, some lessons learned are discussed as follows.

- *Organization Staff Involvement*. Gaining support from top-level management and the employees are among the most challenging factors of KM in government sector. Enterprise ontology developing requires internal staff involvement in order to gain the acceptance. In our project, several working group committee, comprised of over 30 executives and senior officers from different departments, were set up to oversee the ontology development process over one year period. Although the process was time-consuming and laborious, it was necessary for the acceptance by the management and employees.
- *Knowledge Maintenance.* Updates of enterprise ontology are normally inevitable. Laws on excise tax are regularly revised or updated. There have been essentially yearly updates on the Thai excise tax laws related to tax payment, reduction and exemption. One advantage of the ontology-based approach is that the domain knowledge is separated from the database and processing functions. Thus, the ontology and rules can be maintained by the knowledge engineers separately from the database and processing functions. Some knowledge maintenance tools should be adopted to simplify the knowledge base update tasks [30].
- *Inter-operation.* Adopting the ontology-based approach to support data sharing can promote openness and system inter-operation. Nearly all the datasets in the portal were time-sensitive statistical and location datasets that must be updated monthly or yearly. Thus, the open data publishing process should be scheduled

frequently and set up as an organization policy. In addition, applications that utilize the shared data should be developed.

5.3 Conclusions and Future Work

In this paper, we advocate adoption of the ontology-based KM framework in government agencies. KM is important for government agencies in improving service delivery to their customers and data inter-operation within and across the organizations. We focus on the ontology-based approach to capture organizational taxonomy, best practices and global data schema to support building organizational knowledge repository. Our experience in adopting the framework for a national government agency - the Thailand's Excise Department is elaborated. The development of an enterprise ontology and two KM systems that adopted the ontology is described. The systems exemplify benefits of ontology in supporting legal knowledge-based service and open data sharing. Finally, we emphasize that government staff involvement in the ontology development process and knowledge repository updates are among the key factors in adopting the framework. Our planned future work includes adding ontology-based tax form verification services and conducting user evaluation studies with the internal and external entities.

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