A semantic framework for the delivery of e-government information and services: The case of New Zealand

A thesis presented in partial fulfilment of the requirements
for the degree of

Doctor of Philosophy (PhD)

in

Information Systems

at

Massey University, Palmerston North, New Zealand.

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2011

ABSTRACT

The motivation for the research was to add to the body of knowledge associated with the design and construction of a semantic framework that would serve the needs of the e-government community. The purpose of the thesis was to investigate whether a semantic framework could be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet. New Zealand Parliament and local government council were used as a representative domain, where the research question could be addressed and from which general inferences could be made about the delivery of government information across the Internet.

An embedded case study research methodology was employed in this research. The process began by constructing a semantic framework which was then instantiated with information from New Zealand government agencies. Information was then retrieved from the ontology using a query-driven web browser interface. The resulting artefact was evaluated using a triangulated mixed method approach involving expert judgement, simulation analysis and metrics based on the OntoQA method.

Two key conclusions can be made from this research. Firstly, the results of the comprehensive evaluation regime supported the view that the prototype semantic framework constructed to support the delivery of New Zealand governmental information to users in both a stand-alone environment or via a portal, was found to be effective and efficient. Given the similarity of the format and structure of New Zealand's national and local government agencies to jurisdictions overseas there is optimism that the framework could be imported into other e-government initiatives. Secondly, the processes associated with the design and development of the semantic framework and browser interface were carefully monitored and recorded in accordance with design science research practice.

Developers and researchers of e-government would find the results of this research activity, both from an e-government or design science research perspective, informative and useful.

Keywords

Semantic framework, ontology, design science research, E-Government, expert judgement, Protégé-OWL, OntoQA.

ACKNOWLEDGEMENTS

I would like to give my heartfelt thanks to the kind people around me for all the support, help and encouragement I received during my PhD studies. I am particularly grateful for efforts on my behalf, and guidance, provided by my principle supervisor Dr Kinshuk. I am also extremely grateful for the wisdom, good advice, encouragement and friendship from my second supervisor Mr Barry Jackson, and I would like also to extend my appreciation to Dr Richard Whiddett, for his supportive suggestions during my studies.

The assistance given to me by the Horizons Regional Council during my research is very much appreciated, particularly that from Horizons Project Coordinator Mr Chris Veale who was extremely helpful in sharing his knowledge and time with me. I am grateful to all the contributors who responded to my questions in the online discussion groups, and I give thanks to the group of eight experts who generously took time out of their very busy schedules to evaluate the semantic framework, and who made very useful and erudite comments. I thank the many people who assisted me in gathering the use cases, especially Mr Noel Johnson who provided much of the source material on environmental issues. My appreciation also extends to the support from TopQuadrant for allowing me to use TopBraid for research purposes, and to all the users who offered advice on the TopBraid discussion forum.

I would like to express my gratitude to Massey University for the financial support provided by the Vice Chancellors Scholarship, awarded to me at the commencement of my studies, and for the administrative support I have received from both and the School of Management, Massey University and Massey University.

I also extend my thanks to my friends Winifred Jackson and Judith Engelbrecht who have helped with my English and encouraged so much during my studies.

Finally, special thanks go to my family, for their patience and encouragement, without which I would not have completed my research journey.

Ethical approval

The project was recorded on the Low Risk Database, which is reported in the Annual Report of the Massey University Ethics Committee. The notification was dated 15 April 2010.

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1 INTRODUCTION

The development of high-speed Internet and the World Wide Web (Web) has been the driving force behind many of the initiatives to improve the delivery of public and private services to the population at large. One of the beneficiaries of this remarkable technology has been the delivery of various aspects of government services, and the New Zealand government, like many governments overseas, has provided a number of services on-line.

In spite of the success of the Web there is a strong belief that more could be done to improve its effectiveness. A key player in advancing the capability of the Web is the World Wide Web Consortium (W3C), which is a highly respected international community that develops interoperable technologies, standards, specifications, guidelines, software, and tools. Fundamental to the approach taken by the W3C is the use of semantic technologies, which are essentially a collection of languages and specifications that “enable people to create data stores on the Web, build vocabularies, and write rules for handling data” (World Wide Web Consortium (W3C), 2009a, para. 1). This advance on the capabilities of the Web is termed the Semantic Web (SW).

Abecker, Sheth, Mentzas and Stojanovic (2006), while applauding the scientific advances in the theory associated with the SW, argue strongly in favour of application-driven research primarily through the real-world use cases to demonstrate the added value of the SW technology. Abecker et al.(2006) also suggest that the e-government domain provides an ideal test bed for existing SW research. They consider the domain of e-government to be particularly suitable, partly because of its open architecture, but also because e-government exhibits some remarkable characteristics which make it more demanding, but also more promising than common e-business scenarios. For example, there is a high degree of formality in many of its structures, there are many different stakeholders within the same process, there is a huge amount of information that has to be retrieved and accessed across many systems, installations are located at different levels in local, regional, national and international organisations, there is a variety of IT network infrastructures that are managed by different information technology solutions, and systems and networks tend to be closed making it impossible to have one physically integrated system.

In this study, the suggestion by Abecker et al.(2006) is adopted, and application driven research is carried out to examine the use of the Semantic Web in delivering e-government services, with the view to obtaining a better understanding of the design and development processes used in the creation of the environment’s supporting semantic framework.

1.1 The Internet and the World Wide Web

The Internet is a global network of interconnected computers enabling users to share information along multiple channels. Typically, a computer that connects to the Internet can access information from a vast array of available servers and other computers by moving information from them to the computer's local memory. The same connection allows that computer to send information to servers on the network; that information is in turn accessed and potentially modified by a variety of other interconnected computers.

The majority of widely accessible information on the Internet is transferred using the medium of the World Wide Web. The Web is a system of interlinked hypertext documents accessed via the Internet. Computer users typically manage, send and receive information using web browsers. There is a plethora of additional software for users to display the content gathered from the Internet as well as other specialised programs such as electronic mail, online chat, social networks, and file transfer and sharing.

Since the Web’s inauguration, Sir Tim Berners-Lee has played an active role in guiding the development of Web standards (such as the mark-up languages in which web pages are composed), and in recent years he has been very active in articulating his vision of the Semantic Web (SW).

1.2 Semantic Web (SW)

The SW is an evolving extension of the World Wide Web in which the semantics of information and services are defined. This additional information embedded in the semantic content makes it possible for the SW to better respond and satisfy the requests of users. The semantic concept derives from World Wide Web Consortium director Sir Tim Berners-Lee's vision of the Web as a universal medium for data, information, and knowledge exchange. At its core, the semantic web comprises a set of design principles, collaborative working groups, and a variety of enabling technologies. The elements of the SW are expressed in formal specifications. These specifications include the knowledge representation languages RDF (Resource Description Framework), data interchange formats RDF/XML and OWL (Web Ontology Language) with its variants N3 and Turtle; these together with specification languages such as RDFS (RDF Schema) provide a formal description of concepts, terms, and relationships within a given knowledge domain (Cunningham, 2008).

1.3 E-Government

Governments are very dependent on advanced information and communication technologies (ICT) to provide services both in-house and externally to other agencies and to the wider public. In most Western and advanced economies e-government contributes a significant component to the overall information and knowledge economy. Government departments and agencies rely on ICT to provide the evidence base to support their decision-making, and as a result enable a government’s previous decisions and activities to be scrutinized and commented upon (Cunningham, 2008). Cunningham claims that public sector information is an often underutilised national strategic resource that needs to be efficiently and effectively managed if it is to justify the huge level of investment it commands. He also states that government data needs to be properly managed and be sustainable and that comprehensive metadata regimes are required. Such regimes need to facilitate the storing, managing, controlling and preserving of information across domains, in order to support the ongoing use of those resources.

The e-government field emerged in the late 1990s, and since then governments have launched numerous e-government projects in order to provide electronic information and services to citizens, businesses, and other stakeholders. Today e-government is a dynamic research field and research is being conducted all over the world. In the beginning, research focused on national governments and service issues, but more recently, local government and the rights of the citizen have acquired more and more attention.

The New Zealand Government's aim, under its e-government strategy, is to create a public sector that meets the needs of New Zealanders and where the Internet will be the dominant means of enabling ready access to government information, services and processes (New Zealand Government, 2006).

Traditional government web portals provide citizens with access to quite detailed government information; however, it is usually necessary to have some basic knowledge and understanding of the government regulations and structure. Quite often the information that users would like to obtain is inter-departmental, and it becomes difficult to retrieve information when the government departments are configured with different systems and data structure. With the SW, the interoperability problem can be resolved by creating a conceptual knowledge model, where the government structure, services and processes can be integrated within a unified framework.

1.4 Semantic E-Government

Given that public sector metadata is expected to be a crucial element of the semantic web, e-government metadata implementations should consider the potential roles and benefits of the semantic web languages such as RDF and OWL (Cunningham, 2008).

The following points show why e-government is a potential candidate for a semantic web solution:

- There is a huge amount of information that has to be retrieved and accessed across many systems.
- Installations are located at different levels in local, regional, national and international organisations.
- There is a variety of IT network infrastructures that are managed by different information technology solutions.
- Systems and networks tend to be closed.
- It is impossible to have one physically integrated system.
- There are no consistent naming conventions across the various departments and systems.
- The government domain constitutes an obvious research area for the semantic web, as government data is intrinsically formal.
- New Zealand has an e-government initiative but has not ventured into the use of the semantic web.

1.5 Motivation for the research

The motivation for this research is based on three perspectives. Firstly, in the opinion of the World Wide Web Consortium the adoption of the semantic web would see improvements in the way the Web constructs information and responds to users requests. Secondly, Abecker, Sheth, Mentzas and Stojanovic (2006) argue strongly in favour of application-driven research through the use of real-world use cases to demonstrate the added value of SW technology. Thirdly, Abecker et al. (2006) also suggest that the e-government domain provides an ideal test bed for existing SW research. They consider the domain of e-government to be particularly suitable, partly because of its open architecture, but also because e-government has some noteworthy characteristics, which make it more challenging. The e-government domain also provides situations that are quite different to those found in the more common e-business scenarios. For example, there is a high degree of formality in many of its structures and there are many different stakeholders accessing the same process or services. Most governmental installations are located at different levels of government, local, regional, national and international organisations and generally, there is a variety of IT network infrastructures that are managed by different information technology solutions. These systems and networks tend to be closed making it is impossible to have one physically integrated system.

1.6 Research aims and objectives

There is a strong belief by many international experts that the Internet is not reaching its full potential as a deliverer of information (Berners-Lee, Hendler, & Lassila, 2001). In an attempt to address this issue, a number of initiatives have been introduced, for example, Facebook's open graph protocol, iPhones Siri, and the open data initiatives in both the USA and the UK (The Internet Society, 2005). These initiatives bring into focus the possibility of extending the Web using semantic technologies. Some of the large international corporations such as Oracle, IBM, Adobe, Software AG, and Yahoo! are seeking to apply the technology (World Wide Web Consortium (W3C), 2009a). Application areas, like the Health Care and Life Sciences, are looking at the data integration possibilities of the semantic web as a possible way of solving some of their research and development (R&D) problems. W3C's own E-Government Interest Group has also been actively building an international network of support to work with governments on issues of transparency, accountability, and efficiency through open data. The reason for this optimism is that when carrying out information systems development, information connecting data elements is invariably lost as non-semantic databases fail to capture properties that link data elements together. The frameworks on which the ontologies are composed re-establish some of those lost properties and thus permit query language tools to retrieve information that is richer and more integrated. In addition, semantic frameworks are able to link and integrate information gathered from distinct sources and from disparate systems, and create new information by applying inference techniques.

1.6.1 Problem Domain and Scope

The extent of the research domain is illustrated in Figure 1-1. The broad domain suggested by Abecker et al. (2006) is represented by the outer layer, which shows semantic web application-driven research using real-world use cases. The next layer represents the domain of application driven research initiatives combining semantic web concepts and e-government as proposed by Abecker et al.(2006) The inner layer represents the New Zealand e-government domain, and in particular, it identifies New Zealand parliament and local government entities. The latter is the application domain of this research. The domain is believed to be an appropriate representative of the broad domain, since many of the types of structures and governance roles found in the New Zealand environment are also found in many other countries. This is the case of those countries such as Australia, Canada, India and some Pacific Island countries, who have adopted or introduced a variation of the "Westminster" style of parliamentary system (Go, 2003; Patapan, Wanna, & Weller, 2003). An (2009) found in the case of the USA and the UK that they have laws, regulations and policies pertinent to electronic records management and e-government strategy which are similar to New Zealand laws. The interest in adopting e-government systems has been observed by the United Nations, as it claims that there has been significant progress with the e-government readiness of its 192 Member States, especially in the case of middle-income countries (United Nations, 2010a)

Addressing the research question in this way can be seen as a complementary effort to the international attempts to add to the body of knowledge regarding the design, construction and evaluation of e-government-based semantic artefacts.

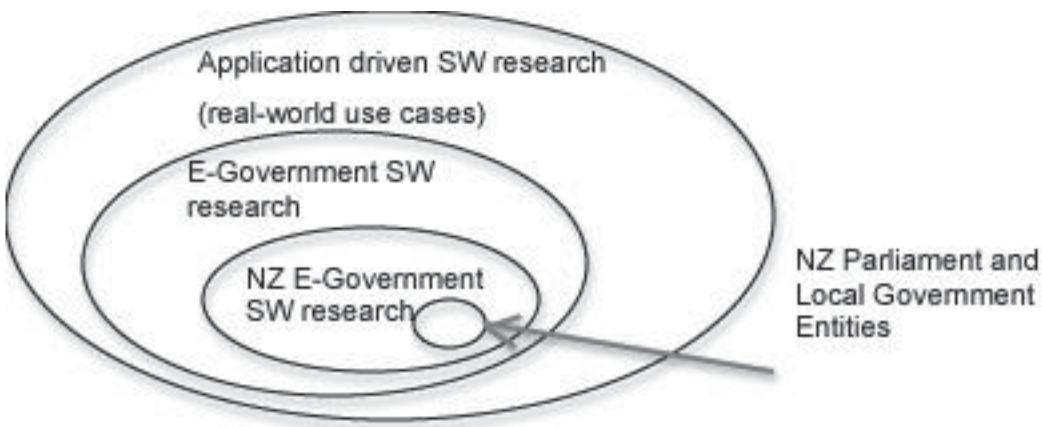


Figure 1-1: Domain and Scope of the proposed SW research

The representative domain is located within the innermost level of Figure 1-1, where information is to be drawn and integrated from the New Zealand parliamentary structure, MPs roles and responsibilities, representative local government councils and authorities, electorate regions and government environmental publications.

1.6.2 Research Definition and Research Question

The purpose of this research is to investigate whether the semantic web can improve the delivery of government information across the Internet. More specifically, this research is concerned with the question whether a semantic framework can be designed, developed and implemented that reflects various governmental structures, and can deliver associated information using an Internet browser. In this research the New Zealand Parliament and local government entities are used as a representative domain, where the research question can be addressed and from which general inferences can be made about the delivery of government information across the Internet.

1.6.2.1 Research Question

Taking an application driven research approach to examine the application of the Semantic Web in delivering e-government services leads to the following research question:

> *Can a semantic framework be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?*

1.6.2.2 Sub-questions

To support this research endeavour, the following sub-questions need to be addressed:

- Which epistemology, research paradigm, methodology and research methods should be adopted?
- What semantic tools and languages are required to design the framework and construct the semantic model?
- What design and construction methods are required to build the semantic framework?
- What authoring tools are required to create and instantiate the semantic environment?
- What authoring tools are required to create a query driven semantic web portal?
- What methods are to be used to validate and evaluate the semantic environment?
- The results of the research will add to the body of knowledge associated with the design and construction of an innovative semantic framework that can be used to deliver governmental information through a query driven web browser.

1.7 Research process

The research process proposed by Creswell (2003) is closely followed in this research. Creswell is a widely cited researcher and author in the field of research design (Bashir, Afzal, & Azeem, 2008; Warfield, 2010). In Creswell's approach, a set of sequential processes is identified; each process builds on the knowledge gained from the previous process, until the overall aims of the research have been achieved (Creswell, 2003, 2007)

Design science research is the paradigm used in this research. This is evidenced by the creation of an innovative purposeful artefact in the form of a semantic framework. In this study, the structure of the New Zealand parliament and local authorities, and the roles and responsibilities of their elected members are used to construct and instantiate the framework of a representative artefact, which is subsequently evaluated. The design science guidelines proposed by Hevner et al. (2004), which provide a practical way of determining the quality and appropriateness of the design science research being undertaken, are adopted and closely followed throughout the entire research process.

The research methodology used in this study can be described as an embedded case study. Within the case study both quantitative and qualitative methods are used to gather data in order to address the research question. The design and construction of the artefact are documented and reviewed as part of the evaluation process together with three practical approaches that are used to evaluate the semantic framework and to validate the design processes used. In the first approach the views of discipline experts are used to validate the ontology. In the second approach the functionality of the semantic framework is addressed by subjecting the system to simulation-based analysis, and in the third approach the content richness of the extracted information is determined by the application of usability metrics.

1.8 Report structure

The thesis is structured into nine chapters, plus a reference section and an appendix. The literature review is contained in chapter 2. Chapters 3-6 address five of the six sub-questions, and the final three chapters are concerned with evaluation (6^{th} sub-question), data collection and analysis, and conclusions respectively.

Chapter one: Introduction

The first chapter comprises an introduction, which provides a contextual overview of the domain of interest and its origins, motivation for the research, and description of the research question, sub-questions and objectives. Reference is also made to the adopted research methodology and subsequent evaluation and analysis.

Chapter two: Literature Review

The literature review discusses and analyses critical points of current knowledge including substantive findings as well as theoretical and methodological contributions to e-government. The review identifies and analyses information which supports the design, construction and deployment of semantic frameworks and artefacts. It also identifies those questions that need further research.

Chapter three: Research Strategy

In this chapter, the research process is described as a sequence of clearly defined steps as proposed by Creswell (2003). In the first step, the research aims and objectives are described. The subsequent steps in the research process essentially address the sub-questions in chronological order. The literature review informs the research processes throughout the entire investigation. The research process concludes with a detailed analysis of the information gathered during the investigation, a conclusion and a critical assessment of the methods used to gather and evaluate the information.

Key outcomes from this chapter are:

- The answer to the research sub-question, ‘Which epistemology, research paradigm, methodology and research methods should be adopted?’ is addressed.
- Design science research guidelines are identified.

Chapter four: Supporting languages, techniques and technologies

This chapter answers three of the research sub-questions identified in Section 1.6.2.2.

- What semantic tools and languages are required to design the framework and construct the semantic model?
- What design and construction methods are required to build the semantic framework?
- What authoring tools are required to create and instantiate the semantic environment?

Key outcomes of this chapter are that the web ontology language is chosen as the most appropriate semantic language and that a variation of Noy and McGuinness’s ontology development model is ideally suitable (2001). The decision to select the ontology authoring tools Protégé OWL and TopBraid Composers is explained and justified.

Chapter Five: Ontology Construction

The construction of the e-government ontology is described in this chapter. Information is gathered from government web sites and other reputable source to instantiate the subdomains: New Zealand Parliament, Horizons Regional Council Management, and Environment Issues.

The usefulness of use cases, Protégé OWL and TopBraid Composer in the support of the design and construction of the ontology is considered. The chapter also brings into focus the application of the Hevner et al. (2004) guidelines in evaluating the quality of the design and construction of the artefact.

Chapter Six: Browser Interface Construction

Further discussion of the research sub-question 'What authoring tools are required to create a query driven semantic web portal' is carried out. The construction of the browser interface is described using TopBraid Ensemble, and evaluated. The Hevner et al. (2004) guidelines are also kept in focus.

Chapter Seven: Evaluation Methods

To answer the research sub-question 'What methods are to be used to validate and evaluate the ontology?' three different, yet complementary, approaches are described:

- Expert judgement: A group of experts in semantic environments are asked to critically comment on the quality and appropriateness of the framework.
- Simulation-based analysis: Scenarios based on the use-case data are used to present requests for information from the system that require the utilisation of the system's unique semantic features.
- Structural evaluation: This approach analyses the ontology's schema and its population, and describes the ontology using a well-defined set of metrics.
- Again reference is made to the design science research guidelines.

Chapter Eight: Data Collection and Analysis

In this chapter data is collected from the three evaluation methods described in Chapter 7. From that data an assessment is made as to whether the research question had been addressed and resolved.

Chapter Nine: Conclusion

- This chapter provides an overview of the thesis and summarises the key conclusions reached. Specific consideration is given to the limitations of the semantic framework, together with the limitations of the adopted research strategy. Finally, comments and assertions are made regarding the usefulness of the research with regard to its contribution to both e-government and design science research.

2 LITERATURE REVIEW

There has been a huge transformation in recent years in the way governments carry out their business and the way they interact with their citizens. This transformation is due almost entirely to the tremendous advances in Information and Communication Technologies (ICT) that have taken place over the past decade. These new forms of government are referred to as e-government.

A set of directions and priorities for information and communication technology was adopted by the New Zealand Government in 2010 (Department of Internal Affairs, 2011), The Government's vision is to ensure that users have easy and reliable access to government services through the Internet for the general public, businesses and commercial enterprises; also included in the vision is the sharing of information between government departments and agencies. In the case of government entities this would be achieved by providing integrated services through data sharing and ensuring interoperability by introducing standards across the entire government enterprise.

In Europe, e-government has the mission of sharing information and providing efficient and effective services to citizens and business across different government bodies and European Union (EU) Member States. A new generation of e-government services outlined in the Action Plan (2011-2015) is to be established under the auspices of the European Commission to empower European citizens and businesses to develop and use open, flexible and collaborative e-government services (European Commssion Information Society, 2011).

The United States has been in the forefront of e-government development. The US Office of E-Government and Information Technology (E-Gov) is leading the e-government project with a vision of applying Internet-based technologies to make it easier for citizens and businesses to interact online with the Federal Government (The White House, 2011).

In this chapter a review of the literature and related material associated with the research problem is carried out. The set of topics and sub topics include are as follows.

The chapter begins in subsections 2.1 to 2.3 with some background material on the domain of the research and presents an overview of some aspects of New Zealand government organisation and considers how some of these aspects could be represented within a semantic framework.

Some of the broader issues of defining, conceptualising and planning e-government services and some examples of e-government initiatives in Europe and the USA are then presented in subsections 2.4 to 2.7.

The final parts of the chapter then introduce some background material on the use of semantic technology and ontology development methodologies. The nature of this research requires considerable understanding of the supporting semantic languages and technologies used in the construction of semantic e-government ontologies; this additional information is then made available in Chapter 4: *Supporting Languages, Techniques and Technologies*. Similarly, information regarding the design, construction and evaluation of the semantic artefact are described respectively in Chapter 5: *Ontology Model Construction*, Chapter 6: *Browser Interface Construction*, and Chapter 7: *Evaluation*.

In support of the notion currently advocated by the information systems research community that careful monitoring and control of the design and construction of innovative artifacts is a research endeavour, Hevners et al.'s seven design science principles are addressed in some detail in Chapter 3. In this section, information is gathered to support the view that the research in design, construction and implementation of e-government based semantic artefacts is part of the research trend that are currently underway by the international e-government community.

2.1 Central Government in New Zealand

In this section, an introduction to, and general description of the New Zealand political system and constitutional structure is included. The knowledge about New Zealand central and local government structure is well represented and reflected in the e-government ontology structure illustrated in Chapter 5 of this thesis.

2.1.1 Constitution

The constitution of New Zealand, which follows the Westminster system, consists of a collection of statutes, referred to as acts of parliament, treaties, decisions of the courts and unwritten constitutional conventions. The constitution system is based on the principle that power is distributed across three government branches: Parliament, the Executive, and the Judiciary.

The notional source of the executive, judicial and legislative power in New Zealand rests with the head of state, the monarch, currently Queen Elizabeth II. The Governor General represents the Queen in the Realm of New Zealand. This system is known as a constitutional monarchy.

2.1.2 Government

The New Zealand Government is formed from a democratically elected House of Representatives. The Government advises the Head of State of New Zealand, who acts on the advice of the Government in all but the most exceptional circumstances.

Based on the power distribution of New Zealand government system, Parliament makes the law. The Executive (Ministers of the Crown also known as the Government) administers the law. The Judiciary interprets the law through the courts.

New Zealand has no single written constitution or any form of law that is higher than laws passed in Parliament. The rules about how the New Zealand system of government works are contained in a number of Acts of Parliament, documents issued under the authority of the Queen, relevant English and United Kingdom Acts of Parliament, decisions of the court, and unwritten constitutional conventions. These Acts establish how people vote, the term of Parliament, the power of Parliament, the formation of the Government, and individual rights.

2.1.3 Electoral System

New Zealand adopted mixed member proportional (MMP) as its electoral system for the House of Representatives in 1994. The term of the Parliament is a maximum three-year term. New Zealand citizens, along with permanent residents who have been in New Zealand for a year and are over the age of 18, are required to enrol; however, it is not compulsory to vote. Every New Zealand citizen who is enrolled as an elector, and who is not disqualified from enrolling, is eligible to be a candidate for election as an MP.

The New Zealand electoral system is a two-tiered system. The lower tier determines the local electorate representative; the upper, over-riding tier determines the proportionality of the political parties in the House of Representative. Each voter has two votes, a party vote and an electorate vote. The party vote determines the upper tier of the electoral system; it decides how many seats (members of parliament) each party gets in parliament. Once the political parties have reached an adequate accommodation, and a government is able to be formed, it is expected that the parties will make appropriate public statements of their intentions. At this point the Governor-General will seek to ascertain where the confidence of the House lies, based on the parties' public statements, and confirm that a government can be formed.

The term electorate has a range of meanings within New Zealand. It can be used to describe the people who are entitled to vote in an electorate, define a voting district where people are entitled to vote and in some situations it can refer to seats within the New Zealand parliament. The Representation Commission determines electorate boundaries, which must be redrawn after each five-yearly population census and after Māori Electoral Option data is received. The Commission decides the electorate boundaries using demographic, cultural and geographic criteria set in law. Under legislation, there are always 16 South Island general electorates. The population quota for each South Island general electorate is calculated by dividing the population of the South Island by 16. Because all electorates are required to be of similar size, the number of Māori electorates and North Island electorates are calculated by dividing the relevant electoral populations by the South Island quota. In the 2008 and 2011 elections the number of electorate general electorate and Maori seats was set at 63 and 7 respectively, of the remaining 120 seats, 60 were set aside for list seats.

2.1.4 Parliamentary system

New Zealand Government is formed from a democratically elected House of Representatives. As one of the three branches of the Government, Parliament makes laws and holds the Government to account for its policies, actions and spending.

2.1.4.1 Parliamentary entities

New Zealand's Parliament consists of the Sovereign and the House of Representatives. The Sovereign's role in Parliament includes opening and dissolving Parliament, and giving the Royal assent to bills passed in the House of Representatives.

The House of Representatives consists of members of Parliament who are elected as the people's representatives for a term of up to 3 years. The usual number of members of Parliament is 120, but there are electoral circumstances when this could vary upwards.

The Government is made up of members of the House of Representatives appointed by the Governor-General as Ministers of the Crown. The Government is then responsible for day-to-day administration of the country. The House must have 'confidence' in the Government for it to continue in office. This is known as 'responsible government'.

After a bill is introduced into Parliament and has been given its first reading, and except when it is 'passed under urgency' it is then referred to a select committee. Select committees are small groups of MPs working on behalf of the House and examining bills in detail. There are up to 13 subject-area select committees, plus any number of ad hoc committees set up from time to time for particular purposes. Select committees often ask the public for submissions when they are considering a proposed law or inquiry.

In Parliament, people have specific responsibilities, for example:

- Sovereign: The role of Sovereign is represented by the Governor-General.
- Speaker of the House: The Speaker presides over the House of Representatives and takes the responsibility of chairing the meetings of the House, making rulings on points of procedure, chairing three select committees, acting as landlord for Parliament's buildings and representing the House to other Parliaments and organizations.
- Deputy and Assistant Speaker: The Deputy and Assistant Speaker are both appointed by the House from amongst its members. The Deputy Speaker may perform the Speaker's role when the Speaker is absent.
- Prime Minister: The Prime Minister, as leader of the Government, is responsible for accounting for its activity by answering questions during question time, delivering the annual Prime Minister's statement and leading the Government's contribution in major debates.
- Ministers: The ministers are appointed by the Governor-General based on the advice given by the Prime Minister. Ministers of the Crown are members of the Executive Government and may also be part of Cabinet. Only members of the House of Representatives can become a Minister. The Ministers are responsible for introducing bills to the House related to their portfolios, and leading debate on those bills. They are also required to account for their portfolios by replying to questions during question time.
- Leader of the House: This person manages Government business in the House.
- Leader of the Opposition: He is the members who leads the largest political party that is not part of the Government. The role of the Leader of the Opposition is to be the leader of the 'government-in-waiting' and to lead opposition responses in major debates.
- Whips: They are the members of Parliament who are organisers and administrators of the members in each of the political parties in the House. The whips take the responsibility of preparing lists of members from their party to speak in debates, making sure that members of their party are in the House when needed, negotiating with other whips on House business, and casting votes on behalf of their parties during a party vote.

2.1.4.2 Executive authorities

New Zealand Cabinet is central to New Zealand government system, it is established by convention and it is an informal body in legal terms. Those with statutory authority to act exercise the legal powers of the executive, including the Governor-General, the Executive Council, and individual Ministers:

- Cabinet: The Cabinet is the central decision-making body of executive government and it provides a collective platform for Ministers to decide significant government issues. The Prime Minister and Ministers of the Crown serve as members of the Cabinet.
- Executive Council: It is the part of the executive branch of government that carries out formal acts of government; it is the highest formal instrument of government. The Executive Council is the body, which legally serves the functions of the Cabinet. By convention, the Executive Council includes all Ministers of the Crown, whether those Ministers are inside or outside Cabinet; the Governor-General presides over, but is not a member of it.

There are currently twenty members in the Cabinet. In additional to a Minister's portfolio responsibilities, a minister may have additional delegated responsibilities. A full list of the Cabinet members can be found from the New Zealand Cabinet Office website (Cabinet, 2007). An example of the range of responsibilities of three members of the Cabinet is shown in Table 2-1.

Table 2-1 List of 3 members in the Cabinet and their responsibilities (Cabinet, 2007)

Ministerial Portfolios	**Other responsibilities**
Rt Hon John Key Prime Minister Minister of Tourism	Minister Responsible for Ministerial Services Minster in Charge of the NZ Security Intelligence Service Minister Responsible for the GCSB
Hon Bill English Deputy Prime Minister Minister of Finance Minister for Infrastructure	
Hon Gerry Brownlee Minister for Economic Development Minister of Energy and Resources	Leader of the House Minister for Canterbury Earthquake Recovery Associate Minister for the Rugby World Cup

In the e-government ontology in this thesis, ministerial portfolios and other responsibilities are found in the `NZParliamentPosition` class as displayed in Figure 2-1

Figure 2-1 Parliamentary positions as represented in the e-government ontology

2.2 Local Government in New Zealand

While Parliament is elected to deal with issues relevant to New Zealand and its people as a nation, local governments enable democratic local decision-making. In New Zealand, local governments are established to provide the well-being of local communities. Local government entities are relatively autonomous and accountable to their communities. Many of the everyday activities of citizens are dependent on services provided by the local city, district or regional councils; these range from the supply of household water, dealing with building permits, drawing of water from rivers and streams, addressing river pollution, providing library services, recreational activities, and refuse collection and recycling, to car parking and street lighting.

The local government system comprising two complementary sets of local authorities: regional councils and territorial authorities. On the 1st November 2010 the New Zealand Government approved the creation of an Auckland Super City comprising the Auckland Regional Council, and four urban cities. The number of regional councils was reduced to 12, the number of territorial authorities was reduced by 6 to 67; the latter comprising city councils down from 16 to 13, and district councils down from 57 to 54. A further classification is the unitary authority, where the local council includes the city and regional role; Auckland City is one such unitary authority of which there are now six in New Zealand including the Chatham Island Council. The semantic framework in this thesis was constructed prior to the formation of the new Auckland City Council, and excludes the Chatham Island Council. These changes to the Auckland City boundaries are not reflected in the e-government ontology in this thesis. The ontology was date stamped in July 2007.

Regional councils are responsible for the administration of environmental and public transport matters, while the territorial authorities administer local roading and reserves, sewerage, building consents, the land use and subdivision aspect of resource management. Each of the local government authorities has their own governance and organisational structure to manage related issues in the area. Governance in terms of council responsibility is about balancing views, resources and need and making decisions that are the best for the community; these decisions are then carried out by council management and staff. The governing body in each local authority is the council, also known as the ‘committee of the whole’.

The national and local governance concepts are illustrated in Figure 2-2, and provide a snapshot of the e-government ontology that has been developed in this thesis. In the figure, two entities are developed to represent national government and local government: Governance Structure and Government Entity. To illustrate the concept, a representative set of local government governance structures are included, together with the national governance structure, which includes Parliament and some of its select committees. All local government entities, namely city councils, regional councils and district councils, and the New Zealand Parliament are included in the Government Entity.

Councils and Parliament delegate responsibilities to committees, for example, Manawatu District Council committees, Manawatu Wanganui Regional Council committees, and Parliament Select Committees. Select committees work on behalf of the House and report their conclusions to the House. In the current parliament there are 13 subject-area select committees, where small representative groups of MPs can examine bills in detail, and hear public submissions on proposed laws.

Figure 2-2: Governance structure of local and national entities

2.2.1 Horizons Regional Council (HRC)

Horizons Regional Council is responsible for the natural resources of the Manawatu-Wanganui region. Regional councils work closely with city and district councils on issues related to natural resources, resource consents, emergency management, flood protection, transport planning and road safety. The Tararua, Manawatu, Horowhenua, Rangitkei, Wanganui and Ruapehu district and Palmerston North City are within the Horizons RC boundary, along with part of the Waitomo, Taupo and Stratford districts.

The management of Horizons Regional Council is under the leadership of the Chief Executive; there are five Management Groups that take the responsibilities of land management, water quantity and quality management, habitat protection, and regulatory and strategic management. This structure is illustrated in Figure 2-3. Also shown in the figure are the four departments in the Regional Planning group, Compliance, Policy and Consents, Research and Senior Environmental Science.

Figure 2-3: Organisational structure of Horizons Regional Council as represented in the e-government ontology

Horizons Regional Council has over 200 job positions distributed across the organisation.

2.2.1.1 One Plan

The first draft of One Plan was proposed in May 2007, and it was still under review in 2011. One Plan is the core regional planning document prepared and proposed by the Horizons Regional Council under the Resource Management Act 1991 (RMA). The document defines how the Manawatu-Wanganui Region intends to manage and nurture the natural and physical resources in its area. The One Plan is one of the mechanisms Horizons Regional Council hopes to use to identify community outcomes in terms of environmental issues in the region. The One Plan covers the entire Manawatu-Wanganui Region that includes seven territorial authorities. Given that this research has the focus on water quantity and water quality issues across New Zealand, only these issues will be represented in the proposed ontology.

2.3 Environmental issues in New Zealand

Environmental issues in New Zealand are described in this section. Environmental issues have been addressed by both local government and national government; it is also one of the primary reasons of including it as the sub-domain in the e-government ontology structure in this research. Primarily because of the small population whose primary industry is agricultural, New Zealand's natural resources have so far suffered less from the pressures of development compared with the other industrialized nations. Nevertheless water pollution, through industrial pollutants and sewage, is one of the environmental issues that the country seeks to address (Ministry for the Environment, 2009). Encyclopedia of the Nations (2008) states that there are 327 cubic km of renewable water resources available in New Zealand, of which 55% are used for farming activity and 13% for industrial purposes. New Zealand cities produce an average of 2.3 million tons of solid waste per year. In New Zealand, Acts, regulations, standards, policies and guidelines have been introduced to care and manage New Zealand's water resources in order to maintain economic growth and the natural environment, cultural heritage and well-being of the people of New Zealand. The Ministries of Environment, Agriculture and Forest, and Health are the government organisations in New Zealand, which are responsible for ensuring the sustainable use of New Zealand's water. The government and local government agencies publish reports and guidelines on water and environmental issues to enable the public, businesses, commercial companies and those in the farming and agricultural rural communities to better manage their environment. A 'snapshot' of the range of publications produced by the New Zealand government is illustrated in Figure 2-4.

Figure 2-4: Government publications on water issues as represented in the e-government ontology

2.4 E-government

As mentioned in the introduction to this chapter, the development of e-government is facilitated by the increasing use and sophistication of ICTs, the Internet and the World-Wide Web.

2.4.1 The Internet and the World Wide Web

The terms Internet and World Wide Web are often treated as synonymous, but in reality, they have quite distinct meanings.

The Internet is a worldwide system of interconnected computer networks that communicate via the standard Internet Protocol Suite (TCP/IP). The networks consist of millions of public, private, academic, business, and government networks that are linked to each other via a multitude of communication technologies, including fibre-optic cables, wireless connections, copper wires and other technologies. The Table 2-2 showing the estimates of the number of Internet users in the worldwide have grown significantly over the past decade (Miniwatts Marketing Group, 2011).

Table 2-2: Internet usage (2011) and growth statistics (2000-2011) (Miniwatts Marketing Group, 2011).

Country	Population	Internet Users	% of Population	Growth 2000-2011
UK	62,698,362	51,442,101	82.0	205.0
Europe	502.748.071	338,460,075	67.3	258.5

USA	313,232,044	245,000,000	78.2	156.9
New Zealand	4,290,347	3,600,000	83.9	333.7
Australia	21,766,711	17,033,826	78.3	158.1
Worldwide	6,930,055,154	2,095,006,005	30.2	480.4%

An interesting feature of the countries represented in Table 2-2 is that New Zealand's use of the Internet has grown by 333.7% since year 2000, and the percentage of the population using the Internet (83.9%) is greater than any other country.

It is claimed that in industrialised countries, between 50%-80% of government contacts are at the local level (European Commission, 2007b). The Smart Cities Regional Academic Network (SCRAN) research group examined the "Smart Cities' countries, namely Norway, United Kingdom, Sweden, The Netherlands, Germany and Belgium, and found that more than 70% of the households had Internet access at home and over 90% enterprises were similarly connected (Vandenbussche & van Soom, 2010). E-government access varies significantly between the "Smart Cities" countries; only 25% of Belgium citizens access the Internet for e-government, whereas corresponding figures in Norway and The Netherlands are 62% and 54% respectively. The use of e-government by enterprises is reasonably high: Belgium 69%, Germany 56% and The Netherlands 85% (Vandenbussche & van Soom). The Pew report (A. Smith, 2010) reported that in an Internet survey 40% of adult Internet users among the survey participants had gone online seeking raw data about government spending and activities. In particular, 23% went online to see how federal stimulus money is being spent, 22% read or downloaded legislation text, 16% visited sites such as data.gov, and 14% went online to find campaign funding information.

Most individual users are connected to the Internet through an Internet Service Provider (ISP). The ISPs not only provide connections to the Internet but also a range of software tools that help manage and control the interaction with other users. Online discussion groups, chat rooms and social networks such as Facebook and Twitter are maintained through the ISP's computers. Some businesses and institutions have a direct connection to the Internet, which allows online conferencing, business transactions and an increasing number of innovative features embracing mobile telephones and other hand-held devices. In addition to providing the technical support for their customers, online services often provide their own information databases.

The World Wide Web (web) is one of the services communicated across the Internet. It is essentially a collection of documents and other resources that are accessed or connected to each other using hyperlinks and URLs. The World Wide Web can provide a vast array of documents including video, graphics and audio, in addition to the traditional text files. How information is presented to the user via a web site depends greatly on the sophistication of the developer, but it is now quite common to use hypertext languages such as PHP and ASP to dynamically access information stored in local and remote databases.

2.4.2 Information and Communication Technologies

Information and Communication Technologies (ICTs) is a term used to describe advanced technologies that are used to manipulate and communicate information. ICT also embraces all mediums used to record, store and broadcast information. It is not necessarily confined to computing systems but rather includes computing hardware, PCs, servers, mainframes, networked and local storage devices such as magnetic disk/tape, optical disks (CD/DVD), or flash memory. Broadcasting systems, radio, television, microphone, camera, loudspeaker, telephone to mobile phones are part of what we understand to be ICT, as are their supporting software data compression technologies such as MP3, MP4, MP5 and MP6. Application software, too, can be viewed as part of the ICT revolution including small business office software, online packages and extensive enterprise packages used by multinationals.

2.4.3 What is e-government?

Prior to the current use of advanced ICTs, governments concentrated on using information technology (IT) to automate the internal working of government agencies by essentially processing data. ICTs now also support the external workings of governance by not only processing data but also communicating interactively with external actors, and in so doing provide a wide range of information services. As a result, the focus grows from just e-administration to also encompass e-citizens, e-services and e-society (Heeks, 2001).

The term e-government has not been uniquely defined within the published literature, and within the public domain there is even more uncertainty and ambiguity (Kovacic, 2009). The root cause of this lack of a clear understanding of the term may be partially explained by the rapid development of the computer and communications field from providing basic computer support for public administration activities, to the use of ICT to provide a wide range of services for the public at large. It is also very likely that the political system, or perhaps more importantly the social and cultural nature of a country has a bearing on the meaning and content of what is meant by e-government.

A term sometimes used as an alternative to e-government is e-governance. The use of this term is not surprising, as many governments have incorporated governance issues in their e-government strategies (Jones, Bench-Capon, & Visser, 1998).

Heeks (2001) uses the term ‘e-governance’ to embrace all ‘e’ activities carried out by government entities. Heeks (2001) outlines three main components of e-governance:

- Improving government processes (e-administration)
- Connecting citizens (e-citizens and e-services)
- Building external interactions (e-society)

Heeks (2008) illustrates these ideas as shown in Figure 2-5.

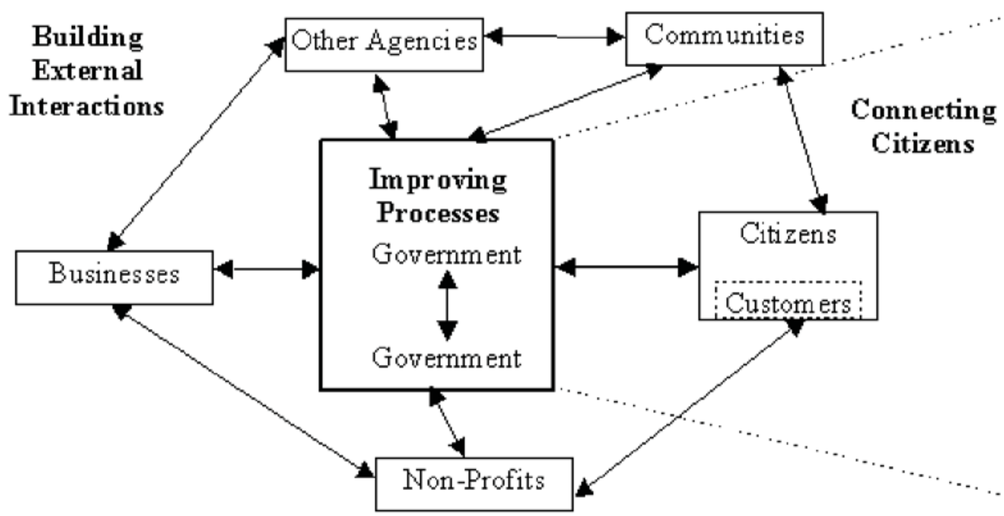


Figure 2-5: Focal Domains of eGovernment (Heeks, 2008)

Heeks (2008) also defines the following connections:

- G2G: Connections within government – permitting 'joined-up thinking'.
- G2C+G2NGO: Connections between government and NGOs/citizens – strengthening accountability.
- G2B+G2C: Connections between government and business/citizens – transforming service delivery.
- NGO2NGO: Connections within and between NGOs – supporting learning and concerted action.
- COI2COI: Connections within and between communities – building social and economic development.
- Where, NGO: Non-Governmental Organisation and COI: Community of Interest.

This approach goes far beyond most existing views of e-government as it includes communication between non-governmental groups. In many ways, this is an ideal situation as users might wish to contrast information from both government and non-government sources. This would require interoperability that might conceivably be possible using a Semantic Web-based environment.

The Commonwealth Network of Information Technology for Development and the United Nations Educational, Scientific and Cultural Organisation (UNESCO) consider governance as, "*the process by which society steers itself*" and largely ignores the internal use of ICTs as a separate activity. (New Zealand Ministry of Economic Development, 2008). A study by Aicholzer and Schmutzer (2000) on electronic government initiatives identified several ways in which ICTs have influenced the way the state, business, commercial entities and society interact and operate. Aicholzer and Schmutzer (2000) summarised these influences as follows:

- Use of the Internet by civil society, non-governmental organisations and professional associations to mobilize opinion and influence decision-making processes that affect them.
- Increasing electronic delivery of government and commercial services and information.
- Electronic publication of draft legislation and statement of direction for public feedback.

The Organisation for Economic Co-operation and Development (OECD), an international organisation of 30 counties, describes e-government as the application of ICTs by governments to deliver the full range of government services (Organisation for Economic Co-operation and Development, 2003). There is belief in the OECD that the Internet and related technologies have the potential to transform the structures and operation of its member governments. There is no requirement to adopt a universal set of ‘e-objectives’ as each member state is able to address its own particular requirements and needs.

In order to make sure the transformed delivery services are designed around the needs of citizens and business, the UK Cabinet Office published the strategy: Transformational Government – ‘Enabled by IT’, which set out the visions and implementation plan to effectively use ICT (UK Cabinet Office, 2005c). The strategy first published in 2005 proved to be a great success in delivering government services and has been widely copied around the world (UK Cabinet Office, 2005c). A further ICT strategy was published in 2010. This strategy was built on previous policy announcements and it seeks to continue to transform public services and increase demand and access to government services through advanced technology (UK Cabinet Office, 2010a).

In New Zealand, a set of directions and priorities was adopted in 2010 for the collective use, development and purchasing of government ICT over the following three years. The new directions and priorities replaced the e-government strategy set out in 2006 (New Zealand Department of Internal Affairs, 2010). Based on the description on the Internal Affairs website (New Zealand Department of Internal Affairs) the five directions are as follows:

- To provide clear leadership and direction.
- To support open and transparent government.
- To improve integrated service delivery.
- To strengthen cross-government business capability.
- To improve operational ICT management.

The priorities for New Zealand Government ICT are mainly focused on:

- Enhancing the governance arrangement with strong leadership of ICT investment and performance;
- Creating an open government environment by improving public access to government services, encouraging the public contribution to policy development and government performance, creating marketing opportunities and services through the reuse of government information;
- Providing integrated serviced delivery through prioritizing investment in shared solutions for integrated services across government, improving the government's web presence;
- Enhancing cross-government business capability, which includes controlling investment in ICT related facilities, standardizing and consolidating business processes, establishing authoritative data source, aligning investment in ICT related training; and,
- Improving operational management.

In Italy, e-government is concerned with the reorganisation of the bureaucratic processes in both central and local public administrations, using a strategy which closely resembles the core concept of the Lisbon Strategy (Webb, 2009), which identified 7 strategic objectives (Minister for Public Administration Reform and Innovation, 2007):

- To improve the efficiency of the Italian public administration.

- To achieve interoperability and full cooperation among administrations.
- To improve the efficiency and transparency of public expenditure.
- To build up e-citizenship by promoting e-Democracy and overcoming the digital divide.
- To adopt a systematic quality and efficiency measurement approach to administrative processes.
- To create a competitive environment for businesses and to boost the growth of the ICT industry.
- Italy to play a more active part in the European administrative innovation process.

Turkey, another member state of the OECD has made considerable progress with e-government. The government established after the 2002 election has taken the opportunity to stimulate the provision of e-services and e-commerce by increasing access to high-speed Internet throughout the country. The “e-Transformation Turkey Project” was developed in 2003 as the major component of the Urgent Action Plan that was aiming to improve economic and social welfare in the country (Cayhan, 2008).

Academics have suggested various definitions for e-government. Some, such as Lenk and Traunmuller (UK Cabinet Office, 2005c) take the view that e-government is essentially about modernising and reorganizing public administration. Whitson and Davis (2001) and Sprecher (2001) consider e-government to be the provision of cost-effective on-line business transaction models for citizens, industries, employees, and other stakeholders. Some academic authors take a much wider view of e-government and include such interactions as e-democracy, e-voting, e-health, e-assistance, e-society, etc. Pascual (Pascual, 2003, p. 5) suggests that e-overnment will, “prompt new styles of leadership, new ways of debating and deciding strategies, new ways of transacting business, new ways of listening to citizens and communities, and new ways of organizing and delivering information.”

The U.S. Government has developed an E-Government Strategy (USA Government, 2002) and Bonham and Seifert (2003) suggest that by adopting e-government more emphasis will be placed on the transformation of operations and on internal and external relations.

In conclusion, the definitions of e-government embrace a continuum from the use of information technology to improve the efficiency and effectiveness of traditional paper and physical based systems, to the use of information and communication technologies to provide access to government services that benefit its citizens, business partners and other stakeholders. In so doing e-government enhances the attempts by government to provide more effective governance and transparency, which enables a country to manage more effectively its social and economic resources. There is also a growing belief that e-government will transform the way people view governments and change attitudes to leadership and accountability.

In terms of this thesis, the e-government components that are of key relevance appear to be a mixture of e-administration, e-democracy and e-services. These are consistent with the definitions expressed by the OECD countries, including New Zealand. To differentiate those e-government activities that use Semantic Web technologies from those that do not, the term semantic-e-government will be used in this thesis.

2.4.4 The public sector

The public sector is that part of the economic and administrative life which deals with the delivery of goods and services for and by the government. These include activities such as delivering social security, administering urban planning and organising national and civil defences. The European Commission (2003) states that the public sector plays a key role in Europe's society and economy; it creates more and better jobs, supports citizens' welfare, and ensures that the socio-economic fabric of its society is equitable and healthy. According to the European Commission, public administrations, being major services providers for businesses within the public sector, will in the future face increasing demands to provide efficient, productive and quality services.

The use of the Internet over the last decade has increased exponentially and it is not surprising that governments have moved to apply ICTs in a massive way. It is often claimed that better services have been provided, and costs have been reduced by adopting at least one e-government feature, for example, businesses and companies are able to send their annual reports through email rather than hard copy, which is reducing printing cost and the impact on the environment (HM Government, 2010). Government agencies routinely query, inform and transact with the public, and being able to publish government documents on the Internet has been seen as reducing government expenditure. It is estimated that the ICT sector in Europe provides a quarter of GDP growth and 40% of productivity growth (2006), and in New Zealand, ICT is contributing 5.1% to GDP and is an integral part of the New Zealand economy (Trade & Enterprise New Zealand, 2006). Not surprisingly, public groups, community organisations and 'concerned' citizens are taking advantage of this new medium and associated transparency of government processes to develop critical opposition to government policies and to coordinate their activities. Benkler (2006) commented that the ICT appears as the form of Internet to provide people a platform to interact with and access to the social system for collection of politically salient information, observations and comments. Benkler also asserted that the emergence of a new, decentralized, open and activist approach is fulfilling the responsibility of the custodian in political issues and debates. However, Cropf (2009) points out that each country's economic, social, political and culture characteristics and relations are varied, which result in the different impacts of ICT on political and social issues from country to country. Netchaeva (2002) commented that there is no doubt that the US and UK are acknowledged as leaders in the development of e-government by almost all studies and surveys. However, the establishment of e-government does not necessary ensure the achievement of real democracy. Netchaeva (2002) points out that majority of the web population access the Internet for entertainment information collection instead of using it as a medium of participating in political activities. There are still many contradictory opinions on ICT's influence to e-democracy, and the impact of e-democracy can only be fully understood by more rigorous evaluation (Netchaeva, 2002) (Parliamentary Office of Science and Technology, 2009).

Based on the studies of Murchu, Zhdanova and Breslin (2006), the government portal takes the role as a one stop shop to provide collective information for group of users who have common interests. The increasing need for data integration and information among the community is the result of diversity of the government information, and the highly dynamic nature of the organisation and mobility of the users. According to Murchu, Zhdanova and Breslin (2006) users have demanded search engines on government websites, quick response to their e-mail enquiries, and instant access to up-to-date documentation/policies. When the European Action Plan 2011-2015 was being developed, the UK Minister of State for the Cabinet Office outlined the objectives and priorities for establishing a new generation of open, flexible and personalised e-government services at local, regional, national, and European level. These priorities are mainly focused on the following areas (UK Cabinet Office, 2010a):

- User empowerment: citizens and businesses are able to be more involved with government issues through the use of ICT; government should provide easy access to government information, improve transparency of government policies and encourage involvement of users and businesses in policy making.
- Internal market: unified and seamless services should be developed by the government to provide accessible services anywhere in Europe.
- Efficiency and effectiveness of government: the use of ICT enables government to deliver better, more reliable, more affordable and faster public services by reducing the administrative cost, improving organisational processes and promoting a more sustainable and green economy.

- Pre-conditions for developing e-government: it is essential to set up a number of technical and legal pre-conditions to enable the implementation of e-government services across Europe, which includes providing interoperability services that support sharing of information, and deployments of one-stop-shop approaches.

2.4.5 Benefits of e-government

One of the primary objectives of e-government is to increase productivity through higher efficiency and to offer better quality services and innovation based on information technology (IT) (Kavadias & Tambouris, 2004). Sabol and Mach (2006) extended the benefits of e-government to include the following points:

- Increased users' accessibility: Users will be able to access the services at more convenient times, via a user-friendly environment, and by using advanced communication channels such as mobile devices. Thereby, the accessibility of the web services eliminates the necessity for citizens to meet with officials directly in their offices. On the administrative side, it helps to access or retrieve files, and linked information can now be stored in integrated databases rather than as hardcopies stored in disparate locations.
- Inclusion: It refers to the ability to provide services to the unemployed, elderly and disabled users.

Fahnbulleh (2005) suggested that there are additional benefits that focus more on the relationship between government and its citizens:

- Creating a stronger and closer relationship between citizens and government.
- Providing easier access to government for all.
- Allowing greater access to decision-making.
- Empowerment of citizens.
- Providing more transparency in government, which in turn leads to more accountability.

In the *Digital Quality of Life* report produced by Information Technology and Innovation Foundation (ITIF), a USA based non-partisan research and educational institute, information technology is considered to be the principal driver of increased economic growth in the United States and in many other countries (Atkinson & Castro, 2008). The report also shows that IT has led to dramatic improvements in the quality of life for individuals, such as better education and health care, cleaner and more energy-efficient environments and safer and more secure communities (Atkinson & Castro, 2008).

E-government is convenient and cost-effective for businesses, government agencies, and citizens by providing quick and efficient access to the up-to-date information. For example, the U.S. Government Printing Office provides online access to databases containing the full text of public documents produced by the three branches of government. Similar portals for online government services can be found in many other countries. In the United Kingdom, Directgov (European Commission, 2007a) provides a portal to government public services and the National Archives is home to multiple online databases of digitized public documents, including government publications and historical documents (UK Cabinet Office, 2010b).

Recent advances in IT enable citizens to hold government officials more accountable for fraud, waste, and abuse. People from all walks of life can interact with politicians and make their voices heard. Blogs, moderated chat-rooms and interactive surveys allow politicians to appreciate the views of the people they represent. These technologies can create a more transparent government, allowing voters to immediately see how their elected representatives are addressing issues of the day. In the United Kingdom, the Electoral Commission provides a searchable database of campaign contributions and expenditures of candidates and parties. The Federal Election Commission in the United State of America provides a comparable system (Deibert, Palfrey, Rohozinski, & Zittrain, 2008).

In addition to the above benefits, some researchers argue that there are environmental benefits, primarily associated with the ‘paper-less society’ (Okot-Uma, 2000, P5). The United States government provides internal government forms for federal employees significantly reducing the use of paper (Horrigan, 2005). The 2004 Gershon report (Gershon, 2004) recommended that the benefits for British government’s ICT investment have shown to reduce the time spent for accessing and handling information by professionals, and those staff can be free from spending time on unproductive tasks.

There is a growing belief that the adoption of e-government systems has been met with approval from the public at large. Citizens participate in online discussions of political issues with increasing frequency, and young people, who traditionally display minimal interest in government affairs, are drawn to e-voting procedures (Urdiales, de Trazegnies, Salceda, & Sandoval, 2009).

2.4.6 Issues with implementation and development of e-government

There are a number of potential barriers related to the implementation of e-government. Fahnbulleh (2005) identified the following:

- Concerns about inadequate security and privacy of data.
- Unequal access to computer technology by citizens.
- High initial costs of setting up an e-government solution.
- Resistance to change.

These barriers do not exist in isolation. There can be, and frequently are, interactions between the variables. For example, resistance to change might be influenced by a lack of trust, and the digital divide may widen further because of inadequate funding.

From a technological standpoint one of the key requirements of e-government is to achieve service integration and interoperability. Unfortunately, achieving service integration and interoperability in the domain of government services is a challenging task, since the e-government domain has both horizontal as well as vertical semantic barriers, which are primarily the result of users possessing different interpretations and viewpoints of the knowledge elements (Sabol & Mach, 2006).

2.5 Examples of E-Government

In this section, three geographical areas are discussed where technological innovations have not only led to improved efficiency and effectiveness of government processes but have also seen progress in providing e-governance initiatives, namely EU including the UK, USA, and New Zealand.

2.5.1 E-government in Europe

2.5.1.1 European Union

The European Union (EU) is an economic and political union of 27 member states. With almost 500 million citizens, the EU, generates an estimated 30% share (US$18.4 trillion in 2008) of the nominal gross world product (International Monetary Fund, 2009). The EU grew out of the European Economic Community in 1967. The initial group of members comprised: Belgium, France, Italy, Luxembourg, Netherlands and West Germany. The EEC, the European Atomic Energy Community (Euroto) and the European Coal and Steel Community (ECSC) later merged to form the Economic Community (EC) and in 1973, the EC was further enlarged to include Denmark, Ireland and the United Kingdom. Greece joined in 1981, and Spain and Portugal in 1986.

The European Union (EU) was established by the Treaty of Maastricht in 1993 and built upon the existing EEC structure. Austria, Sweden and Finland joined the newly established EU in 1995, and Malta, Cyprus, Slovenia, Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, and Hungary in 2004, followed in 2007 by Romania and Bulgaria. There have been further treaties since then, and several others are currently seeking membership.

An economic and monetary union (EMU) comprising 17 of the 27 member states of the EU has adopted the euro (€) as their common currency and sole legal tender.

The Amsterdam Treaty was signed in 1997, and it established the European Communities and certain related Acts: The Treaty of Nice was signed in 2001, which amends the Maastricht Treaty and the Treaty of Rome; Treaty of Lisbon, which is particularly relevant to e-government, was signed in 2007 and was ratified in November 2009.

The Lisbon Treaty included a strategy which defined the vision to make the EU "the most dynamic and competitive knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment by 2010" (European Parliament, 2000, p. 1).

Governments in Europe are facing various challenges, such as security, aging of the populations, and terrorism, which have led to changes in the delivery of e-government services. This has resulted in considerable modernisation and innovation in the member states as the overall European Union economy grows. As the EU continues to embrace more countries, which has led to greater diversity and complexity, the need to ensure that the states have equivalent systems and process, means that improved communications are required. Although standardisation is voluntary, it plays an essential role in areas such as interoperability, privacy and accessibility to services (European Commission, 2011). It is reported that the information and communication technologies sector within the EU contributes substantially to GDP and employment, and is responsible for about 50% of the EU's productivity growth over the past few years (European Commission).

2.5.1.2 Ministerial E-Government Conferences

E-government initiatives in the EU have been addressed in earnest since 2000. One of the most significant events was the establishment of the E-Government Working Group (EUPAN). The group, comprising experts from the Member States, has as its principal objective the promotion of the exchange of views, experiences and good practices in the field of e-government, with a particular emphasis on the public administration of e-government.

The role of e-government has been supported at Ministerial E-Government Conferences, which are held every two years. The European Council, in 2000, called on the Commission to set up an eEurope action plan to focus on education, cheaper Internet access, e-commerce, security of networks and information, e-health and e-government (European Commission, 2000).

The first Ministerial Conference was held in Brussels, 2001. At the conference, the Ministers re-affirmed their commitment to rapid e-government development and resolved to give a higher priority to e-government issues than had been proposed in 2000 (European Commission, 2001). In the conference report, the ministers identified several criteria of good e-government:

- Ensure inclusion: Citizens and businesses must be at the focus of any implementation, and that interoperability of a variety of network infrastructures and services was essential.
- Promote trust and security: Networks must guarantee safe and secure access to e-government services.
- Openness and participation: Government must make sure citizens feel confident and positive about engaging electronically with government agencies.
- Integration and interoperability: Seamless service must be provided to customers. Integration across government department, agencies and boundaries must be a necessary requirement. The report identified five dimensions of integration: integration of services, integration with back office, integration by standard platforms, integration of data and integration of distribution channels.

The Ministers at the conference recognised that the transformations towards e-government must go beyond the first generation of Internet-based provision of information to fully interactive services. Ministers invited the European Commission to make the necessary investments in research and technological development to ensure interoperability and dependability in the next generations of infrastructures and open systems (European Commission, 2001). The Ministers stressed that they would like to see greater synergy between e-government activities under the responsibility of different services.

The 2nd Ministerial E-Government Conference was held in Brussels in 2003. Based on the conference report (European Commission, 2003), the objectives of the conference were to:

- Consolidate and extend the existing consensus in Europe regarding the strategic priorities for e-government.
- Demonstrate where Europe currently stands in this fast-evolving and competitive field.
- Identify interactive public e-Services currently available.
- Illustrate how, at present and in the years ahead, citizens and businesses can benefit from on-line service provision.

The overall focus was on three themes: the role of e-government for European competitiveness, a better life for European citizens, and the e-cooperation in central and local government.

The 3rd Ministerial E-Government Conference was held in Manchester in 2005. The European Commission sought to refocus the Lisbon Agenda on the role of the European Information Society to promote growth and jobs in a manner that is fully consistent with the objective of sustainable development (European Commission, 2005). At the conference the i2010 E-Government Action Plan, which is part of the EU's i2010 strategy, was discussed. This plan was adopted by Council in June 2006 (European Commission, 2006). The plan identified five priorities:

- Access for all: European Union member states were committed to ensuring that by 2010, all citizens, including socially disadvantaged groups, become major beneficiaries of e-government.
- Increased efficiency: European Union member states were committed to achieving gains in efficiency, and agreed to comparatively evaluate their programmes.
- High-impact e-government services: The services enabled the public to have Internet access to all public services and procedures. Agreement was also sought from the Member States that they would cooperate to achieve the goals set out in the i2010 strategy.
- Putting key enablers in place: Interoperable electronic identification management (eID) systems to be in place by 2010.
- Strengthening participation and democratic decision-making: Citizens and businesses must be at the centre in the design of on-line services.

The 4th Ministerial E-Government Conference was held in Lisbon in 2007. The Conference revolved around four main themes related to ICT and public services (European Commission, 2007b): increased growth and jobs, increased participation and transparency, improved cohesion, and more effective and efficient administration.

A National Progress Report on E-Government in the EU27+ was presented at the Ministerial E-Government Conference (European Commission, 2007a). The report stated that the following had been achieved:

- Public services had become more effective nationally and more interoperable at European level through the use of ICT; higher quality public service had been delivered across Europe; billions of euros were saved through efficiency gains, and transparency and accountability of administrations were increased.
- Impressive progress had been made in transforming public administrations, thereby boosting economic growth by placing citizens and businesses at the centre of government services.
- Member States had developed and agreed roadmaps for mutual recognition and authentication of electronic identities, for cross-border e-Procurement and for inclusive e-government.
- Efforts had been made in reducing administrative burdens for both citizens and businesses; it was stated that efficient and effective administration had contributed to economic growth and jobs.
- Improved e-Participation activities and the willingness of public administrations to share good practices had been witnessed in European countries, for example, the deployment of ePoll project had been set up in Italy, France and the UK.

The 5th Ministerial E-Government Conference was held in Malmö in 2009. The Ministers agreed on four main political priorities for e-government up to 2015 (European Commission, 2009):

- Empowering citizens and businesses: E-government services were to be designed around users' needs. There was to be increased access to public information, enriched transparency, and the involvement of stakeholders in the policy process to be improved.
- Reinforcing mobility and Single Market: By adopting seamless e-government services the aim of this priority was to increase the mobility of European citizens across the EU, in particular, students, workers and retirees.
- The efficiency and effectiveness of public administrations: Continued efforts in improving e-government will lead to improvements in organisational processes and promote a sustainable low-carbon economy.
- Implementation: Appropriate key enablers will assist in the implementation of these policies.

2.5.2 E-government in UK

The Cabinet Office plays a major role in providing guidance and making standards for the use of information technology in government and the delivery of government services. The e-government Unit works with government departments to develop standards for performing electronic services.

A significant development in the framing of government ICT policy was the release and subsequent implementation of the Gershon Report in July 2004 (Gershon, 2004). The report focussed on public sector efficiency the aim being to improve the delivery and use of public resources. The following aims were identified:

- To make savings the market segments relevant to government departments.
- To lower prices and provide public services with needed resources.
- To provide a better quality or quantity of service, or provide superior value for money over existing arrangements.
- To make better use of scarce existing in-house professional commissioning and procurement resources.

The review looked at transactional services across government departments and agencies, also including local government services. This was in line with the UK's stated e-government strategy.

It is interesting to note that Sir Peter Gershon was subsequently approached by the Australian government to undertake a review in March 2008 of the Australian Government's use of Information Communication Technology. This was published in August 2008 (New Zealand State Services Commision, 2008b). The review is particularly relevant as it was undertaken during the period of the global financial crisis. Again, the main focus was on efficiency and effectiveness, but what was of interest was the notion that government IT processes should promote a green image, for example, reducing the carbon footprint.

In 2005, the Chief Information Officers' Council and the Service Transformation Board produced the Transformational Government report (UK Cabinet Office, 2005c), which outlined a strategy to transform government services to enable the public service to offer members of the public and other stakeholders personalised services designed around their needs and not the needs of the provider (UK Cabinet Office, 2005c). Three key transformations were identified to achieve the vision:

- The IT enabled service has to be designed around the citizen or business. This step has the effect of making the customer better informed and provides more efficient services by reducing the duplication costs and improving process.
- A shared service approach has to be promoted by the government. The key areas include standardisation, simplification, information and infrastructure. Additionally, broadening and deepening of the level of professionalism in the areas of planning, delivery, management, skills and governance ICT was also demanded.

In December 2006, Sir David Varney published his report, *Service transformation: A better service for citizens and businesses, a better deal for the taxpayer*, (Varney, 2006). In his report, Varney suggested a number of key changes he considered were necessary across government channels to enable more focus to be placed on citizen and business needs:

Identify the service areas common to citizens and business and aim to deliver meaningful information to them.

Provide the public sector with the greatest benefits in terms of effective service delivery and interconnected government processes. Varney believes that this can be achieved by establishing principles based on a coordinated multi-channel approach to government delivery and making e-government the primary source of governmental information and transactional services.

Establish a robust and transparent performance management and governance framework placing more focus on the public sectors, therefore ensuring that the citizen and business benefit from receiving a more responsive service.

Take opportunities to clarify and secure identity information held by the government. Varney believes that a key part of quality public service delivery is to make better use of information gathered from the service user.

Make significant improvement to the operation of government e-services contact centres and face-to-face services. The report states that improving the overall transparency and performance of government operations includes the use of benchmarks and standards and setting targets for service.

In essence, it has been the Varney’s report and the need to embrace its goals and strategies that has influenced the European Community Lisbon Strategy which has guided the development of e-government services in the United Kingdom (Varney, 2006).

This third annual Transformational Government report outlines the progress that has been made during 2008 (UK Cabinet Office, 2009). The report acknowledges the dramatic shifts in the world economy but stresses the ongoing commitment of the UK Government to deliver on its promises set out in the 2005 Transformational Government strategy. These include putting the citizens first, sharing services and professionalising IT enabled business change. In addition, the environmentally-focused Greening Government ICT strategy was launched.

2.5.2.1 UK Government Portals: UKonline

UKonline was a "portal" website of the UK Government linking to public sector information. The site was launched in 2001 and was maintained by the Office of the e-Envoy (later the E-Government Unit, part of the Cabinet Office).

The site featured news, links, and search facilities connecting together much of the government's web presence, though later this pan-government search facility was removed. Visitors to the site were able to search for information on a variety of topics (for example, agriculture, finance and health) and retrieve a list of government departments that were able to provide them with more information. It was also possible to do such things as apply for a passport, buy a television licence, register to vote or complete and send a Tax Self-Assessment form, but only if users left the website, as they could not actually perform the transactions on UK online.

The site was replaced in 2004 by the more citizen and business centric services: BusinessLink and Directgov.

2.5.2.2 BusinessLInk

Business Link is the government-funded business advice and guidance service in UK, delivering integrated business support through two main channels; an online portal (http://www.businesslink.gov.uk) and advisors working at a local level, supported by a national helpline.

The portal in its current form was launched in May 2004 as part of the Transformational Government programme; a larger initiative aimed at rationalising and converging hundreds of government websites on fewer, larger and more usable sites. By 2011, it is intended that http://www.businesslink.gov.uk will host the majority of official government information for businesses. Three “super-sites” within the portal are business, health and general information.

2.5.2.3 Directgov

Directgov was launched in April 2004, replacing the UK online portal. Rather than just providing links to government departments as UK online had done, Directgov carried its own material, designed around users' needs. The first three sections were for motorists, disabled people and parents.

Since 2004, the site has grown from 300,000 visits a month to over ten million, and it involves 18 government departments.

In April 2006, Directgov moved from the e-Government Unit (eGU) within the Cabinet Office to become part of the Central Office of Information (COI), an executive agency of the Cabinet Office.

As part of the Transformational Government strategy, an annual report was published in January 2007 stating that hundreds of government websites would be shut down "to make access to information easier" for people. It was reported at the launch of the strategy that of 951 sites, only 26 would definitely stay, 551 would definitely close and hundreds more are expected to follow. About £9 million a year was expected to be saved over three years by cutting back on sites that do not serve a useful purpose. However it emerged shortly afterwards that this was misleading, as a large proportion of the 'blacklisted' sites had no plans for closure. As of 1 April 2008, Directgov moved again, from COI to the Department for Work and Pensions (DWP), in a machinery of government change.

Some 18 million visits were made to the Directgov website in the month of March 2009. It is a Hitwise Top 10 award winner for the fourth quarter of 2008. It ranked No.2 based on market share of visits among UK websites (UK Directgov, 2009).

2.5.2.4 UK Government Interoperability Framework

In March 1999, the UK government published the white paper entitled, *Modernising Government,* which detailed corporate IT strategy for government that would, "encourage [IT] systems to converge and interconnect" and so "maximise the benefits to both central and local government" (HM Government, 1999, p. 47). The Cabinet Office responded to this white paper and established a new Office of the e-Envoy as part of the Prime Minister's Delivery and Reform team, and as a result the first strategic framework for agreed applications across the whole of the public sector was defined. A key function of the interoperability framework was the setting out of the technical policies and standards for achieving interoperability across government departments and the wider public sector. This could be considered to be the first version of the

Government Interoperability Framework (e-GIF), which was subsequently refined by the Office of the e-Envoy.

2.5.2.5 e-GIF

The e-GIF (E-Government interoperability framework) was designed to meet the requirement of merging information across government (UK Cabinet Office, 2005a). It outlined the technical policies and specifications for achieving interoperability coherence across the public sector by applying information and communication technology (ICT) systems. It was intended that a pragmatic approach be taken based upon accurate knowledge of trends, standards, products and skill capabilities of the IT workforce. The e-GIF architecture is set out in Figure 2-6. It is based on Version 6.1 of the e-GIF (2005), which covered the E-Government Metadata Standard (e-GMS), Government Category List (GCL), Government Data Standards Catalogue (GDSC), XML and XML schemas, and the Technical Standards Catalogue (TSC).

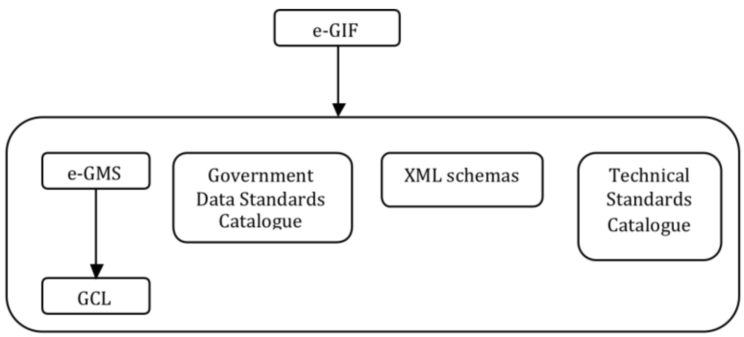


Figure 2-6 e-GIF Architecture (UK Cabinet Office, 2005a)

Specifications for e-GIF components were defined, for example:

- XML and XML schema: These were to be used for system data integration and transformation. XML schema was chosen as the main schema language.
- e-GMS: Based on the international Dublin Core model. The e-GMS defined the elements, refinements and encoding schemes to be used by government officers
- GCL: An encoding scheme for the Subject element of the e-GMS. The purpose of GCL encoding scheme was to make things easier for citizens to find information from all the electronic resources in the UK public sector.
- GDSC: Described the rationale, approach and rules for setting and agreeing on the set of Government Data Standards was to be used in the e-GIF and other interchange processes. These standards were also recommended for data storage at the business level. GDSC comprised of two parts, the first part considered the general principles, i.e. the rationale, approach and rules for

setting standards, whereas the second part included the Data Types and Data Items standards.

- Technical Standard Category: Each component of e-GIF contained specifications and included version numbers and notes. In order to keep alignment with the changing requirements of public sectors and evolution of the technology, the Technical Standard Category defined the set of specifications that complied with the technical policies defined in e-GIF.

The E-Government Unit subsumed the Office of the e-Envoy in 2004, which, until late 2005, continued to develop the e-GIF and its supporting processes. Doubts about the value of e-GIF were expressed in 2008 and the Unit began concentrating more on developing the high-level cross-government enterprise architecture and processes implicit in the transformational government strategy, *Transformational Government-Enabled by Technology* (UK Cabinet Office, 2005c). A case study was carried out by Hopkirk (2008) to review the progress of implementation of the E-Government Interoperability Framework in UK between 2000 and 2008. In this report, feedback was collected from the e-GIF community in terms of achieving framework compliance. Feedback indicated that the framework was successfully approved across the public sectors, the awareness of interoperability improved, commitment was shown in developing the e-GIF by the suppliers who signed up to e-GIF compliance, and the ability to keep the e-GIF standard up to date was accepted by local authority communities (Hopkirk, (2008). However, feedback from both the private and public sectors identified a number of issues associated with e-GIF compliance. Both suppliers and customers had insufficient knowledge about the framework and how to apply e-GIF standards. A lack of sanctions for non-compliance led to some of the larger suppliers showing little motivation to engage, which in turn suggested that government agencies were not seriously committed. As it became apparent that the government was placing more emphasis on the development of the cross-government enterprise architecture there was a loss of credibility in Hopkirk (2008). Hopkirk (2008) felt a number of things could have been done better, for example: a clear and explicit mandate for e-GIF compliance with meaningful sanction for non-compliance, more cohesion between government stakeholders to ensure a common approach and a more enthusiastic marketing of the framework (Hopkirk (2008).

In 2008, in response to the failure of the e-GIF, a cross-government enterprise architecture (xGEA) group was created (UK Cabinet Office, 2005c). The new group began migrating the e-GIF regime into the XGEA focusing solely on the public sector.

2.5.2.6 UK Government Enterprise Architecture

The cross-Government Enterprise Architecture (xGEA), was first realised in November 2005 and in 2011 still remains a key element of the UK's government's *Transformational Government - Enabled by Technology* strategy (UK Cabinet Office, 2005c). The Chief Technology Officer (CTO) Council, comprising of the Chief Information Officers (CIOs) of the various government and local government agencies, was charged with developing the strategy. Its first priority was to publish a standard Enterprise Architecture reference model, which would help align existing and emerging technical architectures across government with the xGEA.

The vision of xGEA can be expressed as a set of views and exemplars to allow decision makers to make the right choices to best transform government enabled by IT. It is expected that using an 'exemplars' approach will enable public sector bodies to submit their good practice assets for use by other organisations (UK Cabinet Office, 2005c). The xGEA comprises: reference model, a repository of enterprise architectures, opportunity portfolio of potential exemplars and a set of processes based on industry practices for describing the exemplars and the EA models. These four items are described as follows:

1. xGEA Reference Model

The xGEA Reference Model consists of number of domains representing different aspects of enterprise architecture. Over time the framework will provide a common language for each of the domains of interest, which will facilitate better communication of shared exemplars. This sharing will be supported by the identification and use of relevant international standards.

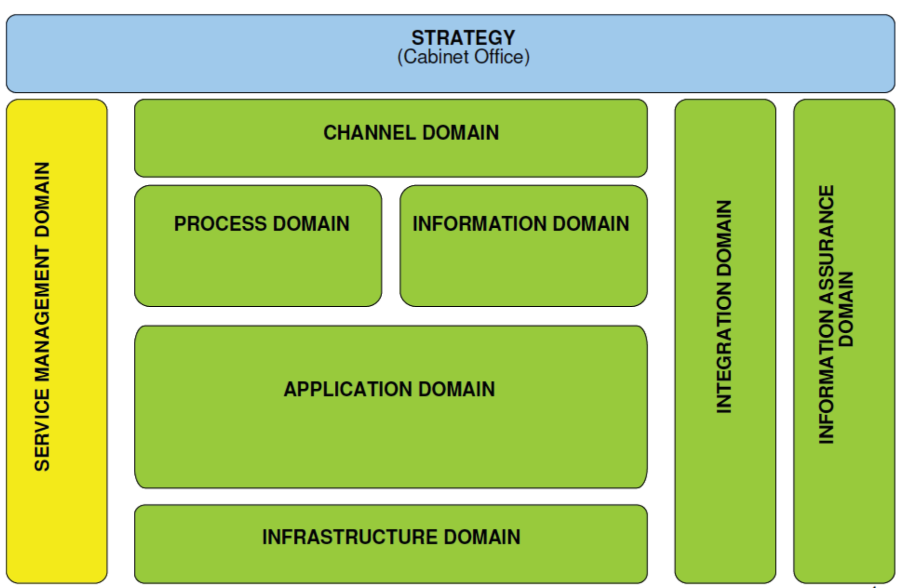


Figure 2-7 The xGEA Reference Model (UK Cabinet Office, 2005b)

When a new system is being developed in the public sector the developer seeks to align the process with the xGEA. To support this process each government agency offers training programmes to educate the staff in an appropriate manner.

During the development of the new system the developer refers to each of the domains in turn. The domains were described in the UK Enterprise Architecture report (UK Cabinet Office) as follows:

- Strategy domain: Strategic business objectives are identified in order to assist the agency in meeting its target state.
- Channel domain: All technology development is architected to separate business logic and presentation logic.
- Process domain: Information system development takes account of business data and processes common across the agency.
- Information domain: The domain identifies, processes and manages information.
- Application domain: The domain includes supporting applications and software packages, such as: business intelligence and management, records management and archiving.
- Infrastructure domain: The infrastructure domain includes operating systems and failure protocols etc.
- Integration domain: The business must be well managed to link with associated systems and deal with all incoming and outgoing data.
- Information assurance domain (security): All security issues are addressed in this domain.
- Service management domain: Operational principles, enterprise processes and activities are covered in this domain.

2. Repository of enterprise architecture assets

The repository holds information, in the form of exemplars, which has been collected and generated by departments. These exemplars will then be available for use by other government departments. The repository also provides a common reference point for those organisations that have not started to develop their own enterprise architecture (UK Cabinet Office, 2005b).

3 Opportunity Portfolio of potential exemplars

The portfolio of opportunities enables a user to identify suitable exemplars (UK Cabinet Office, 2005b).

4. The process for identifying sharing and reuse opportunities

According to the description of UK Cabinet Office (2005b), this process provides a practical approach of developing the xGEA through identifying the opportunities within the government department, where there is the potential for sharing. The process also creates a forum to encourage organisations to propose exemplars that might be used in the future.

Other benefits offered by the architecture include the following items:

- To promote common infrastructure development.
- To improve the management of risk.
- To promote efficient use of resources.
- To enable sustainable alignment of business and its IT functions.
- To share standards to promote better inter-working between agencies.
- To generate increased competition in the supply of IT services and products.
- To improve business agility and reduce costs.

2.5.3 E-government in the United States of America

The United States has been at the forefront of e-government development. The US e-government strategic vision has remained consistent for years. The vision for reforming government is guided by three principles: citizen-centered (not bureaucracy-centered), results-oriented and market-based (The White House, 2011). The Federal Government's Chief Information Officer, within the Office of E-Government and Information Technology, leads the development of application-based internet-based technologies with the purpose of providing effective and efficient services to citizens and businesses, and improving cooperation with the Federal Government to save taxpayer dollars and improve citizen participation (The White House, 2011).

According to Seifert (2009), the development of e-government in the US has passed through several stages. The term e-government started to take shape in the US federal government during the late 1990s. President Clinton during his presidency in 17th December, 1999 released a memorandum on the subject of electronic government. The memorandum defined the foundation principles, that the government should be citizen-focused to satisfy the citizens' needs when they request government information and services, and that the citizens' privacy should be protected. Bush Government announced the PMA (President's Management Agenda) in August 2001, in which indicated to implement the e-government with the emphasis of business-like practises and principles, three principals were stated in the PMA that the government should be citizen-centered, results-oriented and market-based (Seifert, 2009). In December 2002, President Bush signed the E-Government Act of 2002 into law, the law serves as the primary legislative vehicle for e-government development in the US with the focus on regulations related to federal government IT management, information security and services and electronic information.

A series of initiatives and projects have been developed over the following decade to achieve the PMA's vision of citizen-focused e-government. Seifert (2009) provides some examples of these projects, such as the E-Authentication initiative to develop a government-wide approach to electronic identity systems; creation of various thematically organised portals, such as recreation.gov, govbenefits.gov, business.gov and regulations.gov. The FEA (Federal Enterprise Architecture) was formed in February 2002 by OMB (Office of Management and Budget) with the objective of improving citizen services. Agency-centric systems were to be replaced with integrated, citizen-centric application and processes by deploying a sets of interrelated "reference models" designed to facilitate cross-agency analysis and opportunities for collaboration within and across agencies (Office of Management and Budget of USA, 2007).

The 2010 United Nations E-Government Survey shows that the United States continues to score high in the e-government development, gaining the top ranking. Based on the report, the US e-government portal is well developed with a broad spectrum of e-services for its citizens; it is created to support citizens' participation on political issues, decisions and to provide feedback (United Nations, 2010b).

2.5.4 E-government in New Zealand

New Zealand State Services Commission stated that,

> E-government is a way of tapping unrealised potential for high quality government in New Zealand. It enables government agencies to separately and collectively lift their performance and deliver better results through using information and technology in new, more collaborative, ways. (New Zealand State Services Commision, 2004, para.1)

The *Digital Strategy 2.0 (New Zealand State Services Commision, 2008a)* sets out the actions to be taken to meet the needs of New Zealanders and drive productivity and economic growth by applying ICT. The report addressed three interrelated action areas that should be supported by using ICT: social, economic and cultural. The strategy outlined three ways of improving the effectiveness of ICT :

- Content: Government information, national heritage archives, geographic spatial data and maps will need to be digitised to make them available for citizens to access on the Internet.

- Confidence and capability: The level of confidence and skills for all New Zealanders to use and involve in the interactive electronic environment will need to be increased.
- Connection: Connection and access to the New Zealand ICT infrastructure using mobile, computer and telecommunications network will need to be at a reasonable cost.

These concepts are illustrated in Figure 2-8. The three action areas are interrelated and support each other to provide support to targeted user groups *(New Zealand State Services Commision, 2008a)*:

- Communities: ICT is an important tool for realising the social, cultural and economic ambitions of communities and citizens.
- Businesses: Access to ICT will increase the business productivity and opportunities for creating innovative products. It is estimated that the ICT sector will contribute 10% of New Zealand's GDP by 2012.
- The government: The integrated services and information will be delivered across government agencies; the services are intended to provide a reliable, citizen-centric and cost effective service to the public.

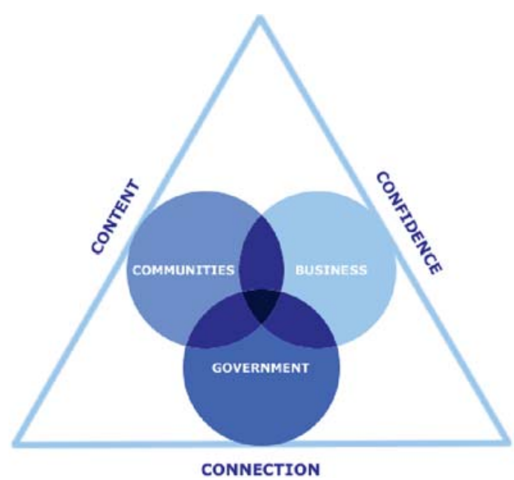


Figure 2-8 The relationship among the interrelated action areas to be focus for implementing the ICT :
(New Zealand State Services Commision, 2008a)

2.5.5 E-government Interoperability Framework (NZ e-GIF)

The New Zealand Interoperability Framework (NZ e-GIF) provides the body of knowledge regarding the e-government interoperability, standards and the methodology for choosing and developing standards to add into the body of knowledge.

The 2002 interoperability paper (New Zealand State Services Commision, 2002) proposed the endorsement of New Zealand Interoperability (NZ e-GIF) as the Government's policy on achieving the electronic interoperability among the public sectors. The 2002 paper (New Zealand State Services Commision, 2002) gave the definition of the e-GIF as "a set of policies, technical standards and guidelines covering ways to achieve interoperability of public sector data and information resources, information and communications technology (ICT), and electronic business process" paper (p. 2). Based on the interoperability report, the e-GIF is one of the foundations of the New Zealand e-government strategy. The strategy seeks to improve data integration and business processes with the view to improve customers' experience of government and to gain efficiency and effectiveness within government. The paper pointed out that the realization of government information and services integration will be a fundamental barrier that will continue to exist without implementation of the e-GIF.

E-GIF version 3.3 is the 10th and current version, and is categorized by using a "layer model" (New Zealand State Services Commision, 2008b). New Zealand government uses the layer model to classify its IT system functions. It simplifies the system by separating the system functions into different levels. Those layered components in the model only communicate with others on adjacent levels. Figure 2-9 illustrates the layout of the layer model.

Figure 2-9: e-GIF version 3.3 Layer Model
(New Zealand State Services Commision, 2008a)

The details of the layer-based e-GIF standards are as follows based on the New Zealand Digital Strategy (New Zealand State Services Commision, 2008a):

- Network layer: This layer provides data transport details, such as network standards or protocols.
- Data integration layer: The standards in the area of data exchange and process, such as the standard code for information interchange and markup language for file transfer, are outlined in this layer.
- Business Services layer: It includes the services and data from a business point perspective, such as standards for converting technical components to business information.
- Access and Presentation layer: It presents the standard and guidelines on representing and accessing business systems to customers, such as website representation standards and authentication standards for online services.
- Web Services layer: This is the layer that impacts on all the other structural layers. It covers a set of standardized applications to connect and integrate web-based services over the Internet. It is crucial for agencies applying the common approach to deliver the integrated services to customers.
- Security layer: This layer interfaces with all the structural layers. This is because security is needed through every component of the system. The four main functions addressed in the security layer are: confidentiality, integrity, availability and accountability.
- Best Practice layer: This layer comprises the international standards and local conventions that support best practice. Agencies use these standards to support the interoperability with the other agencies.
- E-government Services layer: This layer includes the actual implementation of the IT functions that are available for re-use by public sector agencies, which are compliant with e-GIF.

2.5.6 The use of XML (Extensible Mark-up Language)

The XML standard has been adopted in the Data Integration layer and Business Services Layer in the New Zealand e-GIF. The advantages of using XML in e-GIF are as follows (Cabinet, 2007):

- XML can be readable by both computers and humans, making the editing, debugging and creating of XML documents much easier.
- XML is supported by a wide range of platforms and can be interpreted by a wide variety of tools. This improves the interoperability.

- XML can generate data in various forms; for example, applying style sheets to the same XML document can generate the file into HTML and PDF forms.

2.6 User interaction with e-government

Users of e-government are enabled to receive benefits by being able to access government information and resources, leading to further involvement with government decision making and public affairs. Three hypotheses were proposed by Reddick (2001) to measure the interaction between the users and the government: social-demographic, e-democracy and citizen interaction.

Social-demographic: This interaction is associated with the digital divide, such as, whether males are more likely to interact with e-government than females? Is a better-educated person more likely to be involved with e-government than the average person? Are young people more likely to spend time engaging in e-government?
The Hart/Teeter's survey (2000) conducted in the USA in 2000, concluded that younger males, better educated and higher income earners tended to have more access to the e-government services than the public as a whole.

E-democracy: In this interaction, the following question is asked: Do the users' trust and confidence in e-government have any effect on the frequency of use?
The Hart/Teeter's (2000) survey found that there was no significant relationship between the frequency of visiting the federal government web site and perception towards trust and confidence in e-government.
West (2004) and Reddick (2005) suggested that members of the US Republican party showed more interest in e-government than Democrats, whereas, the Democrats were more likely to trust and have confidence in the government. Tolbert and Mossberger (2006) found that visiting the federal government website was statistically associated with the citizen's perception of government's responsiveness, increase in website transparency and accessibility.

Citizen interaction: Whether e-government meets the citizens' requirements of access to information or services, is the subject of this interaction. Do the citizens have a positive experience when using an e-government website? Does a citizen's experience of interaction with the government improve because the received information is in a digitised form? Reddick (2005), in his survey found that 44% of respondents were usually able to find the information or services they required, 14% could always find the information they required, and less than 5% found it difficult accessing the information or services they required. Overall, Reddick's (2005) survey showed that most US citizens were positive about their interaction with E-Government.

The 2010 United Nations e-government Survey (2010b), undertaken in 2009 and published in 2010, recognises that many countries are seeking to revitalise public administration, improve public management, and to lead the civil service into higher efficiency, transparency and accountability. The report discusses the challenges that countries are facing because of the global financial and economic crisis and concludes with a survey on the preparedness of countries in terms of the e-government provision (United Nations, 2010b). The report notes that since the last edition of the survey, in 2008 (United Nations, 2008), governments have made great strides in the development of online services, especially in middle-income countries.

In Table 2-3 the e-readiness index and the e-participation index of the top 25 countries for 2011 and 2008 are displayed. In this table, the data from Republic of Korea were provided by its associated government organisation instead of undertaking the proper survey that was carried out by the third party organisations. The data led to the results of having Republic of Korea ranked as the top in both E-Government Development Index and E-Participation Index, in using the statistics it is important to note the following definitions:

- E-Readiness index / ranking focuses mainly on the ‘government to citizen’ (G to C) and ‘government to government’ (G to G) aspects of e-government.
- The e-government readiness index is a composite index comprising the web measure index, the telecommunication infrastructure index and the human capital index.
- E-participation index / ranking aims to capture the dimensions of government to citizen interaction and inclusion, by assessing the extent to which governments proactively solicit citizen input. The e-participation index is a composite of the indices e-information, e-consultation, and e-decision making.

Table 2-3: United Nations e-Government Survey (United Nations, 2008, 2010b)

E-Government Development Index Top 20 Countries			
Country	Rank 2011	Rank 2008	Index
Republic of Korea	1	6	0.8785
USA	2	4	0.8510
Canada	3	7	0.8448
UK	4	10	0.8147

E-Participation Index Top 20 Countries			
Country	Rank 2011	Rank 2008	Index
Republic of Korea	1	2	1.0000
Australia	2	5	0.9143
Spain	3	35	0.8286
New Zealand	4	6	0.7714

Netherlands	5	5	0.8097
Norway	6	3	0.8020
Denmark	7	2	0.7872
Australia	8	8	0.7863
Spain	9	20	0.7516
France	10	9	0.7510
Singapore	11	23	0.7476
Sweden	12	1	0.7474
Bahrain	13	42	0.7363
New Zealand	14	18	0.7311
Germany	15	22	0.7309
Belgium	16	24	0.7225
Japan	17	11	0.7152
Switzerland	18	12	0.7136
Finland	19	15	0.6967
Estonia	20	13	0.6965

UK	5	25	0.7514
Japan	6	12	0.7571
USA	7	1	0.7571
Canada	8	11	0.7286
Estonia	9	8	0.6857
Singapore	10	10	0.6857
Bahrain	11	-	0.6714
Malaysia	12	-	0.6571
Denmark	13	3	0.6429
Germany	14	-	0.6143
France	15	4	0.6000
Netherlands	16	16	0.6000
Belgium	17	28	0.5857
Kazakhstan	18	-	0.5571
Lithuania	19	20	0.5286
Slovenia	20	-	0.5343

2.7 E-government Issues

The development of the Internet has resulted in significant changes being made in the access and processing of government information obtained through the use of ICT. As the use of e-government has increased, there has been a growing need to ensure that its delivery is effective and efficient if it is to meet the users' expectations. In this section, the critical issues adversely affect the users' expectation for using and accessing government digital services are addressed. These critical issues were based on the suggestions made by Lau (2003) and Vanka et al. (2007), and include the problem of availability of technical support, the barrier created by the digital divide, concerns about privacy and security, and issues with trust and confidence. In this section, two of these e-government issues are selected for further consideration: technical support and trust and confidence. These are issues that are most commonly addressed especially within Eurpean e-government practice. In addition, a more recent concern is the adverse current global economic environment; this is discussed in 2.7.3; and issues related to New Zealand e-government practice are addressed in 2.7.4.

2.7.1 Technical Support

E-government relies on technology to provide seamless on-line services to users. However, as Lau (2003) and Vanka, Sriram and Agarwai (2007) point out, there is a lack of an established and recommended e-government architecture that has the capacity to provide effective services with sufficient integration and interoperability to be accessible to all citizens and businesses. Lau (2003) and Vanka et al. (2007) also claim that government services are spread across various legacy systems and emanate from different platforms, possess different requirements and use different technologies, and as a result make it difficult to deploy new applications that are aimed at sharing or interacting with data from several systems. Vanka et al. (2007) provide a list of typical technical issues, which they claim adversely affect the implementation and development of e-government:

- Lack of integration and interoperability: Government departments have their own sets of data, applications and systems; these diverse systems prevent the formation of seamless on-line services required to deliver effective e-government.
- Lack of knowledge sharing: By not sharing information and data, the citizens do not gain sufficient knowledge to be able to make informed decisions.
- Lack of standards: Without agreed standards for defining and naming data elements and concepts, the cost, security and sustainability of the system are suspect.

Vanka et al. (2007) suggested that creating and deploying a user-centred, standards-based enterprise architecture framework would be one way these technical issues could be addressed.

2.7.2 Trust and Confidence

Citizens are not likely to use e-government services without the promises of trust and security provided by the website (Lau, 2003; Vanka, et al., 2007). Governments have the responsibility of protecting their citizens' privacy and making sure information will not be misused. Governments share this role with organisations, businesses and other individuals to make sure that systems and networks are properly used (Vanka, et al., 2007). The challenge for e-government developers is to maintain the security of personal information, while at the same time providing efficient data sharing services.

To address some of these issues, particularly in those countries within the OECD, the Council of the OECD in 2002 issued revised guidelines in their report, *OECD Guidelines for the Security of Information System and Networks: Towards Culture of Security*. The focus of the guidelines was the promotion of security in the implementation and development of information systems and networks, and the adoption of new ways of thinking and behaving by all the participants when performing transaction and communication activities across networks.

2.7.3 The challenge and effect of the global economic crisis

The world is facing the problem of global financial and economic crisis and has put governments under pressure in their provision of effective and efficient e-government services. In its 5th Ministerial E-Government Conference (2009), the members of OECD countries concluded that it was crucial for countries to look at setting up strategic investment priorities in new technical activities to support and benefit the long-term sustainability of government economies.

At the conference the results of a report were presented. The report stated that most of the OECD countries were taking steps to ensure more focus was placed on those projects that realised the most tangible benefits when implementing e-government development (OECD, 2009). The report also showed that while some countries within the OECD had instigated cost cutting measure in the public sector, a few countries (such as Germany, Korea and the United States) had managed to grab the opportunity to seek long-term benefits by investing strategically in innovative technical activities. Countries such as New Zealand and Australia were focusing more on improving efficiency and effectiveness of e-government services.

The report investigated the priorities that had been adopted to maintain or enhance the coherence of the e-government services during the economic downturn. These priorities included expanding service accessibility by increasing the broadband speed, improving back-office integration by the standardisation of information and data, and reengineering and automation of internal services. The OECD report also stated that the effects of budget cuts were expect to occur in 2009 and extend into the following years. Some countries such as the United Kingdom and Austria anticipated a decrease of e-government spending, whereas the United States and Germany were expected to continue to invest in innovative ICT activities as a way of supporting their long-term aims for e-government.

2.7.4 Issues and recommendations to New Zealand e-government

A memorandum (Monika O’Sullivan, personal communication, 19 May 2009) submitted to the New Zealand State Services Commission (SSC) in 2009, outlined a number of issues and recommendations associated with the delivery of e-government services in New Zealand, for example:

- Agency defragmentation: O’Sullivan (2009) argues that the adoption of the New Public Management (NPM) model in 1980s led to a separation of government agencies and poor resource management, which has hampered attempts to introduce on-line services delivery. O'Sullivan suggests that coordination needs to be made on behalf of individual agencies and ministries if the integration of e-government is to be successful. O'Sullivan also proposes as the mid-term recommendation, that a strategic plan be developed to provide guidance for an e-government integrated approach.

- Stability in organisational changes: The memorandum mentions the likelihood of opposition to the mandatory integration and suggests that a phased approach to integration be adopted, arguing that a phased approach would allow flexibility in the implementation of formal policies by the State Services Commission.
- Governance consideration: It is suggested in the memorandum that the responsibility of funding e-government services could be given to a centralized system under the auspices of the SSC, and that SSC should make sure that on-line services can be trusted and made secure and at the same time the performance should be monitored to ensure transparency and accountability.

2.8 Semantic e-government

There are significant number of challenges that need to be overcome if interoperability of the e-government domain is to be achieved. These challenges are centered on, but not limited to, the numerous semantic differences of interpretation of laws, services, administrative processes, and in some situations, many different languages within and across regions and countries. Despite attempts at standardisation, there is a huge variety of IT solutions, all of which have to be networked. To overcome the problems associated with different meanings of data, objects and interfaces will require specific semantics (Stojanovic, 2006).

Stojanovich (2006) is of the opinion that after years of successful and interesting research, the Semantic Web needs to be evaluated using dynamic, heterogeneous real world problems. Stojanovich (2006) takes the view that the e-government domain provides an ideal test bed for Semantic Web research, as it could attempt to resolve the problems associated with applying a knowledge-based solution to a citizen-centric and citizen-empowering environment.

Numerous projects and proposals have been put forward in support of applying semantic concepts to e-government. To illustrate this assertion three examples are listed below:

- "Infrastructure for the Semantic Pan-European E-Government Services", where Semantic Web Service (SWS) specifications address technological components of the National/European Interoperability Framework (Vitvar, Kerrigan, van Overeem, Peristeras, & Tarabanis, 2006);

- “Towards a Semantic Interoperability in an e-Government Application”, where the project examines the semantic requirements to build flexible and interoperable artefacts to support the introduction of e-government services (Bettahar, Moulin, & Barthes, 2009); and,
- “Semantic interoperability in eGovernment initiatives”, which examines how semantic technologies and standards have been incorporated into the interoperability frameworks in e-government agencies in Europe and the United States (Guijarro, 2009).

2.9 E-government projects

There has been an increase in the use of e-government services worldwide (Kovacic, 2009; United Nations, 2010b). In support of these development a number of e-government projects have been carried out, especially within the European Union and the United States, to explore the use of different architectures to deliver government and services using electronic means (European Commission, 2010).

In this literature review of e-government projects, the first two projects, OntoGov (Section 2.9.1) and SmartGov (Section 2.9.2), although undertaken some time ago, provide foundation concepts that support the design and construction of semantically-driven e-government services. The final two, Interactive Knowledge Stake (2.9.3) and Cloud for Service Oriented Architecture (2.9.4) briefly describe some of the current projects, that seek to advance the understanding of semantic environments, and which may have implications in the future for the delivery of e-government services.

2.9.1 OntoGov

OntoGov was a research and development project that was partially funded by the European Commission within the Information Society Technologies Programme. The project started in 2004 and was completed in 2006. The project aimed “*to develop, test and validate an ontology-enabled platform that [would] facilitate the consistent composition, re-configuration and evolution of E-Government services*” (Abecker, Apostolou, Hinkelmann, Probst, & Stojanovic, 2004). At the time of the commencement of the project, there were only a very few developed ontology projects in E-Government (Kavadias & Tambouris, 2004; Tambouris, et al., 2004). OntoGov differed from the other e-government projects as it addressed the service implementation and service integration issues during the development of e-government services, whereas other projects focused more on providing a framework to facilitate the development, deployment and uniformity of e-government applications.

OntoGov Architecture

The initial public service provision model, as described by Tambouris et al. (2004), is illustrated in Figure 2-10.

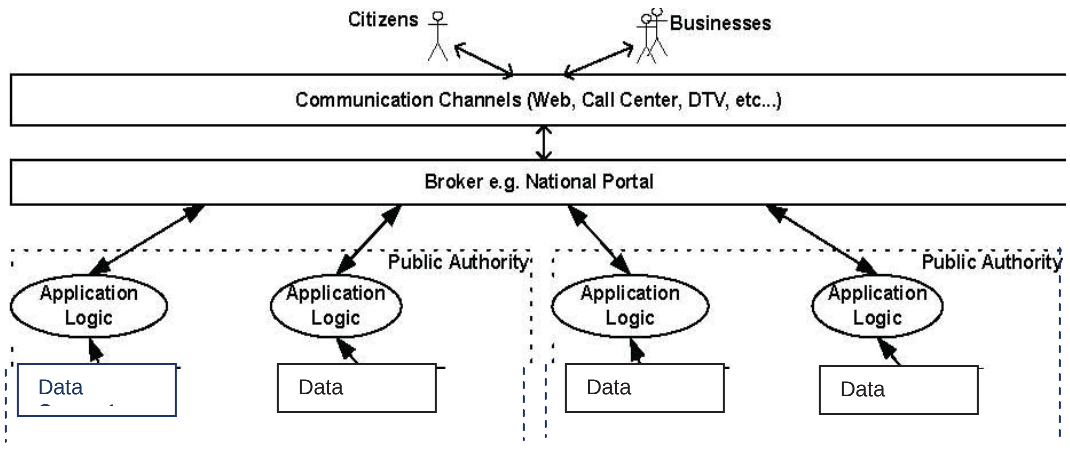


Figure 2-10: Current service provision model (Tambouris, et al., 2004)

In this diagram, the current service provision model is divided in four parts:

- Data sources: These sources are located in the back office; each of the data source represents a different domain or service.
- Processes: The processes for retrieving the information from data sources are available by running the software application.
- Broker: The broker links to the appropriate public service required.
- Communication channels: These are responsible for providing the interface to citizens and businesses.

In the above model, data is retrieved by different applications located at various public authorities. This requires users to have some understanding of how the components are linked and where they are located.

The proposed service provision framework is illustrated in Figure 2-11.

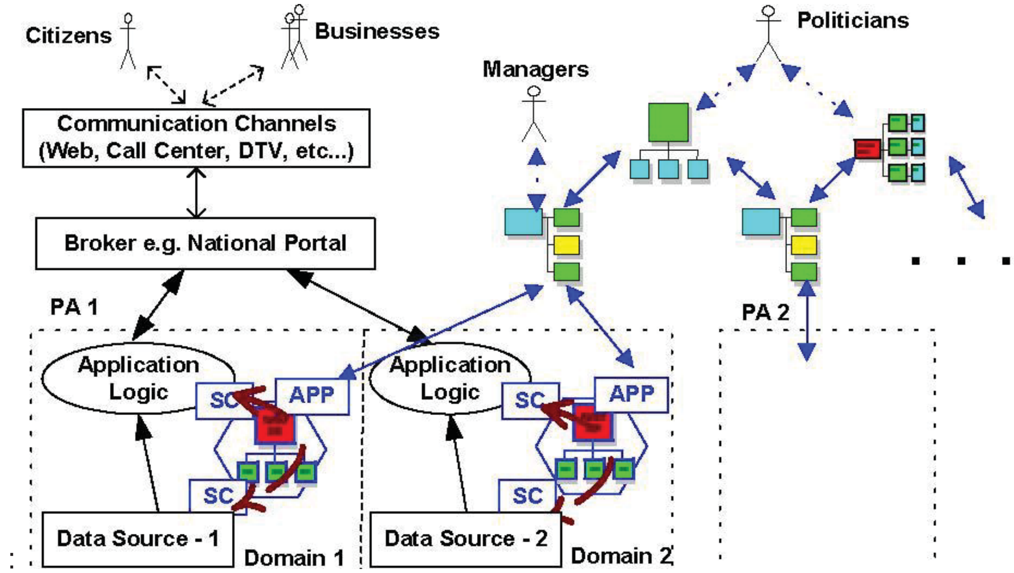


Figure 2-11: Semantic Provision Model (Tambouris, et al., 2004)

As shown in the Figure 2-11, the new framework consists of several components divided into two major levels: conceptual level and technical level. The following steps illustrate the steps followed to develop the model:

- Conceptual level: Working towards the semantic framework:
- Identify services/knowledge domains that are relevant.
- Derive a semantic framework (Domain Ontology) for each of the services identified in the previous step.
- Identify and retrieve the common concepts and properties from the domain ontology that can be used to construct the upper level National Semantic Framework (National Ontology). This is a form of mapping exercise.
- Derive a prototype European Semantic Framework with services that are of specific interest.
- Technical level:
- Develop the communication service configuration model between Domain Ontology, Data Sources and Application Logic.
- Develop all interfaces for citizens, managers and politicians at different levels (local, national, European level).

In the proposed model the public service retrieves knowledge from applications, located in domains, which have themselves been integrated by mapping from external sources.

2.9.2 SmartGov Project

SmartGov was a 24-months research and development project that was funded by the European Union. The aim of the project was to specify, develop, deploy and evaluate a knowledge-based platform. The project was started in February 2002 and was completed in 2004.

The purpose of the SmartGov platform was to support public sectors in their provision of transaction services by simplifying their development, maintenance and integration with the existing IT systems (SmartGov, 2002). The objectives of the project are as follows:

- To specify and develop a knowledge-based repository for governmental transaction services. The repository should include the basic transaction services elements that are used to build up the transaction services, as well as the specific domain information and knowledge.
- To specify and develop the SmartGov services for creating and maintaining the e-government services, and for integrating with the existing IT systems.
- To investigate process models within the public sector and social aspects in order to facilitate the SmartGov platform and fulfill its potential.
- To deploy the SmartGov platform in one ministry and one local authority, and evaluate it by creating some public transaction services.

SmartGov Platform

The SmartGov platform was developed by integrating various technological areas, such as knowledge based systems, Internet and user-centric interfaces.

Developing a knowledge repository was the key function in the SmartGov approach. The knowledge repository captured the domain knowledge in an explicit way, and at the same time separated the technology-related issues from process and domain-specific topics, which enabled the public sectors employees with expert domain knowledge to work on the development and maintenance of transaction services. The combination of certain technology areas was used to establish the SmartGov platform; these technologies included areas such as knowledge based systems, Internet and user-centric interface. In order to reach the harmony between the various technologies, extensive use of XML was made as it provided rich semantics, structure and functionality. Technologies such as knowledge management, web technologies, interoperability and accessibility were applied.

Figure 2-12 below illustrates the SmartGov platform.

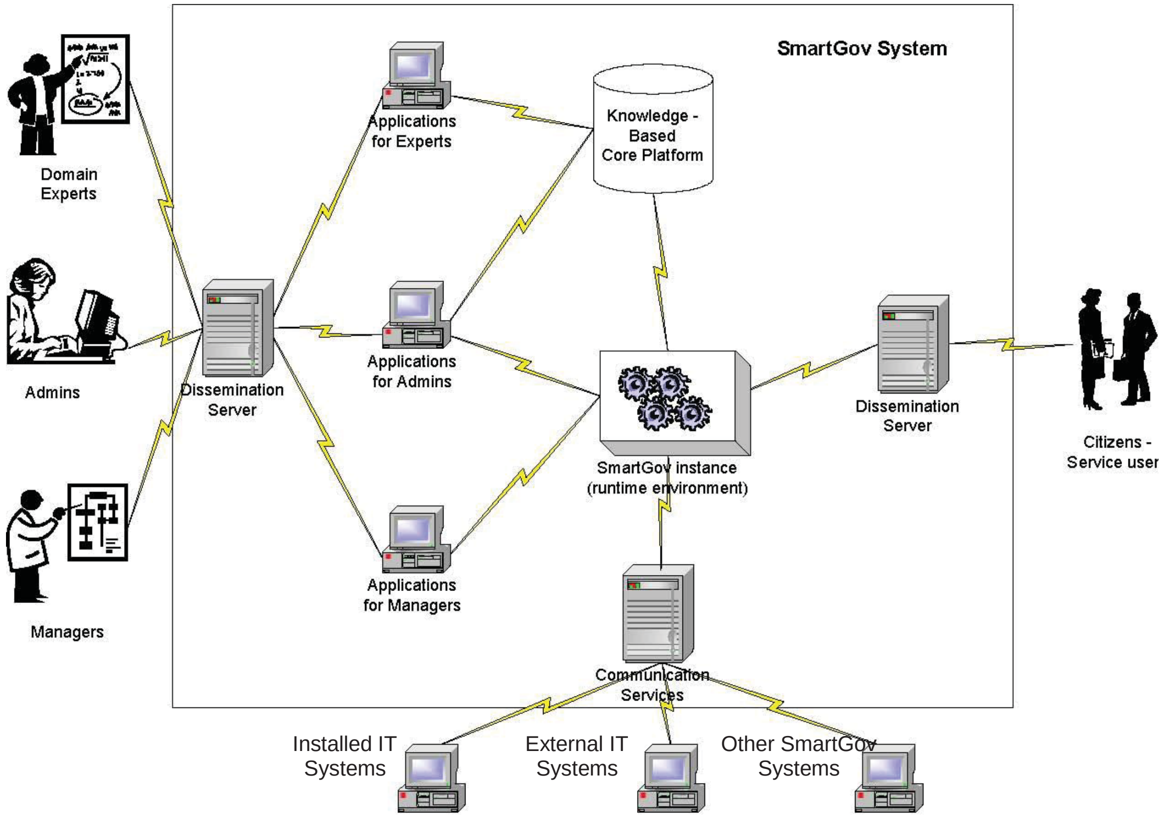


Figure 2-12: The platform of SmartGov system (Tambouris, et al., 2002)

In Figure 2-12, there are four main stakeholders. Details of the roles for these stakeholders are given by Tambouris, et al. (2002):

- Experts: The public sector employees who have the expert knowledge about the domain and required processes. The experts are responsible for maintaining the system's database.
- Managers: These are the managers who work in the Public sector. They are the ones who wish to retrieve useful information from the system.
- Supporting staff: Primarily IT staff, who are involved with implementing features of the transaction service platform and who provide technical support.
- End-users: Citizens or businesses who seek information from the Public sector.

In the centre of the figure is the unit called SmartGov Instance. When a service transaction is requested it is deployed through a service instantiation. This procedure automatically generates an instance, which comprises all the information and functions, such as web pages, forms, information repositories and all the programs needed to operate the service within the web environment. The Dissemination Server handles the presentation layers with the stakeholders, and those elements generated by the service instantiation. The SmartGov system maintains links with the Installed IT

Systems for data exchange and mapping, and at the same time, it links with the External IT Systems for external information updates.

2.9.3 Interactive Knowledge Stack (IKS)

Not all of the projects are linked directly to e-government but they do offer an interesting approach in the development of small, dedicated projects that might be useful later. The Interactive Knowledge Stack is a project part-funded by the European Commission. Its purpose is to provide an open source technology platform linking to projects utilising semantically enhanced content management systems (Knowledge and Media Technologies, 2011). The user community has access to an active group of experts, enthusiasts and academics contributing to the semantic CMS technology.

Each of the projects is OSI-compliant with no licence fees. The projects offer opportunities for innovation and flair in the use of semantic technologies. Visitors and participants are encouraged to try them out, and give feedback on how they may be improved.. Brief descriptions of two of the projects are set out below:

- Interactive Knowledge Stack (Knowledge and Media Technologies, 2011):
- The stack describes the main vision of the IKS project. It has a layered architecture for semantic content management.
- Interaction and presentation layer: This layer provides user centred interaction with knowledge objects.
- Knowledge management layer: It includes the ontology-structured knowledge base, classes, properties, instances, rules and reasoning, and business processes.
- Distribution, interpretation and retrieval layer: It includes transaction services and components, and retrieval processes using query semantic query languages.
- Persistence layer: This layer provides typical database functions.
- Apache Stanbol (Knowledge and Media Technologies):
- This is a modular software stack with reusable set of components for semantic content management. There are a number of applications within the stack, which create semantic-drive content management systems by adding semantic services to existing content management systems.

2.9.4 Cloud for Service Oriented Architecture (Cloud4SOA)

The cloud consists of an interoperability framework and platform to facilitate user-centric, semantically enhanced, service-oriented applications design, deployment and distribution (T. Anderson, 2010). “Cloud” is essentially a metaphor for the Internet, and "cloud computing" uses the Internet to access applications, data or services that are stored or running on remote servers (T. Anderson, 2010). Any company that provides its services over the Internet can be called a cloud computing company.

2.9.4.1 Generic Cloud Computing PaaS architecture

There is no single structure to represent cloud computing, for example, there are over 150 different representations on Google (2011). However, review of eighteen architectures that focused on Cloud computing interoperability resulted in the Cloud4SoA Consortium proposing an architecture depicted in Figure 2-13.

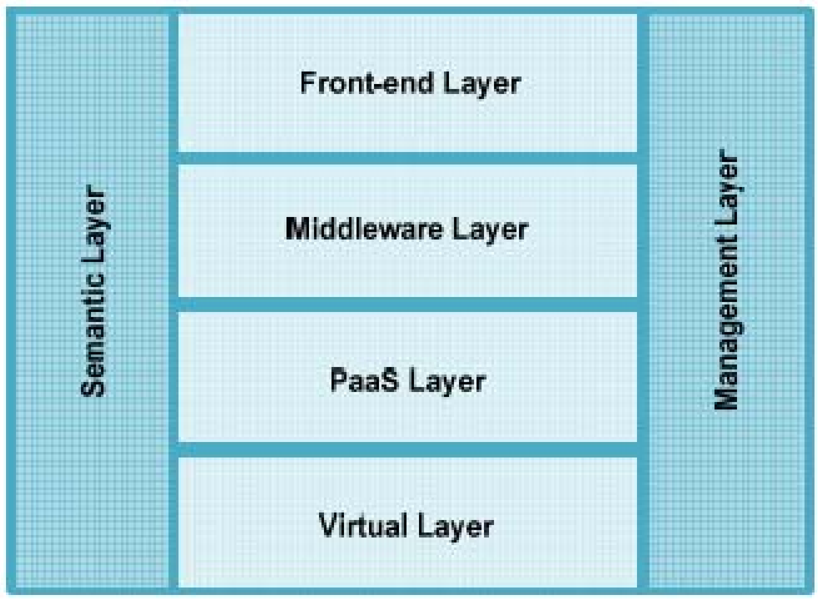


Figure 2-13: Generic Cloud computing PaaS architecture (Cloud4SoA consortium, 2011)

The following list introduces these layers (Cloud4SoA consortium):

- Virtual/infrastructure Layer - Infrastructure-as-a-Service (IaaS): This layer is concerned with the provision of physical and virtualized resources. Effectively, a company can outsource its hardware needs to another organisation. The users of IaaS companies rent and access over the Internet items such as off-site server, storage, and networking hardware. This enables them to reduce maintenance costs and wasted office space. Amazon, Red Hat, Microsoft and VMWare are some of the many organisations that offer IaaS (Ludwig, 2011).
- PaaS and Middleware layers: The layers provide the appropriate tools for the deployment of applications, and they enable the configuration and management of the infrastructure. The user company can adopt a variety of solutions for developing and deploying applications over the Internet, such as virtualized servers and operating systems. Again this has the potential to save the user

company money on hardware and simplifies collaboration between a widely dispersed workforce. Some of the biggest PaaS providers are Microsoft Azure and Google App Engine (Ludwig, 2011).

- Front-end Layer - Software-as-a-Service (SaaS): The Software-as-a-Service layer is the one the user company is most likely to use. The portal is the usual means of access. For example, an application located on a remote server that can be accessed over the Internet would be considered as SaaS. Typical examples include Netflix, Cisco's WebEx and Salesforce's CRM (Ludwig, 2011). The portal accessing the e-eovernment knowledge base in this thesis could be viewed as a SaaS.

Also included in Figure 2-13 is the suggestion made by Charlton (2009) that a description of Cloud services should include deployment and management, and a semantic layer to provide platform-neutral specifications to overcome issues associated with portability and semantics.

2.9.4.2 Cloud4SOA

Cloud4SOA is a three year European project Seventh Framework Programme (FP7) initiative funded to the value of €2.74 million (Cloud4SOA, 2010). The project's fundamental aims and objectives are to contribute towards Cloud interoperability by embracing the following research and innovation related activities:

- Identify and analyse semantic interoperability problems: A comprehensive analysis on both IaaS and PaaS layers is to be undertaken, which will seek stakeholder experience, requirements and feedback. The product of this exercise will be the design and construction of a cloud semantic interoperability framework; which in turn will act as a roadmap for creating similar user-oriented platforms.
- Construct reference architecture: It is intended that the most problematic semantic interoperability issues will be addressed by constructing an open, generic architecture for a semantically interoperable Cloud. The approach will adopt a service-oriented architecture, using lightweight semantics, and user-centric design and development principles.
- Develop a proof of concept platform: The Cloud4SOA Reference Architecture will be applied in different scenarios and environments across the European economic and business communities.

Architectural reference architecture

In June 2011, the final version of the Cloud4SOA Reference Architecture was made public (Cloud4SoA consortium, 2011). The purpose of the architecture is to resolve semantic incompatibilities that arise between heterogeneous Cloud computing Platforms. To some extent, it builds on the knowledge derived from the generic Cloud architecture. The reference architecture is shown in Figure 2-14.

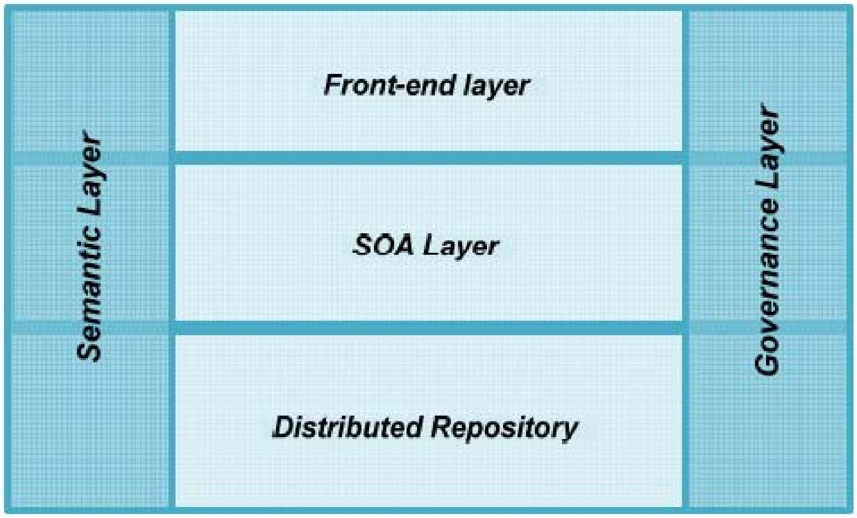


Figure 2-14: Abstract view of Cloud4SOA Reference Architecture (Cloud4SoA consortium, 2011)

The three horizontal layers have the following roles (Cloud4SoA consortium, 2011):

- Front-end Layer: The focus of Cloud4SOA is user-centric, and its purpose is to provide the application developers with easy access to the Cloud4SOA functionalities. It facilitates the seamless interaction to both Cloud-based application developers and Cloud PaaS providers.
- The SOA Layer: The core functionalities offered by the Cloud4SOA system are implemented in this layer, for example: service discovery, announcement and deployment. The SOA Layer consists of a set of tools that utilises the semantic annotation expressed in the Semantic Layer and the functionalities of the Distributed Repository to provide services, for example: security, discovery, deployment, recommendation and migration services. The SOA Layer also acts as an intermediary to the services offered by the other layers.
- Distributed Repository: In this layer, the technical infrastructure is put in place. Its main components provide mechanisms for search and discovery, and database support.
- The Semantic and Governance layers extend across and impact all the horizontal layers:

- Semantic Layer: The semantic models and tools offered by Cloud4SOA are to be found in this layer. Their purpose is to resolve semantic interoperability conflicts that are raised between different PaaS offerings.
- Governance Layer: It is essentially a toolkit for monitoring the lifecycle of Cloud4SOA services. The Cloud4SOA Governance Layer is responsible for implementing and maintaining EU governance policies in Cloud4SOA platforms.

2.10 Semantic Web

"The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries" (World Wide Web Consortium (W3C), 2009c). The use of the Internet continues to grow at an astounding speed, and it is clearly an integral part of our daily life and business. People expect organisations, particularly those providing public services, to provide information at the press of a button. This expectation creates a huge challenge to many agencies, as information is invariably located in disparate locations and often in a format that is not easily retrieved. What would have taken several days or weeks to compile is now expected to be delivered in seconds, and in an accurate and unambiguous form.

Frequently, when people access the Internet, seeking information on a given topic, they may find that they are overwhelmed by huge amounts of information – some relevant and some not. Human intervention is invariably required to sort out the results in order to find the answers people really need. Sorting the information out can take time even with the help of powerful search engines and keywords. Some of the typical problems facing the users include the use of different names, structures or scales for the same information, and information represented at different levels of granularity, clarification or precision (Klischewski, 2006). The problem may be further complicated as people may have to search different sources in order to get a complete picture of their requirements, and manual linking of information may still be required.

To address some of the above weaknesses and to enhance the cooperation between computers and people, (Berners-Lee, et al., 2001) proposed the Semantic Web as an extension of the existing web which was regarded as unstructured and lacking in meaningful expression of the web contents. The idea was to exchange information by applying well-defined semantic meaning to the information, but at the same time enabling the information to be processed by computers. The Semantic Web provides a framework for the sharing and reusing of data and resource across the Internet (Horrocks, Patel-Schneider, & Frank van Harmelen, 2003; W3C, 2004; World Wide Web Consortium (W3C), 2006). Berners-Lee, Hendler and Lassila (2001) argue that the Semantic Web is needed to share not only the data from different systems, but also the meaning of the terms. Klischewski (2003) also points out that Semantic Web is about integrating data by operating across borders of different systems and organisations, and trying to solve the interoperability problems from the data perspective (Kavadias & Tambouris, 2004; Wimmer & Traunmüller, 2002). One can imagine a situation where a client submits a planning application request to a council. Not only is the client interested in the regulations and policies of the Council but also any necessary and important information related to the environmental and cultural matters and probably to other issues perhaps involving transport, water, or land use. Because such a request involves information retrieving from different sources and systems a knowledge structure needs to be formed that integrates the various components in a meaningful way. Traditional database solutions to such a problem would not link data elements except via primary and secondary keys. Such keys carry no meaning in themselves and this is unlike the Semantic Web solution, which links elements using properties, roles and classes. In fact, the Semantic Web through its use of roles and classes provides a better representation of ‘use cases’ scenarios than the common relational database solutions. In addition, there is no requirement for data to share exactly the same meaning or definition of a concept in order to facilitate integration. The Semantic Web enables the transfer of data from different systems without having to share the same definition of the concept.

By 2002 Semantic Web technologies had matured enough to provide a platform for application system development, and many research and development groups began applying their knowledge at various levels, from putting category information on the web to making computers relate more at a semantic level (Euzenat, 2002). Since the Semantic Web was introduced by Berners-Lee et al. in 1999, actions were taken by organisations such as the World Wide Web Consortium to establish standards and procedures to support the development of Semantic Web (World Wide Web Consortium (W3C), 2009a, 2009b).

2.10.1 Semantic Web and e-government

As mentioned above, the Semantic Web aims to solve the problems of difficulties in providing interoperability, loss of meaning and the need for automated computer processing when running administrative processes and services across the Internet.

E-government is a domain that is dominated by semantic issues. Klischewski (2006) argues that the domain of e-government is unique and challenging because of its enormous and huge demands in achieving interoperability. The interpretation of e-government terms has semantic differences, which can appear in various areas, such as law, regulations, citizen services and administrative processes. Klischewski (2006) claims that attempting to integrate and interpret disparate information from a wide range of e-government domains located across regions, cities and nations, places high demands on e-government resources. Data obtained from some sources might be so complex and semantically difficult to reconcile it might not be possible for the software to automatically process the integrations (Kavadias & Tambouris, 2004; Wimmer & Traunmüller, 2002). It is now a requirement that governments provide e-government services which are effective, simple to use, shaped around and responding to the needs of the citizens. It is no longer acceptable to provide a notional service(Sabol & Mach, 2006). Sabol and Mach (2006) also expressed their concern about the high demands of government resource sharing and information retrieving. According to Sabol and Mach (2006), most problems are related to the huge amount of information that has to be retrieved and accessed across systems, which are managed by different information technology solutions. Sabol and Mach (2006) consider that these problems are likely to be at all levels: local, regional, national and international levels, all of which will have to be networked. Because of the variety of IT network infrastructures and the trend to build closed systems and networks, it is impossible to have one physically integrated e-government system. Standardization will certainly support integration; however, it would still be impossible to combine the different perspectives (Kavadias & Tambouris, 2004; Wimmer & Traunmüller, 2002). Kavadias and Tambouris (2004) have identified a number of issues:

- Unsatisfying user experience: The inability of the user to find and retrieve the desired information. This is invariably due to the non-unified structure, style and principles embedded in the system (Kavadias & Tambouris, 2004).
- Lack of interoperability: Lack of front-back-end and back-to-back interoperability on the technical level. A frequently cited problem of interoperability at the organisational level is where data and information have to be exchanged vertically (between national authorities and regional authorities) but horizontally (between regional authorities) (Wimmer & Traunmüller, 2002).
- Poor document management: The system is not able to carry out specific tasks and important tasks. For example, archiving the processes or being able to find where the information is located (Klischewski, 2003).
- Barriers in information retrieval: Standardization of the metadata is a prerequisite in information management. To address this issue in the UK, the Office of the e-Envoy (2001) was the first government organisation to provide metadata components including definitions for content management metadata.

Sabol and Mach (2006) identified four capabilities that a semantic e-government interface should possess:

- Concept-based searching: Retrieving archived data, located in multiple locations, by searching using conceptual knowledge representations.
- Semantic data integrator: Data can be shared and understood across different systems.
- Semantic service discovery and choreography: Semantic services enable the reuse of existing services.
- Virtual consultant: The virtual consultant can help developers construct environments by matching the needs of the user with the available products and service.

Gruninger and Lee (2002), and Sabol and Mach (2006) conclude that the combination of the Semantic Web and e-government is a realistic objective and that the e-government domain is an excellent test bed for semantic technologies research.

2.11 Ontology

The Oxford Online Dictionary provides the following definition of ontology: “The branch of metaphysics dealing with the nature of being" ("Ontology," 2008). Smith (B. Smith, 2003) provides the following definition from an information systems perspective:

> An ontology is … a dictionary of terms formulated in a canonical syntax and with commonly accepted definitions designed to yield a lexical or taxonomical framework for knowledge-representation which can be shared by different information systems communities. More ambitiously, an ontology is a formal theory within which not only definitions but also a supporting framework of axioms is included. (p. 161)

Clearly demonstrated by Smith (B. Smith, 2003), information scientists do not view ontology from a philosophical perspective; neither does Gruber (1993) , who provided one of the most cited definitions, “An ontology is a formal explicit specification of a shared conceptualization” (p.199). In this definition, an explicit specification means the concepts and relationships of the conceptual model are given explicit terms and definitions, where the ontology is expressed as a set of definitions based on a formal vocabulary that can be used to describe a certain domain (Fensel, 2001). Noy (2005) points out that the sets of explicit definitions and frameworks can be represented in ontology-based semantic languages that can be interpreted and understood by both humans and machines.

Four of the fundamental concepts used to define an ontology are: classes, individuals, attributes and relations (Noy & McGuinness, 2001). In the following discussion of these elements, examples based on the researcher's view of the New Zealand parliamentary system have been added.

- Classes (concepts): Classes are about collections of abstract objects. Classes can include individuals or other classes. Parliament, Cabinet, and Members of Parliament can all be treated as classes.
- Individuals (instances): These are the most basic elements in an ontology. Instances represent each of the individuals within a class. Both concrete objects and abstract individuals can be individuals. For example, Lees-Galloway is the individual of the class of Members of Parliament. A class can subsume or be subsumed by other classes, such as the class Parliament subsumes the class Cabinet. As with the object-oriented structure, subclasses inherit all of the attributes and relationships of the super classes.
- Attributes: These are the properties assigned to objects in the ontology; in essence these are used to describe objects. Each attribute has either a name or a value. For example, for the Members of Parliament class, Name, Address and Telephone Number are its attributes.
- Relationships: Relationships provide a link between two objects in the ontology. It is this feature that makes ontologies extremely useful, as they enable semantic meaning to be preserved in the ontology. The relationships 'is-a' and 'isSubClassOf' enable a class hierarchy to be formed, for example, Cabinet 'isSubclassOf' Parliament. These topics are comprehensively discussed in Chapter 5: Ontology Construction.

In addition to the above fundamental concepts, ontologies are able to perform complex computations. For example, the inference rule is able to process an expression such as: "members of Cabinet are members of Parliament", so the program will automatically conclude that if Lees-Galloway is a Member of the Cabinet, he is also a Member of Parliament as well. The computer does not understand the information. It is the inference rule which makes the computer process the term in a way that can be understood by human beings.

2.12 Ontological Approach to Semantic E-Government

Klischewski (2003) and Wimmer and Traunmuller (2002) stated that knowledge representation, intelligent retrieval and promoting communication were some of the possible applications for the Semantic Web. Gruninger and Lee (2002) also pointed out that most of the Semantic Web would be based on the use of ontologies. The creator of the web, Berners-Lee regards ontologies as a critical component of the Semantic Web (Berners-Lee, 2009). These views of the future have been confirmed as demonstrated by the efforts of the World Wide Web Consortium (W3C), which has made numerous recommendations regarding the future direction of the Semantic Web and its associated languages and tools (World Wide Web Consortium (W3C), 2009b; World Wide Web Consortium (W3C), 2004a; World Wide Web Consortium (W3C), 2009b).

In 2003/2004, Daddieco (2004) and Hovy (Hovy, 2003) were of the opinion that ontologies could be used to structure e-government information and that governments around the world were beginning to conduct ontology-based projects in e-government services. This opinion was confirmed, for in 2008, the W3C formed a new interest group dedicated to the advancement of good practices and guidelines for the use of Open Web Standards in e-government (World Wide Web Consortium (W3C), 2009a). The mission of the eGovernment Interest Group is to document, advocate, coordinate and communicate best practice (New Zealand State Services Commision, 2002). In support of this mission, three interest groups have been formed (World Wide Web Consortium (W3C), 2010c):

- Usage of Web Standards: The role of the group is to identify best practice by analysing the successes and failures of efforts at opening, sharing, and re-using knowledge systems. The purpose is to identify those technical paths that lead to better public services. The group argued that compliance factors within countries should be eased to promote improved web accessibility and better addressing of government needs.
- Transparency and Participation: The role of this group is to develop standards for open government information, and promote linkable public sector Information. The group is also seeking ways to increase citizen participation, make better use of tools to increase citizen awareness, and identify those services that citizens and businesses consider important.
- Seamless Integration of Data: The role of this group is to Identify and apply state-of-the-art integration strategies to build useful, deployable, and proof-of-concept systems, which integrate actual government information and present it to the target user. It is expected that these applications would be specific to a given user group and that XML, SOA and Semantic Web technologies would be employed.

2.12.1 *Systems Development Methodologies*

George, Batra, Valacich and Hoffer (2007) state that a system development methodology provides guidelines to follow for completing every activity in the systems development lifecycle, including specific models, tools, and techniques.

Traditional system development is usually regarded as a slow and changeable process, and incremental development is normally required to develop and manage the system (Jacobson, Christerson, Jonsson, & Overgaard, 1993). Success of the system development largely depends on having a plan that includes an organised, methodical sequence of tasks and activities (Satzinger, Jackson, & Burd, 2004).

Satzinger et al. (2004) categorise system development into two approaches: the traditional approach, often referred to as structured system development approach, and the object-oriented approach.

2.12.1.1 Structured systems development approach

In this approach, structured systems using structured analysis, structured design and structured programming techniques are used (Satzinger, et al., 2004). It is an approach based on the decomposition of the systems development life cycle (SDLC) and graphic representation of the data flow process (George, et al., 2007).

During the design phase, two techniques are used to help the developers define the system processing and data required by the system, namely entity relationship diagram (ERD) and dataflow diagram (DFD) (Yourdon & Constantine, 1975). The ERD is a data modelling technique used in information systems development, which takes a graphical representation of the entities and describes the relationships between them (Batini, Ceri, & Navathe, 1991). DFD is a process model which shows the movement of data between external entities and processes, and data stored within a system. Both George et al. (2007) and Satzinger et al. (2004) point out that the structured approach has more focus on process modelling. However, some developers believe that process is not as stable as data, and any changes in a process can lead to substantial maintenance issues.

2.12.1.2 Object-oriented (O-O) approach

This is an approach to system modelling. It views the system as a collection of related objects that work together to complete the tasks. Instead of separating process and data, as in the structured approach, the object-oriented approach is more directly related to reality because a real-world object has properties (similar to data) and behaviour (similar to process). According to Satzinger et al.(2004), O-O analysis defines the types of objects in the system and what user interactions are required to complete the tasks; O-O design shows the interaction among the objects to complete tasks, and refines the definition of each type of object to enable it to be implemented with a specific language or environment. In the O-O approach, an object refers to a type of thing, a classification or class represents a collection of similar objects, specialised classes can be the subclass for one particular class, and subclasses inherit characteristics of the class above them.

2.12.1.3 Ontology development

Ontology has been widely used in knowledge-based applications as a source of formally defined terms for communication. Ontology aims at capturing the knowledge domain in a generic way to produce a commonly agreed understanding of the knowledge domain that can be communicated between people and various application systems (Sure, et al., 2002). Ontology development is the process of producing an ontology, and the concept of ontology engineering is based on software engineering (Pinto & Martins, 2004).

Kim and Choi (2007) consider ontology to be a kind of software as it includes collection of data, documents-centred computer program, procedure, system operation and a tool for mapping the real world in a computer. Kim and Choi (2007) state that in order to create software, a development process and methodologies need to be defined and followed. Software development requires large input of resources and processes that strive for better quality and timely completion. The development of ontology requires a process similar to the software development; the ontology development process refers to the activities people need to carry out when building ontologies Kim and Choi (2007). Fernandez-Lopez (1999) suggests that ontology development should apply the same standards used in normal software development, with adaptations made to address the special characteristics of ontologies.

Pinto and Martins (2004) suggest specific ontology development stages:

- Specification: This stage identifies the purpose and scope of the project.
- Knowledge acquisition: In this stage knowledge is gathered about the domain by using elicitation techniques or by referring to relevant documents. Brainstorming, interviews and questionnaires are some of the techniques that can be used in this activity.
- Conceptualisation: This stage is concerned with describing the proposed ontology using a conceptual model which takes into consideration the

specifications obtained in the previous step. The conceptual model also describes the relationships between groups of concepts.

- Formalisation: Transforming the conceptual model into a formal model is the purpose of this stage. In other words, the descriptions found in the previous steps are represented in a formal way.
- Implementation: Implement the formalised model in a knowledge representation language.
- Evaluation: Technically judge the quality of the ontology.
- Documentation: A record is kept of what was done, how it was done and why it was done. It is always good practice to write down the terms and concepts associated with the ontology to improve the clarity, and to facilitate maintenance, annotation, use and reuse.
- Maintenance: Update and correct the implemented ontology.

2.12.1.4 Ontology life cycle

Both Fernández-López (1999), and Pinto and Martins (2004) suggest that ontology development has been influenced by software engineering methodologies. Fernández-López (1999) also claims major differences in the two approaches, for example, knowledge acquisition is rarely present in software enineering, and the design phase for software engineering is not divided into conceptualisation and formalisation. Pinto and Martins (2004) have also made suggestions on extended IEEE standards for ontology development, such as during the pre-development process. However, this approach has been overtaken by the acceptance of the ontology development community that using the recommendations of the W3C is the best way to go (World Wide Web Consortium (W3C), 2006b). In addition to studying the environment in which the ontology is to be operated, the possibility of integrating the ontology into other systems also needs to be reviewed. It is not recommended to go directly from the requirements specification to coding in the ontology development design phase. Pinto and Martins' (2004) research shows that the development of an ontology follows an evolving prototyping life cycle (also called evolutionary prototyping). In this life cycle, once a prototype is completed, the developers are able to modify the software requirement specification to meet what was learned (Pinto & Martins, 2004). There is an expectation that the prototype improves each time it is modified, and the modification continues until the ontology satisfies the evaluation criteria and meets all the system's requirements. Evaluation is carried out for the entire system development life cycle. The approach is illustrated using a model in Figure 2-15.

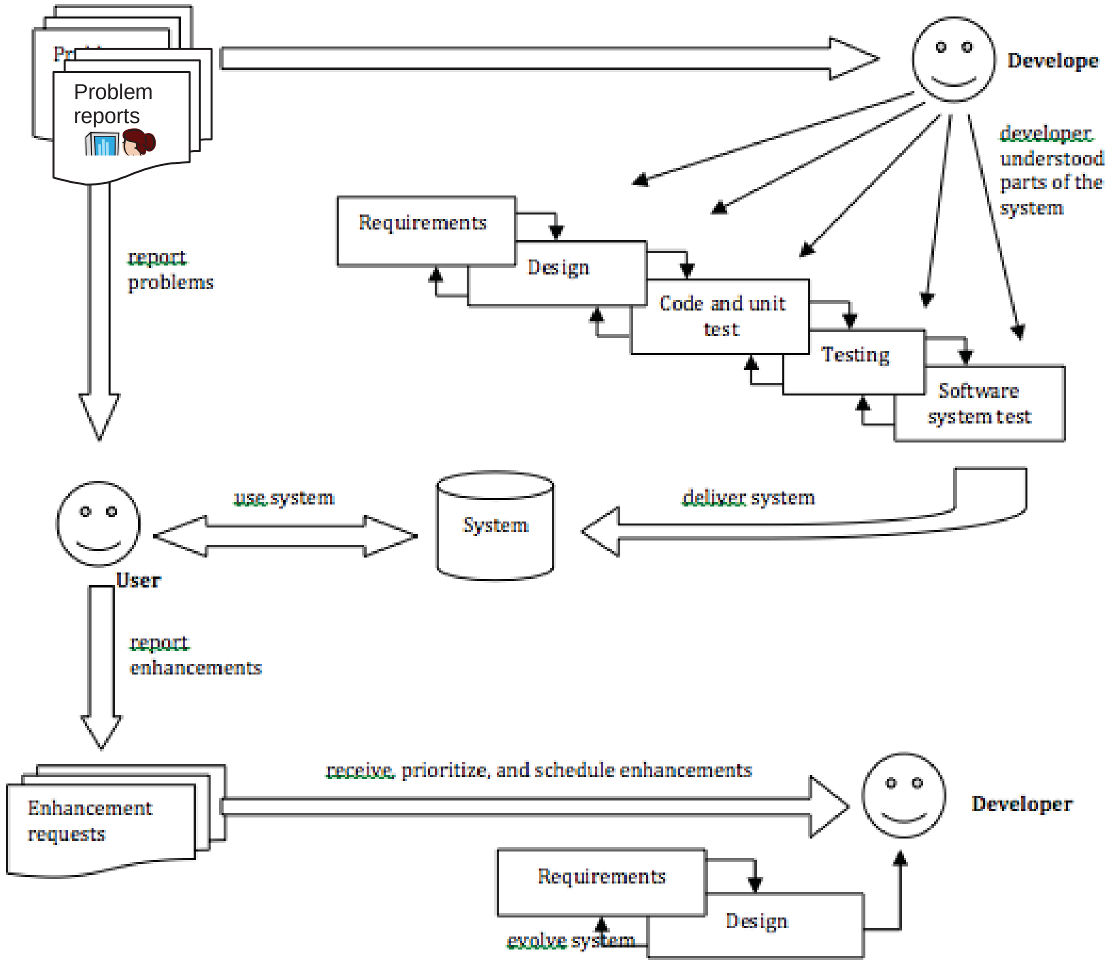


Figure 2-15 Adopted from Pinto & Martins's evolutionary Prototype (Pinto & Martins, 2004)

In the model, the 'initial' system is sent to the customer. As the users use the system, they detect problems and send requests to the developer with new features. The developer works on the system and applies sound configuration-management practices to improve it, and adds the new functionalities. This cyclic process continues until the customer is satisfied with the final product. In this approach the exact requirements of the solution cannot be set out in advance. As the customer or end-users become closely involved in the development process, they have an active contribution as each prototype moves closer in performance to the final solution.

This approach is different from the waterfall approach as the developer can always go back to any of the previous stages of the life cycle, and it is different from an iterative approach as there is no clear understanding at the outset as to what the systems is expected to do (Pinto & Martins, 2004).

2.12.2 Ontology Construction Methodologies

According to Guarino and Welty (Guarino & Welty, 2002) one of the principal requirements of developing a good ontology is to have a general, domain-independent methodology that provides guidelines. Therefore, selecting a suitable ontology development methodology to create the e-government ontology is an important decision in this research. Ontology development has been performed by many different groups, using different methodologies, and by applying different methods and techniques. As Breitman et al. (Breitman, Casanova, & Truszkowski, 2007a) claim, no method is the most appropriate in all circumstances. The purpose of this section is to discuss different ontology development methodologies as a way of understanding the complexity involved in ontology development process.

2.12.2.1 Uschold and King's method

One of the first ontology development methods was proposed by Uschold and King (1995). It was based on their experience gained in the development of the Enterprise Ontology, which Uschold and King (1995) had previously completed.

The process is illustrated in Figure 2-16.

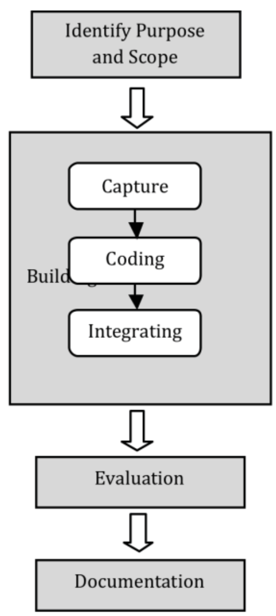


Figure 2-16: Adopted from Uschold and King's ontology development process (Uschold & King, 1995)

The process can be outlined as follows Uschold and King (Uschold & King, 1995):

- Identify purpose and scope: The goal for this process is to define why the ontology is being built and for what is it going to be used, and what the relevant terms on the domain will be.

- Building the ontology: This is broken down into three activities:
- Capture: Identify the key concepts and relationships within the domain, produce precise and unambiguous textual definitions for the key concepts and relationships.
- Coding: The concepts and relationships defined in Capture activity are formalised. This involves three tasks: (1) committing to basic terms that will be used to specify the ontology, (2) choosing a representation language, and (3) writing the code.
- Integrate: This activity considers the possibility of reusing existing ontologies.
- Evaluate the ontology: Technical criteria are used to verify that the specifications have been satisfied.
- Document the ontology: The ontology is fully documented, both describing the structure and processes but also fully annotating the concepts that were used.

Gómez-Pérez et al. (2004a) and Breitman et al.(2007a) have both criticised Uschold and King's (1995) method for the lack of support for the conceptualisation process before implementing the ontology. Breitman et al. (2007a) suggest that an intermediate representation should be included to support users, and to decide which concepts should be included and how they should be classified.

2.12.2.2 Toronto Virtual Enterprise Method (TOVE)

TOVE was proposed by Gruninger and Fox (1995), and it was based on the authors' experiences during the development of ontologies for business organizations. The process is outlined in Figure 2-17.

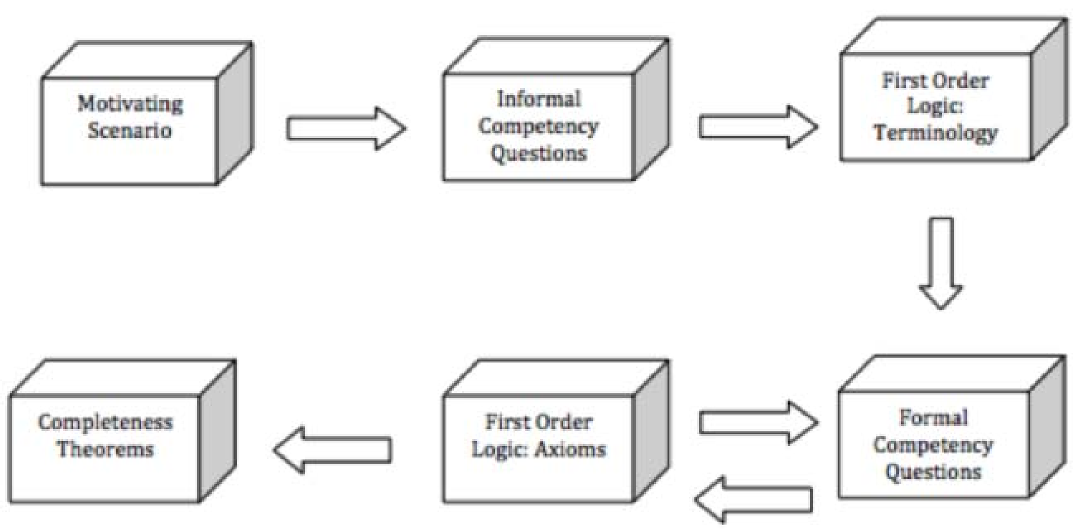


Figure 2-17: Stages of the TOVE method (Michael Gruninger & Fox, 1995)

As illustrated in Figure 2-17, the following stages are identified:

Stage 1: Description of motivating scenarios: Identify the set of problems that motivate the need for development in the enterprise. These problems carry the informal semantics of the concepts and relations to be covered in the ontology.

Stage 2: Formulation of informal competency questions: The competency questions are used to define the initial scope of the problem domain.

Stage 3: Specification of terminologies with a formal representation: A set of concepts is defined based on the competency questions. These form the basis of the formal specification of the ontology. These concepts of the ontology are presented in a formally defined language, such as first-order logic.

Stage 4: Formal competency questions: The competency questions are then framed using a formal defined language.

Stage 5: Axiom specification: The rule/axioms that specify the objects and their relationships in first-order logic are then formally defined.

Stage 6: Verification of ontology completeness: The evaluation is actioned in order to verify the ontology's completeness.

Jones, Bench-Capon and Visser (1998) claim that TOVE has a strong focus on evaluation, especially when the evaluation process is concerned with checking for completeness. However, Breitman et al. (2007a) believe that TOVE fails to adequately describe the concepts and problems derived from motivating scenarios; in their view the scenario technique is best used to observe dynamic environments, rather than provide identification of static entities. Breitman et al. (2007a) go on to say that the scenario technique is best used to observe dynamic aspects of a given environment.

2.12.2.3 Methontology Method

The Methontology method is based on experiences acquired in building an ontology in the chemical domain (Pinto & Martins, 2004). According to Pinto and Martins (2004) Methontology was influenced significantly by software engineering methodologies, and consequently adopts an evolving prototyping life cycle. A series of project management activities are included in the Methontology process, and these are performed in parallel with the development activities (Gómez-Pérez, et al., 2004a). Breitman et al. (2007a) divide the Methontology development process into three activities:

- Ontology management activities: These activities include the identification, scheduling, control and quality assurance of the tasks to be performed.

- Ontology development-oriented activities: Environmental and feasibility studies are conducted in a predevelopment stage Later, the formal development process are performed, these include specification, formalisation, implementation and management.
- Ontology support activities: These activities are related to knowledge acquisition, alignment, documentation, evaluation, integration, merging and configuration management. These are usually carried in parallel with the development activities.

In the development process, once the first prototype has been specified the concept model is then built. The formalisation and implementation are then carried out. The developer can always go back to any stage to make changes or refinements.

Figure 2-18 shows the ontology life cycle proposed by Methontology. As shown in the figure, the management and support activities are carried out at the same time as the development processes.

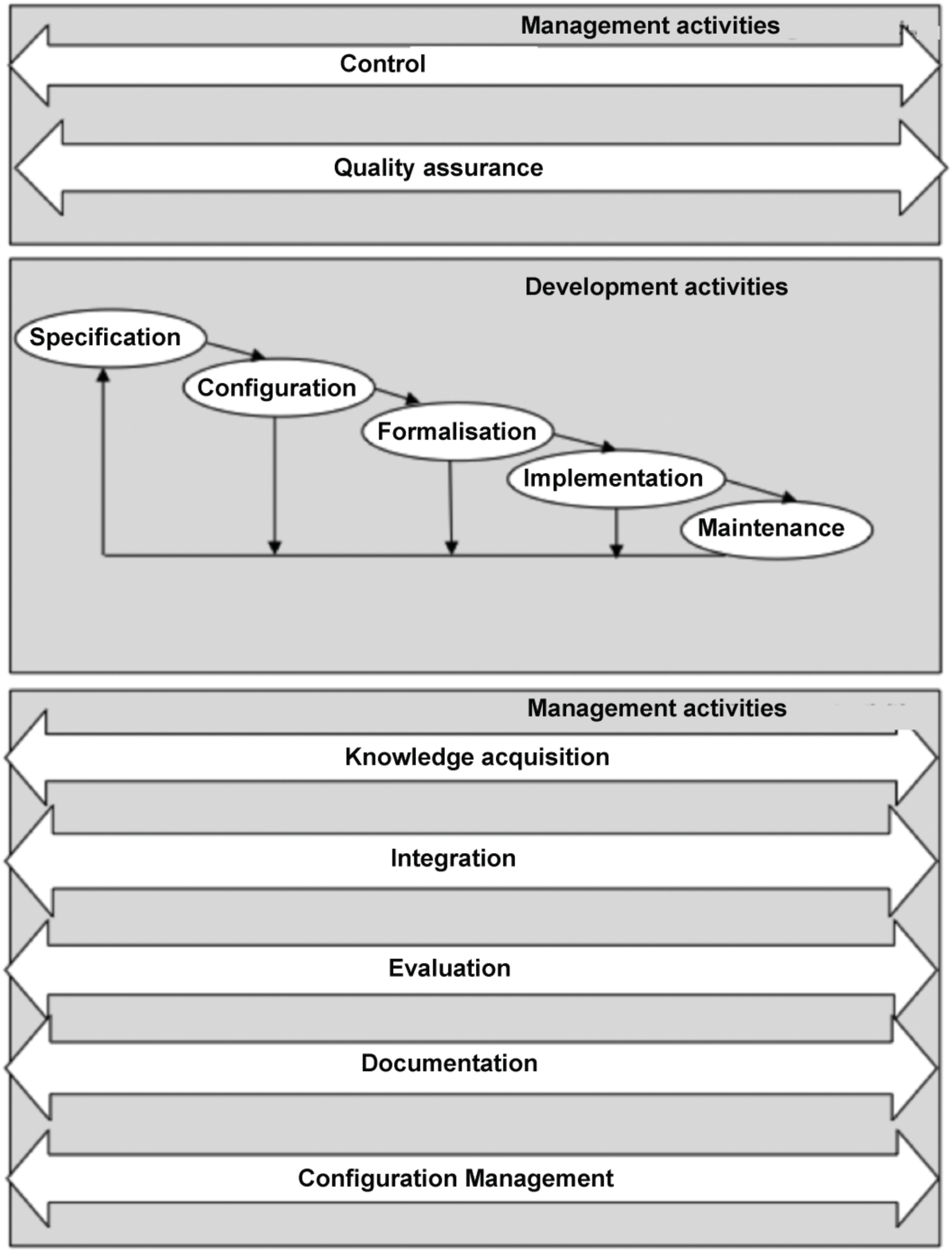


Figure 2-18: Methontology development activities (Gómez-Pérez, Fernández-López, & Corcho, 2004b)

According to Gómez-Pérez et al. (2004a), the knowledge acquisition, integration and evaluation is greater during ontology conceptualisation, and decreases during formalisation and implementation. Gómez-Pérez et al. (2004a) provide reasons as to why this occurs:

- Most of the knowledge is gathered at the beginning of the ontology building activity.
- The integration of other ontologies into the one under construction should be performed before the implementation.

- To avoid spreading error into the later stages of the ontology life cycle, conceptualisation must be evaluated.
- Documentation and configuration management are carried through the life cycle of Methontology development process.

2.12.2.4 Comparing ontology development methodologies

Pinto and Martins (2004), taking a historical perspective, claim that the first ontologies were constructed without reference to any method or methodology. Criteria were subsequently established as more ontologies were built and the ontology building process was better understood. According to Pinto and Martins (2004) TOVE was one of the first generation of ontology building methodologies, but they also point out that it possessed inadequate maintenance activities. Jones et al. (1998) mention that Methontology, when compared with TOVE, had a limited number of maintenance issues. Pinto and Martins (2004a), consider Methontology to be a second generation of ontology development methodology.

Choosing an ontology development process is not an easy task, and it would be impossible to find one best ontology development method that fits all situations (Breitman, et al., 2007a; Gómez-Pérez, et al., 2004a). Breitman et al. (2007a) suggest the best solution might be to choose the most appropriate method from among different possibilities or form a composition of different ontology development methods. Pinto and Martin (2004) suggest that Methontology and TOVE are the two of the most representative ontology development methodologies that could create ontologies from scratch. These two methodologies have their own unique features, which are set out as follows:

- Methonotology and TOVE adopt an ontology life cycle based on the evolving prototype life cycle model (Gómez-Pérez, et al., 2004a),
- TOVE adopted the stage-based model. Based on Jones et al. (1998) comparison, the stage-based approach seemed to be the most appropriate for the projects with a clearly defined purpose and requirements, whereas the evolving prototype model was more applicable when the purpose had not been clearly identified. Pinto and Martins (2004) suggest that the two methodologies have their own development stages.
- There is no separation between formalisation and implementation in the TOVE methodology, because knowledge is directly represented in first-order logic.

The ontology is intended to bridge the differences between the knowledge-based system and the reality (Jones, et al., 1998). Therefore, the connections between the formal and informal description are regarded as essential to the character of ontology development (Pinto & Martins, 2004). Pinto and Martins (2004) suggested some ontologies are more appropriate for building formal ontologies than others, some are more suitable for informal ones, and some allow for both. Based on the analysis carried out by (Pinto & Martins, 2004).

- TOVE allows the construction of formal ontologies because they are carefully implemented in first-order logic.
- Methontology is limited to the construction of formal ontologies. However, the intermediate representation used in Methontology helps to conceptualise knowledge and simplify implementation.

Jones et al. (1998) suggested that the comprehensive guidelines have to be provided as part of a complete methodology to assist developers in making choices at a variety of levels, from the high-level framework structure to the most detailed level. However, there are no approaches that cover all the process involved in ontology building.

- Mehtontology provides a more concrete set of guidelines and descriptions for each of its activities (Jones, et al., 1998).
- TOVE does not provide much guidance on how the activities should be performed (Jones, et al., 1998).

2.12.3 OWL / Protégé Ontology Construction Methodologies

Over the past decade there has been significant progress in the design and use of ontologies, and at the same time the size and complexity of the ontologies have increased (Janik, Scherp, & Staab, 2011). Solutions to address these issues include: the development and acceptance by the research and business community of the web ontology language OWL, the development of third generation ontology development methodologies, and the development of ontology authoring tools. In Chapter 4 of this thesis the decision is taken to use Protégé and OWL to construct the e-government ontology, and in this section only ontology development methodologies that use these two technologies are discussed.

- Ontology Language (OWL) is used to describe the ontology based knowledge structures (Horridge & Patel-Schneider, 2009)
- Protégé is a free, open source application for ontology development and editing that supports OWL (Protégé, 2007)

2.12.3.1 Kanga / ROO Ontology Development Method

Kanga is a tool that facilitates ontology construction that is specifically designed to meet the needs of the domain expert with the intention of speeding up the construction process and lead to higher quality ontologies (Kovacs, Dolbear, Hart, Goodwin, & Mizen, 2006).

Kanga is a methodology for authoring ontologies that takes into consideration two viewpoints. The first viewpoint is obtained from the domain expert who provides a human-readable description of what is required of the system. This is referred to as the conceptual aspect. The second viewpoint is referred to as logical aspect, which takes the conceptual ontology provided by the domain expert and converts it into a Semantic Web language such as OWL (Denaux, Dolbear, Hart, Dimitrova, & Cohn, 2010).

The ontology engineering process is iterative and includes four key steps as shown in Figure 2-19.

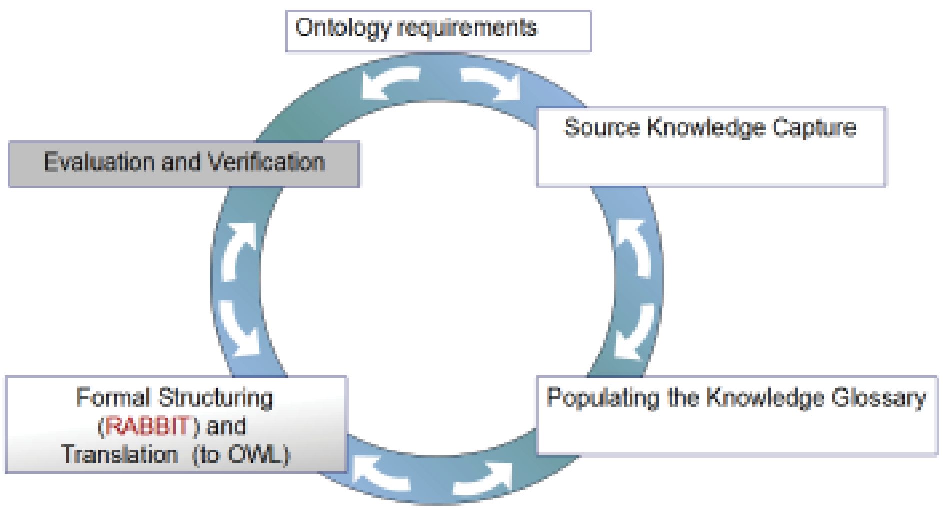


Figure 2-19: The phases of the Kanga Methodology (Denaux, et al., 2010, p.7)

The five steps have the following purposes:

1. The requirements of the ontology are identified including the scope and purpose.
2. Information is gathered from documents and other sources, including the possibility of reusing ontologies.
3. Information relevant to the proposed ontology content is entered into a knowledge glossary.
4. Key concepts and relationships are formally defined using structured English sentences, which are then converted into the web ontology language OWL.

5. The constructs within the ontology are verified and validated.

The domain expert is responsible for carrying out the first three steps without the involvement of knowledge engineers.

In the fourth step, the knowledge engineer converts the structured English sentences into OWL. In step 5, validation of the ontology is performed.

The knowledge glossary in step 3 consists of lists of key and supporting concepts, together with relationships. To support the documentary process and assist maintenance of each concept, relationship and instance are given a natural language description.

ROO (Rabbit to OWL Ontology authoring tool)

The names ROO, OWL, Rabbit and Kanga originate from animal characters in the A.A.Milne classic Winnie-the-Pooh (Milne, 1926).

ROO is a Protégé plug-in that guides and supports domain experts who have little or no knowledge of semantic engineering principles, to build conceptual ontologies (Denaux, et al., 2010). The key features of ROO are as follows:

- It is grounded on the Kanga ontology development methodology.
- A controlled language is used to submit knowledge constructs; this language reflects the needs of domain experts and is compliant with OWL 1.1.
- ROO guides and supports the user through the ontology construction process.

The main architectural elements of the ROO tool and their interactions are shown in Figure 2-20.

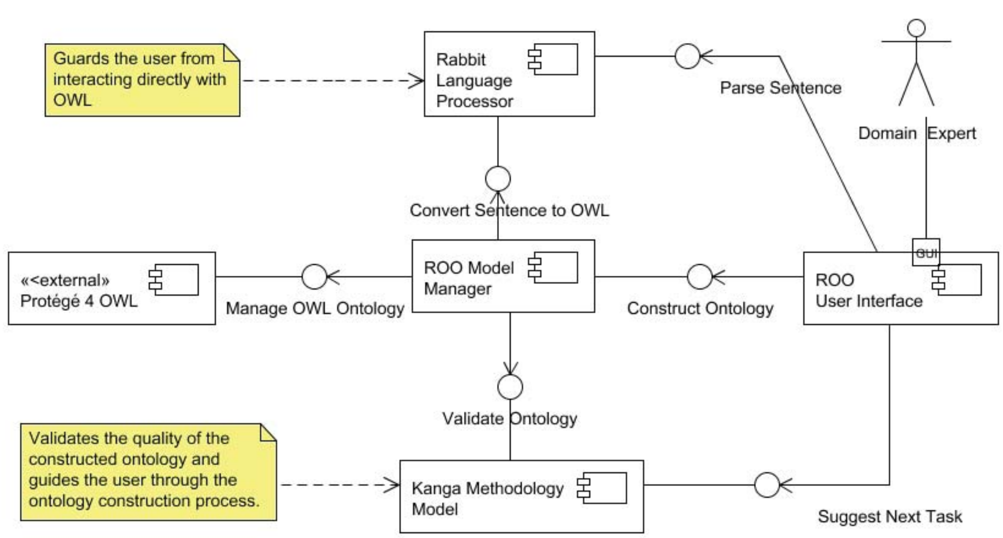


Figure 2-20: UML component diagram depicting architectural elements of ROO (Dimitrova, et al., 2008, p.4)

ROO guides the domain experts throughout the first three steps of the development process by offering task suggestion rather like a wizard, which monitors the user's activities and suggests appropriate actions that the user might then take.

Instead of directly editing OWL or the Manchester Syntax, the domain experts edit the ontology using the control language 'Rabbit'. Errors in syntax are highlighted by the Rabbit editor, which provides appropriate feedback. Finally, the error free sentences are parsed through the Rabbit Language Processor.

2.12.3.2 Noy and McGuiness Ontology Development Method

Noy and McGuinness (2001) suggested an iterative process to help designers to develop ontologies. The process model is inspired from the object-oriented system design and is based on their ontology-development experience using Protégé. Noy and McGuinness (2001) point out that major differences exist between the object-oriented system development and ontology development. For example, the object-oriented systems have primary focus on the behaviour and process of a class, whereas ontology systems have more focus on the structural properties of a class.

The seven steps of the Noy and McGuinness's (2001) iterative process are listed below:

Step 1: Determine the domain and scope of the ontology

Noy and McGuinness (2001) suggest beginning with the ontology development by asking series of questions, such as:

- What is the scope of the ontology?
- What is the domain of the ontology?
- For what we are going to use the ontology?
- What are the expected outcomes to be delivered from the ontology?
- Who are the target users of the ontology?

The answers to these questions help the developer limit the scope of the ontology. Answers to these questions may change during the development process, as this development process is an iterative process, and developers can always go back to these questions at any given time.

In this research, scope has been set within New Zealand e-government. This is based on the assumption that the structure of governmental agencies in New Zealand is representative of other governments internationally.

Noy and McGuinness's (2001) suggestion about asking the questions has been adopted. Instead of simply listing the questions, users are asked what they would like the product to provide, and this information is then recorded in a series of use cases. More details about defining the scope and domain are addressed in Chapter 6.

Step 2: Consider reusing existing ontologies

Noy and McGuinness (2001) suggest the developers to try to find similar ontologies. If the developer is able to refine and extend the located ontology then it is incorporated into the current ontology. The purpose of reusing the existing ontologies is to save the developers time and money. According to Noy and McGuinness (2001), lot of ontologies have been developed in electronic form and can be imported into an ontology development environment such as Protégé. However, in this research, no obvious New Zealand based e-government ontologies are available. However, ontologies such as Dublin Core and FOAF could be imported to ease the problem of naming basic attributes, and increase the opportunity to link with other ontologies with similar naming conventions.

Step 3: Enumerate important terms in the ontology

It is useful to write down all the terms related to the domains that may appear in the ontology. This process is similar to brainstorming which is often suggested as something that should be done at the beginning of a traditional system design. This process can assist the developer identify concepts within the model. In this research, some of the important concepts that could be included are MPs, Political Parties, Ministries, Parliamentary roles, water and geographic areas.

Noy and McGuinness (2001) consider the two most important steps in ontology design are developing the class hierarchy and defining properties of classes. Usually the developer will make some classes in the hierarchical order and then continue with describing properties of these classes. As it is an iterative process, developers will repeat these two steps a number of times.

Step 4: Define the classes and the class hierarchy

Noy and McGuinness (2001) suggest there are three different approaches that can be used to develop a class hierarchy:

- Top-down development process: This process begins with the identification of the most general terms in the domain, followed by the identification of the more specialized terms. For example, in this research, Geographical entity and Governance Structure could be viewed as the more general terms (classes), and more specialised terms would be New Zealand Geographical Regions and Parliamentary Electorate Regions.

- Bottom-up development process is the opposite of top-down development; it starts with the most specialized terms and then moves to identify the general terms.
- Combination development process is a combination of the top-down and bottom-up approaches. The developer may start with some noticeable terms within the domain, and then generalize or specialize in an appropriate way.

According to Noy and McGuinness (2001) and Breitman et al. (2007a) there is no best way of developing an ontology. The approach adopted by developers to some degree depends on the developer's view of the structure of the domain and the ontology. However, Noy and McGuinness (2001) also point out that the combination approach is usually the easiest way for many ontology developers as starting with the terms in the middle tends to provide more descriptive concepts in the knowledge domain.

Step 5: Define the properties of classes

The terms created in Step 1 cannot all be treated as classes. Some of the terms such as title and personal profile are properties of the Person class, and these properties become slots attached to classes. There are two major types of properties: object properties and datatype properties. Object properties are relationships between two individuals, whereas datatype properties describe the relationship between an individual and data values. The data values are usually represented in XML Schema Datatype value or an `rdf literal`. Figure 2-21 describes the two types of properties:

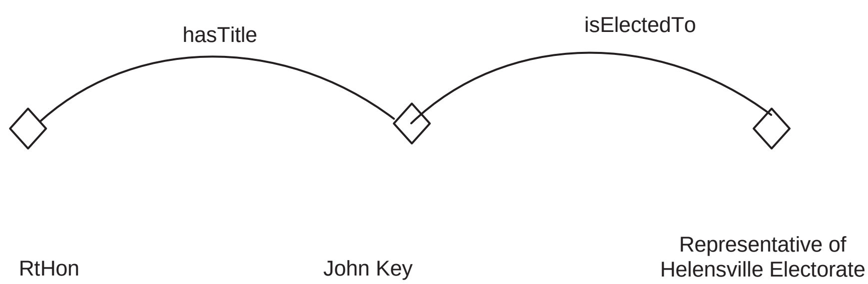


Figure 2-21: Illustration of the property `isElecteTo` and hasTitle

- The object property, isElectedTo, links the individual John Key to the individual electorate of Helensville.
- The datatype property, hasTitle, links the individual John Key to the data literal RtHon, which is of type xsd:string.

All subclasses of its upper classes inherit the property of that class. For example, all the properties of the class `PoliticalParty` will be inherited by all subclasses of `PoliticalParty`.

Step 6: Define the facets of the properties

Noy and McGuinness (2001) point out that aspects related to the properties include the value type of the properties, the cardinality, and other values the property can take, such as domain and range of the property. In OWL, the object property is used to describe relationships between two individuals; a class of individuals is defined by the relationships that these individuals belong to. Restrictions are then applied to define these classes in OWL, such as cardinality restrictions.

Property cardinality

Cardinality (cardinality restrictions in OWL) defines how many values a property can take. Property cardinality can be specified numerically in Protégé OWL, where maximum cardinality of N means a property must have at most N values, for example, a person can be only elected to at most one position as a member of Parliament, or a person may not be elected as a member of the Parliament.

Property type

As described before, a datatype property links the individual with an XML datatype value, where a value-type facet describes what type of values a property can take. Noy and McGuinness (2001) list the most common value types as follows:

- String: The value of it is a simple string; it is used for properties such as name, title.
- Number: Describes properties with numeric values.
- Boolean: Simply yes-no flags.
- Enumerated: Specifies a list of specific allowed values for a property.

Domain and range of a property

Properties link individuals from the domain to individuals in the range, for example, the property `hasPoliticalParty` would link individuals belonging to the class `Person` to individuals belonging to the class `PoliticalParty`. In this case, the domain of the `hasPoliticalParty` is `Person` and the range is `PoliticalParty`. Noy and McGuinness (2001) suggest several different ways of defining the domain and the range. One approach would be to define a domain and a range for a property; another approach might take the most general classes to be the domain or range. However, Noy and McGuinness (2001) suggest there should be a balance between general and overly general, for example, some individuals in the `Person` class may be assigned to some `AssignedGovernancePosition`. In this case, `Person` class becomes the domain for property `isAssignedTo` and `AssignedGovernancePosition` becomes the range. In Figure 2-22 there are five main subclasses under `AssignedGovernancePosition`. Instead of applying the property `isAssignedTo` to each of the possible subclasses of `AssignedGovernancePosition` class it is only necessary to apply the relations to `AssignedGovernancePosition`, as all the subclasses of `AssignedGovernancePosition` will inherit all the properties from its upper class. On the other hand, the range cannot be too general. The `Thing` class is regarded as the most general class in the ontology.

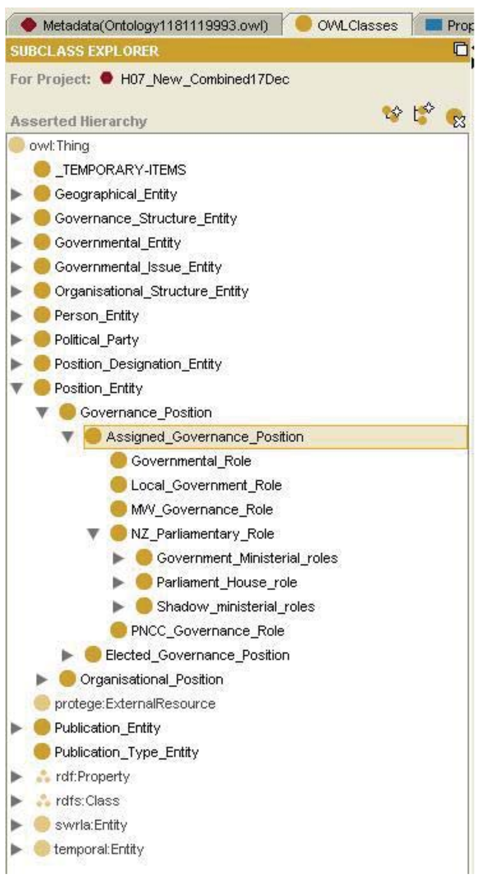


Figure 2-22: The hierarchical class structure of 'AssignedGovernancePosition'

Step 7: Create instances

Creating individual instances of class is the final step in the ontology development processes. Noy and McGuinness (2001) propose three ways to create individuals: choosing a class, creating an individual instance of the chosen class, and filling in the value or related individual for its responded properties. Figure 2-23 shows the definitions for individual `Anderton_Jim` in `Person` class.

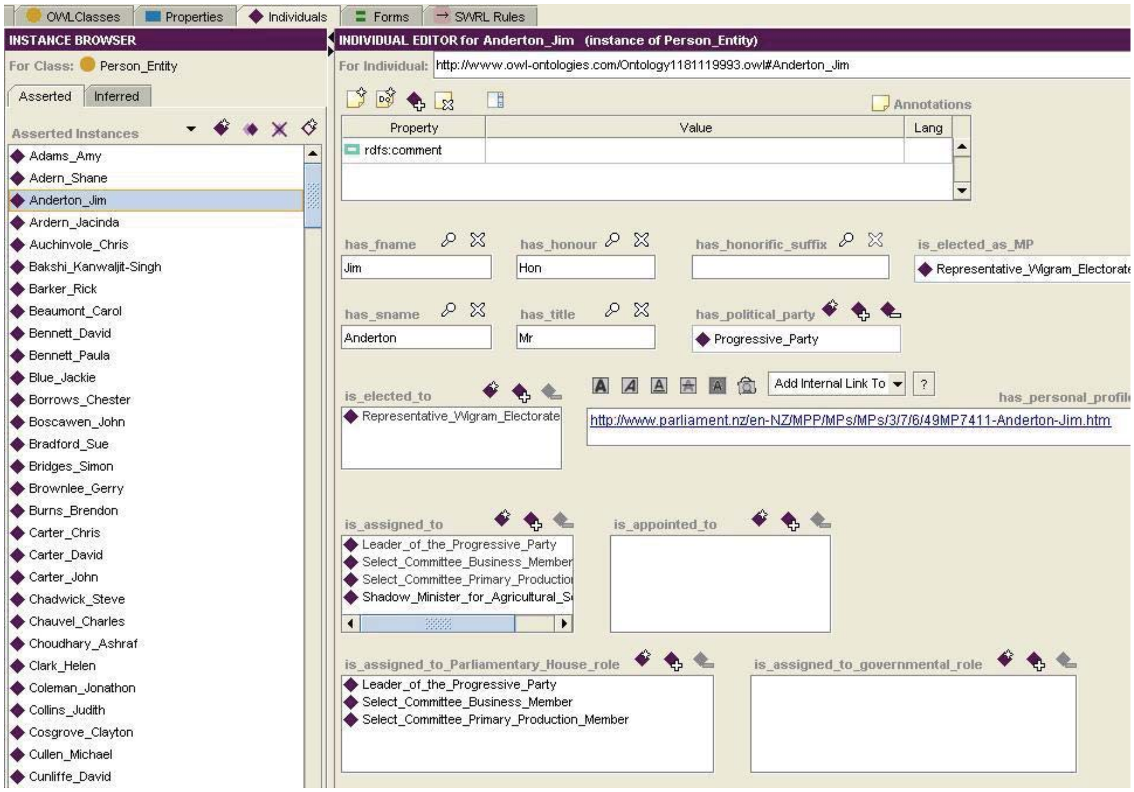


Figure 2-23: Defining the instance `Anderton_Jim` in the `Person` class

2.12.3.3 Use cases

Many practical suggestions embedded in ontology development methodologies include the use of use cases (Benbasat, Goldstein, & Mead, 1987; Bjorn-Anderson, 1985; Boland, 1985). It is a practical way to identify the target audience, the actors involved and the sources of information and, of course, the deliverables. More information on this topic can be found in Chapter 5.

2.12.3.4 Choosing an ontology development method

The semantic framework under considertion is expected to be fairly large, complex and to require the researcher to perform all the roles of semantic engineer and a significant number of the domain experts roles. From that perpspective alone the researcher would benefit greatly if the methodology was able to be dovetailed into an ontology authoring tool such as Protégé-OWL or TopBraid Composer.

In terms of the ontology development methods discussed in this review, both Noy and McGuinness (2001) and Kanga (Denaux, et al., 2010) are both very promising. That is not to say that the Methontology could not be used but there was little evidence in the literature that it had been used with Protégé by many researchers. Although Kanga could be used with Protégé or TopBraid Composer all the literature links it to ROO methodology.

Of the two possibilites, the Noy and McGuinness' (2001) approach provides a more detailed set of guidelines than Kanga. In fact, they have many steps in common. The major difference is the role of the domain expert; this is significant in Kanga's case and as access to such domain experts in the current research is unlikely, the Noy and MacGuinness (2001) approach is found to be the most suitable.

Also taking into consideration Breitman et al.'s (2007a) comment that there is no one methodology that meets all the requirements of specific situation, the most promising approach would be to adapt Noy and McGuinness' (2001) approach by adding a step to include use cases as a way of generating competency questions and establishing system requirements.

2.13 Ontology Evaluation

The focus of modern information systems is moving away from "data processing" towards "concept processing" (Boudreau, et al., 2001). In other words, the object of interest is no longer an atomic piece of data but a semantic concept, which is located and interpreted within a particular perspective. The developer is able to provide several solutions to a given problem, and in the case of ontology development, several different ontologies can be constructed representing different perspectives of the same corpus of knowledge. Nevertheless, one should be able to say which one suits a predefined set of criteria the best.

The literature appears to support the notion that ontology evaluation is concerned with the process of assessing an ontology from the point of view of a particular set of criteria, in order to determine whether the given ontology provides a better set of outcomes than another ontology or application. Ontology evaluation assists the ontology engineer to select ontologies that match his/her needs the best (Hartmann, et al., 2004).

2.13.1 Evaluation Approaches

The choice of an evaluation approach depends on what is being evaluated and for what purpose. Brank et al. (2005) suggest four different categories:

- Comparison against a 'gold standard'
- Using an ontology within an application and evaluating the results

- Comparisons with a source of data about a domain of interest covered by the ontology
- Evaluation by humans to determine how successful the ontology meets a set of predefined criteria

Brank et al. (2005) suggest a number of approaches to evaluation that fall into two main categories: evaluating competing ontologies and comparing the ontology to the corpus of knowledge to which the ontology refers. It is the latter of the two categories, which is the most important in this research.

There are inherent problems in trying to evaluate an ontology as there may be some uncertainty as to what is being evaluated (Brewster, Alani, Dasmahapatra, & Wilks, 2004). A particular ontology reflects the interests of the knowledge users whose interests and expectation were taken into consideration when the design of the ontology was undertaken. One approach might be to present users with the ontology and ask users to rate its usefulness in terms of some agreed criteria. In this case, identifying the users is crucially important as are the possible evaluation criteria, such as complete, correct, coherent and sensible (Brewster, et al., 2004). Brewster et al. (2004) suggest an approach, which addresses the degree of congruence or ‘fit’ between the ontology and the corpus of knowledge it is expected to represent. Brewster et al. (2004) propose a three-step approach to data-driven evaluation:

- Identify keywords and terms: A measure of the degree of congruence between the lexical terms in the corpus compared with those in the ontology.
- Query expansion: A measure of how effective the ontology is at taking a ‘seed’ query and reformulating it to improve retrieval performance.
- Ontology mapping: A measure of the percentage of the set of terms identified in the corpus that is mapped to the ontology.

Gangemi, Catenacci, Ciaramita and Lehmann (2006) provide an integrated formal model for the evaluation and validation of ontologies. They model evaluation as a diagnostic task involving ontology descriptions which include the roles and functions of the component elements. Gangemi et al.(2006) define three main types of evaluation: functional, usability-related, and structural evaluation.

Functional evaluation focuses on measuring how well the ontology is serving itspurpose. This is an approximate measure as the relationship between an ontology and a conceptualization is by no means clear cut (Guarino, 2004). Appropriate functional measures that are widely used in information retrieval (Baeza-Yates &

Ribeiro-Neto, 1999) were modified by Gangemi et al.(2006) to apply to ontology evaluation:

Precision

$$OP = \frac{n_{TP}^{O_k(L)}}{n_{TP}^{O_k(L)} + n_{FP}^{O_k(L)}}$$

Recall

$$R = \frac{n_{TP}^{O_k(L)}}{n_{TP}^{O_k(L)} + n_{FN}^{O_k(L)}}$$

where

$O_k(L)$ set of models relative to a given conceptualization C and logical language L

$n_{\mathrm{TP}}^{O_k(L)}$ number of True Positives for the ontology

$n_{FP}^{O_k(L)}$ number of False Positives

$n_{FN}^{O_k(L)}$ number of False Negatives

According to Gangemi et al.(2006) precision and recall of an ontology graph can be measured using experts. Usability profile evaluations are concerned with the quality and usefulness of the annotations, which contain information about structural, functional and user-oriented properties of the ontology (e.g. versioning, ownership) Gangemi et al.(2006). Structural evaluation focuses on syntax (e.g. graph structure) and on formal semantics. The approach is to define a general function that enables the number of graph properties to be counted. These properties could include depth and width of the graph, density, or modularity Gangemi et al. (2006).

Hartman et al. (2004) consider ontology content evaluation and usability particularly useful prior to using the ontology in IT systems. They make a distinction between black box (task-based) and glass box (component) testing. In the black box scenario, the ontology is tightly integrated in an application in which the overall performance is measured and compared with previous evaluation data. Glass box testing usually involves evaluation at three points in the development life cycle: (1) in the pre-modelling stage, (2) during the modeling stage, and (3) after its release. Hartman et al. (2004) go on to describe a classification grid for ontology evaluation methods based on the following questions:

- What is the method like in terms of its goal, functions it supports, and at which stage can it be applied?
- How useful is the method for developers, engineers and project managers, and how usable is it (usability) and for what type of use cases?

Fensel (2001) distinguished between heavyweight and lightweight ontologies to express axiomatic richness of an ontology. Heavyweight ontologies make intensive use of axioms to model knowledge and restrict domain semantics, whereas those that do not are referred to as lightweight ontologies.

A more pragmatic approach to ontology evaluation has been taken by Noy (2004) who has argued that, although most functional and structural evaluation approaches are necessary for experts, none are really useful for consumers whose requirements are to determine which ontologies exist and which ones are applicable to the consumers' specific needs. Using this pragmatic approach three techniques have been proposed by Noy (2004):

- Ontology summarization: The provision of an abstract summary of what the ontology covers.
- Epinions for ontologies: The provision of a rating system for ontologies not unlike those provided for consumers using epinions.com.
- View and customization: The provision of a view of an ontology that takes into consideration features of the ontology and the level of expertise required of the user.

2.13.2 Ontological Richness

Metric-based techniques offer a quantitative perspective of ontology quality. OntoMetric (Lozano-Tello & Gomez-Perez, 2004), OntoClean (Guarino & Welty, 2002, 2004) and OntoQA (Tartir, Arpinar, & Sheth, 2008) are perhaps the most widely known. OntoMertric consists of a hierarchical framework distributed across five dimensions. Once the framework is populated, the suitability of the ontology can be determined. OntoClean involves assigning four features to each class in the ontology, namely rigidity, identity, unity and dependence. These features are then used to detect violations of rules built into the four features. The OntoQA evaluation tool differs from the other two tools in that it works on populated ontologies. By taking into consideration the 'instance information', a better measure of the quality of the ontology can be obtained.

OntoQA provides two categories of metrics: key schema metrics and key instance-based metrics. Key schema metrics are associated with the design of the ontology and key instance-based metrics are concerned with the placement of instance data within the ontology (Tartir & Arpinar, 2007; 2008):

2.13.2.1 Key Schema Metrics

- Relationship Richness: This metric measures the ratio of properties and sub-classes for a class and reflects the diversity of the types of relationship in an ontology. The assumption is made that an ontology that contains mainly inheritance properties is less rich than the one that has a larger proportion of non-inheritance properties.

  $$RR = \frac{|P|}{|H| + |P|}$$

  where (|P|) to the total number of non-inherited properties defined in the schema, and |H| represents the number of inherited properties.

- Inheritance Richness: The inheritance richness metric measures the average number of sub-classes per class. In essence, it measures the distribution of information across the different levels of the ontology's inheritance tree. Hence, a shallow (or horizontal) ontology would indicate a wide range of knowledge with possibly a lower level of detail.

  $$IR = \frac{|sub\mathrm{C}|}{|C|}$$

2.13.2.2 Key Instance metrics:

- Attribute Richness: The attribute richness metric measures the average number of attribute properties per class. This metric reflects the quality of the ontology design and the amount of information pertaining to instance data. A shallow (or horizontal) ontology would indicate a wide range of knowledge with a lower level of detail.

  $$AR = \frac{|\mathrm{att}|}{|C|}$$

- Class Richness: The class richness metric measures the distribution of instances over classes. It is defined as the ratio of the number of non-empty classes (classes with instances) to the total number of classes in the ontology.

  $$CR = \frac{|C'|}{|C|}$$

- Connectivity: This metric is defined as the number of instances of other classes that are connected to instances of the selected class (Cn). The sub-tree root classes would form the set C(Cn).

  $$Cn = |I_j, P(I_i, I_j) \wedge I_i \in C_i(I)|$$

- Class importance (Imp):

Essentially, this metric is concerned with the distribution of instances over classes. This measure is defined as the number of instances that belong to the sub-tree rooted Ci, compared to the total number of instances in the KB.

$$Imp = \frac{|C_i(I)|}{|I|}$$

- Inheritance richness (IR): This metric describes the distribution of information in the chosen sub-tree per class. It is defined as the average number of subclasses per class in the sub-tree

$$IRc = \frac{\sum_{C_i \in C} |H^c(C_i, C_j|}{|C'|}$$

Classes in an ontology with a very specific domain will have a low IR_c, while a wide domain ontology will have a high value.

2.14 Chapter Conclusion

There are a number of review topics in this thesis which have not been described in this chapter but have instead been placed in chapters where their relevance is more apparent. For example, in Chapter 4, a review of research philosophies, paradigms, methodologies and methods is performed, including design science research. In Chapter 4, a review and comparison of the semantic languages and ontology authoring tools is undertaken, and ontology evaluation approaches are described detailed in Chapter 7.

The following chapters will describe the findings from two points of view. Firstly, it will show how a semantic e-government framework is designed, developed and constructed and how useful it will be for future researchers and developers of semantic e-government, and secondly it will show that design science research has been performed which will have a positive effect on future information systems research where semantic technologies are a central component.

3 RESEARCH STRATEGY

After a brief description of the nature of research the chapter discusses the philosophical foundation of research paradigms and assumptions. The research strategy followed in this research is that proposed by (Crotty, 1998, p. 7). The justification for this approach is that Crotty's approach has been widely supported by social science researchers for many years. His book, *The foundation of social research: Meaning and perspectives in the research process* (1998), is widely cited in the literature, for example Google Scholar (2011) has Crotty's book cited 2189 times; specific citations include (Blaxter, Hughes, & Tight, 2006; Creswell, 2007; Scale, 1999). Sections of the chapter are devoted to each of the steps suggested by Crotty to identify the most appropriate research methodology and methods for this research.

The chapter concludes with a description of the overall research strategy adopted in this thesis with detailed analysis and justification of the methods used to gather and evaluate the information.

3.1 Research and how is it performed

There are many definitions of research in the literature. The Compact Oxford English Dictionary ("Research," 2009) and the Cambridge Advanced Learner's Dictionary ("Research," 2008) consider the essential elements of research to be a systematic study that contributes to a better understanding of a phenomenon. Stenhouse (1981), strongly associated with education research, considers research to be "a systematic and sustained inquiry, planned and self-critical, which is subjected to public criticism and empirical tests where these are appropriate" (p. 113). Vaishnavi and Kuechler (2008), from their perspective of 'Design Science Research', define research as, " an activity that contributes to the understanding of a phenomenon " (p. 7).

On the basis of these definitions it would be reasonable to conclude that the principal aim of research is to contribute to a body of knowledge by improving our understanding of a given phenomena, designing and constructing an innovative artefact, devising a new application, and ensuring the approach and findings are open to public defence.

Crotty (1998) suggests that in developing research, the researcher should be concerned with asking four questions:

- Epistemology: What epistemology informs the theoretical perspective underpinning the research?

- Theoretical perspective: What philosophical stance is required to inform the choice of methodology and therefore provide a context for the process and the grounding of its logic and criteria?
- Methodology: What methodology governs the strategy, plan of action, and the process or design that lie behind the choice and use of particular methods?
- Methods: What methods, techniques or procedures are to be used to gather and analyse data related to the research question or hypothesis?

This approach complements the views expressed by Burrell and Morgan (1979), who described how a person's philosophy and assumptions about the world can be applied to research at three levels: The philosophical level, which represents beliefs about the world; the social level, which describes how research should be carried out, and the technical level, which states what methods and techniques should be used.

A graphical representation of Crotty's four questions is illustrated in Figure 3-1.The figure has been adapted from the Saunders, Lewis and Thornhill (2007, p. 132) 'research onion'. The outside layer provides an overview of philosophical enquiry. It includes branches of philosophy such as epistemology and metaphysics, and academic philosophies such as religion, language and science. In the figure the academic philosophy of science is divided into two groups, interpretivism and positivism. The next layer is the theoretical perspective in the form of research paradigms. A representative set of research methodologies is then displayed primarily associated with the interpretivist and design science paradigms. The inner layer simply references qualitative and quantitative methods of enquiry.

The arrowed lines represent the path taken by the researcher in addressing Crotty's four questions. In the outer layer the choice of epistemology is made. The next layer is concerned with identifying the most appropriate philosophical stance. The choice of methodology and methods are determined in the final two layers.

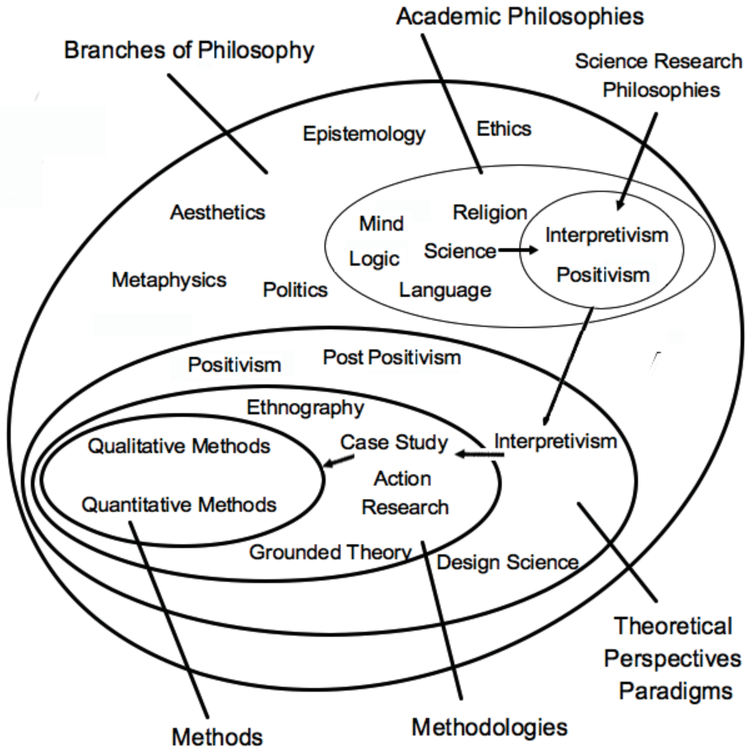


Figure 3-1: The research onion (Adapted from Saunders et al. (2007, p. 132))

With reference to this research, Crotty's four questions are answered in the following four sections of the chapter. At the end of each section a rationale is provided to justify the answer given. The answer then guides the direction of the research process in the following section where Crotty's next question is addressed.

3.2 Research Philosophy

Addressing Crotty's four questions in systematic and thoughtful manner enables the researcher to choose the most appropriate research methodology and methods to address the research question.

This is the first step in ascertaining what methodology and methods are appropriate to address the research aim and research question identified in this thesis. Answering Crotty's first question provides an answer to part of the first sub-question stated in Chapter 1 "What epistemology is appropriate for this research?"

3.2.1 Branches of Philosophy

Philosophy can be divided into a number of branches. Five of the most referenced are: metaphysics, epistemology, ethics, politics, and aesthetics (Landauer & Rowlands, 2010). The first three are where the majority of philosophical activity falls, and it is these three that are considered in this section of the chapter. The paraphrased definitions are largely based on those provided online by the School of Philosophy, Divinity and Religious Studies at the University of Aberdeen (University of Aberdeen, 2010).

3.2.1.1 Metaphysics

Metaphysics deals with the so-called first principles of the natural order, and is concerned with explaining the fundamental nature of reality, of being, and the world. The fundamental questions include: Can we act freely? What is existence? What is time and space? Even questions such as, 'What is body and soul?' fall under the metaphysical umbrella ("Metaphysics," 2010)

3.2.1.2 Epistemology

Epistemology is the study of knowledge. It is concerned with such questions as: Is knowledge of anything really possible? Is our knowledge certain? How do we get our knowledge? What things can we have knowledge about? What exactly is knowledge? ("Epistemology," 2010). Maynard and Purvis (1994) state that, “Epistemology is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate” (p. 10).

3.2.1.3 Ethics

Ethics is the study of values, for example, the rightness and wrongness of actions. It is concerned with such questions as: What is good/evil? Is there such a thing as objective morality or do we, or some other beings create it? How we should live our lives? (Lu, Dong, & Fotouhi, 2002).

3.2.2 Research Philosophy

A research philosophy is concerned with taking ‘what is believed to be true’ to ‘what is known to be true’ (Klischewski, 2003). More pragmatically, it is a belief about the way in which data associated with an observable occurrence should be gathered, analysed and used.

Most academic subjects have a philosophy, for example the philosophy of science, philosophy of mathematics, philosophy of logic, philosophy of law, and philosophy of history. In Figure 3-1, only the relationship between epistemology and philosophy of science is shown; others not considered relevant to this research have been omitted. Generally speaking, the philosophy of science is concerned with the assumptions, foundations, methods and implications of science, but there are other spheres of interest that fall within the philosophy of science, such as metaphysics, logic and ethics. A particular philosophy of science, which is of high relevance to this research activity, is that of design science. This philosophy places emphasis on the knowledge that accrues when a scientific or technical artefact is created. It places less importance on the utility of the artefact and more on the design and construction process.

3.2.3 Section Summary and Conclusion

In order to address the research aim of this thesis a number of sub-questions have to be answered. The principal ones are those concerned with the processes involved in the methods, design, construction, effectiveness and efficiency of both the semantic framework and associated web-based interface. Cross (2001) asserts that the science of design,

> …refers to that body of work which attempts to improve our understanding of design through “scientific” (i.e. systematic, reliable) methods of investigation…the study of the principles, practices, and procedures of design…includes the study of how designers work and think, the establishment of appropriate structures for the design process, the development and application of new design methods, techniques and procedures, and reflection on the nature and extent of design knowledge and its application to design problems. (p. 53)

In addition, there is a requirement in this research to demonstrate that the knowledge gained makes a significant contribution to the field of technology and science. These assertions strongly suggest that design science falls within the philosophy of science, therefore the other branches of philosophy are therefore not considered.

3.3 Research Paradigms and Assumptions

This is the second step towards the goal of ascertaining what methodology and methods are appropriate to address the research aims and research questions identified in this thesis. In answering Crotty’s first question the underlying epistemology is now assumed to be the ‘Philosophy of Science’. This second step seeks to answer Crotty’s second question, “What theoretical perspective should be adopted?” The result of this process will determine the research paradigm and associated research assumptions.

3.3.1 Research Paradigms

The Merriam-Webster online dictionary defines a research paradigm as “a philosophical and theoretical framework of a scientific school or discipline within which theories, laws, and generalizations and the experiments performed in support of them are formulated” ("Paradigm," 2011).

According to Hussey and Hussey (1997), the term research paradigm describes the progress of scientific practice taking into consideration the assumptions and philosophies of those involved, the nature of knowledge, and how the research process should be carried out. Kuhn (1996) considers that assumptions or beliefs about the world can be considered a paradigm. Piaget's "schema" and Senge's (2006) "mental models" are forms of paradigm that are found in education research, but the overall perspective is the same; they seek to support the organisation of information taken from the world around us. Essentially, the paradigm is a framework consisting of an accepted set of theories, methods and ways to define data.

Kuhn (2001, pp. 35-42, 92, 99-100) believes that research consists of three phases: the pre-paradigm phase, the normal phase, and the revolutionary phase.

- Pre-paradigm phase: In this phase there is no consensus on any particular theory. This phase is characterized by several incompatible and incomplete theories. If the actors eventually move towards one conceptual framework and there is significant agreement as to an appropriate choice of research methodology and techniques then the science moves onto the next phase.
- Normal science phase: This second phase is characterised by a series of experiments to address and solve puzzles within the dominant paradigm. If serious anomalies arise, and if they cannot be resolved within the existing paradigm, then the research moves to the revolutionary phase.
- Revolutionary phase: In this phase the underlying assumptions of the field of endeavour are re-examined and a new paradigm is established. Once the new paradigm is accepted then the science returns to the second phase, and normal science is performed.

Kuhn goes on to suggest that sometimes it is necessary to iterate through the last two phases until the desired outcomes are achieved.

In the Western tradition of science, two major research philosophies dominate, namely positivism and interpretivism (Galliers, 1991; Hussey & Hussey, 1997). Orlikowsky and Baroudi (1991) proposed three categories based on the underlying research epistemology; positivism, interpretivism, and critical theory. Guba and Lincoln (1994) went further and identified four philosophies for qualitative research; positivism, post-positivism, critical theory, and constructivism. Simon (2008) suggests that design science is a research paradigm.

Rather than adopt a single philosophical approach it is probably more useful for the researcher to think of a continuum of research assumptions and practices from which the researcher may select depending on the nature of the research problem. In keeping with this approach, and applying it to ‘business’ research, Channon (1982) argues that the positivist and interpretivist paradigms are both valid in ‘business’ research and have relevance to most forms of research. However, the weight or authority one should attach to each of them might be an issue that will need careful consideration.

The following five paradigms associated are considered in this report: positivism, post positivism, design science, critical theory and constructivism.

3.3.1.1 Positivist Paradigm

French philosopher August Compte laid the foundation tenets of positivism (also called logical positivism) in the nineteenth-century. Positivists generally assume that reality is objectively given and can be described by measurable properties, which are independent of the observer (researcher) and the research instruments (Levin, 1988). Levin goes on to state that from a positivist standpoint phenomena should be isolated and that observations should be repeatable. This usually involves manipulation of reality with variations in only one single independent variable and the observation of changes in the dependent variables in order to propose relationships between them. The intention is to enable predictions to be made.

Lincoln and Guba (1985) have provided a contemporary view of the positivist paradigm. Lincoln and Guba made the following points about what they believe of positivism:

- Ontology: There is a single reality.
- Epistemology: The knower and the known are independent.
- Axiology: Inquiry is value-free.
- Generalisations: Time and context free generalisations are possible.
- Causal links: There are real causes which are linked to effects.
- Deductive logic: Emphasis is placed on arguing from the general to the specific (a priori hypothesis testing).

Salamani and Akbari (2008) added the following complements to the positivist view provided by Lincoln and Guba:

- Methodological: All research endeavours should be quantitative and that is the only way that valid generalisations and laws can be substantiated.
- Operational: Having concise and meaningful definitions increases the likelihood that facts can measure quantitatively.

- Reductionistic: In order to improve understanding of a concept, problems should be reduced to the simplest possible elements.

Positivism has had a particularly successful association with the physical and natural sciences. However, the ontological, epistemological and methodological positions of positivism have been questioned for some time by philosophers, psychologists and historians of science (Hanson, 1958; Hirschheim, 1985; Sabol & Mach, 2006). Many authors are calling for a more pluralistic attitude, particularly towards information systems research methodologies (Bjorn-Anderson, 1985; Leffingwell & Widrig, 2001; Remenyi & Williams, 1996). On the other hand, Orlikowsky and Baroudi (1991), making specific reference to information systems research, claim that a quantitative research methodology still has a role in information systems where measures of variables under investigation can be quantified, where hypotheses can be formulated and tested, and where inferences about a phenomenon can be made by taking a sample from a stated population.

3.3.1.2 Post Positivist Paradigm

In the mid-1950s, scientists and philosophers such as Jacob Bronowski and Karl Popper began to question the use of the strict, traditional positivist paradigm, and thus there emerged a new philosophy, that of post-positivism (Bronowski, 1956; Popper, 1959).

Post positivism is consistent with positivism in assuming that an objective world exists but it assumes the world might not be fully understood and that variable relations or facts might be only probabilistic, not deterministic. This suggests that the stringent philosophical positions of positivism have to take into account our less than perfect knowledge of reality and our lack of ability to be totally objective and detached, particularly in social situations. Miles and Huberman (1993) record that in the early 1990s, post positivists began to blend qualitative methods to positivistic methods and experimental designs (Miles & Huberman, 1993). Guba and Lincoln (1994) propose three amendments to positivism when defining post positivism:

- An objective reality cannot be perfectly understood.
- Researchers are subjective and, as such, can only know about reality to a degree of probability.
- Experimental method can be used, including hypothesis refutation, using both quantitative and qualitative methods.

Miles and Huberman (1994) propose a set of evaluation criteria based on the post positivist approach:

- Objectivity / Confirmability: Is there freedom from unacknowledged researcher bias? Is there explicitness about inevitable bias?
- Reliability / Dependability: Is the process of the study consistent and reasonably stable over time and across researchers and methods?
- Internal Validity / Credibility / Authenticity / Truth-value: Do the findings of the study make sense? Are they credible to the people studied, members of the research community, and others?
- External Validity / Transferability / Fittingness: Do the conclusions of a study have any larger import? Are they transferable to other contexts? Do they fit with what we already know? How far can findings be generalized?
- Utilization / Application / Action Orientation: What does the study do for participants? What is the pragmatic value of the research?

3.3.1.3 Interpretivist Paradigm

The study of phenomena in their natural environment is the key to the interpretivist philosophy together with the acknowledgement that scientists cannot avoid affecting those phenomena they study. Interpretivist researchers acknowledge that there may be many interpretations of reality, but maintain that these interpretations are in themselves a part of the scientific knowledge they are pursuing.

Interpretivists contend that only through the subjective interpretation of, and the intervention in reality, can reality be fully understood. Interpretivists assume that knowledge and meaning are acts of interpretation; hence there is no objective knowledge that is independent of thinking by thoughtful humans. Interpretive research is fundamentally concerned with meaning and it seeks to clarify and understand each person's definition of a situation (Schwandt, 1994). Kaplan and Maxwell (1994) suggest that as interpretive research unfolds the focus will fall upon the human mind to make sense of what has been observed.

Interpretive researchers make the assumption that access to reality can only be achieved through social interactions such as language, consciousness and shared meanings. Borland (1985) argues that the philosophical base of interpretive research is hermeneutics (study of interpretation theory), and phenomenology (study of human experience). Interpretive researchers seek to understand phenomena by examining the significance assigned to them by actors in the environment.

Interpretivists reject the notion that observations are theory-neutral; they also reject the existence of universal laws. According to Guba and Lincoln the interpretivist takes a different position (1994):

- If there is agreement between competent and trusted researchers then knowledge based on accepted constructions is formed.
- If there is no agreement then multiple 'knowledges' can coexist.

Bryman (2004) and others, including more recently Morgan (2007), argue for a more pragmatic approach to research where thematic elements from both the qualitative and quantitative paradigms combine. Mingers (2001) has a similar view when he states that "different research methods (especially from different paradigms) focus on different aspects of reality and therefore a richer understanding of a research topic will be gained by combining several methods together in a single piece of research or research program" (p. 241).

Interpretivism promotes the use of qualitative data in the creation of knowledge about a phenomenon (Kaplan & Maxwell, 1994). The paradigm takes a unique situation and attempts to make deep contextual meaning (M. D. Myers, 1997). However, the legitimacy of the approach is being challenged in terms of reliability, validity, and generalisability.

- Reliability: Reliability describes how well a particular assessment method provides consistent results. Triangulation, where several independent methods are used to study the same phenomena, has a greater reliability than a single methodological approach. According to Hammersley and Atkinson (1983) qualitative research findings can be made more reliable if the researcher combines participant observation with interviews and documentary sources.
- Validity: Qualitative research depends on the presentation and analysis of dependable descriptive data. In this way, the researcher creates a better understanding of the learning experience gained during the study. Remenyi, Williams, Money and Swartz (1998) suggest three ways to strengthen validity: obtain data from multiple sources, provide a chain of evidence, and have experts review the process [artefact].
- Generalisability: Generalisability is a measure of the extent to which the knowledge gained during the study is applicable to situations outside the specifics of the current enquiry (Weber, 1997). In the interpretive situation the research goal is to provide sufficient case description (including data collection procedures) that would allow a researcher to follow a similar process in another case (Allemang & Hendler, 2008). A single case study is unlikely to provide

sufficient evidence to make meaningful generalisations; however, it can be very useful if it can confirm the presence of an unrecorded phenomenon (Van Maanen, 1988). According to Remenyi et al. (1999), this is adequate for the purposes of exploratory research. Yin (2003) suggests that a case can be generalisable to theoretical propositions.

The interpretivist approach has been growing in strength in the Information Systems field from the mid 1990s onwards (Klein and Meyers, 1990, Walsham, 1993, Walsham 1995). Walsham claims that, “Interpretive research in information systems (IS) is now a well-established part of the field” (2006, p. 321).

3.3.1.4 Design Science Paradigm

Although the terms 'Science of Design' and 'Design Science' first appeared in 1964, it is generally accepted that it was Herbert Simon who in the 1990s brought them into prominence through his seminal work, 'The Sciences of the Artificial' (Kehagias, et al., 2008). Simon (1996) considers design science a pragmatic research paradigm, where real-world problems are solved by the creation and deployment of innovative artefacts. Simon believes that, "the engineer, and more generally the designer, is concerned with how things ought to be - how they ought to be in order to attain goals, and to function" (pp. 4-5), and "both the shape of the design and the shape and organisation of the design process are essential components of the theory of design" (pp. 130-131).

Jones and Gregor (2007) comment that the current trend in design science is to emphasise the role of the artefact, not only during the design process but as the product of the research. On the other hand Cross (2001) places more emphasis on the knowledge that is gained during the construction process:

> We must not forget that design knowledge resides in products themselves; in the forms and materials and finishes, which embody design attributes. Much everyday design work entails the use of precedents or previous exemplars – not because of laziness by the designer but because the exemplars actually contain knowledge of what the product should be. (p. 4)

March and Smith (1995) propose that building an innovative and creative system is sufficient to be considered a contribution to the research community:

> Building the first of virtually any set of constructs, model, method, or instantiation is deemed to be research, provided the artefact has utility for an important task. The research contribution lies in the novelty of the artefact and in the persuasiveness of the claims that it is effective. Actually, performance evaluation is not required. (p. 260)

Hevner, March, Park and Ram (2004) are of the belief that design science is a problem-solving paradigm, whose objective is to build an artefact which is then evaluated. Appreciating the nature of the problem domain, being aware of and understanding issues, and seeking technological solutions, are central to this paradigm.

Hevner and Chatterjee (2010) subsequently defined design science research as follows:

> Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artefacts, thereby contributing new knowledge to the body of scientific evidence. The designed artefacts are both useful and fundamental in understanding that problem. (p. 5)

3.3.1.5 Design Science Research in Information Systems

Lee points out that technology and behaviour are not dichotomous in an information system, but are inseparable (Lee, 1991). Lee argues that in an information system, the technological subsystem and the behavioural subsystem transform each other. Lee also suggests that the effect of this mutual interaction is two subsystems, which are completely different from their original form Figure 3-2.

On the basis of this mutual interaction of the two subsystems, Lee strongly advocates for a broader understanding of the nature and depth of information systems research, and he recommends doing design-science research in addition to natural-science research. By re-establishing the IS field to embrace the design of information systems for real-world uses, real and relevant research would be performed.

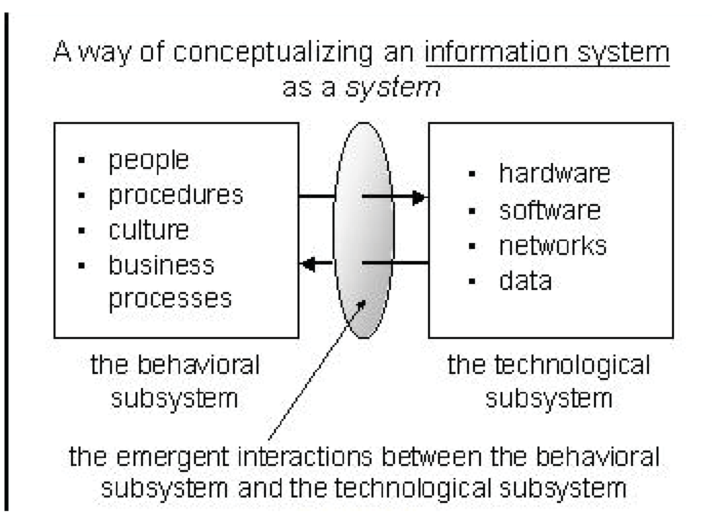


Figure 3-2: Emergent interaction between behavioural subsystem and the technological subsystem (Lee, 1991)

The adoption of design science research is seen to be an effective way of improving the usefulness of an information technology (IT) artefact when addressing business problems (Nunamaker, Chen, & Purdin, 1990). Further support has followed, the most notable contributions, according to Gregor (2005), being from Livari (2007b), March and Smith (1995) and Hevner et al. (2004).

Several authors have made strong arguments in favour of using the design science research paradigm in information systems as it emphasises:

- The role of the IT artefact in IS research (Benbasat & Zmud, 2003; Weber, 1997).
- The professional status of IS research (Benbasat & Zmud, 1999; Hirscheim & Klein, 2003)(Benbasat & Zmud, 1999; Hirschheim & Klein, 2003).

Two paradigms have dominated research in information systems over the past two decades: behavioural science and design science (Hevner, et al., 2004). The former is concerned with developing and verifying theories that explain or predict human or organizational behaviour, whereas the design-science paradigm is concerned with increasing the knowledge associated with the development and introduction of innovative artefacts into the information systems domain (people, organisations and technology).

Hevner et al. (2004) gathered information from several design research traditions and created a design research paradigm ideally applicable to information systems research. Their objective was to provide a concise conceptual framework and clear guidelines for understanding, executing, and evaluating information systems research using the design research paradigm.

The set of seven guidelines proposed by Hevner et al. (2004), which are intended to assist information systems researchers' conduct, evaluate and present design science research, is shown in Table 3-1.

Table 3-1: Set of guidelines for design science research in information systems (*Hevner*, et al., 2004)

1	Design as an artefact	"Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation" (2004, p. 83). Furthermore, Hevner's group defines IT artefacts as "constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems." (2004, p. 77)
2	Problem relevance	"The objective of design-science research is to develop technology-based solutions to important and relevant business problems" (2004, p. 83).
3	Rigorous evaluation	".. the utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods" (2004, p. 83).
4	Contribution to the academic world	".. effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies" (2004, p. 83).
5	Rigorous methods of construction and evaluation	"Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact" (2004, p. 83).
6	Design as a search process	'.. the search for an effective artefact requires utilizing available means to reach desired ends while satisfying laws in the problem environment" (2004, p. 83).
7	Dissemination of the research finding	The last guideline addresses the importance that the work be published in both the academic community and in the practitioner's community (2004, p. 84).

3.3.1.6 Critical theory Paradigm

The underlying epistemology of critical theory is subjectivist. It is based on the belief that reality is virtual, and that social, political, economic, ethnic, and other factors shape reality. Geuss (1981), as cited in Tartir and Arpinar (2007), states that critical theory is "a reflective theory which gives agents a kind of knowledge inherently productive of enlightenment and emancipation" (2007, p. 2).

Critical researchers assume that social reality is rooted in the past and is continually being created, and recreated by people. However, the ability of people to deliberately attempt to change their social and economic circumstances is constrained by the various forms of social, cultural and political domination that surround them. Under these circumstances, as stated by Klein and Myers (1999), the main role of the critical researcher is to "act as a social critique, focusing on what might be viewed as restrictive and alienating conditions of the status quo" (p. 69).

Kincheloe and McLaren (2005) claim that the role of highlighting conflicts and contradictions in contemporary society is emancipatory. Grundy (1987) is in full agreement with Kincheloe and McLaren when he states that “critical approaches have a fundamental interest in emancipation and empowerment to engage [the participant] in autonomous action arising out of authentic, critical insights [facilitated by the researcher] in the social construction of human society” (p. 19).

Critical theory explicitly acknowledges the subjectivity of the researcher and actively recognizes those researched. Mihevc’s (1987) study, as cited in Tartir, Alpinar and Sheth (2008), claims that in the case of critical theory, “the voice of the researcher is limited in comparison to that of the participant”, and “those researched have the first right to name reality to articulate how social reality functions, and to decide how issues are to be organized and defined” (p. 88).

3.3.1.7 Constructivism Paradigm

Routledge Online Encyclopedia of Philosophy defines constructivism to be "an epistemological perspective about the nature of scientific knowledge" (Martinez-Romero, Vazquez-Naya, Munteanu, Pereira, & Pazos, 2010). In this view of constructivism, the behaviour of humans is determined by their identity, which itself is shaped by society’s values, history, practices, and institutions.

Constructivists argue that knowledge and truth are dependent on the perspective of those involved (Schwandt, 1994) therefore all truths are relative to some meaning, context or perspective. This leads constructivists to claim that knowledge is constructed by scientists, and is based on their personal view of the world (Oestereich, 1999).

A central genre of constructivism has been the concern with subjective meanings, for example, how individuals or members of society apprehend, understand and make sense of social events and settings and how this *sense-making* enables them to adapt to the very environment in which the sense-making is being observed. Constructivists have also been particularly concerned with the interplay of subjective, objective and inter-subjective knowledge, where inter-subjectivity is the process of knowing others' minds (Schutz, 1974).

3.3.2 Research Assumptions

Positivist and interpretivist paradigms can be defined by associating the paradigm with one or more philosophical assumptions. The paradigm the researcher selects to underpin the research is often based on their assumptions about the world at large.

Burrell and Morgan (1979) propose four sets of philosophical assumptions; ontological, epistemological, methodological, and human nature, whereas Hussey and Hussey (1997) adopted Creswell's (1994) suggestion that human nature should be seen in terms of axiological and rhetorical assumptions. In Table 3-2 the five assumptions are compared against the two main research paradigms, quantitative and qualitative.

Table 3-2: Quantitative and Qualitative Paradigms and Research Assumptions

	QUANTITATIVE PARADIGM (Positivist)	QUALITATIVE PARADIGM (Interpretive, Design Science)
Ontological	There is but one reality and it is a reality that is independent of the observer (Creswell, 1994; Hussey & Hussey, 1997).	Realities are constructed by the observer, and consequently there are multiple realities. Realities are socially constructed (Creswell, 1994; Hussey & Hussey, 1997).
Epistemological	The investigator and the object of investigation are independent from each other and the object can be researched with an independent, objective perspective, where only observable and measurable phenomena are worthy of adding to the body of knowledge (Creswell, 1994; Hussey & Hussey, 1997).	The researcher interacts with the object of research and can affect that object. Factors, which are not observable and measurable, are valid and important in researching the domain of interest and adding to the body of knowledge (Creswell, 1994; Hussey & Hussey, 1997).
Methodological	The methodological assumptions are concerned with the entire research process and take cognisance of the other assumptions, ontological, epistemological, axiological and rhetorical (Creswell, 1994).	
	Quantitative research as followed by the positivist is deductive in nature. Concepts and constructs are measured and used to test theories and hypotheses. Causal relationships are the norm as are generalisations to enable predictions and understanding. Emphasis is placed on validity and reliability of the research instruments (Creswell, 1994; Hussey & Hussey, 1997).	Qualitative research based on the interpretive paradigm adopts inductive logic. The knowledge emerges through close interaction between the researcher and respondents. Verification of acquired information is supported through the use of triangulation methods. Methods include observations, in depth interviews and content analysis of documents (Creswell, 1994; Hussey & Hussey, 1997).
Axiological	Strict positivist researchers believe they can observe the phenomena in a completely independent and detached manner. That their approach is 'value free' (Creswell, 1994).	The interpretivist researcher acknowledges that their very presence influences the research process. The values the researcher possesses cannot be ignored and should be discussed openly at some point in the research process (Creswell, 1994).
Rhetorical	The research report is written in a formal style, reflecting the perspective of an objective scientist (Creswell, 1994)	The research report is often written in an informal style, possibly reflecting the personal views of the researcher (Creswell, 1994).

In summary, the qualitative paradigm focuses on providing a detailed description of a particular research topic using an inductive approach, which usually involves a few cases. On the other hand, the quantitative paradigm takes a deductive approach, acquiring information across a wide number of cases, with the intention of testing pre-specified concepts, constructs, and hypotheses that make up a theory. Another major difference is the role of the researcher. In quantitative research, the researcher is ideally an objective observer that neither participates in, nor influences what is being studied. In qualitative research, however, it is thought that the researcher can learn the most about a situation by participating and/or being immersed in it. In the qualitative paradigm data is usually gathered using techniques such as in-depth interviews, or content analysis of documents, whereas, quantitative paradigm numerical or measureable data is collected using questionnaires, surveys or laboratory experiments.

3.3.3 Section Summary and Conclusion

3.3.3.1 Research Paradigm

The positivist and the post positivist paradigms do not apply to this research for a number of reasons. From an ontological perspective there is no suggestion that there is one reality. For example, it would be difficult to accept that there is only one way that a semantic framework can be constructed and that there could be only one framework. Similarly, from epistemological and axiological points of view it is clear that the structure of a semantic environment will strongly reflect the views and skills of the developer and not be independent as would be required in a positivist tradition. Causality and reliability would not be possible, as different semantic artefacts purportedly representing the same knowledge base would not necessarily behave in a consistent manner. Both paradigms are fundamentally associated with quantitative assessment, hypothesis testing and refutation, which do not apply to this research.

Some aspects of critical theory are to be found in this research, for example, there is the possibility that using the application would develop the feeling of emancipation and empowerment. However, this is not the focus of this research therefore critical theory is seen to be an unsuitable paradigm. The researcher also rejects the appropriateness of the constructivist paradigm, and while acknowledging that she cannot be totally objective, rejects the view that knowledge gained from this research would be based entirely on her personal view of the world.

The design science paradigm falls within the interpretivist tradition and is seen to be the most appropriate. The reasons behind this decision are very persuasive. In the first instance the phenomena are studied in their natural environment. Secondly, while there will be many interpretations of this research and similar research, the interpretivists believe that these interpretations are in themselves part of the scientific enquiry that is being pursued. The choice of the design science paradigm is even stronger as it emphasises the role of the artefact, its design and the way the design process is organised. These are actions that are strongly emphasised in this research.

The adoption of the design science paradigm permits the researcher to follow and apply the guidelines as shown in Table 3-1. Carefully following these guidelines ensures the research is acceptable to the information systems research community.

3.3.3.2 Research Assumptions

The choice of design science research as the research paradigm implies the following research assumptions:

- Ontological: The research is based on the interpretivist ontological assumption as it is recognised that the opinions of individuals using the technologies are subjective and the participants possess differing views of reality.
- Epistemological: The research approach, which also involves gaining the views and other non-measurable values from the participants through interviews and questionnaires, acknowledges the interpretivist epistemological assumption.
- Axiological: The research process includes value-laden variables. Providing opportunities for the participants to discuss their concerns and viewpoints might conceivably address some of these issues.
- Methodological: The interpretivist methodological assumption is the most dominant in this research. The key factors are that only three research domains are investigated, triangulation of research methods is possible, and the views and opinions of participants are gathered.
- Rhetorical: The research report created by the researcher adopts the positivist rhetorical assumption as it is a Doctor of Philosophy thesis and a formal rigorous approach is required.

Before choosing the research method, the appropriate methodology needs to be identified. This is the subject of the following section.

3.4 Research Methodology

This section addresses Crotty's third question: What methodology governs the strategy, plan of action, and the process or design that lies behind the choice and use of a particular method?

On the basis of the answers to Crotty's first two questions the research process is operating under the epistemology of the 'philosophy of science' and a theoretical perspective of the 'design science paradigm'.

3.4.1 Methodology and Method

In this research the meaning of the terms methodology and method are those defined using the online dictionaries, Oxford Dictionaries, and Merriam-Webster respectively. Methodology is "a system of methods used in a particular area of study or activity" ("Methodology," 2011), and method is "a systematic procedure, technique, or mode of inquiry employed by or proper to a particular discipline" ("Method," 2011).

3.4.2 Research Method

Myers (1997) defines a research method to be a series of theoretical and/or practical steps that move the research from the underlying philosophical concepts and assumptions to research design, data collection and analysis. Saunders, Lewis and Thornhill (2007) describe research design as a blueprint which, when traversed, enables researchers to find the answers to the research questions. The blueprint also identifies the possible constraints, and legal and ethical issues that might arise during the research process. Yin (2003) defines research design as a logical sequence of activities that link the initial research questions to the logical conclusion using processes based on observation and/or experimentation. This is not unlike the description by Bourma and Ling (1980) who emphasise the point that research design is about attempting to answer the research questions and realise the research objectives. Research method in this research is understood to include all of the above meanings.

Morgan and Smircich (1980) argue that the choice of a research method should be dependent on the nature of the phenomena being explored. The choice would impact on the skills and research practices of the researcher, including the way data is sampled, collected and analysed. This approach is further developed by Bryman and Bell (2007), who state that the choice of the research design "reflects decisions about the priority being given to a range of dimensions of the research process" (p. 40).

In the following sections, three types of research methods are discussed; qualitative research methods, quantitative research methods, and mixed research methods. These classifications are somewhat arbitrary as many information systems researchers adopt a pluralist approach (Hirschheim, Klein, & Nissen, 1991). For example, Minger's (2001) multi-method perspective addresses a research problem by drawing upon contributions from different types of theoretical perspectives. Whether the researcher is a positivist or interpretivist is of secondary importance to the need to match the problem to the ‘best fit’ research methods. Such a pragmatic approach fits in well with that described by Goles and Hirschheim (2000), as by drawing on the philosophical base of pluralism it avoids the need to work entirely within a given paradigm.

3.4.3 Research Methodologies

Given that the interpretivist paradigm (design science) has been selected as the most appropriate paradigm under which this research is undertaken, only qualitative research methodologies are considered in this section. The possibility of having one or more quantitative methods in the overall research design is still permitted if a pluralist approach is adopted (Goles & Hirschheim, 2000).

Four research methodologies are discussed: action research, case study research, ethnography and grounded theory.

3.4.3.1 Action Research

There are numerous definitions of action research; however, one of the most widely cited is that of Rapoport (1970), who states that action research “aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework” (p. 499). This definition draws into the mix the collaborative aspect of action research and emphasises the ethical dimension of qualitative research. The definition given by Baskerville and Myers (2004) that action research “aims to solve current practical problems while expanding scientific knowledge” (p. 329), claims that action research not only addresses practical problems but also adds to the body of knowledge. Action research differs from most other research methods in that the researcher seeks to create organisational change during the investigation (Baburoglu & Ravn, 1992).

Baskerville and Myers (2004, p. 333) describe four research assumptions relevant to action research:

1. The purpose of any action should be established before action is taken.
2. Action must be practical.
3. Practical action must inform the theory, and as a consequence theory must be adjusted based on the outcome of the action.
4. Action and reasoning must be socially situated. In other words action researchers must be participant observers, and that collaborative involvement

in reasoning, action formulation, and action taking is required. A social setting supports reflection and subsequent action is then seen as a social act.

3.4.3.2 Case Study Research

The term "case study" has two different meanings. It can be used to describe a research methodology or define a social or scientific field of interest of a group within an organisation. In this thesis both meanings are used, however, in this section its role as a research methodology is the object of the discussion.

According to Creswell (1998), a case study is "an exploration of a…bounded system... a program, an event, an activity, or individuals" (p. 61). A more detailed description is provided by Yin (2003) who states that a case study research method takes information from multiple sources and in so doing gains a broader and more in-depth understanding of the target environment, which, when subjected to triangulation methods is able to enhance the validity of the research. In Yin's approach the researcher is able to acquire information from a variety of information sources including documentation, interviews, and artifacts. Boudreau, Gefen and Straub (2001) further add to our understanding of case study when they claim that case study research takes a contemporary phenomena within a real life context, and empirically examines a small number of entities. Boudreau et al. (2001) go on to say that case study is not designed to study a large unit or enterprise, but instead its purpose is to focus on a single issue, activity or unit of analysis.

Case study research can be performed within most research paradigms and philosophical assumptions. Yin (2003), Dubé and Paré (2003), and Benbasat, Goldstein and Mead (1987) are supporters of positivist case study research, whereas Walsham (1993), Orlikowski and Baroudi (1991), and Alavi and Carlson (1992) support interpretive case study research. It is claimed that case study research is the most frequently used qualitative method in information systems (Alavi & Carlson, 1992; Orlikowski & Baroudi, 1991).

3.4.3.2.1 Types of Case Study Research

According to Yin (2003), there are three types of case study research: exploratory, descriptive, and explanatory.

- Exploratory case study is aimed at defining the hypotheses and research questions to be used in a subsequent study, or at determining the feasibility of a particular set of research procedures.

- Descriptive case study presents a complete description of a phenomenon within the chosen unit or context.
- Explanatory case study seeks to explain how events have occurred, and is usually concerned with cause-effect relationships.

Yin (2003) proposes a further form of case study where there is more than one sub-unit of analysis.

- Embedded case study: This approach facilitates the integration of both quantitative and qualitative methods into a single research study (Scholz & Tietje, 2002; Yin, 2003). The embedded case study design is an empirical form of inquiry well suited to descriptive studies, where the objective of the research is to describe the features, context, and process of a phenomenon.

Benbasat et al. (1987) claim that the descriptive form of case study is particularly well suited to information systems (IS) research.

The process of undertaking the case studies research proposed by Yin (2003, p. 50), often referred to as the COSMOS case study model, is shown in Figure 3-3. In this model the process follows five basic phases: develop the theory, select the domain of interest and form research questions, undertake the case study, carry out data analysis within and between cases, and lastly, formulate the conclusion and carry out reflection.

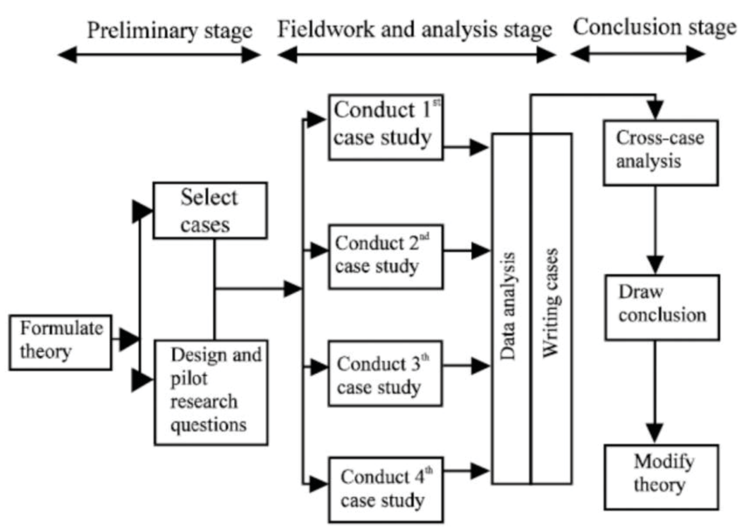


Figure 3-3: Stages involved in conducting case studies research (Yin, 2003, p. 50)

3.4.3.2.2 Strengths and limitations of case studies research

Case study is located within a real world environment. The researcher observes and records detailed information that is rich and insightful and which promises to advance the quantum of knowledge about a phenomenon. Case study is particularly useful for applied fields of study such as information systems, administration, and information rich environments.

Although focusing on a single case raises issues of generalisability, the researcher is able to formulate a narrative description that is interesting and meaningful and which can be viewed as a prototype for more detailed research and study at a later date.

However, there are a number of limitations associated with case study research that need to be considered:

- Subjectivity and Ethics: It is imperative that the researcher exhibits a high level of integrity and awareness when working in their chosen domain of interest if bias is to be avoided. Guba and Lincoln (1981) refer to a particular concern in what they describe as “unusual problems of ethics. An unethical case writer could so select from among available data that virtually anything he wished could be illustrated” (p. 378). They also suggest that care must be exercised in all aspects of case study research including the evaluation and report writing.
- Generalisability: Many researchers take the view that results obtained from case study research cannot be applied outside the immediate domain of interest. Yin (2003) strongly disagrees, and draws a difference between analytic generalization and statistical generalization: "In analytic generalization, previously developed theory is used as a template against which to compare the empirical results of the case study" (p. 32-33). Yin is quite emphatic when he states that treating a single case study as being comparable to taking a single sample from a universe of cases is clearly not appropriate.
- Validity and reliability: Validity is concerned with the appropriateness, meaningfulness and usefulness of a test to measure what it is supposed to measure. It is important in case study research to take into consideration all forms of validity: construct validity, internal validity, external validity and reliability (Paré, 2004; Yin, 2003).
- Construct validity: The degree to which a test measures an intended hypothetical construct.
- Internal Validity: The degree to which inferences concerning causal relationships can be said to be true.
- External Validity: The degree to which study results generalize to populations and contexts beyond the particular ones included in the studies themselves.
- Reliability: The degree to which an assessment or instrument consistently measures an attribute.

- To improve construct validity researchers endeavour to gather and use information from multiple sources (Denzin, 1984; Yin, 2003). Denzin ("Methodology," 2011) and Anderson (1991) claim that triangulation is not limited to data, but also applies to investigator, theory, and methodology. Denzin ("Methodology," 2011) describes these four approaches:
- Data source triangulation: There is data consistency when taken from different contexts. This involves time, space and persons.
- Investigator triangulation: Different researchers examine the same phenomenon.
- Theory triangulation: Researchers with different theoretical perspectives interpret the same results.
- Methodological triangulation: This approach accesses the same problem using differing methods to gather data, interviews, observations, questionnaires, and documents.

3.4.3.3 Ethnography

Ethnographers spend a significant amount of the time within the study environment, and “immerse themselves in the lives of the people they study and seek to place the phenomena studied in their social and cultural context” (Lewis, 1985, p. 380). Ethnography is applied extensively in information systems research primarily in organisational settings, for example, information systems development (Hughes, Randall, & Shapior, 1992) and management of information technology (Davies, 1991; Davies & Nielsen, 1992).

3.4.3.4 Grounded Theory

According to Martin and Turner (1986), grounded theory is "an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data" (p. 343). There is strong emphasis in grounded theory on developing a mutual exchange between the data collection phase and analysis phase. Orlikowsky (1993) claims that the method is particularly useful in developing context-based, process-oriented descriptions and explanations of phenomena.

3.4.4 Section Summary and Conclusion

Ethnographic research is not an appropriate research methodology. Although the evaluation of the semantic artefact does draw upon scenarios extracted from the ‘real’ world, there is no direct attempt in this research to consider the social and cultural setting in which the research takes place. There are some elements of grounded theory in the research as there is some attempt to give value to the role of the semantic framework in society. However, the significance of this connection is quite modest in terms of the overall research effort.

The research endeavour shares some features of action research in that it aims to solve practical problems while expanding scientific knowledge, and there is some agreement that practical action during the design and development processes does inform the theory. However, it is not possible to claim that reasoning and action are socially situated, and that there is a collaborative team involved in reasoning and action.

Of the four methodologies described in this section, case study is the most appropriate. In the first instance it satisfies Creswell's (1998) requirement that the study is concerned with a bounded system where the research endeavour is on a single event or activity. That is the situation here, where the research focuses on a semantic artefact designed and constructed to meet the specific requirements of an e-government semantic framework. Secondly, the descriptive form of case study envisaged by Yin (2006) where a complete description of the phenomenon is presented, is particularly relevant as it conforms to the requirement of the design science paradigm discussed in the previous section. That is the situation in this research, where the documentation of the process of creating an innovative artefact leads to better understanding of the design process. Thirdly, the embedded case study methodology proposed by Scholz and Tietje (2002) and Yin (2003) is pertinent as it creates the opportunity to accept both interpretivist and positivist methods to be incorporated into the study, and it caters for research where the objective is to describe features, context and process of a phenomenon.

A number of issues arise when using case study and these need to be addressed in the research plan (Guba & Lincoln, 1981; Yin, 2003). These relate to subjectivity and ethics, generalisability, and validity and reliability.

3.5 Adopted Research Methods

This section addresses Crotty's fourth question, "What methods, techniques or procedures are to be used to gather and analyse data related to the research questions or hypothesis?"

On the basis of the answers to Crotty's first three questions the research process is operating under the epistemology of the 'philosophy of science', a theoretical perspective of the ‘design science paradigm’, and an ‘embedded case study’ is the research methodology.

3.5.1 Qualitative Research Methods

Myers (2000) states that "those who are not familiar with qualitative methodology may be surprised by the sheer volume of data and the detailed level of analysis that results even when research is confined to a small number of subjects" (para. 22).

Some of the methods employed in qualitative research are briefly discussed in the following paragraphs. These methods are frequently combined.

3.5.1.1 Observation

The participant observer is one who aims to be as unobtrusive as possible, so that he/she does not disturb unnecessarily the research dynamics. The participant adopts a recognised role that is recognised within the group. The non-participant observer is the most frequently used approach, and in this situation the researcher has the role of researcher (Miles & Huberman, 1993).

3.5.1.2 Interviews

To be successful in this method the interviewer needs to win the confidence of the interviewees and be as unobtrusive as possible. In a structured interview the researcher decides the structure of the interview and sets out with predetermined questions. Some researchers use semi-structured interviews where there are some pre-set questions but the interviewees are given the opportunity to make comments or even suggest alternative questions (Miles & Huberman, 1993).

3.5.1.3 Sampling

If generalisations are a principal purpose of the research then representative or 'naturalistic' sampling is used (QuickMBA, 2011). There are numerous sampling methods that fit into this category; they are broadly grouped into structured and unstructured forms, as can be seen in the following examples (Guba & Lincoln, 1985):

- Structured observation: Observed data are gathered from pre-determined categories of behaviour, and systematic sampling is performed.
- Time sampling: Observations may be made at regular time intervals and the behaviour of the individual at the point in time is noted and recorded.
- Event sampling: It is an approach where the occurrence of a specific behaviour is noted and a record kept.

- Point sampling: In this method, individuals are the focus of attention one at a time over a given period of time.
- Unstructured observation: All observations that might be of interest are recorded.
- Diary method: This method records events, attitudes and feelings.
- Video recording: It is a method where data can be extracted later as the recoding is analyse.

3.5.1.4 Written source materials

Written documents are useful sources of data in qualitative research (QuickMBA, 2011).

3.5.1.5 Questionnaires

Questionnaires require the respondents to respond to a series of questions. Some question types include fixed alternative, open ended, and projective questions (QuickMBA, 2011):

- Fixed-alternative questions: Appropriate when the possible replies are few and fairly straightforward. Usually in the form of multiple-choice questions or itemised rating scales.
- Open-ended questions: Allow the respondent to better able to express their views and opinions. Ideally suited to exploratory research.
- Projective methods: Vague questions are used in an attempt to project a person's attitudes from the response. Well suited for exploratory research.

The three commonly used rating scales are: graphic, itemized, and comparative (QuickMBA, 2011).

- Graphic: An X is marked, usually on a line representing a continuous range of values.
- Itemized: The respondent has to choose from a limited number of categories. The Likert scale is such an example.
- Comparative: The respondent compares attributes.

3.5.1.6 Expert Judgement

Expert judgment consists of information provided by qualified experts in the chosen discipline (Meyer & Booker, 2001) Meyer and Booker consider expert judgment to be “valid data and comparable to other data” (p. 21). They also emphasise how important it is to ensure the experts are carefully selected and that any bias is alleviated.

Anderson, Sweeney, Willimas & Martin (2008) claim that when expert judgment is sought, "empirical evidence and theoretical arguments suggest that between 5 and 10 experts should be used" (p. 729).

The Delphi method is another method, which extracts the views and opinions of experts. A group of experts is selected and a multiple-round survey is carried out over a period of time. The goal of this is to reach a consensus among the group by the end of this multiple-round questionnaire process.

3.5.2 Quantitative Research Methods

Prior to the introduction of post-positivist philosophy quantitative research was primarily associated with the scientific method. However, over the past two decades information systems research has adopted either a post-positivist or qualitative stance. Jenkins (1985) composed a list of thirteen research methods, which at that time represented the key research methods used in management information systems research. Some of these he considered as falling into both the qualitative and quantitative research domains. The research methods, briefly described below, are in descending order based on the strength of the methodology in hypotheses testing. This reflects the level of control the researcher can exert over the research process (Jenkins, 1985). Those falling entirely in the qualitative domain have been omitted from the original list of thirteen.

3.5.2.1 Experimental simulation (Quantitative and Qualitative)

A closed simulation model is used to mirror the 'real world'. The subjects in the model, usually humans, are exposed to some action and their responses are recorded. The nature and timing of the experimental events are completely determined by the researcher (Jenkins, 1985).

3.5.2.2 Free simulation experiment (Quantitative and Qualitative)

Jenkins (1985) claims that this methodology is similar to experimental simulation as it is the researcher who chooses the closed setting in which the experiment is undertaken. However, in this methodology the researcher and the behaviour of the human subject determine the nature of the events and when they take place.

3.5.2.3 Laboratory experiment (Quantitative)

Laboratory experiments take place in a setting especially created by the researcher for the investigation of the phenomenon. With this research method, the researcher has control over the independent variable(s) and the random assignment of research participants to various treatment and non-treatment conditions (Boudreau, et al., 2001). Jenkins makes comment:

> With this methodology, the researcher manipulates the independent variables, controls the intervening variables, and measures the effect of the independent variables on the dependent variables. Human subjects are commonly used in a laboratory setting. (Jenkins, 1985, p. 104)

3.5.2.4 Field experiment (Quantitative and Qualitative)

Field experiments involve the experimental manipulation of one or more variables within a naturally occurring system and subsequent measurement of the impact of the manipulation on one or more dependent variables (Boudreau, et al., 2001)..

3.5.2.5 Opinion research (Quantitative)

> The objective of this methodology is to gather data on attitudes, opinions, impressions and beliefs of human subjects. This is accomplished by asking them via questionnaires, interviews, etc. The methodology allows testing of a priori hypotheses and offers an iterative approach to the generation of hypotheses. (Jenkins, 1985, p. 105)

3.5.2.6 Archival research (Quantitative and Qualitative)

> This methodology is primarily concerned with the examination of historical documents. Secondarily, it is concerned with any recorded data. All data are examined ex-post-facto by the researcher. (Jenkins, 1985, p. 105)

3.5.3 Mixed-Method Research

Three forms of classification have been applied to Mixed-Method research (Creswell, et al., 2003).

3.5.3.1 Mixed method design.

This design can be divided into two sub-categories:

- Mixed model research:
  Both quantitative and qualitative projects are used together in more than one stage of the study (research questions, research methods, data collection and analysis, and interpretation) (Teddlie & Tashakkori, 2003).
  Example: A large group of participants are surveyed, and subsequently a sub-sample of those participants are interviewed (Byrne & Humble, 2007).
- Mixed methods research:
  Incorporates techniques from both quantitative and qualitative methods in a

single study (Byrne & Humble, 2007). The data are collected concurrently or sequentially, and the data are integrated at one or two stages in the research process (Teddlie & Tashakkori, 2003).

Gil-Garcia and Pardo (2005) strongly advocate for the multi-method approach when researching e-government environments. In such investigations the researcher interacts with those being researched, and findings are the outcome of this interactive process with an emphasis on the meaning and understanding of the phenomenon under the spotlight. As pointed out by Hammond (2005), the multi-method approach provides an opportunity to triangulate the results and promote validation.

Example: A survey is carried out using mostly close-ended questions or possibly a Likert-type scale. The respondents are then able to comment in their own words in their responses to some of the questions (Byrne & Humble, 2007).

3.5.3.2 Multidimensional design

Both quantitative and qualitative projects are undertaken. The projects are complete in their own right, and the methods used have their own worldview. Each is designed to answer a particular question, and the results of the research are then triangulated to form a unified, and perhaps more complete, understanding (Morse, 2003).

3.5.3.3 Multi-case study

In this research data are collected using both quantitative and qualitative methods and they are then combined in the analysis phase of the research process (Byrne & Humble, 2007; Teddlie & Tashakkori, 2003).

In summary, Byrne and Humble (2007) consider the mixed-method and multi-method approaches to have a number of advantages:

- The use of multiple methods can ameliorate some of the disadvantages of ‘single’ methods. One method’s weakness is counterbalanced by another method’s strength.
- Methods can be chosen for their suitability in dealing with specific problems or issues.
- Confirmatory and exploratory questions can be addressed during the same investigation.

Greene, Caracelli and Graham (1989) are also strongly supportive of mixed-method research and propose the following advantages:

- Triangulation: The consistency of findings obtained through different research techniques is improved.
- Complementary: The results of one method inform and enhance the results obtained from other methods and vice versa.
- Development: Other techniques might become apparent.
- Initiation and expansion: A broader range of questions can be formed as each method brings into play another perspective on the problem domain.

3.5.4 Section Summary and Conclusion

The methods identified as being relevant to this research activity depend entirely on the approach taken by the researcher. In this situation the researcher will critique the design and development methods used in the construction of the web-based artefact by comparing it against the Hevner et al. (2004) guidelines. In addition three practical approaches will be used to collectively address the research aims and research questions posed in this thesis. These approaches include a number of methods identified in this section, which in turn fall within the auspices of the philosophy of science, design science paradigm and case study. In the first approach, experts are invited to comment on the validity of the semantic framework. In the second approach, the researcher demonstrates the utility of the semantic framework by submitting queries to the e-government ontology, and in the third and final approach, the schema and instance metrics are used to determine the level of richness in the research ontology.

Approach 1: Validation of the ontology by experts. Experts are exposed to the semantic framework and are asked to critically comment on the quality and appropriateness of the framework. The methods used in this approach are:

- Experimental design: It is a closed simulation model, which mirrors a segment of the ‘real world’ (Jenkins, 1985).
- Design science: The design and construction process used to construct the innovative ontological artefact is evaluated (Hevner, et al., 2004).
- Opinion research: The views, opinions and impressions of human subjects are to be obtained via questionnaires and interviews (Jenkins, 1985, p. 105).
- Expert judgement questionnaire: Information is provided by qualified experts in the chosen discipline (Meyer & Booker, 2001).

Approach 2. Simulation based analysis: Scenarios based on use-case data are used to present requests for information from the system that require the utilisation of the system's unique semantic features. Each request will be in the form of a query and the results displayed via a web browser. The methods used in this approach bring together several different perspectives:

- Design science: Using simulation techniques the researcher seeks to demonstrate that the artefact is innovative and that it is effective (March & Smith, 1995, p. 260). This is directly related to the guidelines proposed by Hevner et al. (2004).
- Experiment simulation: The researcher designs a closed setting experiment to simulate a segment of the 'real world'. The researcher chooses the type and complexity of the queries and when to submit them to the ontology (Jenkins, 1985, p. 104).

Approach 3. Structural evaluation: The schema and instance metrics will be obtained from the e-government ontology to ascertain the degree of richness within the structure of the ontology and the level of the instantiation. Other metrics associated with the instance connectivity and class importance will be determined.

Further classification of the methods can be achieved by viewing the three approaches collectively. It is a mixed method as defined by (Byrne & Humble, 2007), in that both quantitative and qualitative methods are used. For example, in approach 1, the views of experts are used and in approach 3, numerical data is obtained. The research can also be classified as multidimensional in that each method has its own view and that different questions are posed in the three approaches (Morse, 2003). Finally, it can be viewed as an embedded case study as perceived by (Scholz & Tietje, 2002) as the objective of the overall design science approach is to describe features, context and process of a phenomenon.

Having answered all four of Crotty's questions the overall research design for this study can be described as 'a design science based, mixed method, embedded, multi-dimensional study'.

3.6 Research Design

The information outlined in the Figure 3-4 represents the position after the acceptance of the research proposal.

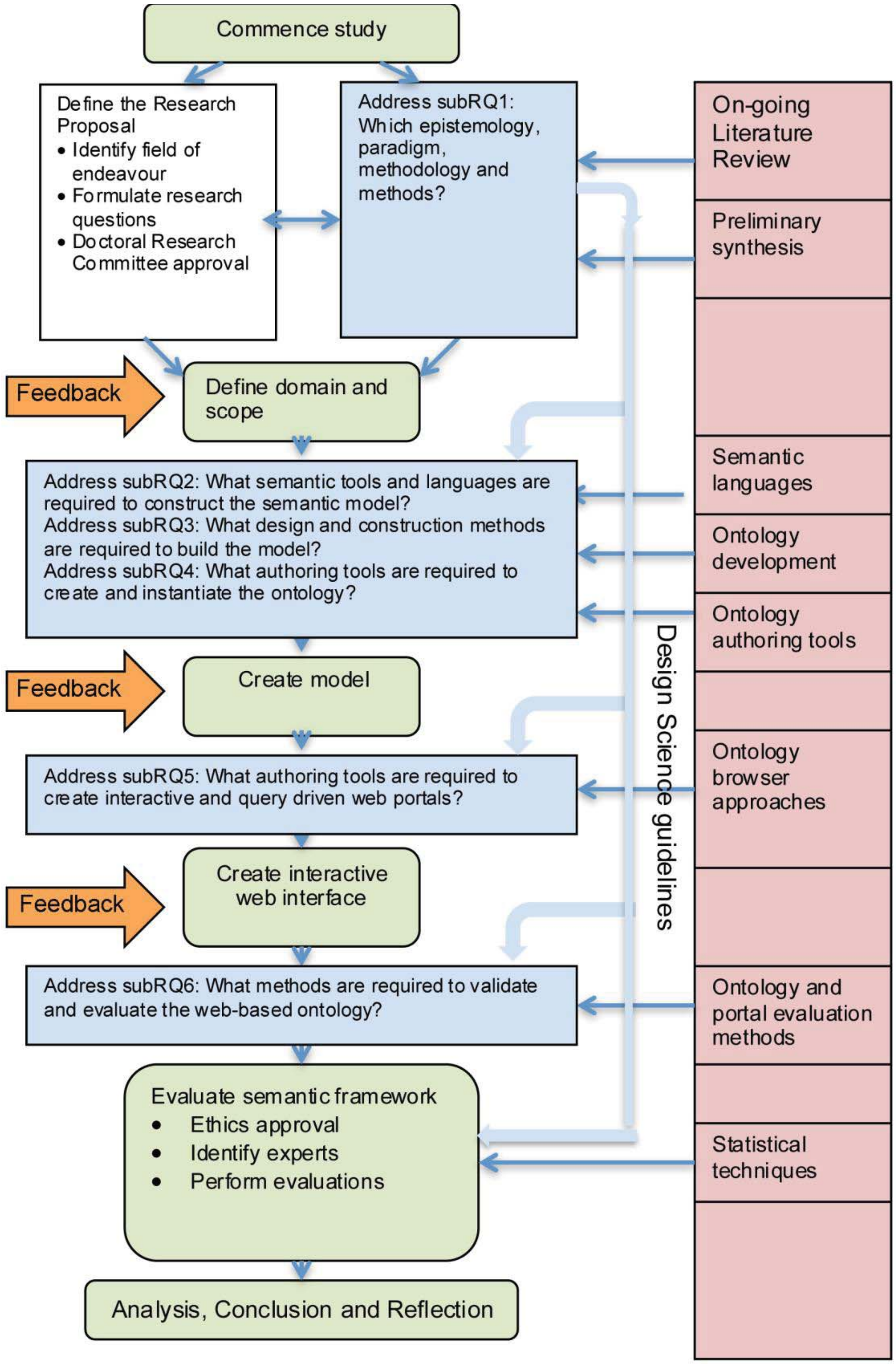


Figure 3-4: Research Design

The proposal outlines the field of endeavour, perceived problem, aims and objectives of the research and the significance of the research. It also includes a brief review of previous research, expected outcomes and their importance, and identifies a number of research sub-questions. The proposal also answers the first research sub-question, and as a result identifies the research methodology to be design science and case study to be the research method.

The figure lists the activities that will have to be addressed to achieve the desired outcomes of this research. These outcomes can be viewed as milestones, for example, define domain and scope, create semantic model, and create interactive semantic web interface. Also shown in the diagram is where it is expected that some external feedback will be requested to ensure validity and quality. The proposal identifies a further five research sub-questions that will need to be addressed, and these are also shown in the figure. To ensure compliance with the design science paradigm, the design, development and evaluation processes is carefully monitored and documented to ensure that the constructed artefact is innovative and can be positively validated against well-established and internationally recognised criteria. The literature review has been on-going and provides sound academic support during the entire research process.

3.7 Chapter summary and conclusions

The research process commenced with confirmation of the research question, discussed in Chapter 1 of this report. After receiving information in the form of use cases, based on the views and expectations of likely users of an e-government service domain and scope of the research question was defined. As shown in Figure 3-4, feedback was obtained from senior research students, visiting experts and PhD supervisors at a PhD workshop organised by the Advanced Learning Technologies Research Centre (ALTRC) at Massey University. During the PhD workshop, construction suggestions have been made by two senior PhD students and one visiting researcher regarding on the level of detail and boundary of the research that would be required to make the study meaningful.

After considering the epistemology, paradigm and methodology of the problem environment the decision reached was that this study could best be described as ‘a design science based, mixed method, embedded, multidimensional study’. Another key conclusion reached in this phase of the research was that design science research was applicable, and that the seven guidelines proposed by Hevner et al. (2004) could be used to confirm that the research was design science research.

The next stage in the process, discussed in Chapter 4, was to identify which semantic tools and languages would be the most appropriate to construct the semantic model envisaged in this research that would best address the research question. The conclusion reached was that an ontology-based solution was the most appropriate, and that the ontology language promoted by World Wide Web Consortium, the web ontology language OWL, was the most relevant. Associated with this decision were other key languages such as RDF, RDF(S), SPARQL and SWRL. Encouraging feedback was received from attendees at a further meeting of the ALTRC.

Given the decision to construct an ontology based on OWL, the next step was to determine what design and construction method should be adopted. As discussed in the Literature Review and Chapter 5, the decision was to adapt the method proposed by Noy and McGuinness (2001), by incorporating information gathered from use cases. This approach is covered in Chapter 5: Ontology Construction.

The construction of the ontology using OWL directly was seen to be quite challenging, as was the construction of an interactive web interface to the ontology, and a review of possible authoring tools was undertaken. Protégé OWL and TopBraid Composer were deemed to be the ones providing the best support.

Prior to the construction process, detailed in Chapter 5, further use cases scenarios were obtained from a range of interested parties, the details of the use case template can be found in Appendix 11.1.1, and the summary of the target users and details for use case collection can be found in Appendix 11.1.2. These use cases were then incorporated into the modified 7-Step Process advocated by Noy and McGuinness (2001). On completion of the construction of the e-government ontology, instantiation of the model was then performed using data gathered from government websites and other reputable sources. Due diligence was paid to the fundamental values associated with the design science paradigm to ensure that a valuable contribution to the academic world was made. Feedback from members of the ATLRC was again received and, in addition, constructive feedback was received from attendees at a presentation given by the researcher at the Asia-Pacific E-Government Workshop (APEGW 2006). During the meetings with Horizon stuff, two presentations were delivered on the purpose and general overview of the research and introduction of the key domains and components of the ontology, these presentations are given by the researcher to selected Horizons Regional Council staff; after which useful comments were received. In a demonstration of the iterative nature of the design methodology, feedback and constructive comments were obtained from the group of experts who evaluated and reviewed the e-government ontology and assessed the quality of associated semantic framework. Information related to this feedback can be found in Chapter 8: Data Collection and Analysis.

The final stage of the development process was the design and construction of the interactive, query driven web-browser interface. The TopBraid suite of authoring tools supported this process. Use case scenarios were again used to identify possible views of the information stored in the ontology. The web-ontology experts also had the opportunity to evaluate the ontology's query-driven web interface and a number of recommendations were received, of which a number were actioned. Information related to this feedback can be found in Chapter 8: Data Collection and Analysis.

On conclusion of the construction process, evaluation of the research endeavour was undertaken. Two approaches were addressed. Firstly, information relevant to the Hevner et al. (2004) seven guidelines of design science research, observed and documented in the several chapters of this thesis, was used to assess whether or not a design science research endeavour had been successfully undertaken. These guidelines related to artefact design, problem relevance, rigorous methods of construction, and design as a search process. Secondly, as described in Chapters 7 and 8, three different approaches were used to evaluate the quality of the semantic framework:

- Feedback from experts. Eight experts in semantic environments were asked to critically comment on the quality and appropriateness of the framework.
- Simulation-based analysis. Scenarios based on the use-case data were used to present requests for information from the system that required the utilisation of the system's unique semantic features.
- Metric-based analysis was undertaken to determine the degree of richness in both the schema and instance data.

In Chapters 8 and 9, an analysis of the research findings was undertaken using methods associated with case study research, and which addressed issues related to reliability, validity and verifiability. The research process was also scrutinised and critiqued by the researcher. The process concluded with comments related to possible improvement to the research process and future research directions.

4 SUPPORTING LANGUAGES, TECHNIQUES AND TECHNOLOGIES

The design and construction of a semantic framework is a crucial element in this research endeavour. Not only is it vitally important to ensure that the processes followed result in a framework that is effective and efficient and fully satisfies the needs of the potential users, but also it is extremely important that international standards are fully complied with, in relation to its design and construction. This chapter addresses some of these demands.

In this chapter the following research sub-questions are addressed:

- What semantic tools and languages are required to design the framework and construct the semantic model?
- What authoring tools are required to create and instantiate the semantic environment?
- What authoring tools are required to create a query-driven semantic web portal?

In accordance with the design science paradigm and Hevner's (2004) seven guidelines discussed in Chapter 3 this chapter makes a clear and verifiable contribution to the academic world by identifying the most appropriate set of semantic languages and authoring tools required to construct a semantic framework. To support this claim, the chapter describes a rigorous and extensive review process, which involves the searching of relevant sources of information contributed by experienced and knowledgeable authors and practitioners.

The chapter is divided into two sections. In the first section, the languages that are used in the creation of semantic web environments are considered, and in the second, emphasis is placed on the supporting techniques and technologies that are used to create and deploy semantic environments.

4.1 Supporting Languages

The current World Wide Web (WWW) is essentially a huge library of interlinked documents that are transmitted across the Internet and delivered to users. In most situations computer software is concerned only with the delivery and presentation of the content of the documents; it is the responsibility of the users to connect all the sources of information and interpret the information themselves. The semantic web attempts to enhance the current web, to enable computers rather than users to connect, process and interpret the information (Taniar & Rahayu, 2006). This approach requires that the languages used to describe the information should be standardised (Decker, et al., 2000; Horrocks, 2008). Taniar & Rahuyn (2006), and Decker et al. (2000) suggest that these standards should apply to both the document's syntactic form and to its semantic meaning.

The next section provides an overview of the role of the World Wide Web Consortium, which is to ensure compatibility and agreement among the key stakeholders in the formation of new standards for the World Wide Web. This is followed by a detailed discussion on the structure of the semantic languages recommended by the consortium, and to support this discussion, examples are provided, often with snippets of code based on examples taken from an early version of the e-government ontology developed in this thesis.

4.1.1 World Wide Web Consortium

The World Wide Web Consortium (W3C) is an international standards organization for the World Wide Web. The consortium is made up of member organisations, which maintain full-time staff for the purpose of working together in the development of standards for the World Wide Web. W3C was created to ensure compatibility and agreement among industry members in the adoption of new standards. Prior to a standard being recommended by the W3C, the standard's document is subjected to a public and W3C-member organisation's review. In this research, only those semantic languages recommended by the W3C are used.

4.1.2 Semantic Web Stack

Berners-Lee (2000) proposed his first version of the architecture of the Semantic Web in 2000. The architecture was based on a hierarchy of languages where each language utilised the structures and capabilities of the layers below Figure 4-1.

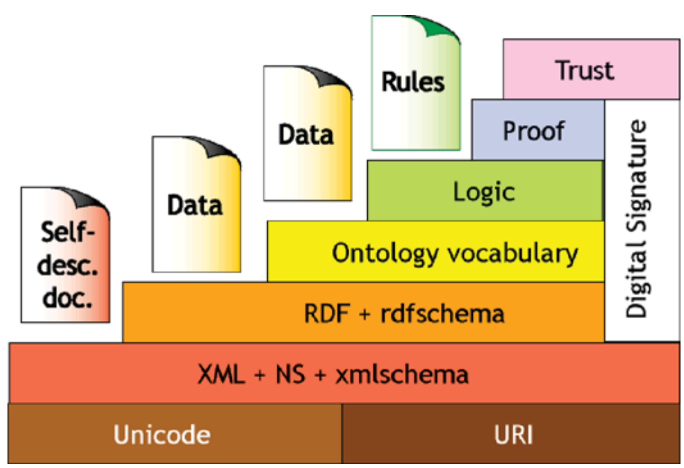


Figure 4-1: Semantic Web Architecture (Berners-Lee & Swick, 2000)

After the acceptance of the Web Ontology OWL as a W3C recommendation (World Wide Web Consortium (W3C), 2004a), more attention was then given to the Rules layer. For example, Horrocks, Parsia, Patel-Schneider & Hendler (2005) suggested that rather than a single stack the architecture could be divided into two towers, where one tower would focus on languages and the other on rules. More criticism of the Stack was made by Gerber, Barnard and van der Merwe (2007), who claim that the Stack is not truly an architecture as it does not depict functionality. Despite these reservations about the Stack, the 2009 version of the Stack proposed by Berbers-Lee (2009), is used in this thesis as it identifies the essential languages and technologies that are required to support the Semantic Web. The 2009 version of the Semantic Stack is displayed in Figure 4-2

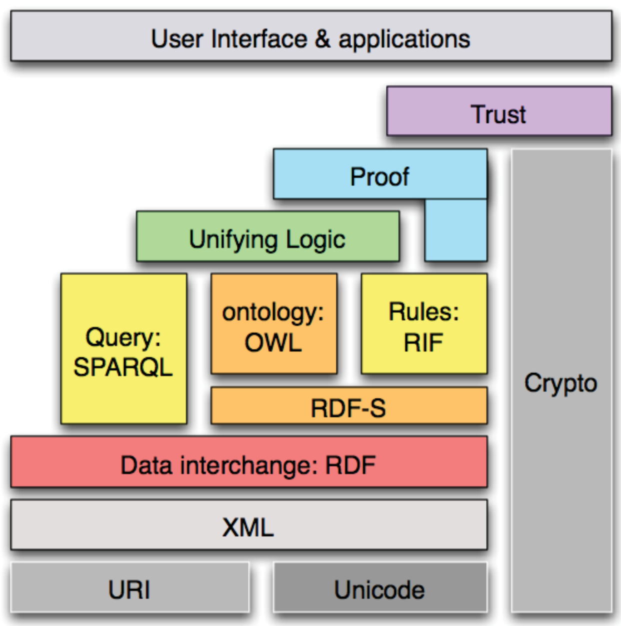


Figure 4-2:Semantic Stack - 2009 version (Berners-Lee, 2009)

4.1.3 Universal Resource Indicator (URI)

A URI is a string of characters used to identify all physical or abstract resources on the Internet (Breitman, et al., 2007b). Breitman et al. (2007b) point out that the URI is essential for structuring the Semantic Web as it provides a distributed and united information platform, and a global naming scheme that is stable, distributed and effective. Berners-Lee, Fielding and Masinter (2005) argue that this uniformity allows different types of resource to be interpreted consistently across contexts, allows the introduction of new types of resources without modifying the exiting format, and also makes it possible to reuse the identifiers in a different context.

URI has a number of subsets:

- Uniform Resource Locator (URL) specifies where a known resource is available and the mechanism for retrieving it.
- Uniform Resource Name (URN) is a persistent, location-independent resource identifier. An example is `urn:isbn:0-123-45678-9`.
- Internationalized Resource Identifier (IRI) is a generalization of the URI. It also allows the use of Unicode characters in the identifier.

4.1.3.1 URIref

A URIref is a URI, together with an optional fragment identifier attached to the end of the URI. In the following example, the fragment identifier `person` is separated from the URI by the "#" character: `http://www.topbraid/egovernment#person`

Absolute and relative URIrefs are available; the latter requires that the source URI be previously defined. Using the previous example, the previously defined source would be `http://www.topbraid/egovernment`, and the relative URIref `#person`.

4.1.3.2 Namespace

Namespace (also called XML Namespace) is based on the W3C recommendation (World Wide Web Consortium (W3C), 2009b). An XML namespace is a collection of element types and attribute names. The namespace is identified by a unique name, which is a URI reference. Therefore, any element type or attribute name in an XML namespace can be uniquely identified by a two-part name, the name of its XML namespace and its local name (similar to the fragment identifier). All XML namespaces are declared with an '`xmlns`' attribute, for example: `<cars:part xmlns:cars="http://www.cars.com/xml"/>`

4.1.3.3 QName

QName stands for qualified name and it defines a valid identifier for elements and attributes. Using URI references avoids the problems of long namespace names and the presence of prohibited characters (World Wide Web Consortium (W3C), 2009b). In documents conforming to this specification, element and attribute names appear as qualified names. Syntactically, they are either prefixed names or unprefixed names. Attribute-based declaration syntax is provided to bind prefixes to namespace names and to bind a default namespace that applies to unprefixed element names.

A namespace may appear as QName (qualified name) in the form of P:L where the single colon separates the name into a namespace prefix P and a local part L. The namespace prefix has to be associated with a namespace URIref N.

Table 4-1 shows some of the namespaces, base URI and Default Namespaces that are defined in the e-government ontology:

Table 4-1 Namespaces, URIref and Prefix

Namespace	URIref	Prefix
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#	rdf
rdfs	http://www.w3.org/2000/01/rdf-schema#	rdfs
xsd	http://www.w3.org/2001/XMLSchema#	xsd
dc	http://purl.org/dc/elements/1.1/	dc
geo	http://www.w3.org/2003/01/geo/wgs84_pos#	geo
Base URI	http://www.topbraid/egovernment	
Default Namespace	http://www.topbraid/egovernment#	

4.1.4 Unicode

Unicode is an important standard that has been widely used in the computing industry. It establishes the consistent encoding, representation and handling of text required in IT-based writing systems. Unicode was developed in conjunction with the Universal Character Set standard and published in an electronic book form as The Unicode Standard.

Version 6.0 of the Standard (Unicode Consortium (Unicode Inc.), 2011) consists of a collection of more than 100,000 characters covering textural information in over 90 language scripts, and includes associated symbols and punctuation.

The Standard has been implemented in many information technologies, such as Java, the Microsoft .NET Framework, and, more importantly from the Semantic Web perspective, the extensible markup language XML.

4.1.5 Extensible Markup Language (XML)

XML is a general-purpose markup language for documents containing structured information. HTML (hypertext markup language) is the standard language in which web pages are composed and presented to the user. The most significant difference between HTML and XML is that HTML describes presentation and XML describes content. An HTML document rendered in a web browser is *human* readable. XML is aimed toward being both human and *machine readable*. The design purposes of XML emphasize interoperability, simplicity, standardization and usability over the web (World Wide Web Consortium (W3C), 2011).

The XML layer, together with both XML namespace and XML schema definitions ensure that there is a common syntax used in the semantic web. An XML document contains elements that can be nested and that may have attributes and content. XML namespaces allow different markup vocabularies to be specified in one XML document, and the XML schema serves for expressing the schema of a particular set of XML documents.

Consider a simple example extracted from the e-government ontology in this research:

```
<NZ_Govt_MP>
            <firstname>Amy</firstname>
            <surname>Adams</firstname>
</NZ_Govt_MP>
```

The example shows how XML represents basic details about one of New Zealand Government MPs. The name of “Amy Adams” has no particular meaning to the computer as it is simply a string of text. The string “Amy Adams” is converted into two parts using labels. Each label consists of two “tags”; an opening tag <NZ_Govt_MP> and a closing tag </NZ_Govt_MP>. The collection of tags and content are called ‘elements’, elements may be nested as shown in the example. The computer now knows that “Amy” is the first name and that “Adams” is the surname. Sometimes it is useful to provide more information to the content of the element in order to identify the unique items. For example, the property `personal_profile` can be added, which points to a web page on the New Zealand Government’s web site.

```
<NZ_Govt_MP>
            <firstname>Amy</firstname>
            <surname>Adams</surname>
            <personal_profile>
                  <A HREF="http://www.parliament.nz/en
                  NZ/MPP/MPs/MPs/5/7/e/49MP169951-Adams-
                  Amy.htm">Adams&apos;s Profile
                  </A>
            </personal_profile>
</NZ_Govt_MP>
```

The nested element <personal_profile> provides additional information about this particular government MP.

As indicated in the Semantic Stack, XML plays an important role in knowledge representation and semantic web development. Ontology description languages have built upon many of the features from XML, such as the use of the datatype property, the use of tags, sequentially ordering elements, machine processing of data, and enabling documents to be structured and defined (Breitman, et al., 2007a).

4.1.6 Resource Description Framework (RDF)

XML and RDF are two important integrated languages used to support the Semantic Web. This concept is illustrated in Figure 4-2, Semantic Stack.

XML permits users to create their own tags to enhance the machine readability of data. However, XML does not say anything about the meaning of the tags unless additional software is used (Bosak & Bray, 1999). RDF provides a standardized, interoperable way to semantically describe XML based data (Gómez-Pérez & Corcho, 2002; Manola & Miller, 2004).

RDF is based on the idea that 'things' being described have properties, which in turn have values. Gómez-Pérez & Corcho (2002) describe the RDF data model as consisting of interrelated RDF statement, where each statement is based on a set of triples: subject, predicate and object:

- Resource: A resource is the subject in a 'triple'. A URI plus an optional identified ID names the resource.
- Predicate / Property: The predicate in a 'triple' defines specific aspects, characteristic, attribute, or relation of a resource..
- Object: This is the object in a 'triple'. It assigns a value to a property of a specific resource..

In RDF, the subject, predicate (properties or attributes) and object are each uniquely identified by a URI, except in the case where the object is a literal, or when a blank node is used (Berners-Lee, et al., 2001).

4.1.6.1 RDF Graph

Manola and Miller (2004) indicate that the use of URIs enables RDF statements to be displayed in a graph with nodes and arcs representing their properties and values. For example, the set of three triples in Table 4-2 states that Amy Adams is elected as the parliamentary representative of Selwyn, and that the Selwyn representative represents the Selwyn electorate, which in turn has an electoral code of S10. All of the elements of the triples except the electoral code S10, which is a literal, are uniquely defined by URI.

Table 4-2 RDF triples showing the relationship of Subject, Predicate and Object

	subject	predicate	object
1	http://www.topbraid/egov#	http://www.topbraid/egov#	http://www.topbraid/egov#

	Representtive_Selwyn	is_elected_as_MP	Adams_Amy
2	http://www.topbraid/egov# Representtive_Selwyn	http://www.topbraid/egov# represents_electorate	http://www.topbraid/egov# Selwyn_Electorate
3	http://www.topbraid/egov# Selwyn_Electorate	http://www.topbraid/egov# has_electorate_code	S10

The triples are displayed in graph format in Figure 4-3. The nodes that are URIrefs are shown as ellipses, while nodes that are literals are shown as boxes. Arcs are shown as arrowed lines and are labelled with names of the predicates, which are also URIs.

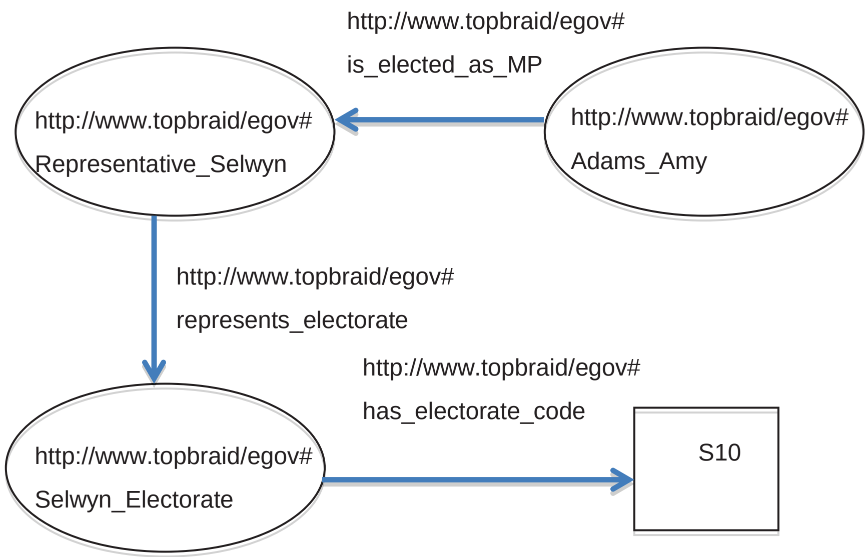


Figure 4-3: RDF graph showing the relationship subject, predicate and object

The corresponding rdf code using the reification element, `Statement` takes the following form:

```
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:egov="http://www.topbraid.egov#">
<rdf:Statement rdf:about="egov:is_elected_as_MP">
            <rdf:subject rdf:resource="egov:Adams_Amy"/>
            <rdf:predicate rdf:resource="egov:is_elected_as_MP"/>
            <rdf:object rdf:resource="egov:Representative_Selwyn"/>
</rdf:Statement>
<rdf:Statement rdf:about="egov:represents_electorate">
            <rdf:subject rdf:resource="egov:Representative_Selwyn"/>
            <rdf:predicate rdf:resource="egov:represents_electorate"/>
            <rdf:object rdf:resource="egov:Selwyn_Electorate"/>
</rdf:Statement>
<rdf:Statement rdf:about="egov:has_electorate_code">
            <rdf:subject rdf:resource="egov:Selwyn_Electorate"/>
            <rdf:predicate rdf:resource="egov:has_electorate_code"/>
<rdf:object rdf:datatype="&xs;string">S10</rdf:object>
</rdf:Statement>
</rdf:RDF>
```

4.1.6.2 RDF Language

RDF is an infrastructure that enables the encoding, exchange and re-use of structured metadata. It works as a language for representing information about resources in the WWW. The RDF language namespace prefix is usually `rdf:` and is (syntactically) defined at `http://www.w3.org/1999/02/22-rdf-syntax-ns#`. The RDF vocabulary includes the following elements (World Wide Web Consortium (W3C), 2000):

```
rdf:type - A predicate used to state that a resource is an instance
of a class
rdf:XMLLiteral - Class of typed literals (i.e., of XML literal
values)
rdf:Property - Class of properties
rdf:Alt, rdf:Bag, rdf:Seq - Containers
rdf:List - Class of RDF Lists
rdf:nil - Instance of rdf:List representing the empty list
rdf:Statement, rdf:subject, rdf:predicate, rdf:object - used for
reification (described below).
```

The `rdf:type` and `rdf:Property` elements are briefly discussed in the following section.

RDF reification element `rdf:Statement` disassembles a statement (triple) to its parts and allows the whole statement or parts of the statement to be used in other triples. The whole triple can then be treated as a resource, which allows assertions to be made about the statement.

RDF itself serves as a description of a graph formed by triples. To allow a standardized description of taxonomies and other ontological constructs, a RDF Schema (RDFS) is required together with its formal semantics.

4.1.7 RDF Schema (RDFS)

Allemang and Hendler (2008) state that RDFS enhances the data descriptive graph structure of RDF by providing additional features to add discipline to the graph structure, to enrich data relationship, and to enable data to be constrained in a meaningful way. The vocabulary for RDFS is described in full as a W3C Recommendation (World Wide Web Consortium (W3C), 2004b). The specification extends the definition of some of the elements of RDF. For example, it sets the domain and range of properties, and relates the RDF classes and properties into taxonomies using the RDFS vocabulary.

The concepts of resources, classes, properties and constraints found in RDFS are illustrated in Figure 4-4. In the diagram, a class is depicted by a round rectangle, a resource is depicted by a large dot, and arrows link a resource to the class it defines.

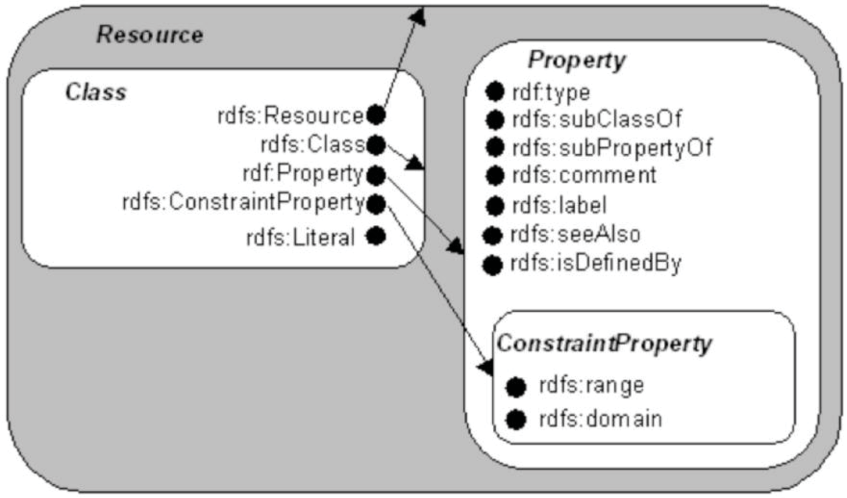


Figure 4-4: Classes and resources as Sets and Elements (World Wide Web Consortium (W3C), 2000)

4.1.7.1 DFS classes

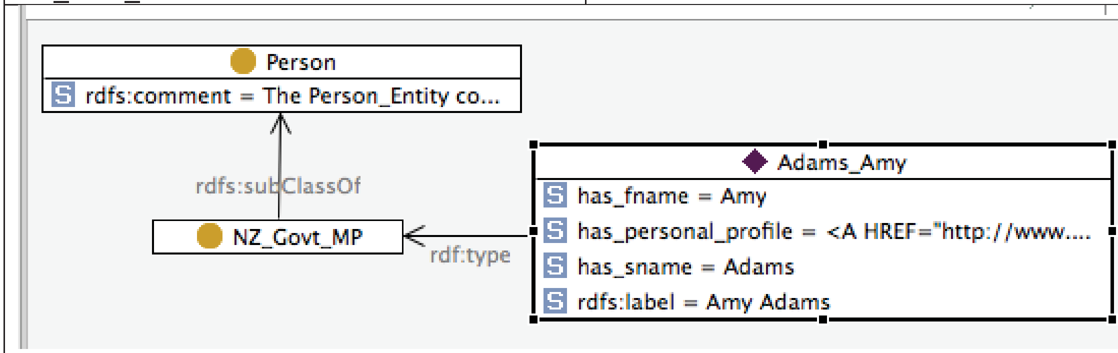
The following resources are the core classes that are defined as part of the RDF Schema vocabulary. Every RDF model that draws upon the RDF Schema namespace (implicitly) includes these.

- `rdfs:Resource`: All things being described by RDF expressions are called resources, and are considered to be instances of the class `rdfs:Resource`.
- `rdfs:Class`: Classes can be defined to represent almost anything, such as Web pages, people, document types, databases or abstract concepts. When a schema defines a new class, the resource representing that class must have an `rdf:type` property whose value is the resource `rdfs:Class`.
- `rdf:type`: This indicates that a resource is a member of a class, and as a result has all the characteristics that are to be expected of a member of that class. The value of an `rdf:type` property for some resource is another resource which must be an instance of `rdfs:Class`. The resource known as `rdfs:Class` is itself a resource of `rdf:type` `rdfs:Class`.

The concepts, `df:type`, `rdfs:class` and `rdfs:subClassOf` are illustrated in Table 4-3. The data described have been adapted from the e-government ontology developed in this research.

Table 4-3 Class subclasses and type (Code, diagram and screen dump)

Example 1	
The class NZ_Govt_MP is a subclass of the class Person Amy Adams is a member of the class NZ_Govt_MP	:NZ_Govt_MP rdfs:subClassOf :Person :Adams_Amy rdf:type :NZ_Govt_MP




```
<rdf:RDF xmlns="http://www.topbraid/egovt#"
     xml:base="http://www.topbraid/egovt"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
    <NZ_Govt_MP rdf:ID="Adams_Amy">
        <has_fname rdf:datatype="&xsd;string">Amy</has_fname>
        <has_sname rdf:datatype="&xsd;string">Adams</has_sname>
        <rdfs:label rdf:datatype="&xsd;string">Amy Adams</rdfs:label>
    </NZ_Govt_MP>
    <rdfs:Class rdf:ID="NZ_Govt_MP">
        <rdfs:subClassOf rdf:resource="#Person"/>
    </rdfs:Class>
    <rdfs:Class rdf:ID="Person"/>
</rdf:RDF>
```

4.1.7.2 RDFS properties

Properties in RDFS are relations between subjects and objects in RDF triples, i.e., predicates. All properties have a defined domain and range. The domain of a property states that any resource that has a given property is an instance of the ‘domain’ class, and the range of a property states that the values of a property are instances of the ‘range’ class.

These are instances of the `rdf:Property` class and provide a mechanism for expressing relationships between classes and their instances or super classes.

- `rdf:Property`: This represents the subset of RDF resources that are properties,
- `rdfs:subPropertyOf`: This property specifies a subset-superset relation between classes. The `rdfs:subPropertyOf` property is transitive. Only

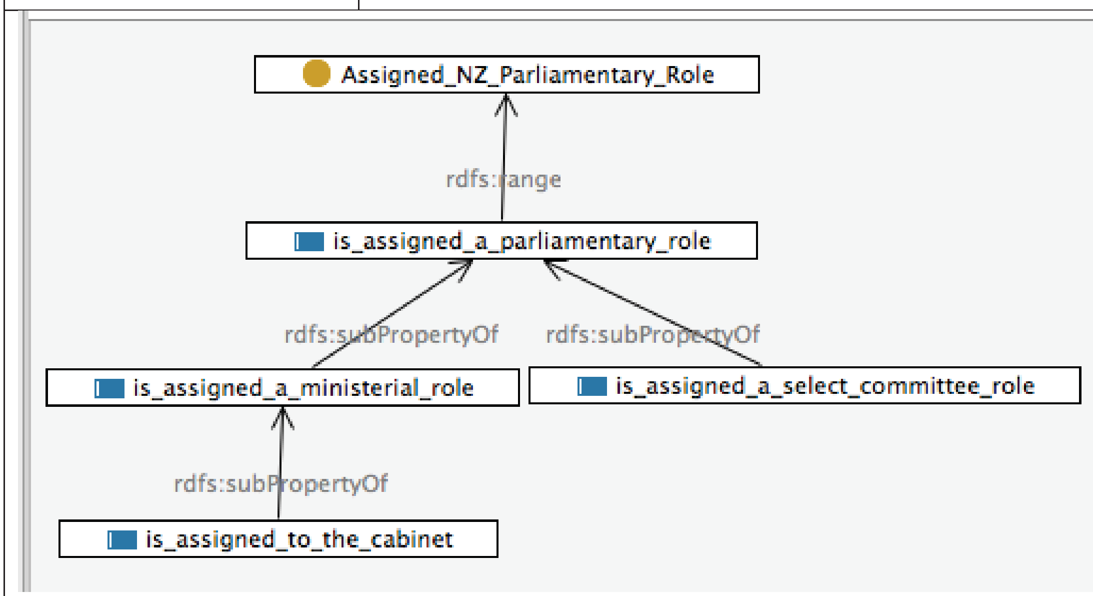
instances of `rdfs:Property` can have the `rdfs:subPropertyOf` property and the property value is always of `rdf:type rdfs:Property`.

The concept "`subPropertyOf`" is illustrated in Table 4-4. The data described have been adapted from the e-government ontology developed in this research.

Table 4-4 Sub-properties (code, diagram and screen dump)

Example 2	

Some MPs are assigned a Ministerial role in Parliament
 	
Some MPs are assigned a Select Committee role.
 	
Among those MPs assigned a Ministerial Role can also be assigned a position in the Cabinet
	`:is_assigned_to_a_ministerial_role`
	`rdfs:subPropertyOf`
	`    :is_assigned_to_a_parliament_role`
	
	`:is_assigned_to_a_cabinet_committee_role`
	`dfs:subPropertyOf`
	`    :is_assigned_to_a_ministerial_role`
	
	`:is_assigned_to_a_select_committee_role`
	`rdfs:subPropertyOf`
	`    :is_assigned_to_a_ministerial_role`



```
<rdf:RDF xmlns="http://www.topbraid/eogov#"
     xml:base="http://www.topbraid/eogov"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
   <rdfs:Class rdf:ID="Assigned_NZ_Parliamentary_Role"/>
       <rdfs:domain rdf:resource="#Assigned_NZ_Parliamentary_Role"/>
       <rdfs:subPropertyOf rdf:resource="#is_assigned_a_parliamentary_role"/>
   </rdf:Property>
   <rdf Property rdf:ID="is_assigned_a_parliamentary_role">
       <rdfs:domain rdf:resource="#Assigned_NZ_Parliamentary_Role"/>
   </rdf:Property>
   <rdf Property rdf:ID="is_assigned_a_select_committee_role">
       <rdfs:subPropertyOf rdf:resource="#is_assigned_a_parliamentary_role"/>
   </rdf Property>
   <rdf Property rdf:ID="is_assigned_to_the_cabinet">
       <rdfs:subPropertyOf rdf:resource="#is_assigned_a_ministerial_role"/>
   </rdf:Property>
</rdf:RDF>
```

4.1.7.3 Serialised Formats

RDF/XML is a normative syntax. However, other serialization formats are used as well. The Turtle and N3 syntaxes are more verbose than RDF/XML and so are fairly popular. The Notation3 (N3) is designed as a readable language for data on the Web that goes beyond RDF (it contains logical extensions and rules). The following code uses N3 notation:

```
@prefix egov: <http://www.topbraid.egov#>.
@prefix xs: <http://www.w3.org/2001/XMLSchema>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
<egov:has_electorate_code> rdf:object "S10"^^<&xs;string>;
     rdf:predicate <egov:has_electorate_code>;
     rdf:subject <egov:Selwyn_Electorate>;
     a rdf:Statement.
<egov:is_elected_as_MP> rdf:object <egov:Representative_Selwyn>;
     rdf:predicate <egov:is_elected_as_MP>;
     rdf:subject <egov:Adams_Amy>;
     a rdf:Statement.
<egov:represents_electorate> rdf:object <egov:Selwyn_Electorate>;
     rdf:predicate <egov:represents_electorate>;
     rdf:subject <egov:Representative_Selwyn>;
     a rdf:Statement.
```

Note: The ‘`a`’ in the triples is a syntactic shortcut for `rdf:type`.

4.1.8 Web Ontology Language (OWL)

The Web Ontology Language (OWL) is a recommendation of the World Wide Web Consortium (W3C) (2004a). It is an international standard for developing semantic web environments (Horrocks, 2003). OWL extends RDFS by adding more advanced constructs to describe the semantics of RDF statements. It includes descriptions of classes, properties and their instances. It also provides additional constraints, such as cardinality, restrictions of values, and characteristics of properties such as transitivity. It is based on description logic and so brings reasoning power to the semantic web (World Wide Web Consortium (W3C), 2004a). Berners-Lee, Hendler and Lassila (2001) consider the reasoning power of the semantic web to be absolutely crucial for the success of the semantic web, "For the semantic web to function, computers must have access to structured collections of information and sets of inference rules that they can use to conduct automated reasoning" (Berners-Lee, et al., 2001, p. 2).

Ontology Inference Layer (OIL) and Darpa Agent Markup Language (DAML) are the foundation languages of OWL. The development of DAML was funded in the USA by the Defense Advanced Research Projects Agency and included a markup language and some development tools. OIL, on the other hand, was based in Europe and was funded by the European Union's Information Society Technologies Programme. OWL is written using RDFS and its prime focus is to support the semantic web.

Zuo and Zhou (2003) identified the following aims of OWL:

- OWL ontologies should be suitable for sharing.
- OWL ontologies should be able to evolve and a given resource should be able to point to the version of the ontology that is being used.
- OWL should be able to allow ontologies to interoperate between each other when the same concepts are represented in different ontologies.
- It should be possible to detect any inconsistencies between different ontologies.
- OWL aims to meet a balance between expressivity and computational tractability, which leads to reasoning.
- OWL should be easy to use and be intuitive.
- OWL should be compatible with other standards like XML or Unified Modelling Language (UML).
- OWL should be compatible with internationalisation (usable in different languages).

In OWL, ontologies are constructed using three main elements:

- Individuals: These are the actual objects of the domain. They are equivalent to instances in both frames based systems and object oriented programming.
- Properties: These define the relationships linking/binding individuals together. Properties can be of different types:
- Object properties: These properties link individuals.
- Data type properties: These properties link individuals to types of data (integers, alphanumeric strings, for example)

- Annotation properties: Used to add extra information.

OWL is able to define in more detail the nature of a relationship. For example, properties can be functional, inverse functional, transitive or symmetric. In addition, the domain and range of a property can be defined.

- Classes: Sets of individuals. Class membership of individuals can be stated precisely using restrictions. Individuals can belong to more than one class and it can be explicitly stated that two classes are disjoint.
- OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDFS. This is achieved by providing an additional vocabulary and formal semantics.
- OWL has three expressive sublanguages: OWL Lite, OWL DL, and OWL Full.
- OWL Lite is an 'easier to implement' subset of OWL DL. It has simple class hierarchies and simple restrictions, such as 0 and 1 cardinality.
- OWL DL is based on First Order Logic and therefore it is computationally tractable, so that automated reasoning can be applied. OWL DL supports maximum expressiveness while retaining computational completeness and decidability. As the name suggests OWL DL is intended to support description logic capabilities.
- OWL Full is the union of OWL syntax and RDF. This is the most expressive OWL type. However, the computational tractability is not guaranteed and reasoning is not always possible.

These three languages are layered in a sense that every legal OWL Lite ontology is a legal OWL DL ontology, and every legal OWL DL ontology is a legal OWL Full ontology.

In this research OWL DL species is adopted as it provides more expressive constructs than OWL Lite. OWL DL is also preferred to OWL Full as predictable reasoning support is required.

There are two commonly used versions of OWL, namely OWL1 and OWL2. OWL2 replaced OWL1.1 as the recommended version in October 2009 (World Wide Web Consortium (W3C), 2009b). The new version has been adopted into semantic editors such as Protégé and TopBraid Composer, and semantic reasoners such as Pellet, RacerPro, and FaCT++. OWL2 address some of the shortcoming of OWL1.1 (Patel-Schneider, Sattler, Parsia, Horrocks, & Grau, 2008).

4.1.8.1 OWL 2

The building blocks of the OWL 2 language are shown in Figure 4-5. The ellipse in the centre of the figure represents the abstract notion of an ontology, either in the form of an ontological structure or an RDF graph. The two semantic specifications that define the meaning of OWL 2 ontologies are displayed at the bottom of the figure and the various syntaxes that can be used to serialize and exchange ontologies are at the top of the figure.

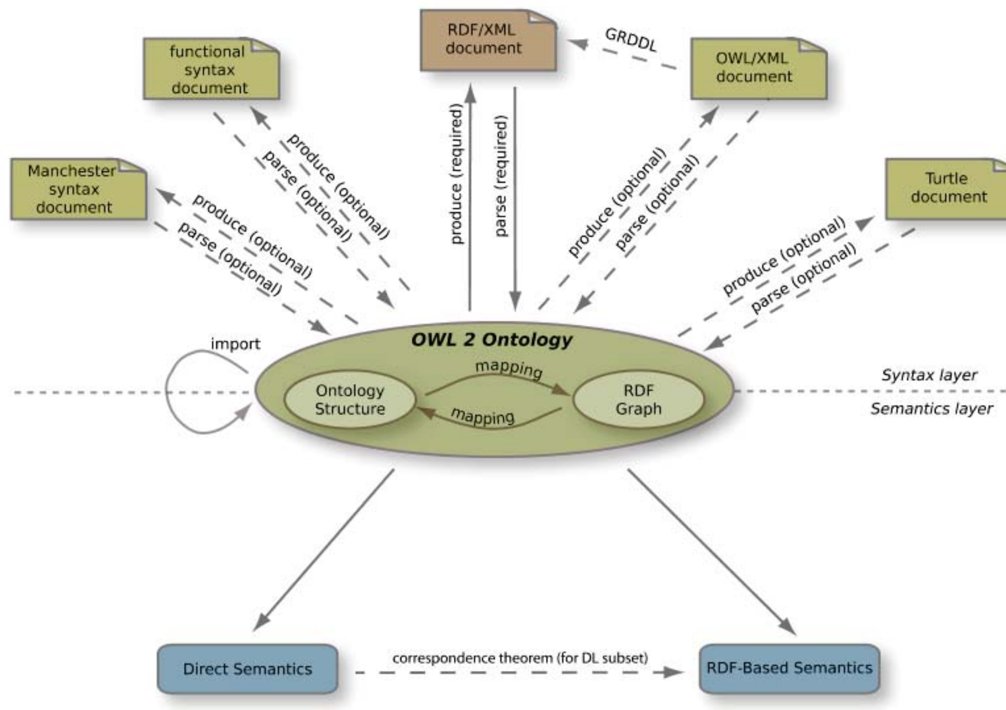


Figure 4-5: The structure of OWL 2 (World Wide Web Consortium (W3C), 2009b)

Generally speaking, only one syntax and one semantics is required when working with OWL 2. In this research the Manchester Syntax is adopted, as it is easier to read and apply than other syntaxes, and is used in many tools and applications such as Protégé and TopBraid Composer (Horridge & Patel-Schneider, 2009). The RDF based semantics is adopted as it better meets the skill-set of the researcher.

4.1.8.2 The Structure of OWL Ontologies

In order to write an ontology that can be interpreted unambiguously and used by software agents, a syntax and formal structure are required for OWL. In the following examples, programming code has been extracted from the e-government ontology developed in this thesis.

4.1.8.2.1 Namespaces

A set of XML namespace declarations are enclosed in an opening `rdf:RDF` tag. These provide a means to unambiguously interpret appropriate vocabularies used in the ontology.

```
<rdf:RDF
      xmlns="http://www.topbraid/egovernment#"
      xml:base="http://www.topbraid/egovernment"
      xmlns:owl="http://www.w3.org/2002/07/owl#"
      xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
      xmlns:protege="http://protege.stanford.edu/plugins/owl/protege#"
      xmlns:xsp="http://www.owl-ontologies.com/2005/08/07/xsp.owl#"
      xmlns:p1="http://purl.org/dc/elements/1.1/#"
      xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
      xmlns:swrl="http://www.w3.org/2003/11/swrl#"
      xmlns:swrlb="http://www.w3.org/2003/11/swrlb#">
...
```

The first declaration identifies the namespace associated with this ontology. The second identifies the base URI for this document. The next three identify the relevant syntax from OWL, RDF and RDFS. There are similar links to SWRL and the Dublin Core.

4.1.8.2.2 Ontology Headers

The `owl:Ontology` tag is used to add important housekeeping tasks, such as comments, version control and inclusion of other ontologies.

```
<owl:Ontology rdf:about="">
<rdfs:comment>A prototype e-government ontology</rdfs:comment>
<owl:imports
rdf:resource="http://www.topbraid.org/owl/2006/07/tbcgeo.owl"/>
<rdfs:label>egovernment ontology</rdfs:label>
...
</owl:Ontology>
```

The `rdf:about` attribute provides a name or reference for the ontology. The `rdfs:comment` permits the author to annotate the ontology, and `owl:imports` results in the importation of another ontology, including its entire set of assertions.

4.1.8.3 Basic Elements

4.1.8.3.1 Simple Classes (Class, rdfs:subClassOf)

In order to reason about individuals it is essential that there is a mechanism to describe the classes to which individuals belong, and the properties that they inherit by virtue of class membership. Every individual in the OWL world is a member of the class `owl:Thing`. Therefore, each user-defined class is implicitly a subclass of `owl:Thing`. Domain specific root classes are defined by simply declaring a named class. For example,

```
<owl:Class rdf:ID="Person"/>
<owl:Class rdf:ID="Position"/>
```

Within this document, the Person class can now be referred to by using `#Person`, e.g. `rdf:resource="#Person"`.

The fundamental taxonomic constructor for classes is `rdfs:subClassOf`. It relates a more specific class to a more general class.

```
<owl:Class rdf:ID="NZ_Govt_MP">
      <rdfs:subClassOf>
      <owl:Class rdf:ID="Person"/>
      </rdfs:subClassOf>
      ...
</owl:Class>
```

4.1.8.3.2 Individuals (instances)

An individual is minimally introduced by declaring it to be a member of a class.

```
<Non_MP_Person rdf:ID="Hammond_David">
```

Note that the following is identical in meaning to the example above.

```
<owl:Thing rdf:ID="Hammond_David" />
<owl:Thing rdf:about="#Hammond_David">
     <rdf:type rdf:resource="#Person"/>
</owl:Thing>
```

`rdf:type` is an RDF property that ties an individual to a class of which it is a member.

4.1.8.3.3 Properties

A property is a binary relation. There are two types of properties:

- datatype properties: Relations between instances of classes and RDF literals and XML Schema datatypes
- object properties: Relations between instances of two classes.

In the following example the property is restricted using domain and range. It relates instances of the class `NZ_MP` to instances of the class `Political_Party`. Multiple domains mean that the domain of the property is the intersection of the identified classes (and similarly for range).

```
<owl:ObjectProperty rdf:ID="has_political_party">
      <rdfs:domain rdf:resource="#NZ_MP"/>
```

```
      <rdfs:range rdf:resource="#Political_Party"/>
</owl:ObjectProperty>
```

Properties, like classes, can be arranged in a hierarchy.

```
<ow:Class rdf:ID="MP_Person"/>
<owl:Class rdf:ID="Assigned_NZ_Parliamentary_Role"/>
<owl:Class rdf:ID="Select_Committe_Role">
     <rdfs:subClassOf rdf:resource="#Assigned_NZ_Parliamentary_Role"/>
     ...
<owl:Class rdf:ID ="Ministerial_Role">
     <rdfs:subClassOf rdf:resource="#Assigned_NZ_Parliamentary_Role"/>
      ...
<owl:ObjectProperty rdf:ID="is_assigned_a_parliamentary_role">
      <rdfs:domain rdf:resource="#MP_Person"/>
      <rdfs:range rdf:resource="#Assigned_NZ_Parliamentary_Role"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="is_assigned_a_ministerial_role">
      <rdfs:range rdf:resource="#Ministerial_Role"/>
      <rdfs:domain rdf:resource="#MP_Person"/>
      <rdfs:subPropertyOf
      rdf:resource="#is_assigned_a_parliamentary_role"/>
</owl:ObjectProperty>
      <owl:ObjectProperty
      rdf:ID="is_assigned_a_select_committee_role">
      <rdfs:subPropertyOf
      rdf:resource="#is_assigned_a_parliamentary_role"/>
      <rdfs:range rdf:resource="#Select_Committe_Role"/>
      <rdfs:domain rdf:resource="#MP_Person"/>
</owl:ObjectProperty>
```

The property `is_assigned_a_parliamentary_role` has two sub-properties, which belong to two subclasses of `Assigned_NZ_Parliamentary_Role`.

4.1.8.3.4 Cardinality

An example of cardinality is shown in the following code. In this case each `General_Electorate_Area` consists of no more than one `Parliamentary_Electorate`.

```
<owl:Class rdf:ID="General_Electorate_Area">
     ...
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="#has_Parliamentary_Electorate"/>
<owl:maxCardinality
     rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger
     ">1</owl:maxCardinality>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>
```

4.1.8.3.5 Property Characteristics

Property characteristics provide a mechanism to enrich reasoning about a property. These properties include:

- TransitiveProperty
- P(x,y) and P(y,z) implies P(x,z)
- SymmetricProperty
- P(x,y) iff P(y,x)
- FunctionalProperty
- P(x,y) and P(x,z) implies y = z
- InverseOf
- P1(x,y) iff P2(y,x)
- InverseFunctionalProperty
- P(y,x) and P(z,x) implies y = z

4.1.8.3.6 Property Restrictions

These two restrictions allValuesFrom and someValuesFrom are local to their containing class definition. In the following example of owl:allValuesFrom for every instance of the class that has instances of the specified property, the values of the property are all members of the class indicated by the owl:allValuesFrom clause.

```
<owl:Class rdf:about="#NZ_Government_Organisational_Publications">
     <rdfs:subClassOf rdf:resource="#Publication"/>
     <rdfs:subClassOf>
          <owl:Restriction>
               <owl:onProperty>
                    <owl:ObjectProperty rdf:about="#is_published_by"/>
                    <owl:allValuesFrom
                    rdf:resource="#NZ_Government_Organisational_Structu
                    re"/>
          </owl:Restriction>
     </rdfs:subClassOf>
     ...
</owl:Class>
```

4.1.8.4 Complex Classes (OWL DL)

OWL DL provides additional constructors with which to form and specify classes. OWL supports the basic set operations, namely enumeration, intersection disjoint, union, and complement; these are named owl:oneof, owl:intersectionOf, owl:disjoint, owl:unionOf, and owl:complementOf, respectively.

4.1.8.4.1 Enumeration

The following example illustrates the use of the `oneOf` construct.

```
<owl:Class rdf:ID="SC_Foreign_Affairs_Defence_and_Trade_Member">
      <owl:oneOf rdf:parseType="Collection">
            <Select_Committee_Role
            rdf:about="#Select_Committee_Foreign_Affairs_Defence_and_T
            rade_Chair"/>
            <Select_Committee_Role
            rdf:about="#Select_Committee_Foreign_Affairs_Defence_and_T
            rade_Member"/>
            <Select_Committee_Role
            rdf:about="#Select_Committee_Foreign_Affairs_Defence_and_T
            rade_Deputy_Chair"/>
      </owl:oneOf>
</owl:Class>
```

Since the class has been defined by enumeration, no other individual can be a `SC_Foreign_Affairs_Defence_and_Trade_Member`.

4.1.8.4.2 Intersection

The following example demonstrates the use of the intersectionOf construct.

```
<owl:Class rdf:ID="MP_Person"
<owl:intersectionOf rdf:parseType="Collection">
<owl:Class rdf:about="#Political_Party"
<owl:Restriction>
      <owl:onProperty rdf:resource="#has_political_party"/>
      <owl:hasValue rdf:resource="#Progressive_Party"/>
</owl:Restriction>
</owl:intersectionOf>

<owl:Class rdf:ID="WhiteWine">
<owl:intersectionOf rdf:parseType="Collection">
<owl:Class rdf:about="#Wine" />
<owl:Restriction>
      <owl:onProperty rdf:resource="#hasColor" />
      <owl:hasValue rdf:resource="#White" />
</owl:Restriction>
</owl:intersectionOf> </owl:Class>
```

This means that if something is `Progressive_Party` and a `Political_Party`, then it is an instance of `MP_Person.`

4.1.8.4.3 Union (and Disjoint)

A common requirement is to define a class as the union of a set of mutually disjoint subclasses.

```
<owl:Class rdf:ID="General_Electorate_Position">
<rdfs:subClassOf rdf:resource="#Elected_NZParliament_Position" />
<owl:disjointWith rdf:resource="#Maori_Electorate_Position" />
```

```
</owl:Class>

<owl:Class rdf:ID="Maori_Electorate_Position">
<rdfs:subClassOf rdf:resource="#Elected_NZParliament_Position" />
<owl:disjointWith rdf:resource="#General_Electorate_Position" />
</owl:Class>

<owl:unionOf rdf:parseType="Collection">
      <owl:Class rdf:ID="General_Electorate_Position"/>
      <owl:Class rdf:ID="Maori_Electorate_Position"/>
</owl:unionOf>
```

The `Elected_NZParliament_Position` is defined to be exactly the union of two disjoint classes, namely `General_Electorate_Position` and `Maori_Electorate_Position`.

4.1.8.4.4 Complement

The `complementOf` construct selects all individuals from the domain of discourse that do not belong to a certain class. This construct is not used in the e-government ontology in this research.

4.1.8.5 Description Logics (DLs)

Description logics (DLs) are a family of logics that are decidable fragments of first-order logic with attractive and well-understood computational properties. OWL DL has semantics based on DLs. They combine syntax for describing and exchanging ontologies, and formal semantics that give them meaning. For example, OWL1-DL corresponds to the SHOIN (D) description logic, while OWL2-DL corresponds to SROIQ(D).

The foundations of DL are concept and role descriptions (roles), where concept represents a class of objects sharing some common characteristics, and a role represents a binary relationship between objects, or between objects and data values. In Table 4-5 and Table 4-6, the following notation is used: *A* and *B* are atomic concepts, *C* and *D* are concept descriptions, and *R* is an atomic role. The semantics is defined using interpretation I that consists of the non-empty set Δ^I (the domain of interpretation) and an interpretation function, which assigns a set $A^I \subseteq \Delta^I$ to every atomic concept *A* and which assigns a binary relation $R^I \subseteq \Delta^I \times \Delta^I$ to every atomic role *R*. The interpretation function is then extended using inductive definitions. The "abstract" LISP-like syntax is displayed in the tables, as it is easier to write using the ASCII character set, and appears closer in form to that used in OWL. According to an accepted convention, each language identifies the constructs used in the chosen Description Logics. The following section illustrates this principle.

4.1.8.5.1 Attribute Language logic (AL) Family of Logics

Description languages are a family of *AL*-language (acronym for attribute language). The *AL* (attribute language) logic is the minimal logic that delivers a practical usable vocabulary. The AL logic forms the core of all other useful logics, and all the other languages are regarded as an extension of it. The *AL* logic is set out in Table 4-5.

Table 4-5 Attribute Language semantics

	Abstract semantics	Syntax	Semantics
Attribute Language	A (uri reference)	A	$A^I \subseteq \Delta^I$
	R (uri reference)	R	$R^I \subseteq \Delta^I \times \Delta^I$
	owl:Thing	$\top$	Δ^I
	Owl:Nothing	$\bot$	ϕ
	complementOf (atomic negation)	$\neg A$	$\Delta^I \backslash A^I$
	intersectionOf	$C \cap D$	$C^I \cap D^I$
	restriction(allValuesFrom)	$\forall R.C$	$\{a \in \Delta^I \mid \forall b.(a,b) \in R^I \Rightarrow b \in C^I\}$
	restriction(someValuesFrom (limited existential quantification)	$\exists R.C$	$\{a \in \Delta^I \mid \exists b.(a,b) \in R^I\}$

4.1.8.5.2 ALC Family of Logics

The *AL* logic can be extended by adding new constructs as shown in Table 4-6. A new logic is defined by selecting additional constructs from the set *{[U][E][N][C]}.* From a semantic perspective some of the combinations in the set are not unique. For example, union (U) and existential quantification (E) can be expressed using negation. The letter *C* is preferred when the combination *UE* is chosen (i.e. ALC ≡ ALUE).

Table 4-6 Extension constructs [U]. [E]. [N] and [C]

		Syntax	Semantics
U	unionOf(C,D, …)	$C \cup D$	$C^I \cup D^I$
E	restriction(someValuesFrom) (full quantification)	$\exists R.C$	$\{a \in \Delta^I \mid \exists b.(a,b) \in R^I \wedge b \in C^I\}$
N	restriction (minCardinality) restriction (maxCardinality)	$\geq nR$ $\leq nR$	$\{a \in \Delta^I \mid \lvert\{b \mid (a,b) \in R^I\}\rvert \geq n\}$ $\{a \in \Delta^I \mid \lvert\{b \mid (a,b) \in R^I\}\rvert \leq n\}$
C	Negation of arbitrry concept (concept description negation)	$\neg C$	$\Delta^I \backslash C^I$

4.1.8.5.3 SHOIN Family of Logics

Further extensions of *ALC* logic are of particular relevance to OWL1 DL.

S role transitivity *Trans(R)* (asserting that role is transitive)

H role hierarchy $R \subseteq S$ (asserting hierarchy of roles)

I role inverse R^- (creating inverse role)

F functionality *R* (functional role in concept creation)

O nominals $\{a_1, ..., a_n\}$ (concept declared by enumeration)

Since these constructors or axioms all extend the *ALC* logic it is only necessary to specify the extensions in the logic name.

OWL1-DL has the description logic *SHOIN(D).* The (*D*) represents the additional support for data values, data types and datatype properties.

4.1.8.5.4 SROIQ(D) Family of Logics

In developing OWL2-DL, further extensions to *SHOIN(D)* logic have been put forward.

R Complex role inclusion (eg. $Parent \circ ancestor \sqsubseteq ancestor$)

Q Qualified number restrictions

Other features added to the *SHOIN(D)* family of logics include: disjoint roles, reflexive and irreflexive roles, asymmetric roles, universal role, and concept constructer $\exists R.Self$. These extensions have produced a family of logics expressed as SROIQ(D).

4.1.9 Rule Languages

To extend rules beyond the constructs that can be achieved using RDFS and OWL, new rule languages have been developed. Two approaches have been developed, namely Rule Interchange Format (RIF) and Semantic Web Rule Language (SWRL). RIF is a recommendation of the W3C (2010a), whereas SWRL is simply a submission of the W3C (2004).

4.1.9.1 Rule Interchange Format (RIF)

The Rule Interchange Format is designed to be an exchange language enabling information to be shared between environments that have been constructed using an array of different paradigms and business models. Essentially RIF consists of a family of languages, called dialects, which have rigorously specified syntax and semantics. The family of RIF dialects is intended to be *uniform* and *extensible*. Uniformity means that dialects are expected to share, as much as possible, existing syntactic and semantic features. Extensibility means that experts should be able to add to an existing dialect in order to meet their own specific needs and requirements. A key tenet underpinning rule exchange through RIF is that syntactic mappings will enable systems with their own unique native language to map via RIF dialects (World Wide Web Consortium (W3C), 2005).

4.1.9.2 Rule Language (SWRL)

SWRL is a popular and frequently used OWL-based rule language that allows users to write rules that can be expressed in terms of OWL concepts (World Wide Web Consortium (W3C), 2004). It provides a more powerful deductive reasoning language than OWL alone. It is built on the same description logic foundation as OWL and offers similar formal guarantees when performing inference. However, it has become less important as any SWRL rule can be successfully represented using SPARQL. For example, the frequently used ‘uncle query’ in SWRL:

```
parent(?x,?y) ∧ brother(?y,?z) ⇒ uncle(?x,?z)
```

can be written in SPARQL as:

```
CONSTRUCT {?x :uncle ?z} WHERE {?x :parent ?y. ?y :brother ?z .}
```

4.1.10 Simple Protocol RDF Query Language (SPARQL)

Simple Protocol and RDF Query Language (SPARQL) is an RDF query language. It can be used to query any RDF-based data, including statements involving RDFS and OWL. SPARQL is a W3C Recommendation (2008), and is a key semantic technology (Berners-Lee, 2009). SPARQL can be used to express queries across diverse data sources, whether the data is stored natively as RDF or viewed as RDF via middleware. SPARQL contains capabilities for querying required and optional graph patterns along with their conjunctions and disjunctions. SPARQL also supports extensible value testing and constraining queries by source RDF graph. The results of SPARQL queries can be results sets or RDF graphs.

Most forms of SPARQL query contain a set of triple patterns called a *basic graph pattern*. Triple patterns are like RDF triples except that each of the subject, predicate and object may be a variable. A basic graph pattern matches a subgraph of the RDF data when RDF terms from that subgraph may be substituted for the variables and the result is a RDF graph equivalent to the subgraph.

An example of an RDF graph, taken from the e-government ontology, showing both the visual and tabular forms of the graph, is displayed in Table 4-7 and Figure 4-6. These graphs show the triples linking the MP, Todd McClay, to his electorate, then to the electorate’s geographical area and subsequently to areas associated with local districts. Other triples associated with the MP have been omitted.

Table 4-7: RDF graph of MP Todd McClay (tabular)

Subject	Predicate	Object
:McClay_Todd	:is_elected_as_MP	:Representative_Rotorua_Electorate
:Representative_Rotorua_Electorate	: has_Parliament_Electorate	:Rotorua_Electorate
:Rotorua_Electorate	:located_in_Parliamentary_Electorate_Area	:Rotorua_Area
:Rotorua_Area	:related_to_City_and_District_Council_Area	:Whakatane_District_Area
..	..	:Western_Bay_of_Plenty_District_Area
..	..	:Taupo_District_Area
..	..	:Kawerau_District_Area
..	..	:Rotorua_District_Area

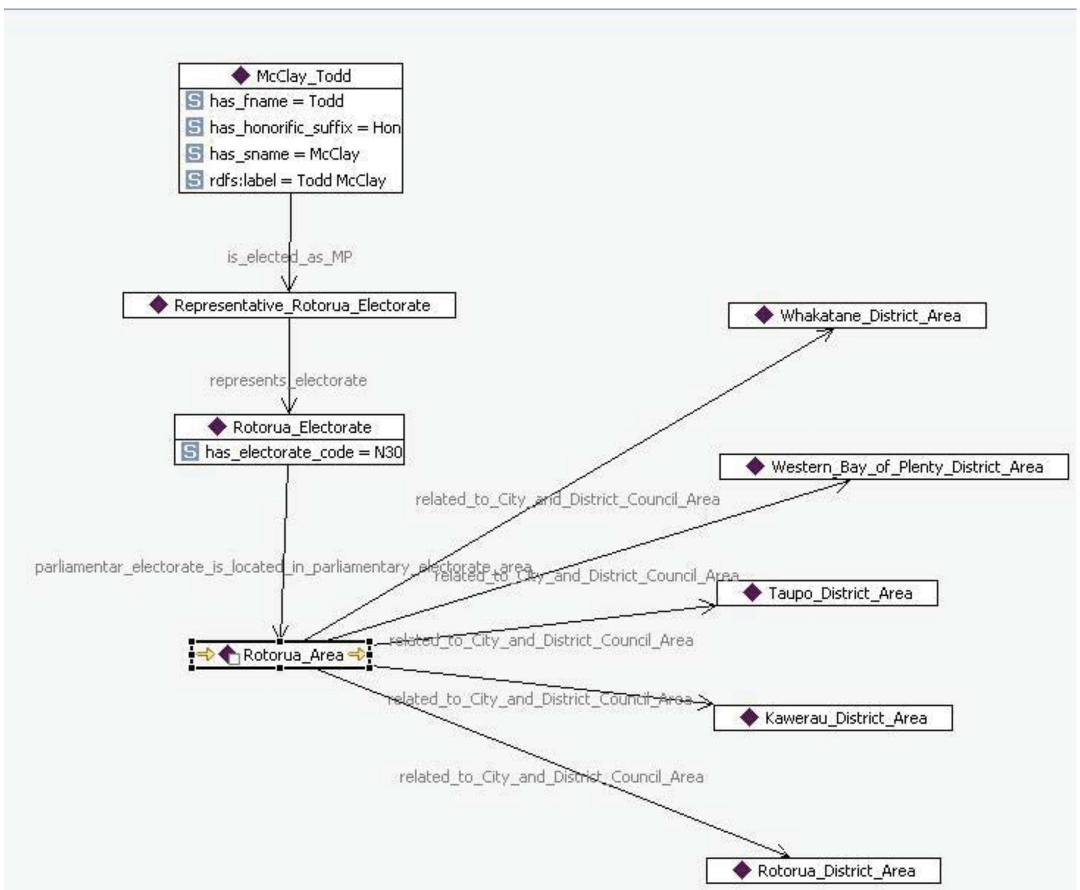


Figure 4-6: RDF graph of MP Todd McClay (visual)

4.1.10.1 Query result forms

Information can be extracted from RDF graphs in a number of ways using query result forms. It is possible, for example, to construct a RDF graph to obtain the necessary results.

- `SELECT:` This syntax returns the list of values of variables bound in a query pattern.
- `CONSTRUCT`: This returns an RDF graph constructed by substituting variables in the query pattern.
- `DESCRIBE:` Returns an RDF graph describing the resources that were found.
- `ASK:` Returns a boolean value indicating whether the query pattern matches or not.

Examples of SELECT and CONSTRUCT result forms follow.

4.1.10.1.1 Select

The basic form of SELECT is either of the following

```
SELECT Variables
FROM Dataset
WHERE Pattern
```

```
PREFIX A: <http://. . . #>
SELECT Variables
WHERE Pattern
```

Variables are indicated by a "?" or "$" prefix. The SPARQL query processor searches for sets of triples that match triple patterns, binding the variables in the query to the corresponding parts of each triple. To make queries concise, SPARQL allows the definition of prefixes and base URIs in a fashion similar to OWL. In this query, the prefix "A" stands for “http://. . . #”

In the following examples, two queries are formed based on triples linked to Todd McClay. Table 4-8 and Table 4-9 show the queries in both plain language and SPARQL format. In each case the result of the SPARQL query appears in the final row of the table.

With the SELECT form, particular variables are selected from the triple pattern, and the resulting bindings are returned as a table of values for the corresponding variables.

Table 4-8 Question 1: Which electorate does Todd McClay represent?

Question	Which Electorate does Todd McClay represent?
Query SPARQL	SELECT ?ElectorateRepresentative WHERE {: McClay_Todd :is_elected_as_MP ?Electorate_Representative. }met
SPARQL Results	?ElectorateRepresentative = Representative_Rotorua_Electorate

Table 4-9 Question 2: Which local districts fall within Todd McClay's electorate area?

Question	Which City or District Councils are related with the Electorate that represented by McClay Todd?

Query in SPARQL	SELECT ?district_council_area
	WHERE {
	:McClay_Todd :is_elected_as_MP ?ElectorateReprestentative .
	?ElectorateReprestentative :represents_electorate ?ParliamentElectorate.
	?ParliamentElectorate
	:parliamentary_electorate_is_located_in_parliamentary_electorate_area
	?ElectorateArea.
	?ElectorateArea :related_to_City_and_District_Council_Area
	?district_council_area.
	}

SPARQL Results	?district_council_area = Kawerau_District_Area ?district_council_area =Rotorua_District_Area ?district_council_area =Taupo_District_Area ?district_council_area =Western_Bay_of_Plenty_District_Area ?district_council_area =Whakatane_District_Area

4.1.10.1.2 Construct

The CONSTRUCT query builds an RDF based on a graph template. The graph template can have variables which are bound by a WHERE clause. The effect is to calculate the graph fragment for each solution from the WHERE clause, after taking into account any solution modifiers. The graph fragments, one per solution, are merged into a single RDF graph.

Figure 4-7 shows an example, describing a small family in a graph using triples.

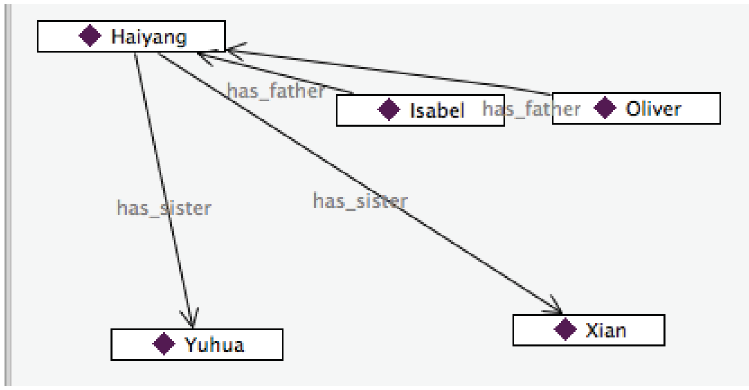


Figure 4-7: A small family of five

This family is then subjected to the following CONSTRUCT, as shown in Figure 4-8:

```
CONSTRUCT {?x :has_aunt ?z}
WHERE {
  ?x :has_father ?y .
?y :has_sister ?z
}
```

Figure 4-8: Creation of new construct property has_aunt

The newly graph with the new construct and set of triples is shown in Figure 4-9

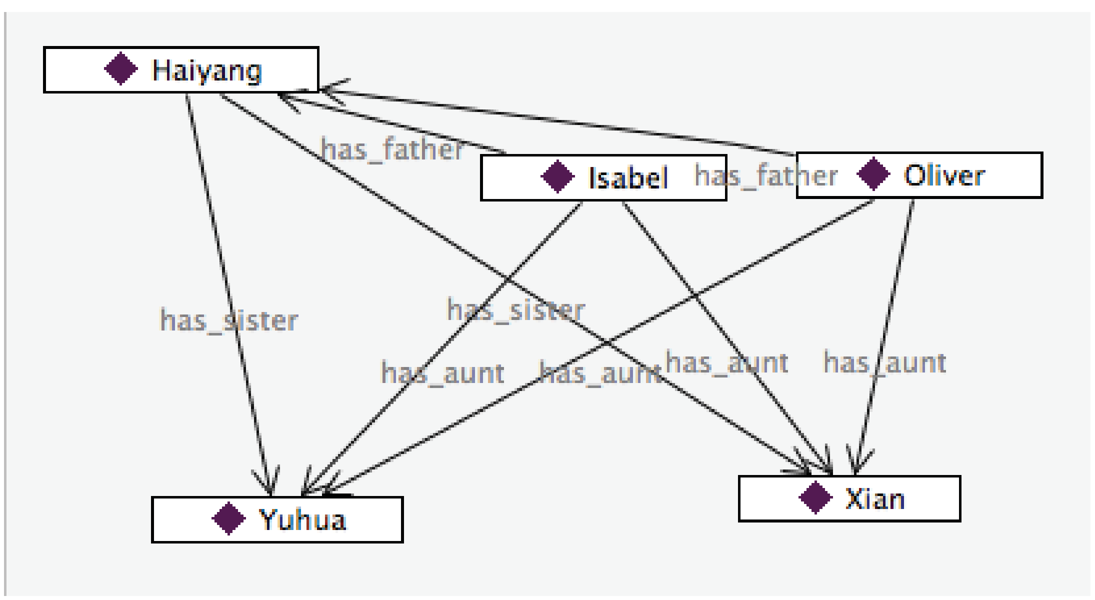


Figure 4-9: Small family of five with new relation 'has_aunt' and associated set of triples'

4.1.10.2 Solution Sequences and Modifiers

The result may be modified using the following keywords with the meaning similar to SQL:

- Order modifier: Puts the solutions in order.
- Projection modifier: Chooses certain variables to narrow the range of alternatives.
- Distinct modifier: Ensure solutions in the sequence are unique.
- Reduced modifier: Permits the elimination of some non-unique solutions
- Offset modifier: Controls where the solutions start from in the overall sequence of solutions.
- Limit modifier: Restricts the number of solutions.

4.1.11 Unifying Logic

Unifying Logic is meant to unify the semantic worlds of RDF, Description Logics, and rules. Of all these languages, RDF, RDFS, OWL and SPARQL are W3C recommendations. However, at the present time there are no significant standardisation efforts towards unifying the logic for the semantic web.

4.1.12 Proof Trust and Cryptography

Proof depends on the effectiveness of the formal semantics and rules are implemented in the knowledge base. Formal proofs together with reliable sources of input will mean that results can be trusted. Cryptography is important as it seeks to ensure that information really does come from trusted sources. No significant progress has been recorded.

4.1.13 User Interface and Applications

It is intended that the final layer, User Interface and Application, will enable humans to effectively use the semantic web applications. In this research, TopBraid Ensemble is used, but this is not likely to be a final solution.

4.1.14 Selected Semantic Languages

Given the 2004 recommendations of the World Wide Web Consortium (W3C) there is little choice but to accept the set of semantic languages named in the Semantic Stack:

- RDF(S)
- OWL2-DL
- SPARQL

The ability of both RDF(S), namely OWL and SPARQL to adequately support aspects of an e-government semantic framework has been demonstrated using a number of examples and snippets of code, based on real-world situations.

4.2 Semantic systems development tools

The choice of authoring tools to construct both the ontology and the interactive browser interface is very important. Not only do the tools have to be easy to use, and be effective and efficient, but, more importantly the constructs they produce must conform to the standards recommended by the World Wide Web consortium.

In subsection 4.2.1, a summary of the review that was carried out in 2007 to ascertain the suitability of the various publically available authoring tools is provided. At that point in time in 2007, the researcher was about to begin the design and construction of the ontology; however, there was uncertainty as to how the ontology would be deployed across the Internet and it was not until 2010 that this question was addressed in detail.

A review was undertaken in 2010, of the available tools thought capable of creating an interactive web interface to the e-government ontology. The details of this review are covered in subsection 4.2.2.

In the light of new developments in the field of ontology development, a reconsideration of the 2007 choice of the semantic web-authoring tool was carried out in 2010. The purpose of this update was to ensure there was full compatibility between Protégé-OWL and the TopBraid Suite of applications. This reconsideration is described in subsection 4.2.3.

4.2.1 Ontology Authoring Tools

In this section the research sub-question, “What authoring tools are required to create and instantiate the semantic environment?” is addressed. The starting point in addressing this sub-question is the recommendation of the W3C in 2004, which states that the most appropriate set of languages to construct the semantic framework includes RDF(S), OWL, SPARQL and rules, such as SWRL. It is therefore imperative that the chosen authoring tool should be able to support these languages.

Gómez-Pérez et al. (2004b) state in their book that developing an ontology is very time-consuming and it is not realistic for developers to implement the ontology without any support of development tools. They go on to say that the first ontology tools were developed in the mid-1990s, and were designed to provide the interface for developers to carry out major activities such as conceptualisation, implementation, consistency checking and documentation. A number of ontology development tools have been developed since that time and many have quite sophisticated capabilities.

Gómez-Pérez et al. (2004b) also suggest that an ontology tool should provide one or more of the following features:

- Developing: This feature enables developers to build a new ontology from scratch. It includes the following functions; editing, browsing, documentation, export/import using different formats, graphical editing, library management, query.
- Evaluating: This feature can be used to evaluate contents of an ontology and its related technologies.
- Merging and aligning: These features can be used to merge ontologies within the same domain.
- Annotating: The developer is able to annotate and describe concepts and resources using this feature.
- Querying and inferencing: Integrating these features within the authoring environment makes querying the ontology or making inferences much easier. These features are strongly linked to the languages used to implement the ontology.

One of the first reviews of ontology editing tools was carried out by Denny (2002). He identified 56 ontology editors. In 2004, an updated review commented upon a further 40 editors, making a total of 96 editors (Denny, 2004). In 2002, one of the most exhaustive and detailed review of ontology tools was undertaken by the OntoWeb consortium (2002), where 11 editors were evaluated. These reviews were undertaken before the W3C's 2004 semantic web recommendations, and included many languages and approaches that were subsequently abandoned. Nevertheless, some tools continued to support these early languages, for example, Youn and McLeod (2006) in their 2006 review, described the virtues of 14 tools, of which only four fully supported RDF(S) and OWL, namely Protégé 2000, WebODE, DOE and LinKFactory. In 2007, Sarker, Wallace and Gill (2007) reviewed 5 tools in detail all of which fully supported RDF(S) and OWL; the five tools being Protégé, Altova Semantic Works, SMORE/SWOOP, CMapTools Ontology Editor (COE) and TopBraid Composer. They listed, but declined to review a further 8, either because they had not been updated for several years (DLworkench, KAON, LinKFactory, OntoEdit) or they were too specialised (COBrA - anatomy ontologies, Contextia – business mapping tool, GraphViz – graphics only). The last of the tools they rejected was Ontopia, as it is a topic map tool rather than an ontology development.

4.2.1.1 Protégé OWL

Protégé was developed by Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine. Protégé is an open source, standalone application that provides a suite of tools to construct domain models and knowledge-based applications with ontologies (Protégé, 2007). "It is perhaps the most widely-used ontology creation tool on the market" (Sarker, et al., 2007, p. 3).

The Protégé platform supports two main approaches to modelling ontologies:

1. The Protégé-Frames editor enables users to build and populate ontologies that are *frame-based*, in accordance with the Open Knowledge Base Connectivity protocol (OKBC).
2. The Protégé-OWL editor enables users to build ontologies for the Semantic Web, in particular using the Semantic Web ontology OWL.

Protégé-OWL has the following features (Protégé, 2007; Sarker, et al., 2007):

- Constructing: Protégé enables the creation, visualisation and manipulation of ontologies using a wide set of knowledge-modelling structures and formats.
- Editing: Ontologies can be edited and created using RDF/OWL script language (including OWL Full, DL and Light) or through its java-based plug-and-play environment. This environment provides a tabbed view of an ontology, allowing the user to do such things as separate classes from subclasses, classes from properties, classes from individuals, and view the characteristics and relationships attributed to each object.
- Exporting: Files can be exported to CLIPS, OWL, N-Triple and Turtle formats.
- Importing: Files can be imported using RDF and OWL formats.
- Merging and aligning: Ontologies covering the same domain can be merged and fully incorporated into a new semantic framework.
- Annotating: The developer is able to annotate and describe concepts and resources.
- Querying and inferencing: Through the use of SPARQL, queries can be put to the ontology. Similarly, inferencing is possible using a menu-driven command.
- Visualising: Protégé-OWL has several plug-ins to view aspects of an ontology, for example OwlViz, which allows the user to view an ontology as a concept map.

Sarker et al. (2007) state in their review that while Protégé-OWL is fairly easy to use when compared to many other commercial and open-source ontology editors, it does require a good understanding of ontology structures, resource types and relationship patterns. However, they claim that there are many onsite guided tutorials and templates to support the novice user, as well as well-supported group discussion boards.

4.2.1.2 Altova SemanticWorks

Altova is an international company headquartered in Beverly, Massachusetts and Vienna, Austria. It is an active member of the World Wide Web Consortium (W3C).

Altova's SemanticWorks software is a commercially available application. Sarker et al. (2007) consider SemanticWorks to be one of the best commercial ontology authoring tools on the market. Altova claim that users who have a strong foundation in OWL/RDF will be able to use the tool effectively when creating and editing ontologies (2007).

Altova SemanticWorks has the following features (Altova, 2007; Sarker, et al., 2007):

- Constructing: The creation of complex ontologies can be performed visually, using intelligent entry helpers, and a fairly intuitive icon system.
- Exporting: RDF/XML or N-triples code are automatically generated.
- Visualising: A visual tree-based view of the ontology is available. The ontology uses 5 different tabs: Classes, Properties, Instances, allDifferent, and Ontologies.
- Syntax and semantic consistency checking: This is instantaneous and simple to use.
- Owl dialect supporting: All three OWL dialects are supported in addition to support for both RDF and RDFS.
- Reasoning: Flaws in coding or logic are easily identified using the built in reasoner.
- Sarker et al.(2007) claim that when using SemanticWorks the user needs to have a good understanding of the ontology and an appreciation of the finer details of the relationships embedded within it. On the positive side, there are plenty of online discussion groups and tutorials available for SemanticWorks users (Sarker, et al., 2007).

4.2.1.3 SMORE / SWOOP

SMORE and SWOOP were initially products of the University of Maryland information and network dynamics lab semantic web agents, usually referred to as the Mindswap project (Mindswap, 2007). However, the Mindswap group no longer supports them; SWOOP is now an open source project. The two ontology editors are very similar except that SMORE has a lightweight integrated web browser component (Sarker, et al., 2007).

SMORE and SWOOP have the following features (Mindswap, 2007; Sarker, et al., 2007):

- Constructing: Users are able to construct ontologies based on the Manchester-Style OWL using a web browser style of 'look & feel' interface. The URI of the ontology (or class/property/individual) can be entered directly into the address bar (SWOOP only). The tool provides hyperlink-based navigation across ontological entities, buttons for traversing the ontology, and annotation style bookmarks that can be saved for later reference.
- Editing: All ontology editing in SWOOP is done online with the HTML renderer. Different colour codes and font styles are used to identify changes to the ontology.
- Collaborating: An Annotation plug-in for SWOOP allows users to write and share annotations on any ontological resource.
- Importing: OWL and RDF can be imported from local files or over the Web using a URI.
- Reasoning: Tableaux reasoner (Pellet) provides understandable and meaningful explanations of inconsistencies, and provides ways to rectify them.
- Exporting: Ontologies can be exported in RDF/XML, Turtle and N3 formats.
- Additional features: The user is able to browse the Internet from within the program and create an ontology based on the structure of a web page.

Sarker et al. (2007) consider the software to be cumbersome, and compared with other products such as Protégé and SemanticWorks, they have a not-so-friendly interface and lack many of Protégé's features. The products are free to download and use, and there are versions for both the Windows and Macintosh platforms (Mindswap, 2007).

4.2.1.4 CMapTools Ontology Editor (COE)

The CMap Ontology Editor (COE) is one of the products created by the Florida Institute for Human & Machine Cognition (IHMC). It is a not-for-profit research institute which investigates topics related to understanding cognition in both humans and machines. COE is an RDF/OWL ontology viewing/composing/editing tool built on top of the IHMC CmapTools concept mapping software suite.

COE has the following features (COE, 2007; Sarker, et al., 2007):

- Constructing: Users are able to construct, navigate and share knowledge models represented as concept maps.
- Importing: OWL and RDF can be imported from local files or over the Web using a URI.
- Analysing: The ontology can be viewed using triples in various formats.
- Editing: New nodes and arcs can be created using click-drag operations. Templates and drop-down contextual menus provide for a user interface.
- Navigating: Search forms using triples, enable relevant information to be found quickly. The base URI of a concept name can be used to automatically locate, import and display the 'home' ontology of the concept.
- Collaborating: COE allows users to collaborate with other developers online.
- Exporting: Ontologies can be exported in RDF/OWL, N3 and Turtle formats.

Sarker et al. (2007) also noted some issues with CmapTools. There were some incompatibility issues with other editing software. For example, intended users require the ability to create mind/concept maps, and there is no SPARQL plug-in or SWRL facility. On the other hand, COE runs on a variety of platforms including Windows and Macintosh OS.

4.2.1.5 TopBraid Composer

In February, 2007, TopQuadrant, a US based company, announced the general availability of its semantic modeling toolset TopBraid Composer™ 2.0. The tool, based on the Eclipse platform, provides support for RDF/S and OWL (including OWL 1.1 and 2 extensions) (TopBraid Composer, 2007). TopBraid Composer is a commercial product, which provides a professional development environment for W3C's Semantic Web standards RDF Schema, the OWL Web Ontology Language, the SPARQL Query Language and the Semantic Web Rule Language **(**SWRL**)** (Sarker, et al., 2007).

TopBraid Composer provides a comprehensive set of features covering the entire life cycle of the semantic application (Sarker, et al., 2007; TopBraid Composer, 2007):

- Constructing: An integrated development environment for semantic web applications is provided.
- Visualising: A variety of windows provide views into the ontology, allowing input, editing and output of resources.
- Google mapping: Embedded Google maps make it possible for users to visualise, and enter the locations of geographical entities.

- Importing: Information from relational databases, UML, XML Schema and Spreadsheets can be imported into an ontology.
- Collaborating: Collaborating allows multiple developers to edit the same ontology concurrently across the Internet.
- Reasoning and Querying: SPARQL queries can be put to the ontology and rules using a description logic reasoner such as Pellet are possible.
- Additional features: Components such as plug-ins can be developed and tested using real-world data. Modules can be deployed as stand-alone applications.

4.2.1.6 Selected Web Authoring Tools

Based on information available in 2007 and outlined in the previous sections, Protégé-OWL was chosen at that time, as the semantic web-authoring tool for this research for the following reasons. The authoring tools SMORE and SWOOP were rejected on a number of grounds. In the first instance, they were considered by Sarker et al. (2007) to be inferior to Protégé-OWL and Altova's SemanticWorks in that they possessed fewer features and were not as user friendly. In addition, the fact that Mindswap no longer supported the two tools, and updates to the software, especially SMORE, had not been issued for several years was an issue given the long term viability of the software over the likely duration of the PhD programme. As Sarker et al. (2007) mentioned, there were some issues with CmapTools, in particular, some incompatibility issues with other editing software, and there is no SPARQL plug-in or SWRL facility. On this basis, CmapTools was not accepted.

Altova's SemanticWorks, TopBraid Composer and Protégé were all considered to be quality software tools and capable of meeting the study's requirements. All three allowed developers to construct the semantic framework and instantiate the ontologies. All language identified in the Semantic Stack were present in the three tools. They all enabled a range of property types to be created and attached to classes. Restrictions to classes and properties were also possible. They also provided functions for querying the information by applying SPARQL, and the classification hierarchy and the logical consistency of the ontology could be checked using reasoners. It was in Protégé-OWL's favour that it was an open source application, whereas, TopBraid Composer and SemanticWorks were commercial products, whose licenses were fairly expensive. Both Protégé-OWL and TopBraid Composer actively supported their corresponding user-discussion groups, but it was Protégé-OWL which had the larger user-base and the larger set of tutorials.

In conclusion, Protégé-OWL was chosen because it possessed most, if not all of the features of TopBraid Composer and SemanticWorks. Like TopBraid it had active user-support network, but perhaps more importantly it was open source, and was widely accepted by the professional user community.

4.2.2 Semantic Web Browser Interface Authoring Tools

In 2010, research moved from developing the ontology framework to seeking ways to deploy the information across the Internet. It was important for the chosen authoring tool to be able to integrate the existing framework into the extended environment as seamlessly as possible. The World Wide Web Consortium (W3C) (2010b) and the organisation SemanticWeb.com (2010) identified a number of web-browser ontology authoring tools. The following is a combined list of the most promising: Web-Protégé, Ontofly, TopBraid Ensemble, Neologism, and Knoodl.

4.2.2.1 Web-Protégé

Web-Protégé is an open source, lightweight, web-based ontology editor, the purpose of which is to support the process of collaborative ontology development in a web environment. Protégé uses the Google Web Toolkit (GWT) for the user interface, and Protégé-OWL for supporting ontology services (Tudorache, Vendetti, & Noy, 2008).

In 2008, Tudorache et al. (2008) stated that the tool was still in the early stages of development and much remained to be done. No further versions appeared before 2010. It is interesting to note that in May 2011 the tool again appeared on the Protégé website with many interesting features and capabilities.

4.2.2.2 Ontofly

Ontofly is an application designed to assist the ontology engineer to create an ontology using a standard web browser (Urbansky, Willner, & Schill, 2010). Urbansky et al. (2010) make the assertion that a domain ontology can be created by an expert more effectively and expeditiously if the ontology is created using data collected directly from the web rather than by using an ontology editor, which tends to gather data indirectly, for example from users. Taking this approach, Ontofly builds the ontology by traversing the various web pages that display domain data, and creates the ontology ‘on the fly’. The ontology can then be used to display imported data.

4.2.2.3 TopBraid Ensemble

TopBraid Suite is a commercial application produced by TopQuadrant. It consists of a set of integrated independent semantic applications comprising: Composer, Ensemble and Live; all components implement W3C recommendations (TopBraid Suite, 2010). TopQuadrant describes Ensemble as a web-based application assembly toolkit, which can be used, once the ontology has been developed, to quickly assemble a variety of dynamic model-based rich Internet applications (TopBraid Ensemble, 2010). Ensemble's built in applications allow the user to traverse semantic models and data, using trees, grids, search forms, maps and graphs. Additional features include popup dialog boxes, multi-page views and SPARQL query forms.

4.2.2.4 Neologism

Neologism is a lightweight web-based vocabulary editor and publishing tool built with Drupal (Basca, Corlosquet, Cyganiak, Fernandez, & Schandl, 2008). Basca et al. (2008) consider vocabularies, which consist of less than 50 terms to be simple and lightweight ontologies. Users can define vocabularies, consisting of classes and properties in a very short time frame and publish them online. According to Basca et al. (2008), it makes RDF vocabulary authoring easy and fun. HTML, RDF/XML and Turtle are supported by the software.

4.2.2.5 Knoodl

Knoodl supports the development of community-oriented OWL based ontologies and RDF knowledge bases (Knoodl, 2010). According to the developer, Revelytix (2010), Knoodl also serves as a semantic technology platform allowing communities to build their own semantic applications using their own ontologies and knowledge bases. Essentially, Knoodl enables a community of users to collaborate, and construct, manage, and deploy ontologies along with other information assets like relational databases or spreadsheets. Working in this way enables organisations to reach a consensus on the meaning of resources, and at the same time create an ever-evolving ontology in a similar way to how Wikipedia operates (Revelytix, 2010).

4.2.2.6 Selected Web Internet Browser-Authoring Tools

For this study, TopBraid Ensemble was selected to be the most appropriate Internet browser-authoring tool. Ontofly is essentially a tool for creating an ontology based on data viewed via a web browser (Urbansky, et al., 2010). Since the ontology in this study had largely been constructed at that point in time, this tool was not required. In the case of Neologism, according to Basca et al. (Basca, et al., 2008) it is designed for lightweight ontologies of less than 50 terms and as the e-government ontology in this study consists of several hundred terms it was seen to be unsuitable. Knoodl (2010) is a community-based tool, which draws its strength from the input of numerous collaborators; that is not the case in this study. Web-Protégé (Tudorache, et al., 2008) had the advantage of seamlessly integrating the e-government ontology constructed using Protege-OWL, but, unfortunately, at that point in this study, October 2010, the application had not been supported for two years, and on that basis it appeared to be a poor choice.

TopBraid Ensemble's features, as listed in section 4.2.2.3, made it ideally suitable for the task of allowing the e-government ontology to be traversed and its contents to be displayed and queried in a variety of forms using an Internet browser. After an initial trial period of 30 days, later extended to 60 days, TopQuadrant provided unlimited access for the duration of the study.

4.2.3 Revisiting Semantic Web Authoring Tools

The choice of TopBraid Ensemble brought into question the role of Protégé-OWL as the preferred choice of OWL authoring tool. Fortunately, it was found that the e-government ontology that had been created using Protégé-OWL could be seamlessly imported into TopBraid Ensemble; some Protégé-type features were lost but this was not too much of an issue. The decision was then taken to use both Protégé-OWL and TopBraid Composer in tandem to further instantiate the ontology or make changes to the framework.

4.3 Chapter summary and conclusions

In this chapter answers to three of the research sub-questions associated with the design and creation of a semantic environment were discussed. In answering the first research sub-question, "What semantic languages are required to construct the semantic model?" the conclusion was reached, as detailed and discussed in Section 4.1, that the semantic languages recommended by the World Wide Web Consortium in 2004 (2004; 2004a, 2004b), and illustrated in the Semantic Stack (Berners-Lee, 2009) should be adopted. These include the semantic ontology languages, RDF, RDF(S), OWL and SPARQL. In addition, it was determined that OWL DL was the most appropriate OWL language as it provides more expressive constructs than OWL Lite, and is also preferred to OWL Full as predictable reasoning support is required. OWL DL, version 2 is also adopted as it is claimed by Patel-Schneider et al. (2008) that it addresses some of the shortcoming of OWL1.1.

The other research sub-questions considered in this chapter, "What authoring tools are required to create and instantiate the semantic environment?" and "What authoring tools are required to create a query driven semantic web portal?" were considered and extensively reviewed in Section 4.2. The conclusion reached, prior to the commencement of the construction of the ontology in 2007, was to adopt Protégé-OWL since it was found to be the most suitable authoring tool to create and construct a semantic environment based on OWL DL. The features offered by Protégé-OWL were extensive and coupled with the fact that it was by far the most popular authoring tool on the market. It had an active set of user discussion boards, and it was free to download and use, and all these together were very persuasive factors (Protégé, 2007; Sarker, et al., 2007). The choice of TopBraid Ensemble as the most appropriate tool for developing a query-driven semantic portal was an easy decision. None of the other tools reviewed in Section 4.2.2 was able to match the extensive set of features offered by Ensemble, such as, allowing the user to traverse semantic models and data, using trees, grids, search forms, maps and graphs; and there were additional features including popup dialog boxes, multi-page views and SPARQL query forms (TopBraid Ensemble, 2010). The fact that the researcher found that ontologies created in Protégé-Owl were able to be imported into TopBraid Composer seamlessly was very useful and consequently enabled both TopBraid Composer and Protégé-Owl to be used together effectively.

From the point of view of the design science paradigm, this chapter has contributed usefully in a number of ways. For example, the reviews of the semantic languages and authoring tools are examples of design science research as they comply with three of the seven guidelines proposed by Hevner et al. (2004, p. 83).

1. Contribution to the academic world: The review process undertaken in this chapter to determine the most appropriate set of semantic languages and authoring tools has provided clear and verifiable contributions in the area of the ontology design methodologies.

2. Rigorous methods of construction and evaluation: In the selection of the most appropriate set of semantic languages and authoring tools, the review process has been rigorous and extensive.

3. Design as a search process: A deep and serious search regime was followed to identify relevant and informative publications contributed by experienced and knowledgeable authors.

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5 ONTOLOGY MODEL CONSTRUCTION

Several ontology development approaches were reviewed and compared in Chapter 2: Literature Review. At the end of the review, an adaptation of Noy and McGuinness's (2001) Protégé-based development process, which incorporated use cases, seemed to be the most appropriate development method to guide the e-government ontology construction in this research. The adapted method involves the original seven processes proposed by Noy and McGuinness (2001), but, in addition, the information gained from the use cases is used to inform and support aspects of Step 1, and the following six processes. This approach is illustrated in Figure 5-1, and as the figure shows there is a reciprocal relationship between Step 1 and the set of use cases.

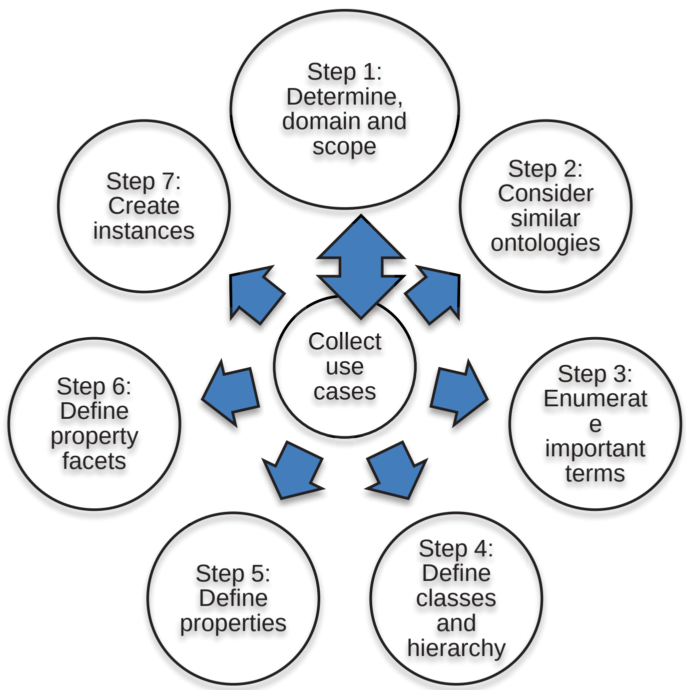


Figure 5-1: Adaptation of Noy and McGuiness ontology development process (2001)

The entire systems development process takes into consideration:

1. The research question:

   Can a semantic framework be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?

2. Design science research principles:

   It is important to ensure that the systems development process follows recognised and accepted methods associated with good design and development practices, and that design choices are founded on sound academic values.

Although authoring tools are not required to support all of the steps suggested by Noy and McGuiness (2001), installing the authoring tool at this stage enabled the researcher to define and insert many of the concepts into the e-government ontology as the construction process evolved. The Protégé-OWL authoring tool was installed along with the Ontoviz plugin to allow Protégé ontologies to be visualised with the help of the Graphviz graph drawing software. The OWLViz plugin enabled OWL ontologies to be navigated easily and switch between the asserted and inferred models after classification.

5.1 Ontology naming convention

While there are no mandatory naming conventions for the web ontology language OWL, there is, nevertheless, a widely acknowledged convention for the naming of classes and properties (Campbell, 2006; Horridge, 2009).

5.1.1 OWL notation

The recommendation is that all class names should start with an uppercase letter and should not contain spaces. This kind of notation is known as uppercase CamelBack notation and is the notation adopted in the e-government ontology used in this thesis. For example, `Person`, `Position`.

Property names start with a lower case letter, have no spaces and have the first letter of the remaining words in uppercase. This notation is referred to as lowercase CamelBack notation. It is also recommended that where possible, properties are prefixed with the word 'has', or the word 'is', for example, `hasMinister`, `isMinisterOf`.

The authoring tool, Protégé-OWL, automatically replaces spaces by an underscore. Having underscore in the naming of instances is allowed. For example, `Key_John` is an instance name.

5.1.2 Thesis notation

Throughout this report, class, property and OWL file names are formatted using the Courier regular font. For example, OWL ontology documents take the form `egovernment.owl` and an ontology class `Person`, and an ontology property `hasMinister`.

5.2 Step 1: Determine domain and scope

Essentially the approach began by addressing the questions proposed by Noy and McGuinness (2001).

1. What is the domain of the ontology?
2. What is the scope of the ontology?
3. What is the purpose of the ontology?
4. What are the expected outcomes to be delivered by the ontology?
5. Who will use the ontology?

Once the domain of the ontology had been determined, reference was subsequently made to the set of use cases that had been collected prior to considering the remaining four questions.

Noy and McGuinness (2001) are of the opinion that the answers to the questions in Step 1 assist the developer in limiting the scope of the ontology. They also suggest that the answers to these questions may change during the development process, as they emphasise the fact that ontology development is an iterative process.

5.2.1 Initial view of the Representative Domain

The New Zealand Parliament and Local Government Entities are the representative domains mentioned in Section 1.6.1. It provided the starting point for the construction of the ontology. The domain is a composite of the following sub-domains: New Zealand Parliament, Local Authority Councils in New Zealand, New Zealand Geographical Areas, and the New Zealand Environment, all of which are typical of current e-government endeavours in New Zealand.

There is also an assumption that information required to instantiate such an ontology embracing these sub-domains with sufficient information to create meaningful scenarios is available to the researcher. It must be remembered, too, that the purpose of the research is concerned with proof of concept and a full-blown semantic environment could not be delivered using the resources available to the researcher.

An initial, and very preliminary view of the domain was developed as shown in Figure 5-2.

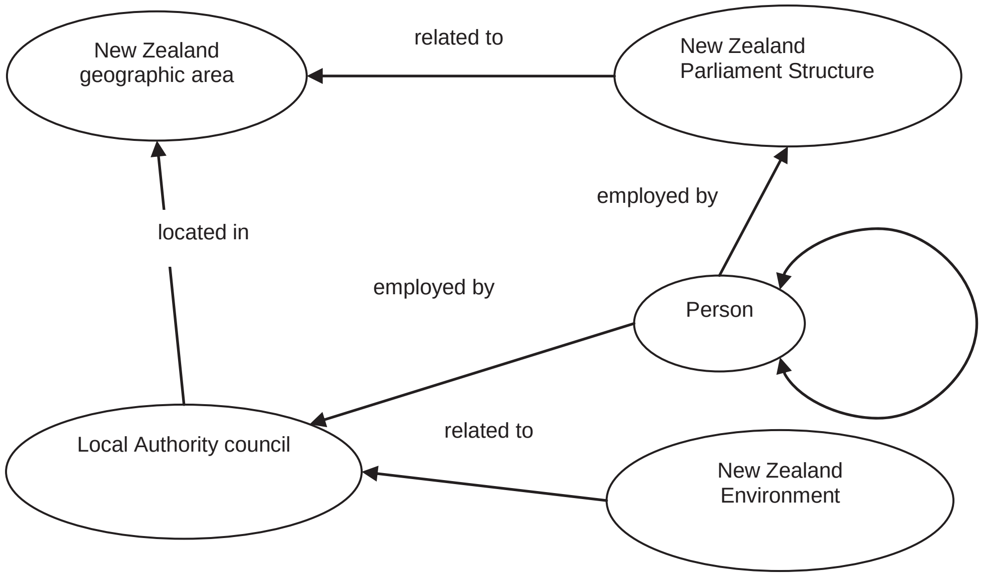


Figure 5-2: Initial view of the representative domain

5.2.2 Use cases

Use cases describe the functional requirement of a system and show the interaction between users and the system (Rubin, 1998). The use case approach was used in this research to determine the domain, scope, purpose, and outcome, and to identify potential users of the ontology.

5.2.2.1 Identification of potential users

A formal arrangement was established with a specialist IS team from Horizons Regional Council. The team agreed to support the researcher's PhD research, provided she shared her results with them and that matters of personal and business sensitivity would be carefully managed.

The Council had recently undertaken a survey seeking the views of ratepayers on the quality of services offered by the Council. The team at Horizons, while not directly providing access to the survey, claimed that the survey indicated that customers were seeking more transparency in their dealings with the Council, and, in particular, there was a clear desire by those in the farming and wider rural community for more information about farm consents and issues relating to river and water quality. There was also a wish from the community for more detailed information about the region's councillors and their roles in managing their portfolios. The Horizons' team also suggested it would be useful to have a way of identifying staff roles and responsibilities within the organisation, as there was no system in place for staff to find that information except by contacting Human Resources. The team arranged for the researcher to receive printouts of Horizon's management structure, names of all staff and their roles and responsibilities. In addition, the team arranged for the researcher to meet with several member of the rural community to seek their views on services provided by the Council, and what they would like to see offered in the future.

The researcher attended a number of meetings chaired by senior regional council staff. These meetings attracted a wide range of interested parties, including environmentalists, farmers, councillors, university staff, and the general public. The researcher did not formally interview any of those people attending the various meetings; however, the researcher noted the type of questions and issues that were put to Horizons' staff.

Prior to the 2008 Election, the researcher was asked by members of the Chinese Association in Palmerston North to talk about the New Zealand parliamentary system. It was clear that the Chinese community had almost no knowledge of the New Zealand political system. Later, when talking to neighbours, the researcher found that many had only a cursory knowledge of how the New Zealand Government operated or the role of Parliament. None had made use of government Internet services. At the request of the researcher, several local residents, fellow students and some members of the Chinese Association met with the researcher in a number of informal settings, where the researcher sought, through the use of unstructured group discussions, the views and requirements of the attendees.

The results of these formal and informal interventions led to the following set of possible users, and their interests:

- Staff members of local government authorities who are interested in the roles colleagues and councillors play in their organisation.
- Users who are interested in the structure of the New Zealand Parliament, and MPs' responsibilities and roles.
- Users who are interested in New Zealand environmental issues.
- Farmers who are interested in regulations or guidelines related to the use of water and land, or would like to apply for permission to use such resources.
- Members of the rural community who would like more information about the roles councillors play on the regional council.

5.2.2.2 Interview process and questionnaire

A form was designed in such a way that it could be used at an interview, or could be completed after a group meeting or discussion. The purpose of the form was to document the needs of the user, usually in the shape of a question, and the resources that are needed to be deployed to provide the appropriate answer to the user. If the user could identify the source of information, this was also recorded on the form, and if not, the developer would enter the likely sources in the use case form. A copy of the form can be viewed in Appendix 11.1.1.

Not all potential users were interviewed by the researcher or completed a use-case questionnaire. For example, questionnaires were compiled by the researcher based on questions submitted by members of the public to regional council representatives at a public meeting held by Horizons Regional Council. Some potential users met with the researcher and completed a questionnaire, usually with the assistance of the researcher. For privacy issues, personal details for those interviewed are not disclosed in this thesis.

5.2.2.3 Preliminary list of the use cases

As suggested by Noy and McGuinness in their guide to ontology construction (2001), a preliminary list of use cases, was formed and used to scope the ontology (Table 5-1). The complete set of use cases is included in Appendix 11.1.2.

Table 5-1: Preliminary list of use cases

Actor (target users)	**Information that users would like to find out**	**Scenarios (knowledge bases) for the information**	**Trigger system**
Farmers	Consent forms and name of contact person.	Organisational Structure, Publications, Position	TopBraid Composer, TopBraid Ensemble
Users who are interested in finding out Parliament information	Information about MPs and their relationship between electorate, geographic area and government entities.	MPs, Geographical Area, Electorate, Governmental Entity	TopBraid Composer, TopBraid Ensemble
Users who are interested in finding out MPs' role in parliament	Information about MPs and their roles in parliament, such as members of Executive, Cabinet, Selected Committees and ministers of Ministries	MPs, positions and organisational structure	TopBraid Composer, TopBraid Ensemble
Users who are interested in finding out environment issues	Information about publications information related to environmental issues and organisations and who publish them	Publication, Organisational Structure	TopBraid Composer, TopBraid Ensemble
Users who are interested in finding out the links between electorates and authorities	Information about electorates with the local authorities they represented and the geographic coverage under the regional authorities.	Electorate, geographic area and local/regional authorities	TopBraid Composer, TopBraid Ensemble

5.2.3 Scope

The field of e-government is extremely wide, as was demonstrated in Chapter 2: Literature Review, so there was a need to limit the scope of the ontology to a more manageable dimension.

Noy and McGuinness (2001) claim that the scope of the ontology can be ascertained by sketching a list of questions, which a knowledge base supporting the ontology should be able to answer. Such questions are frequently referred to as competency questions (1995). These competency questions provide a basis for the validation of the ontology in Chapter 7: Evaluation. Typically the validation would consider the following: "Does the ontology contain enough information to answer these types of questions?" and "Do the answers require a particular level of detail or representation of a particular area?"

In this research the competency questions were derived from the use cases obtained during the initial feasibility of the ontology development process. The ones chosen at this point in the development provide just a representative sketch and were not designed to be exhaustive.

In the domain People, the following competency questions were chosen:

1. Who are the MPs that are members of Executive Council?
2. Who are the National Party MPs that are members of Selected Committees?

In the domain Geographic Area, the following competency questions were chosen:

3. Which City Electorates area or District Electorates area are covered by Manawatu-Wanganui Regional Council Area?
4. Which City Electorates area or District Electorates area are covered by Manawatu-Wanganui Regional Council Area?

In the sub domain Publication, the following competency question was chosen:

5. Which Publication does the Minister of Health publish?
6. List all the positions that belong to the Policy and Consents unit in the Horizons Regional Council.

5.2.4 Purpose of the ontology

The purpose of this semantic artefact, in the form of an ontology, is to provide an ontological framework that has the potential to deliver information sourced from New Zealand governmental agencies across the Internet, and which could be ultimately developed to provide Internet users with a whole range of government information and services.

Expected outcome of the ontology

The expected outcome is that a semantic framework, based on the Semantic Stack set languages and technologies, will be successfully constructed and that the ontology will successfully deliver a subset of governmental information across the Internet based on the following:

- New Zealand Parliament and the roles and responsibilities of its MPs.
- New Zealand parliamentary and local authority electorates and their geographical areas.
- Horizons Regional Council's management structure.
- Environmental publications associated with water issues within the Manawatu-Wanganui Region.

5.2.5 Extended view of the Domain and Scope

Each of the sub-domains in the Figure 5-2 can be treated as a concept or entity in the ontology. The initial view of the sub-domains was extended as shown in Figure 5-3.

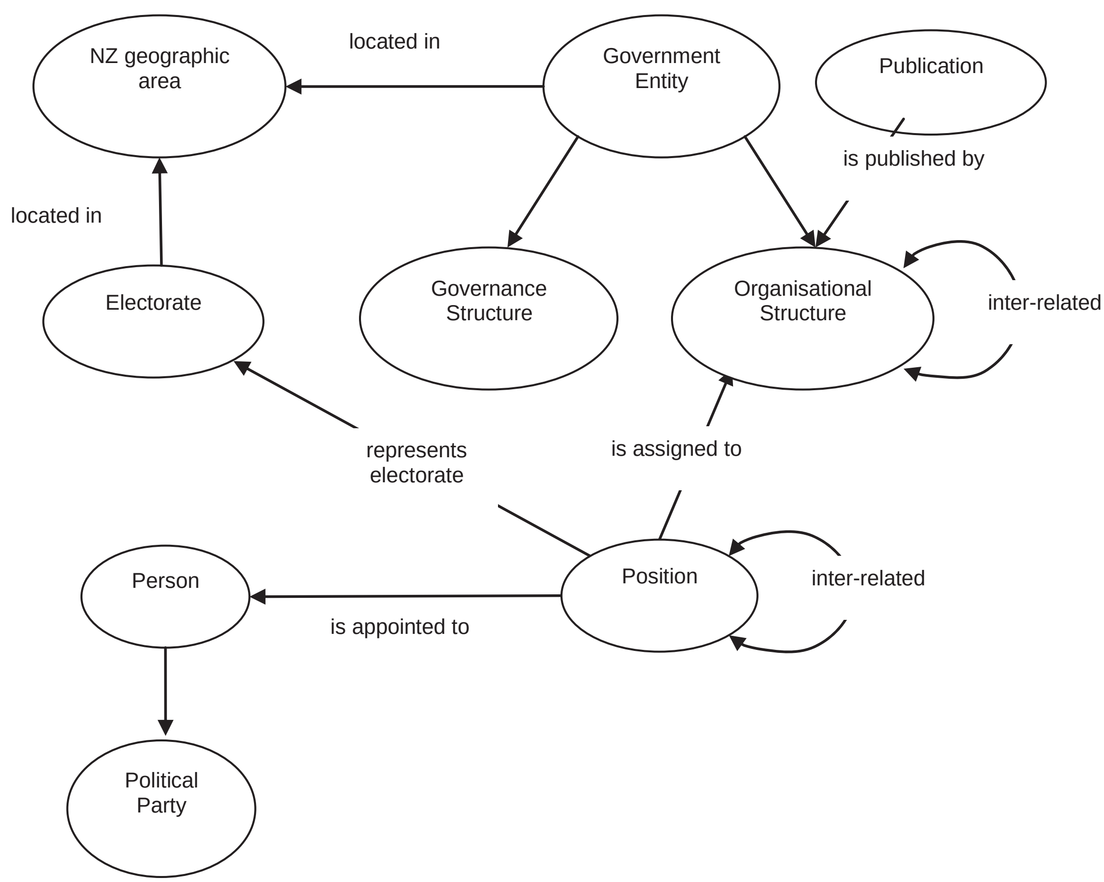


Figure 5-3 Extended domains for the E-government ontology

- New Zealand Parliament Structure: The 'NZ Parliament Structure' shown in Figure 5-2 was expanded to three separate entities to include both the national and local governmental entities, namely 'Government Entity', 'Organisational Structure' and 'Governance Structure'.

  The Governance Structure is concerned with governmental and council committees, which provide governance, either in the New Zealand parliament or within local councils.

  The Organisational Structure shows the organisational administrative structure of New Zealand government and local authorities. Of the local authorities, only Horizons Regional Council is considered in detail, with the assumption that others would be similar in their operations.
- Position: The entity 'Position' was added to the ontology to represent both elected and assigned positions in Parliament, government organisations and local authorities.

  The entity includes information about the roles and responsibilities of individual members.
- Electorate: The entity 'Electorate' was added to the ontology.

  New Zealand's voting system is based on citizens registered on either the General Electorate Roll or the Maori Electorate Roll.
- Publication: This entity was added to cover all environment-related regulations, guidelines and publications published by government agencies.
- Environmental: Water-based issues were listed in the 'Environmental' entity.
- Political Party: The 'Political Party' entity was formed in order to contain information about all parties represented in the New Zealand parliament.

5.3 Step 2: Consider similar ontologies

Noy and McGuinness (2001) suggest that developers seek similar ontologies, which could be either imported or refined and extended to meet the requirement of the proposed system. Regretfully, no existing e-government ontologies were found with similar features to the one outlined in this research. However, there was consideration, by the researcher, to import into the framework an ontology such as the Friend-of-a-Friend (FOAF) ontology as a way of uniquely identifying and profiling a person, and the Dublin Core (DC) ontology for describing publications (World Wide Web Consortium (W3C), 2006a). It was decided not to import the FOAF ontology, as the level of detail for 'people' was likely to be modest in the proposed 'prototype' ontology, given that entering such data would be a trivial exercise if a more comprehensive system were required. The DC ontology was thought to be useful, and as there were local versions of DC in both Protégé-OWL and TopBraid Composer, and it was not necessary to import it from an outside source.

TopBraid Composer ME has the built-in facility to link, using the `sameAs` property, to the metadata knowledge base DBpedia, which allows information normally found on Wikipedia to be imported and queried using ontology based tools. The DBpedia claims that its knowledge base describes more than 3.64 million things, about 50% of which are classified in a consistent Ontology, including more than 416,000 persons, 526,000 places, and 169,000 organisations (DBPedia, 2011). It includes all of New Zealand's current members of parliament, political parties, local authorities, districts, regions and cities. However, it was decided not to include links to DBpedia at this stage of the development, as the benefits were not substantial and adding the facility later would require little effort to implement.

5.4 Step 3: Enumeration of important terms

All the terms related to the nine entities were identified as Noy and McGuinness (2001) recommend as shown in Table 5-2. According to Noy and McGuinness (2001) the enumeration process is useful as it assists in the definitions of classes and properties, which are performed in Steps 4 and 5.

Table 5-2: Useful and important terms related to the ontology

Domains	Terms
Electorate	City Electorate, District Electorate, General Electorate, Maori Electorate, Territorial Authority Electorate
NZ Geographic Area	City Council Area, District Council Area, General Electorate Area, Maori Electorate Area, Territorial Authority Area, Unitary Authority Area
Governance Structure	Local Government Structure, New Zealand Parliament Structure, Select Committee
Governmental Entity	City Council, District Council, Regional Council, National Government
Organisational Structure	Local Government Organisational Structure, New Zealand Government Organisational Structure
Person	Non MP person, New Zealand Government MP, Select Committee Member, title, Portfolio,
Political Party	Government Party, Opposition Parties, Non-Parliamentary Parties, Opposition Provide Confidence and Supply
Position	Governance Position, Local Government Position, Local Organisational Position, Assigned New Zealand Parliamentary Position, Electorate New Zealand Parliament Position
Publication	Local Government Publication, New Zealand Government Organisational Publication, New Zealand Organisational Publication

5.5 Step 4: Definition of classes and class hierarchy

According to Noy and McGuinness (2001), Step 4 outlines the basic framework of the ontology.

Nine classes were identified in Step 1. In addition, to support the class `Publication`, two more classes were subsequently added, `GovernmentalIssue` and `PublicationType`. In this ontology, a publication is associated with a governmental issue, which in turn is concerned with an environment issue. Each publication was given a publication type, such as Consent, Guideline or Report.

These eleven classes can be regarded as the first-level classes, and referred to in this thesis as root classes. Many of these have sub-classes. A complete list is shown in Figure 5-4. The figure also shows that there are 1944 instances in the ontology. These eleven classes are disjoint, in that an individual that is a member of one class cannot simultaneously be an instance of another specified class.

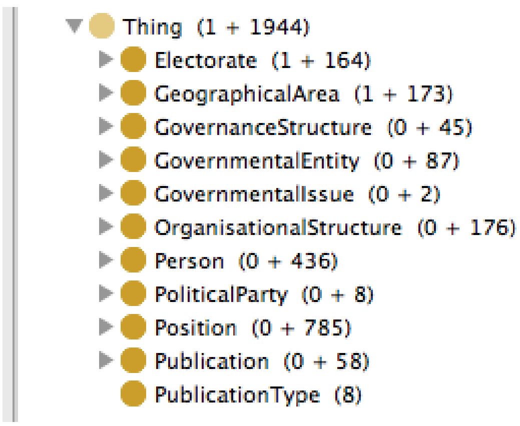


Figure 5-4: The eleven first-level classes of the e-government ontology

The class extension of `owl: Thing` is the set of all individuals. Consequently, every OWL class is a sub-class of `owl: Thing`.

Five levels of class hierarchy have been developed in the ontology. There are 11 first level root classes, 32 second-level sub-classes, 79 third-level, 69 fourth-level, and 2 fifth-level. A full list of classes is available in the Appendix 11.5.

`Root Class` `Person`

The sub-division of the class `Person` was based on the different functions people perform as defined in the ontology. As shown in Figure 5-5, the `Person` class was divided into three parts:

- `NZGovtMP`: This class contains persons who are Members of the Parliament

- NonMPPerson: Persons who are not members of Parliament were placed in this class.
- NZGovtQueen: This class contains only one person, the Head of State.

Sub-Class: NonMPPerson

The NonMPPerson sub-class was further sub-divided into two lower level sub-classes, Employment and Governance; these two sub-classes distinguish those people who are either employed in a national or local government organisation, from those people who have governance roles in local councils.

These two sub-classes Employment and Governance were not made disjoint, as a person could be employed in local government and also be a councillor. The third-level classes associated with the class NZGovtMP are referred to as inferred classes, as their membership is determined using an inference engine.

Figure 5-5: Second and third level classes of the Person class

Sub-Class: NZGovtMP

Membership of the NZGovtMP sub-class is reserved for persons who are MPs. The sub-class was subdivided further to include a number of inferred sub-classes. For example, the class, ExecutiveCouncilMember contains members of parliament who are members of the Executive Council. Similarly, NZGovtElectorateLabourMP and NZGovtElectorateNationalMP contain individual members of parliament who represent an electorate, and whose political party is Labour or National respectively.

An axiom was developed for each inferred class to define the condition of membership. For example, Figure 5-6 shows the class axiom defining the inferred sub-class NZGovtElectorateLabourMP.

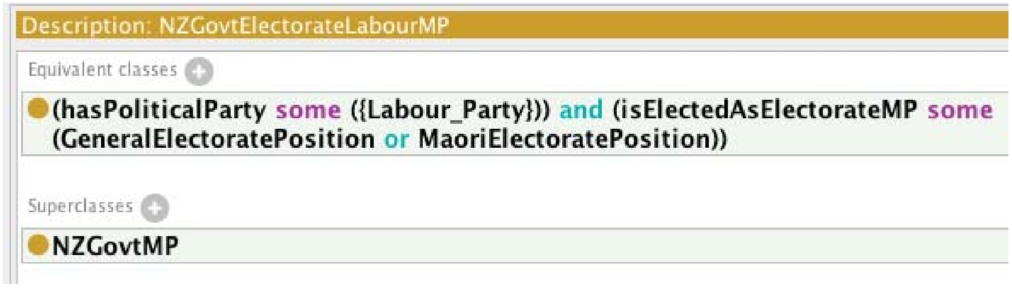


Figure 5-6: Class axiom for the inferred class `NZGovtElectorateMP`

Sub-Class: `SelectCommitteeMember`

The class `SelectCommitteeMember` was made a sub-class of the class `NZGovtMP`. This sub-class was further divided into 18 inferred sub-classes to represent the eighteen Select Committees in the New Zealand Parliament. This arrangement is displayed in Figure 5-7.

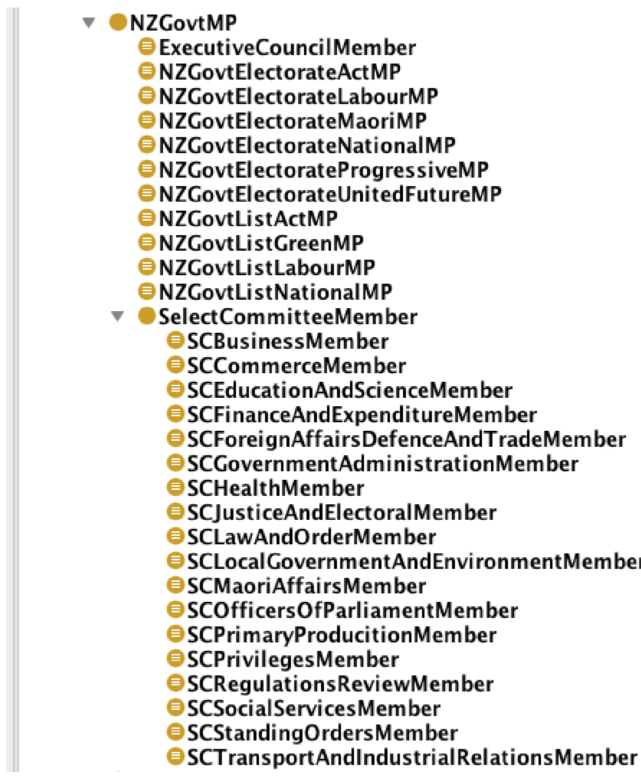


Figure 5-7:The completed list of inference sub-classes for `NZGovtMP` and `SelectCommitteeMember`

Sub-Class: `NonMPPerson`

Further sub-division was carried out for the class `NonMPPerson` into `Employment` and `Governance`, as shown in Figure 5-8.

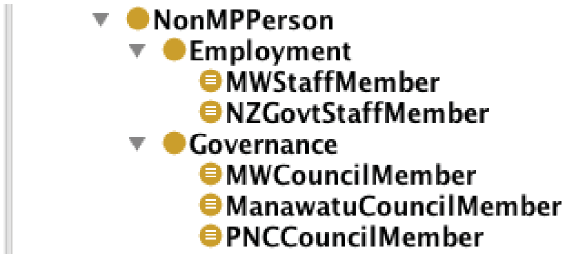


Figure 5-8: The inferred sub-classes for Employment and Governance

The ontology contains sub-classes within the root classes `GovernanceStructure` and `AdministrativeStructure` representing a significant number of New Zealand local authorities, such as cities, districts and regional councils. To have added all local authorities and instantiate all of them with employees and council representatives would be a task well beyond the resources available to the researcher. It was felt that providing full employees details for just one territorial authority, Horizons Regional Council, would be sufficient to show the proof of concept. Taking this into consideration the root class `Employment` was divided into only two inferred classes: `MWStaffMember`, and `NZGovtStaffMember`. These classes represent the members who are employed by the Manawatu-Wanganui Regional Council (Horizons Regional Council) and New Zealand Government Organisations. The class `Employment` would contain many more sub-classes if employees of all local authorities had been included. There would have had to be one sub-class for each local authority.

The `Governance` sub-class was made to include the inferred classes `MWCouncilMember`, `ManawatuCouncilMember` and `PNCCouncilMember` in order to represent council members that govern Manawatu-Wanganui Regional Council, Manawatu District Council and Palmerston North City Council respectively. As in the case of the sub-class `Employment`, the sub-class `Governance` contains only those sub-classes that are to be instantiated with data.

Root Class `Position`

The root class `Position, as shown in` Figure 5-9, contains subclasses, which represent all positions to which persons are elected, appointed or assigned. These include staff who are appointed to positions in local government, or elected positions for councillors and members of parliament, and persons who are assigned specific roles in government.

Figure 5-9 Root Class `Position`

Figure 5-10 displays the full extent of the hierarchy of the root class `Position`. The roles and positions are again limited to classes where information has been instantiated. To include all local authority positions in New Zealand would have been a task extending beyond the scope of this research. However, all the positions for members of parliament have been included.

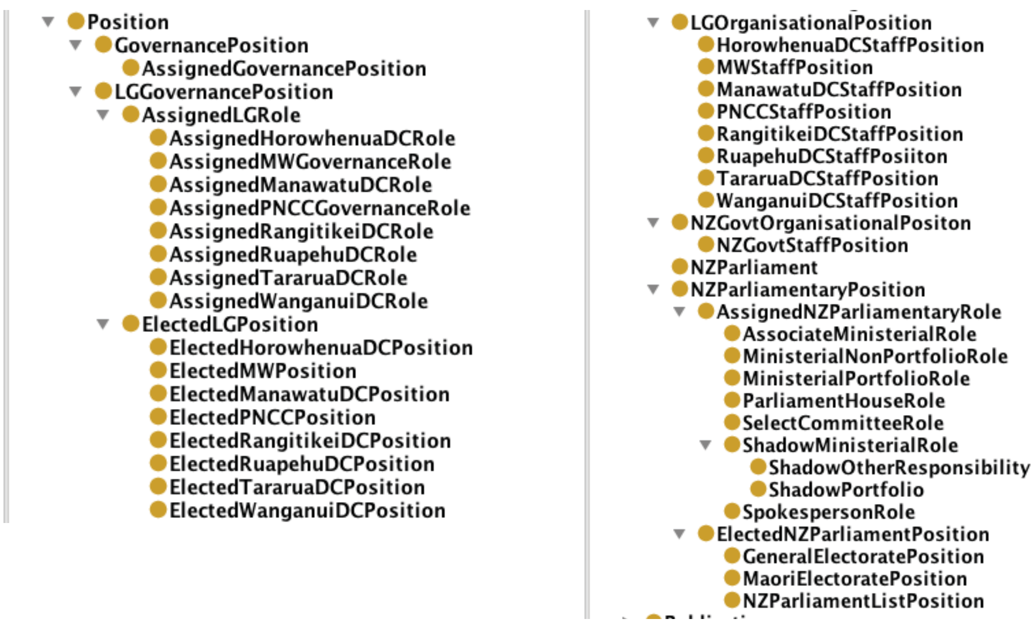


Figure 5-10: Class hierarchy of root class Person

In this ontology, the researcher manually inserted class and instance data. Ideally, it would have been better for class and instance data to be imported into the ontology when required, rather than attempting to include all the information in one giant ontology. Importing would have required the imported data to be in the form of an ontology, such as DBpedia, or have some conversion program available. This approach was initially considered but there were no e-government ontologies available in New Zealand which contained the necessary data, and no local authority approached would agree to provide access to their databases, to enable direct importation. The researcher therefore undertook a number of short experiments to demonstrate that it was possible to import data from another ontology.

5.6 Step 5: Definition of properties of classes

The definition of classes does not provide sufficient information to answer the competency questions that arose from the use cases in Step 1. Step 5 seeks to describe the internal structure of the concepts. From the web ontology language OWL perspective, these descriptors are called properties. OWL distinguishes between two main categories of properties that an ontology builder may want to define (2004a):

- Object properties: These properties link individuals to individuals.
- Datatype properties: These properties link individuals to data values.

Examples of object properties used in this e-government ontology are shown in Figure 5-11. A complete list of properties used in this ontology is available in the Appendix 11.5.2

Figure 5-11: Example datatype properties used in the e-government ontology

The object property `hasPoliticalParty` was defined to link `NZGovtMP` to `PoliticalParty`, as shown in Figure 5-12.

Figure 5-12: Object property linking NZGovt to PoliticalParty

Datatype properties were defined to enable the linking of attributes to instances. However, at this point in the construction, no instances have been inserted into the ontology. A list of these datatype properties is shown in Figure 5-13.

Figure 5-13: Data properties defined in the e-government ontology

Specifically, the format of the hasSname property definition is shown in Figure 5-14..

Figure 5-14: Datatype property hasSname to a string

In addition to the object properties and datatype properties, Dublin Core metadata was used to describe the publications in this ontology, such as the `dc:date` property publication date for the class `Publication`. Concepts in the ontology were explained using the annotation property. For example, Figure 5-15 shows how the class `Electorate` has been described.

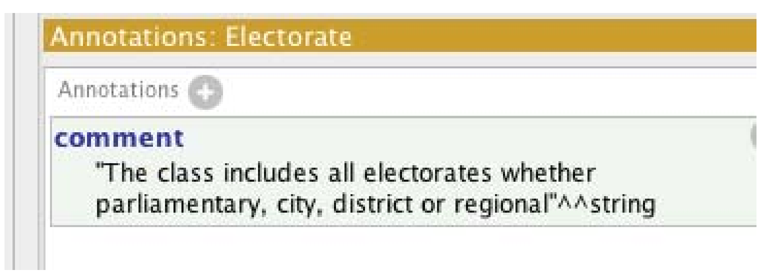


Figure 5-15: Annotation property for Electorate

It is one of the basic features of the ontology language that the sub-classes of a particular class inherit all the properties of that class. For example, in this ontology, all the properties of `Person` will be inherited to all sub-classes of `Person`, for example, `NZGovtMP` and `NonMPPerson`. Noy and McGuinness (2001) suggest that the most general properties should be attached to the top class. This recommendation has been adopted in this ontology, for example, the properties `hasSname`, `hasFname`, `hasTitle` etc. belong to the `Person` class, and as such are available to all sub-classes of `Person`.

5.7 Step 6: Definition of property restrictions

In Step 5, the properties identified in Step 4, are constrained by defining the value type, property cardinality, property's domain and range. The term 'property facets', used by Noy and McGuiness (2001), is replaced by 'property restrictions' when applying to OWL DL.

A property restriction is essentially a type of class description. It describes an anonymous class of individuals that satisfy the restriction. OWL distinguishes two kinds of property restrictions, value constraints and cardinality constraints, and a limited set of constructs for defining global property cardinality: `owl:FunctionalProperty` and `owl:InverseFunctionalProperty` (World Wide Web Consortium (W3C), 2004a).

- A value constraint puts constraints on the range of the property:
- owl:allValuesFrom
- owl:someValuesFrom
- owl:hasValue
- owl:sameAs (datatype property)
- A cardinality constraint puts constraints on the number of values a property can take:
- owl:maxCardinality
- owl:minCardinality
- owl:cardinality
- A functional property is a property that can have only one (unique) value y for each instance x
- A property is inverse functional if the object of a property statement uniquely determines the subject (some individual).

This ontology deploys some if not all of these property restrictions.

5.7.1 Functional and Inverse Functional

The property `isElectedElectorateMP` was constrained in its domain and range as shown in Figure 5-16. The property was declared functional, since for each individual in the domain class `NZGovt` only one individual from the range class can be linked to it. In this case the range of the property comprises the sub-classes `GeneralElectoratePosition` and `MaoriElectoratePosition`.

The property `hasElectedElectorateMP` was declared the inverse property.

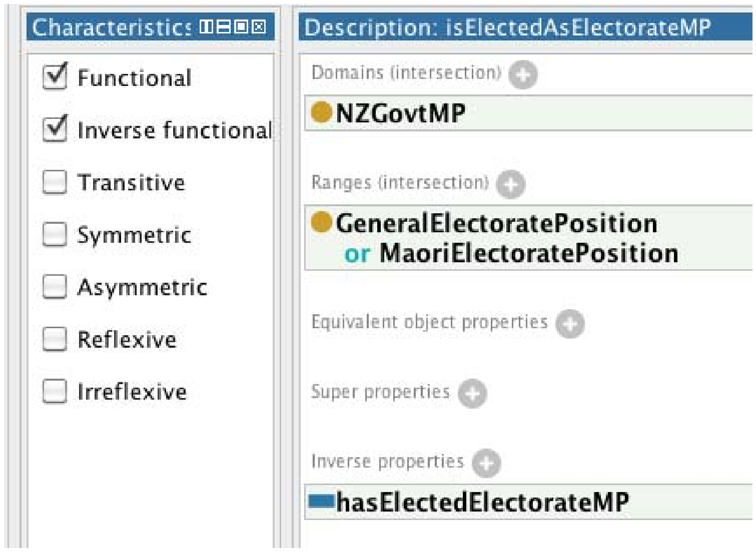


Figure 5-16: Constraints for object property - `isElectedElectorateMP`

To link a member of parliament to a political party, the property `isMember` was used. This was deemed a functional property since an MP can be associated with only one party. However, the inverse was not declared functional since a party could have more than one member associated with it. This information is shown in Figure 5-17.

Figure 5-17: Constraints for object property - `isMember`

5.7.2 Value Constraints

An MP would be a member of the Executive Council if he/she had been assigned a parliamentary ministerial portfolio. This was actioned in the ontology as shown in the following code using the value constraint `owl:someValuesFrom`,

```
<owl:Class rdf:ID="ExecutiveCouncilMember">
  <owl:equivalentClass>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#isAssignedParliamentaryMinisterialPortfolioRole"/>
      <owl:someValuesFrom rdf:resource="#MinisterialPortfolioRole"/>
    </owl:Restriction>
  </owl:equivalentClass>
  <rdfs:subClassOf rdf:resource="#NZGovtMP"/>
</owl:Class>
```

Figure 5-18: Inferring membership of the Executive Council using the value constraint, `someValuesFrom`

The value constraint `sameAs` is observed in Figure 5-19, which links the Prime Minister John Key to the external ontology `DBpedia.org`.

```
<owl:NamedIndividual rdf:ID="Key_John">
   <owl:sameAs rdf:resource="http://dbpedia.org/resource/John_Key"/>
</owl:NamedIndividual>
```

Figure 5-19: Linking John Key to DBpedia.org using the value constraint - `sameAs`

5.7.3 Cardinality constraints

Property cardinality restrictions specify the exact number of relationships that can be attributed to an individual. For example, an elected member of parliament represents one and only one electorate, as shown in the code in Figure 5-20 that was inserted into the ontology.

```
<owl:Class rdf:ID="NZGovtMP">
    <owl:Restriction>
      <owl:onProperty rdf:resource="#isMember"/>
      <owl:someValuesFrom>
        <owl:Restriction>
          <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int"
          >1</owl:cardinality>
          <owl:onProperty rdf:resource="#isMember"/>
        </owl:Restriction>
      </owl:someValuesFrom>
    </owl:Restriction>
</owl:Class>
```

Figure 5-20: Constraining an MP to one and only one political party

5.8 Step 7: Create instances

Creating the individual instances is the final step suggested by Noy and McGuinness (2001). They suggest the first stage of the process is to choose a class and create an individual instance of that class and fill in the property values. This was the process followed in this construction. For example, the class `NZGovtMP` was selected, the instance `Adams_Amy` was then created, and the links for the relevant properties were added. This process is shown in Figure 5-21.

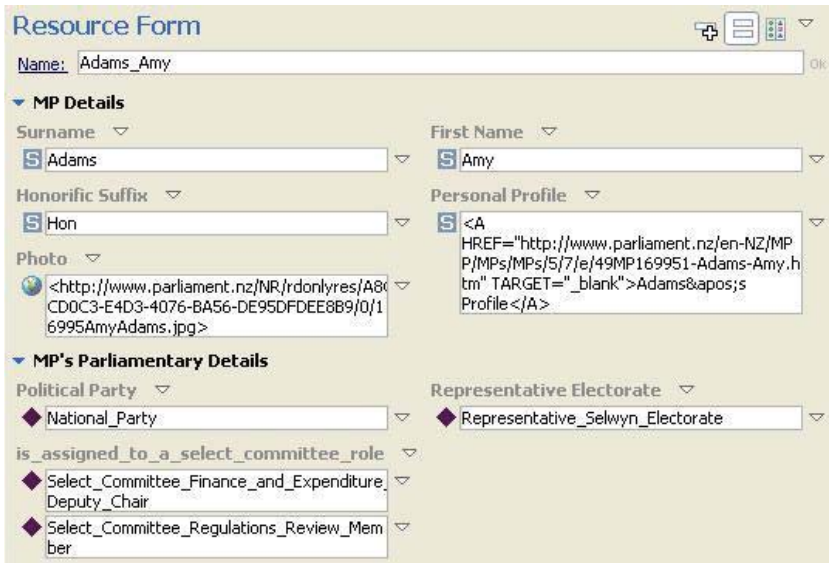


Figure 5-21: Resource Form showing properties for the instance Adams_Amy

This process was followed for approximately 2000 instances in the ontology. Information was gathered from a number of sources:

- Horizons Regional Council provided information about its management structure, staff details and their roles. It included information about the region's geographic boundaries, Horizons' One plan, and related policies and regulations for resource consents.
- Parliamentary information was acquired from government websites, Wikipedia, DBpedia.org, and library resources. Information included party lists, details of New Zealand's electoral system, structure of the government which include the functions of the cabinet, the executive council, ministries, and the titles of people who have specific duties in parliament, such as the Governor-General and the Speaker of the House. All this information was analysed and represented as entity or individual in the ontology.
- Environmental information was gathered from the Internet. It included a number of water quality and quantity related articles and reports published by the

Ministries of Environment, Health, Agriculture and Forestry, and local authorities and other scientific institutes. These reports and articles were grouped as 'Technical Reports', 'Guidelines', 'Regulations and Laws' and 'Projects' in the system.

5.9 System testing and evaluation

The system was tested and evaluated throughout the development process to ensure it met user requirements as defined by the competency questions and use cases. Queries were formed using both SQWRL and SPARQL.

Changes and amendments were made to the ontology system as a result of the feedback and suggestions made by Horizons Regional Council team, target users who were interested in the system, and the group of experts who completed the evaluation questionnaire.

5.10 Chapter summary and conclusions

The ontology development process adopted in this chapter was based on the one proposed by Noy and McGuinness (2001). Using use cases to determine user requirements was a useful addition to the basic approach proposed by Noy and McGuinness (2001). Overall, the researcher found no real problems during the development process, and support from the various user groups was extremely valuable, particularly in gaining a better understanding of the authoring tools and, of course, the supporting Sematic Web languages.

As stated in Chapter 3, design science research is the chosen research paradigm in this research endeavour. In this approach, Hevner et al. (2004) state that the objective of design science research is to build an artefact where the process of design and development leads to the acquisition of knowledge that is useful and meaningful. Hevner et al. (2004) proposed a number of guidelines, which they consider support the information system researcher in determining the value of the research process. The following list addresses the key points discussed in this chapter:

1. Design as an artefact: Hevner et al. (2004) place considerable emphasis on the creation of an innovative artefact during the research process. In this research, a semantic framework, based on information gathered from a number of governmental sources, is constructed. The framework is considered to be innovative and imaginative which meets the needs of the research community in a number of ways. It shows that applying use case scenarios to the Noy and McGuinness (2001) approach does result in a successful construction of the

ontology. It also demonstrates that it is possible to construct a framework that includes both administrative and governance structures at both national and local government levels, which in turn generates the possibility of integrating information from all those sources. The framework also enables geographical information to be brought into the mix, with the potential for users to search across the semantic structure and combine information which links both environmental issues and geographical areas to relevant council employees, councillors and members of parliament. The framework also provides the opportunity to include other national agencies and organisations such as police divisions and health authorities. Of course, the framework has the flexibility to add new organizations, environmental issues, and add further data relating to the structure and management of government ministries and agencies.

2. Problem relevance: Hevner et al. (2004) point out that the purpose of design science research is to develop technology-based solution to resolve the problems that occur in existing systems. In this research, the e-government ontology provides a prototype framework that could be used to deliver government information in an effective and efficient manner to a wide range of users.
3. Rigorous evaluation: Hevner et al. (2004) suggest that the utility, quality and competency of the research have to be demonstrated by performing a well-executed evaluation method. In this research, evaluation was carried out towards the end of the development process. The evaluation, discussed in detail in Chapter 8, considered validation, verification and evaluation. These processes were performed to make sure that the ontology met all the requirements and specifications of a validated ontology system, the design of the system reflected users' requirements, the system did not contain any technical errors, the system was user-friendly, and that it provided a better system compare with the current web portals.
4. Contribution to the academic world: Hevner et al. (2004) suggest that effective design science has to provide a clear and authentic contribution for design artefact and design methodologies. In this research, the adopted design science research methodology has demonstrated that a useful and effective artefact has been created and that the approach will be useful for other developers who are considering similar or comparable projects.

6 BROWSER INTERFACE CONSTRUCTION

The purpose of constructing the browser interface is to demonstrate that the semantic-driven ontology framework is visible to the user using a standard web browser interface. It is not intended in this research to create a highly sophisticated interface that embodies all the features of a well-defined and presented environment but to show that the knowledge base expressed in the semantic framework can be viewed and queried across the Internet.

The interface development process undertaken in this research takes into consideration the following points:

1. The research question:
   Can a semantic framework be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?

2. Design science research principles:
   It is important to ensure that the systems development process follows recognised and accepted methods associated with good design and development practices and that design choices are founded on sound academic values.

The chapter begins by discussing the features of TopBraid Ensemble (TBE), the authoring tool adopted in this research to construct the web interface. The structure and implementation of the interface is then discussed. The chapter concludes with several examples of how information can be retrieved either by traversing the ontology or by submitting SPARQL queries.

6.1 TopBraid Ensemble

As discussed in Chapter 4: Supporting languages, techniques and technologies, TopBraid Ensemble was chosen as the most appropriate tool in this research for the development of the web interface.

TopBraid Ensemble is one of three integrated independent semantic applications forming part of the commercial application produced by TopQuadrant. The other two components are Composer and Live, and all three components implement the W3C recommendations (TopBraid Suite, 2010). Topbraid Composer is an enterprise-class modelling environment for developing Semantic Web ontologies and building semantic applications. TopBraid Live is a Semantic Web application platform optimized for delivering dynamic model-based applications and the final component.

TopBraid Ensemble is a Flex-based web-based application assembly toolkit, which can be used, once the ontology has been developed, to quickly assemble a variety of dynamic model-based rich Internet applications (TopBraid Ensemble, 2010). The user interface runs on a web browser with Adobe Flash installed. Ensemble's built-in applications allow the user to traverse semantic models and data, using trees, grids, search forms, maps and graphs. Additional features include popup dialog boxes, multi-page views and SPARQL query forms.

All interface development is through the web browser and the Eclipse interface with the support of Java SDK.

6.1.1 Deployment of TopBraid Ensemble

A fully functional 30-day trial copy of the Maestro Edition of Topbraid Suite was installed, as the financial cost of the full toolkit was beyond the resources available for this research. TopQuadrant subsequently extended the trial period indefinitely for this research but no subsequent updates were allowed. The Maestro Edition consists of TopBraid Composer, TopBraid Ensemble, and a built-in personal TopBraid Live web server, which directly integrates with both Composer and Ensemble. On completion, the application can be deployed for multi-user use on a server running the TopBraid Live Enterprise Server product, unfortunately not available with the trial copy. The local personal server configuration, while useful during the development phase, had adverse implications during the evaluation phase of the semantic artefact as potential evaluators had to install the toolkit and personal server prior to undertaking any evaluation. Having a number of users independently accessing the ontology via a browser on a local machine was therefore untenable, and a smaller group of experts subsequently provided the feedback.

6.1.2 TopBraid Ensemble User Interface Components

The interface is formed by importing into the application a number of components, selected from a list of predefined components. These components can be connected to each other by post and listen events. The interface components include trees, forms, search forms, results grids and Yahoo maps. (TopQuadrant, 2010). A list of the components used to create the web interface in this study is shown in Table 6-1. The table also describes the function of each component and the associated events attributes that enable connections to be established between components. However, when an event is posted it is not directed at a specific component; the listen event only reacts to specified posts.

Table 6-1: TBE Components used in this research study

Components	Function Description	Event
Tree	Displays the set of classes and sub-classes in the TBC's 'Tree' panel	'Post'
Results Grid	Displays the results for the selected resources in the components 'Tree', 'Search Form', 'SPARQL Editor' and 'Graph Editor and Query'.	'Listen' The component listens to events that are posted from: 'Tree', 'Search Form', 'SPARQL Editor' and 'Graph Editor and Query'. 'Post'
Form	Displays the data associated with the selected resource in the format that has been defined in TopBraidComposer.	'Listen' The component listens to events that are posted from the 'Results Grid'. 'Post' This event is dispatched when user clicks a hyperlink in the form.
Search Form	Displays a form with empty fields for the class selected in the Tree panel. The results of the query are displayed in the Results Grid.	'Listen' The component listens to events posted from 'Tree' for showing the corresponded form format for the selected classes; 'Post' Actioned when the 'Submit Query' button is clicked.
SPARQL Editor	When users enter a SPARQL query the results are displayed in the Results Grid.	'Listen' Populates the component when and Edit Query is posted. 'Post' Actioned when the 'Submit Query' button is clicked.
Graph Editor and Query	The graphical interface enables SPARQL to be generated and run. The results are displayed in the Results Grid.	'Post' Actioned when the 'Submit Query' button is clicked.
Yahoo Map	Displays the location on a Yahoo map when the latitude and longitude are given.	'Listen' Responds to a posted event from the 'Form'.

6.2 Browser interface development process

The process adopted in this research to construct the browser is shown in Figure 6-1.

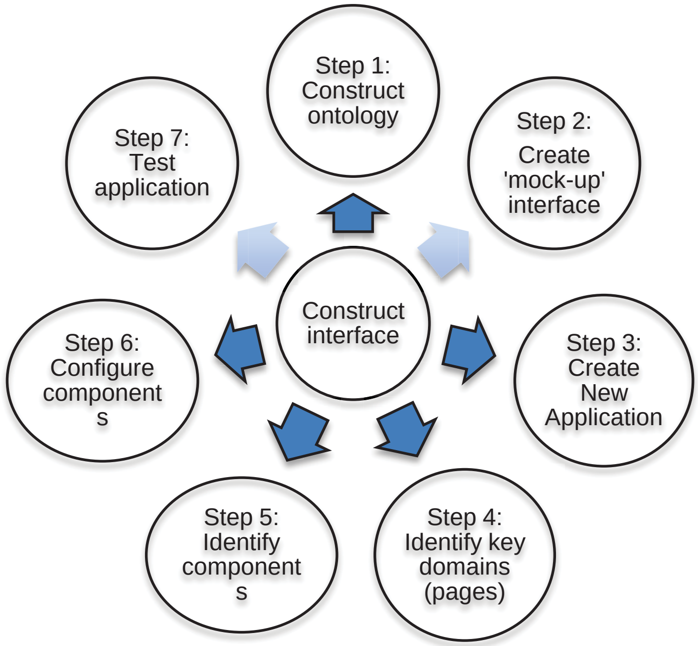


Figure 6-1: Browser interface development process

6.3 Step 1: Construct the ontology

Constructing the ontology was described in Chapter 5: Ontology Construction. To continue with the construction process, the e-government ontology created using Protégé OWL was input into the TopBraid Composer. This was achieved seamlessly. However, subsequent changes to the non RDF/OWL features of the Protégé OWL ontology, such as forms and similar structures, were lost if TopBraid Composer was used to open a Protégé Owl file, as these features are stored in the Protégé OWL project file and not in the RDF/OWL file. From this point forward most of the ontology framework amendments were undertaken in Composer.

6.4 Step 2: Create ‘mock-up’ interface

Prior to the construction of the interface, a ‘mock-up’ interface was created outlining the general structure and arrangement of the TopBraid Ensemble (TBE) application. This mock-up interface is shown in Figure 6-2. The format of the mock-up was partially based on the users requirements gathered from the use cases, and partially on the need to demonstrate that it was feasible to query, access and traverse information stored or created in the knowledge-based semantic artefact.

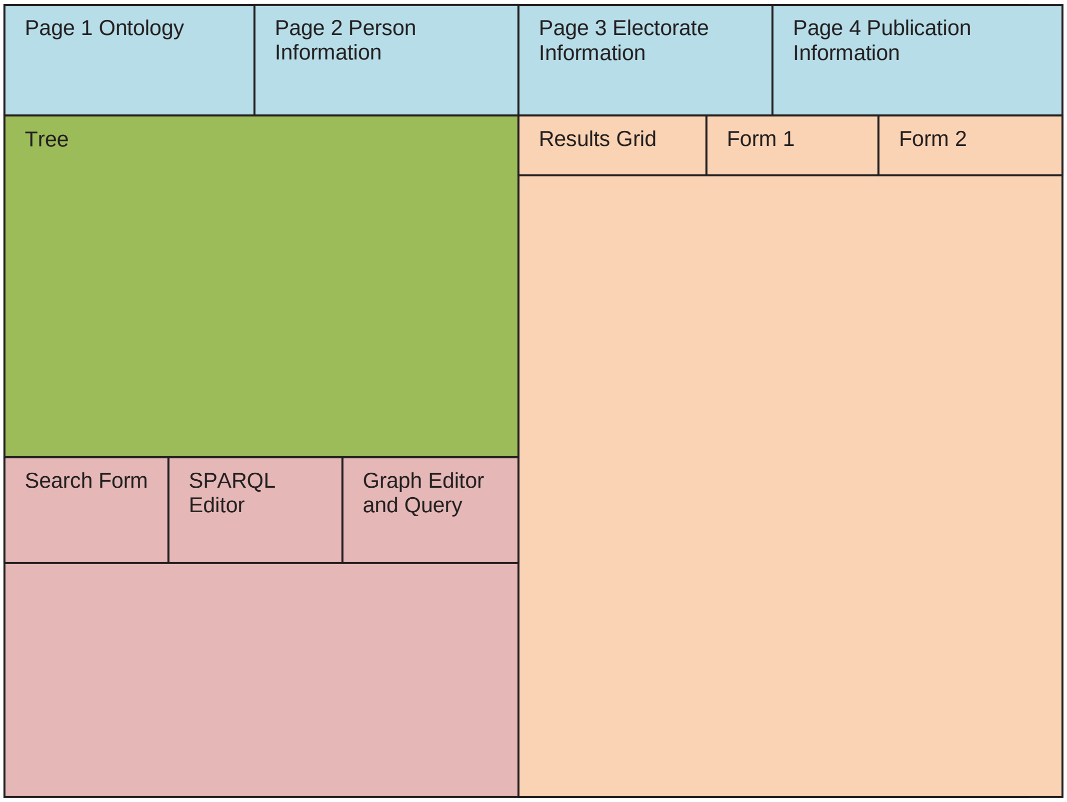


Figure 6-2 Proposed layout of the TBE interface

The proposed interface consisted of four distinct areas:

- Pages section:

  Labels of four pages are listed at the top of the form. Selecting any of the four choices leads to the Tree view being populated with the set of classes associated with the choice of page. For example, when the ‘Page 2: Person Information’ is selected, the Tree panel view displays the Person class and all its sub-classes in hierarchical form.

- Tree section:

  The Tree displays the corresponding tree node based on the page selected in the Pages section. Selection of a given class in the Tree window leads to the Results Grid window being populated with the instances of the selected class.

- Results Grid and Forms section:

  The Result Grid displays the instances based on the class selected in the Tree section. Selection of a specific instance in the Results Grid window leads to the Form panel being populated with information about that instance. The Forms 1 and 2 display information that has either been obtained via the Results Grid window or by submitting a query via the Search Form, SPARQL Editor or Graphics Editor and Query.

- Graphic Editor and Query, SPARQL Editor and Search Form section:
  These three interfaces allow queries to be submitted to the ontology via the browser interface. The results appear in a Form panel.

6.5 Step 3: Create a new application

The development of the interface was performed using a web browser. To begin the development process it was first necessary to create a ‘New Application’. This required the e-government ontology to be opened in TopBraid Composer and the browser’s url set to http://localhost:8083/tbl. The Console is shown in Figure 6-3.

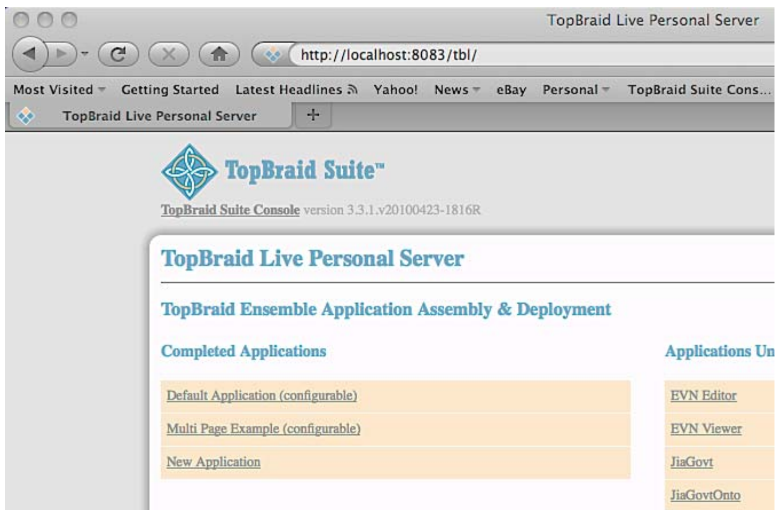


Figure 6-3: TBE suite console

To create a new application, the New Application command was selected in the console panel. It is possible to have several applications linked to a given ontology, but in this case, the decision was made to create one application that could be used by experienced users who were able to query an ontology using SPARQL. An alternative strategy could have been to create an ontology with more support for the typical user; however, that would have required access to TopBraid Live web server, which was not included in the trial Maestro Edition.

The New Application appeared in the browser interface as a blank form, as shown in Figure 6-4. Also displayed in the figure is the Tool Bar, which allows the developer to access a selection of interface components.

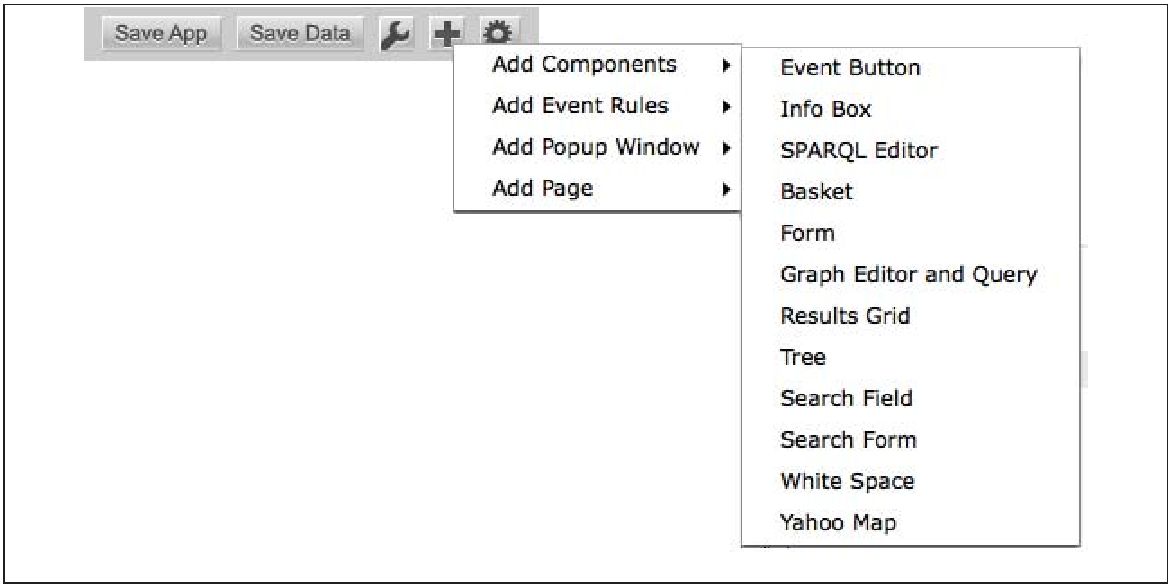


Figure 6-4: TBE: New Application blank form with Add Components pull-down menu

6.6 Step 4: Identify key domains (pages)

Using multiple pages facility is useful as it allows the distribution of information across several pages and avoids the problem of displaying too much information on one page. The number of pages and the level of detail displayed depend upon the ultimate purpose of the interface. As shown in the mock-up interface, the researcher chose to distribute information across four pages. In Page 1: Ontology, the entire class structure of the ontology is accessible. In Page 2: Person information, the information found in the Person class and all its sub-classes are displayed. Electorate Information is available in Page 3, and in Page 4, Publication information is displayed. These pages were thought to be sufficient for illustrating the utility of the interface. A view of the New Application Form listing the creation of the four pages is shown in Figure 6-5. The labels for these pages were subsequently extended to give better indication of their purpose.

Figure 6-5: TBE - New Application form with four pages listed

6.7 Step 5: Identify the components

In this step, the set of components associated with each page in the mock-up interface was identified. A list of components for each page is displayed in Table 6-2. More than one Form was added in some of the pages. In TBE, Form 1 is used to display the information that has been identified by either selecting an instance in the Results Grid or by undertaking a search or query request. Form 2 is used to display the information from, say, a linked file possibly from Form 1.

Table 6-2: Components required In the TBE application

<table>
<tr><td>Page</td><td>Components</td></tr>
<tr><td rowspan="6">Page 1: Ontology
Displays the structure of the entire ontology. This page allows users navigate all the classes and obtain relevant information about a selected resource within a particular class.</td><td>Tree</td></tr>
<tr><td>Search Form</td></tr>
<tr><td>SPARQL Editor</td></tr>
<tr><td>Results Grid</td></tr>
<tr><td>Form 1</td></tr>
<tr><td>Form 2</td></tr>
<tr><td rowspan="7">Page 2: Person
Displays information about instances in the Person class, and sub-classes such as NZGovtMP, Information about MPs is among the information that often required by the potential users.</td><td>Tree</td></tr>
<tr><td>Search Form</td></tr>
<tr><td>SPARQL Editor</td></tr>
<tr><td>Graph Editor and Query</td></tr>
<tr><td>Results Grid</td></tr>
<tr><td>Form 1</td></tr>
<tr><td>Form 2</td></tr>
<tr><td rowspan="6">Page 3: Electorate Information
Displays information relevant to all the Electorates. New Zealand’s MPs are selected from 63 general electorates Users who are interested in finding the relationship between an MPs and the electorate they represented is seen by some users as important.</td><td>Tree</td></tr>
<tr><td>Search Form</td></tr>
<tr><td>SPARQL Editor</td></tr>
<tr><td>Results Grid</td></tr>
<tr><td>Form</td></tr>
<tr><td>Yahoo Map</td></tr>
<tr><td rowspan="6">Page 4: Publication Information
Displays publication resources that are relevant to environmental issues. The regulations, guidelines about the environmental are wanted by farmers and people caring about the environment.</td><td>Tree</td></tr>
<tr><td>Search Form</td></tr>
<tr><td>SPARQL Editor</td></tr>
<tr><td>Graph Editor and Query</td></tr>
<tr><td>Results Grid</td></tr>
<tr><td>Form</td></tr>
</table>

The identified components were selected from the pull-down menu as shown in Figure 6-4, and dragged to an appropriate position on the interface to reflect the mock-up design.

6.8 Step 6: Configure the components

In this step, each of the components needed to be configured to ensure inter-connectivity.

In TopBraid Ensemble, components are connected using primarily mouse click events. When a selection is made using a mouse click, a named event is 'Posted' and the other components in the interface 'Listen' to that event. If the named event is accepted by a given component, then `url` data associated with the source component is passed to the receiving component and, where appropriate, the information is displayed. All the events are described using the Application Configuration Console, which is opened by selecting the icon.

The following process was followed for the initial configuration of Page 1:

1. Configure pages:
   The root node and label for each of the four pages were defined. When a page is selected, the contents of the root node are displayed in the Tree panel. Figure 6-6 shows the Tree panel when the Person page is selected.

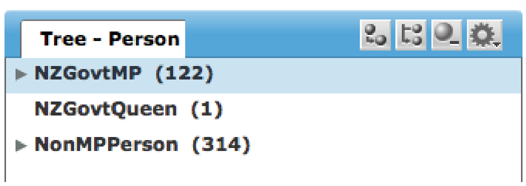


Figure 6-6: Tree – Person

2. The Tree was configured to post an event:
   This was achieved by using the Application Configuration Console:

   - The Tree label was renamed as Tree-Person.
   - A single-click selection was assigned to the event 'Tree–Person–ResultsGrid'.
   - The Console window was then closed.

   Figure 6-7 shows a part of the Results Grid panel when the Class NZGovtMP is selected.

Figure 6-7: Results Grid – NZGovtMP

3. The Results Grid was configured to listen to an event:

   A similar process similar to the post event was followed but this time the Results Grid was connected to Form 1. The result of this is shown in Figure 6-8

Figure 6-8: Information about Phil Goff as displayed in the 'Form 1' component

4. Form 1 and Form 2 are configured as shown in Figure 6-9:

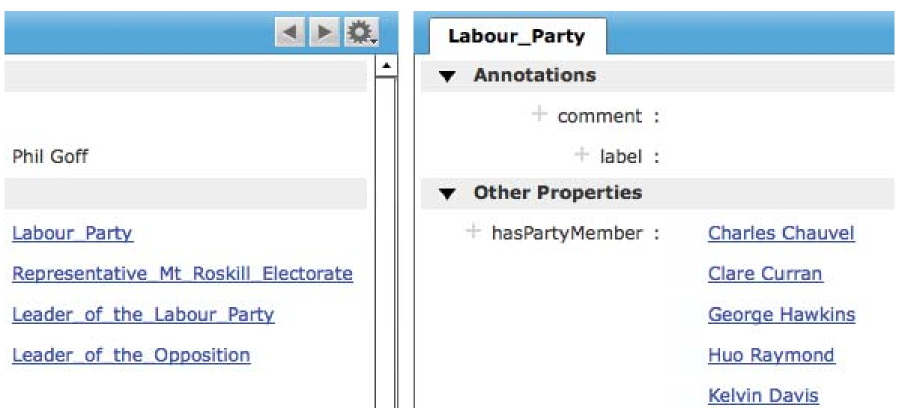


Figure 6-9: List of Labour members of parliament

The overall configuration for the interface is shown in Figure 6-10 and in more detailed tabular form in Table 6-3.

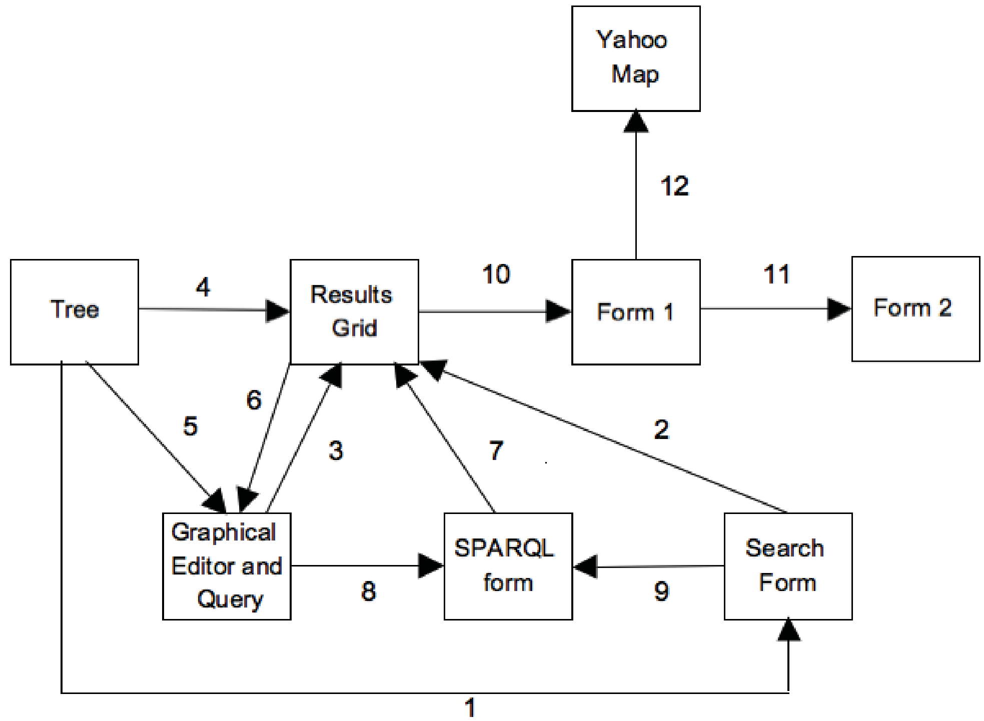


Figure 6-10: Layout of events used in the interface

Table 6-3: List of events used in the interface

Components	Post Event #	Listen Event #	Purpose of the Event
Tree: (Page 1,2,3,4)	1		Despatches the event to the Results Grid and the Search Form
	5		Posts 'Drag from Tree' event
Search Form (Pages 1,2,3,4)		1	Receives the 'Post' event from Tree and updates the display in the Search Form
	2		Despatches the event to populate the Result Grid so that it reflects the Search Form contents.
Graph Editor and Query (Page 2)	3a		Despatches the event to populate the Result Grid when the user selects a node in GraphViz.
	3b		Despatches the event to populate the Result Grid when the user selects the 'Run Query' button.
		5	Adds the item dragged from the Tree into the graph as a new node
		6	Adds the item dragged from the Results Grid into the graph as a new node.
SPARQL Editor (Pages 1,2,3,4)			Posts a query event to the Results Grid when the user clicks on the 'Submit Query' button.
		8	Enables the query to be displayed in the SPARQL Editor.
		9	Enables the query to be displayed in the SPARQL Editor. This is just another way of showing the query in the form.
Results Grid		3a/3b	Populates the Results Grid based on the event

(Pages 1,2,3,4)			from Graph Editor and Query.
		2	Populates the Results Grid based on the event from the Search Form.
		1	Populates the Results Grid based on the contents of the class selected in the Tree.
		7	Populates the Results Grid based on the results of a SPARQL query posted from the 'SPARQL Editor'.
	10		Despatches the event to Form 1 to populate the form with associated information.
	6		Despatches the Drag and Drop event to the 'Graph Editor and Query'.
Form 1 (Pages 1,2,3,4)	11		Despatches the event to Form 2, to display associated information obtained via the hyperlink..
		10	Populates Form 1 with associated information from the concept selected in the Results Grid
(page 3)	12		Posts event to Yahoo Map
Form 2 (Pages 1,2,3,4)		11	Populates Form 2 with information obtained from the hyperlink.
Yahoo Map (Page 3)		12	Displays the map of the given resource in the form of geographical information.

6.9 Step 7: Test application

To demonstrate that the interface is able to display the contents of the knowledge base, several examples are used, which are described in the following section:

- Example 1(Page 1): Trraversing the knowledge base.
- Example 2(Page 3): Using the Yahoo Map to display a graphical location.
- Example 3(Page 4): Submitting a SPARQL query to list publications.
- Example 4(Page 2): Using the Graph editor and Query to submit queries by inserting nodes.

Example 1 (Page 1): Traversing the knowledge base

In this example the Position entity was traversed to find information about the Operations Group Manager at the Manawatu Wanganui Regional Council; once found, information about who reports to the group manager was also displayed. This is shown in Figure 6-11.

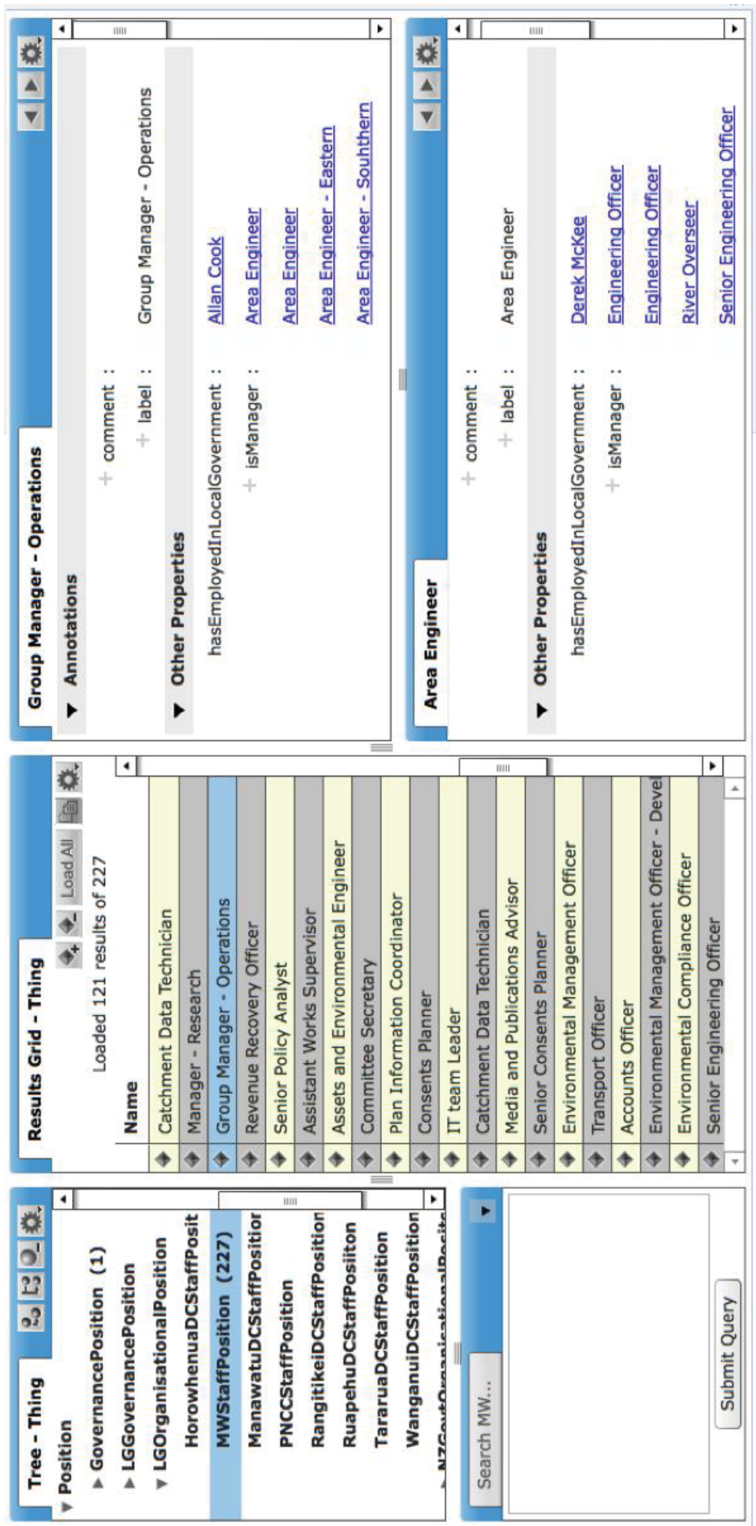


Figure 6-11: Traversing the knowledge base

Example 2 (Page 3): Using the Yahoo Map to display a graphical location

In this example the location of Auckland City electorate was displayed on a Yahoo map. The path to the map is clearly displayed in Figure 6-12.

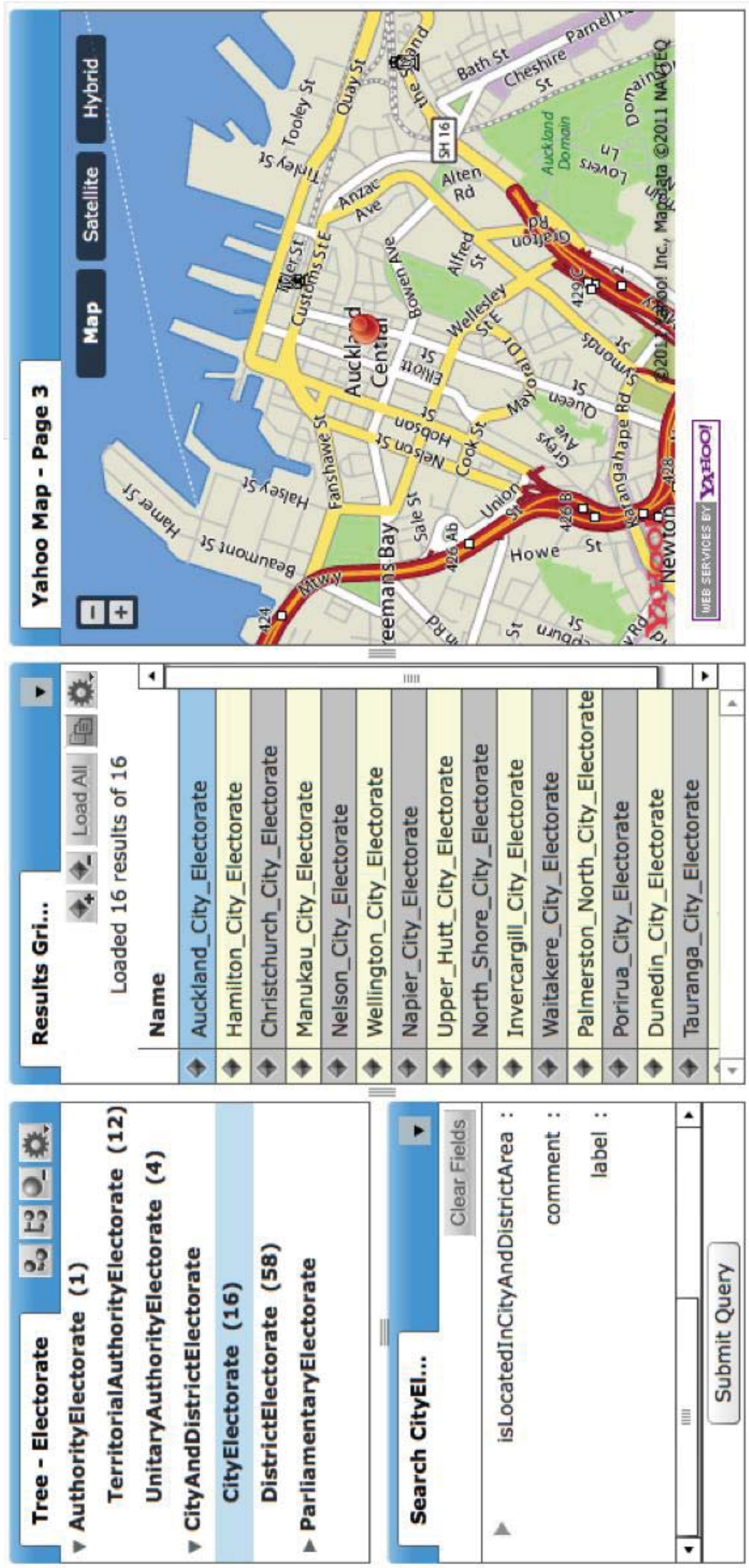


Figure 6-12: Yahoo map of Auckland City Electorate

Example 3 (Page 4): Submitting a SPARQL query to list publications

In this example, a SPARQL query was submitted to display those publications published by the Manawatu Wanganui Regional Council regarding water quality.

Further information was also obtained about the publication relating to a lake in Horowhenua. The results of this query is displayed in Figure 6-13

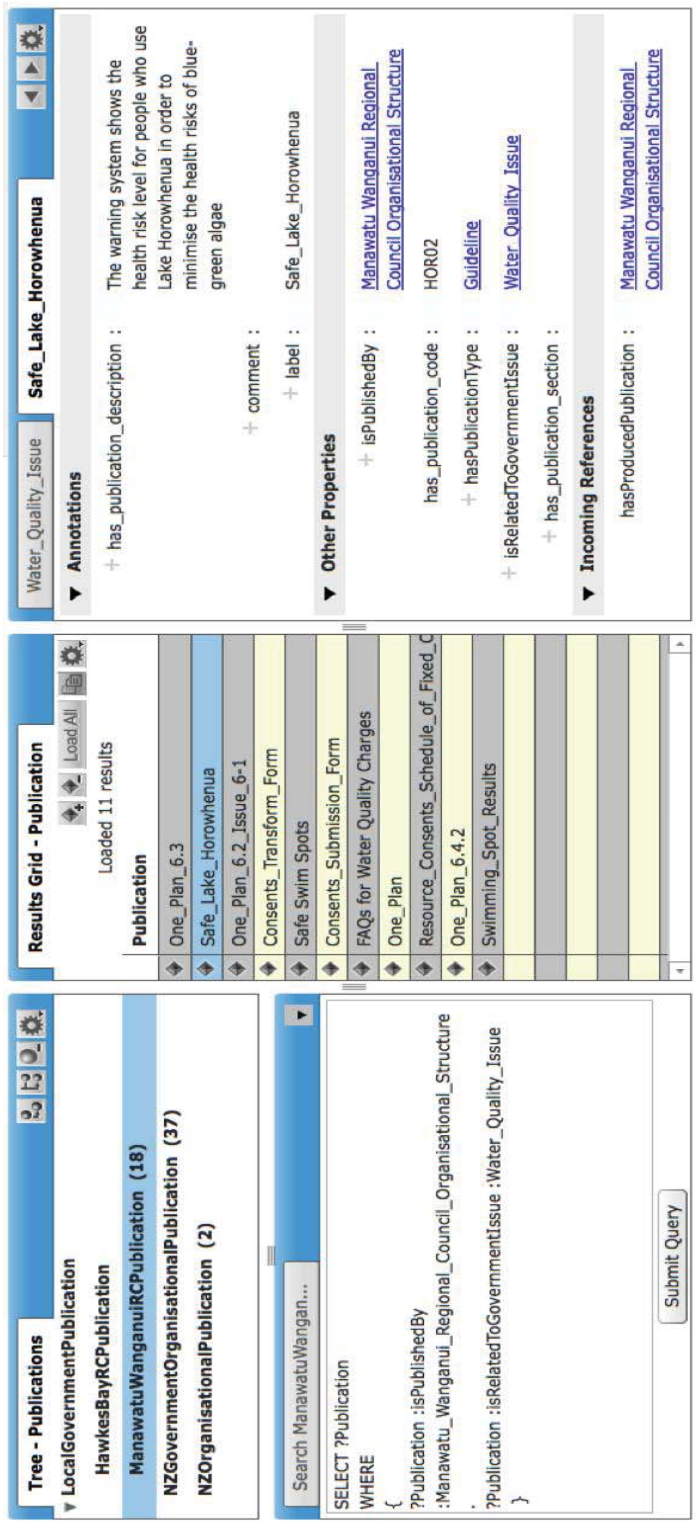


Figure 6-13: Publication by the Manawatu Wanganui Region Council relating to water quality

Example 4: Using the Graph editor and Query to submit queries by inserting nodes.

In this graphical example the purpose was to find those general electorates which fall within the district boundary of John Key's electorate. The names of the current sitting MPs who represent those general electorates were also required.

The following actions were performed in the Graph Editor and Query panel:

- The node 'John Key' was selected.
- The property links 'isElectedAsElectorateMP' and 'hasPoliticalParty' were added from the 'Outgoing' list, as shown in Figure 6-14.

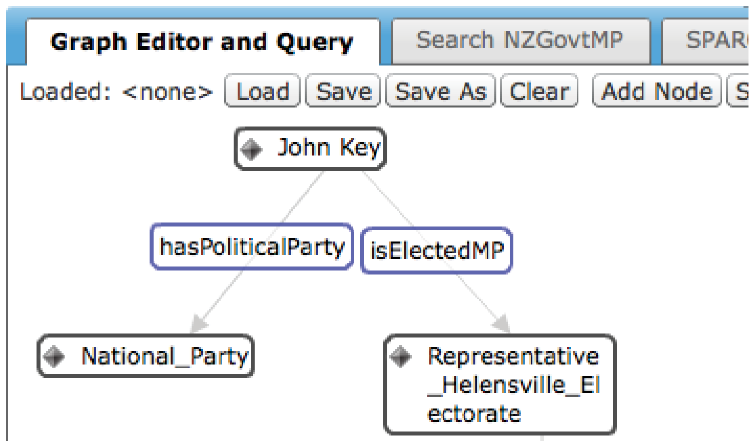


Figure 6-14: The node John Key and outgoing properties

- Additional nodes and properties were added as shown in Figure 6-15.

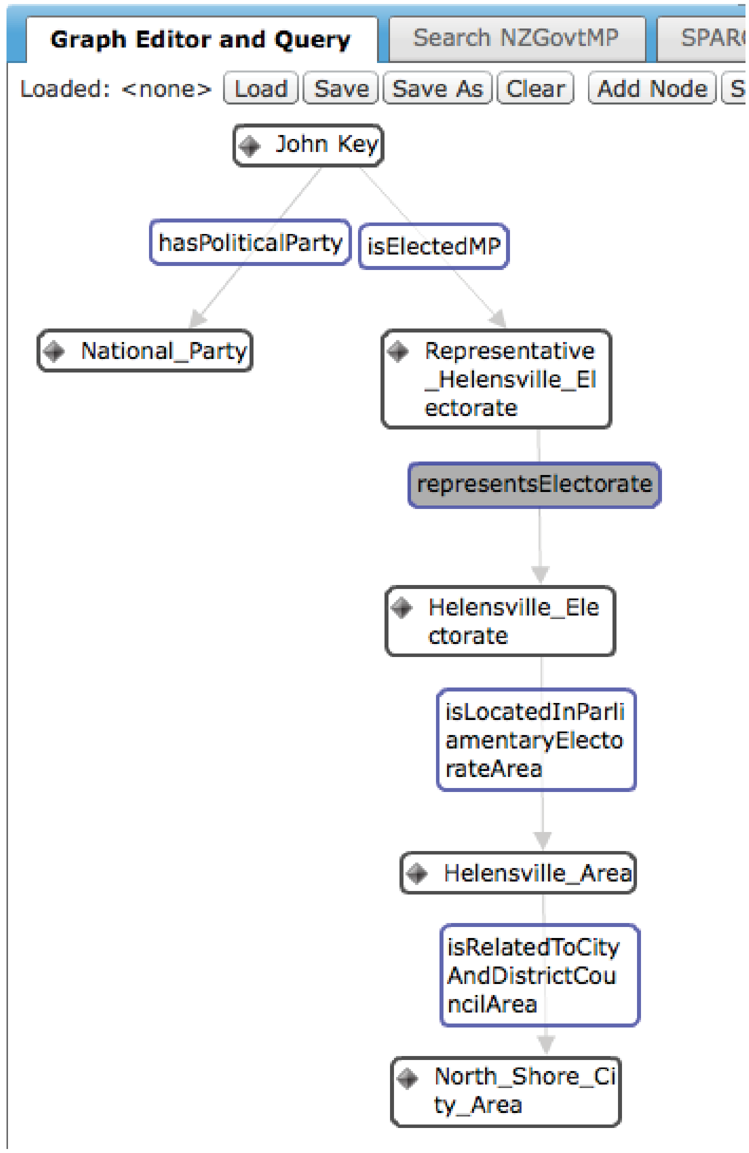
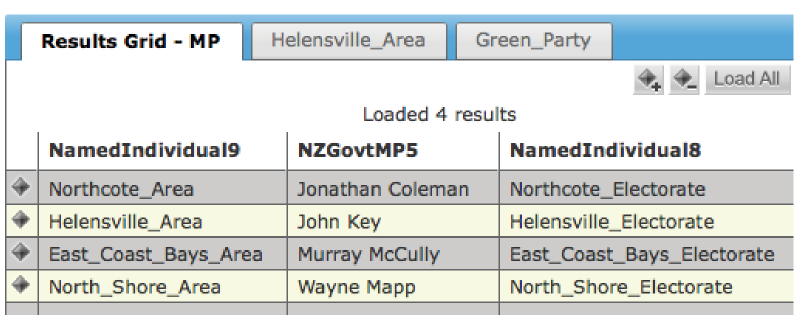


Figure 6-15: The node John Key is extended to include further nodes

In TBE, graphics can be generalised, which allows the user to identify those MPs whose electorates fall within the Helensville area. This was done in this example by selecting the nodes 'John Key', Helensville_Electorate, Helensville_area and Represents_Electorate and then 'generalising' the selection. The resulting submitted query yielded the resulting information in the Results Grid as shown in Figure 6-16.



NamedIndividual9	NZGovtMP5	NamedIndividual8
Northcote_Area	Jonathan Coleman	Northcote_Electorate
Helensville_Area	John Key	Helensville_Electorate
East_Coast_Bays_Area	Murray McCully	East_Coast_Bays_Electorate
North_Shore_Area	Wayne Mapp	North_Shore_Electorate

Figure 6-16 The results for the query using the Graph Editor and Query

6.10 System testing and evaluation

The interface was tested and evaluated throughout the development process to ensure that it met user requirements as defined by the competency questions and use cases.

Changes and amendments were made to the interface as a result of the feedback and suggestions made by Horizons Regional Council team, target users who were interested in the system, and the group of experts who completed the evaluation questionnaire (Chapter 7: Evaluation).

6.11 Chapter summary conclusions

The browser development process followed in this chapter was partially based on the tutorial material provided by TopQuadrant (TopQuadrant, 2010). The construction process demonstrates that the knowledge base expressed by the ontology framework is visible to the users and that an interface application can be established based on the user requirements.

As stated in Chapter 3, design science research is the chosen research paradigm in this research endeavour. In this approach, Hevner et al. (2004) state that the objective of design science research is to build an artefact where the process of design and development leads to the acquisition of knowledge that is useful and meaningful. Hevner et al. (2004) proposed a number of guidelines, which they consider support the information system researchers in determining the value of the research process. The following list addresses the key points:

1. Design as an artefact: Hevner et al. (2004) place considerable emphasis on the creation of an innovative artefact during the research process. In this research, a semantic framework, based on information gathered from a number of governmental sources, is constructed.
   The interface meets the needs of the research community in a number of ways. It shows that by applying systematic approach it is possible to construct an interface that allows the user to traverse the knowledge base either hierarchically, graphically or using query language.
   The interface has the potential to provide a number of different views of the knowledge base including geographical information.
2. Problem relevance: Hevner et al. (2004) point out that the purpose of design science research is to develop technology-based solution to resolve the problems that occur in existing systems. It has been shown in this research that the

browser interface could be used to deliver government information in an effective and efficient manner to a wide range of users.

3. Rigorous evaluation: Hevner et al. (2004) suggest that the utility, quality and competency have to be demonstrated by performing a well-executed evaluation method. In this research, browser evaluation was carried out towards the end of the development process by using the judgement of experts. The system did not contain any technical errors, and although it would not be user-friendly, at this stage, for computer lag reason, it did provide a more integrated and rich environment compared to the current web portals.
4. Contribution to the academic world: Hevner et al. (2004) suggest that effective design science has to provide a clear and authentic contribution for design artefact and design methodologies. In this research, the adopted design science research methodology has demonstrated that a useful and effective artefact has been created and that the approach will be useful for other developers who are considering similar or comparable projects.

7 EVALUATION

In this chapter the last of the research sub-questions is addressed, "What methods are to be used to validate and evaluate the semantic environment?"

The research in this thesis has looked at creating a framework, which can capture and integrate e-government information using semantic technologies. A number of supporting semantic languages and tools have been used to design and construct the framework. The New Zealand Parliament and local government councils have been used as representative domains, with the aim of eliciting inferences about the delivery of government information across the Internet. To ascertain the effectiveness of the semantic framework it is necessary to evaluate using meaningful and appropriate evaluation methods, ideally from several perspectives.

In the first instance it is important to ensure that the evaluation process fully validates the semantic framework created in this research, and secondly, it is important from a design science research perspective that a robust evaluation of the semantic artefact be carried out in order to confirm that it was constructed using sound, professional and international accepted methods, therefore enabling the design and construction of the innovative semantic artefact to qualify as meaningful research.

It is important to note that the fundamental question that is being addressed is not the effectiveness of the developed website, but rather the effectiveness of the semantic ontological framework that is adopted. Consequently the evaluation methods adopted should be considered as abstract in nature.

The chapter begins by discussing the nature and purpose of ontology evaluation particularly in relation to verification and validation. An overview of the various measures that can be used to evaluate a semantic framework and ontology is then provided. The three specific approaches that are used in this research to test the research hypothesis are then described. The first approach is based on the views of discipline experts who are asked to comment on the quality and appropriateness of the semantic framework. The second approach involves simulation-based analysis, where queries based on user-case scenarios are submitted to the e-government ontology and the effectiveness and efficiency of the system to deliver the correct answers is assessed. Finally, in the third approach, a structural evaluation of the semantic framework using richness metrics is described.

The following chapter, Chapter 8: Data Collection and Conclusion, considers the data that have been collected from the three evaluation approaches initiated in this chapter and synthesizes the results to enable conclusions to be drawn.

7.1 Ontology evaluation

7.1.1 Description and purpose

Gomez-Pérez, Fernandez-Pérez and Chorcho (2004b) describe ontology evaluation as a technical judgment, where the content of the ontology obtained during the development or completion of the ontology is compared to a predetermined frame of reference. The frames of reference may include such things as requirements specification, competency questions and real world comparisons.

Strolf et al. (2004) argue that the overall purpose of evaluation is to prove that a system operates in an appropriate way by adhering to the requirements imposed on the system, and that the desired services are provided to the satisfaction of the needs and expectations of the user. In addition they claim that careful application of the verification and validations processes reduces the risk of system failure.

Gomez-Pérez et al. (2004b) consider ontology evaluation consists of two elements, namely verification and validation.

7.1.1.1 Verification

Gomez et al. (2004b) take the view that verification refers to building the ontology correctly in such a way that the definitions embedded in the ontology have been implemented in accordance with the requirements definition and associated competency questions.

Strolf et al. (2004) take a slightly extended perspective when they say that verification asks the following questions:

- Has the system been constructed correctly?
- Is the knowledge base complete?
- Does the inference engine manipulate the information properly?

Taking the views of these two groups of authors into consideration, verification seeks to ensure that the system has been constructed to a high standard and conforms to appropriate professional specifications, and meets the user group’s requirements.

7.1.1.2 Validation

Taking the viewpoint of Gomez et al. (2004b) validation refers to whether the real world is actually modelled by the ontology. They argue that the goal of validation is to prove that the model, as presented by the ontology, is compliant with the analyst and modeller’s perception of the real world.

Strolf et al. (2004) believe validation to be concerned with answering questions of the following form:

- Is the system the right system?
- Is the knowledge used in the artefact, correct?
- Is the system delivering what it is supposed to do?

In other words, validation seeks to confirm that the system delivers what was specified in the requirements specification, and is used for the purpose intended.

7.1.2 Evaluation Approaches and Measures

As discussed in Chapter 2: Literature Review, the choice of an evaluation approach depends on what is being evaluated and for what purpose (Brank, et al., 2005). Brank et al. (2005) suggest four different categories:

- Comparison against a 'gold standard'.
- Using an ontology within an application and evaluating the results.
- Comparisons with a source of data about a domain of interest covered by the ontology.
- Evaluation is undertaken by humans to determine how successful the ontology meets a set of predefined criteria.

Brank et al. (2005) suggest a number of approaches to evaluation. These fall into two main categories: evaluating competing ontologies, and comparing the ontology to the corpus of knowledge to which the ontology refers. It is the latter of the two categories that is the most important in this research as there are no suitable competing ontologies were found in New Zealand or overseas by the researcher.

Hartmann et al. (2004) propose three evaluation stages for glass box testing of an ontology:

- Pre-modelling stage: Evaluating an ontology in its pre-modelling stage essentially involves the quality of the material collected.
- Modelling stage: Evaluating an ontology in its modelling stage occurs when the developer checks the quality of the work currently completed. Appropriate quality checks include, consistency, logical errors, and syntax. Competency questions could be used to ensure that the domain model represents the necessary concepts.
- After release: Evaluating an ontology after its release is mainly performed by ontology experts. Evaluation activities of this type usually consist of matching the

ontology characteristics against a set of qualitative criteria. According to Meyer and Booker (2001) expert judgment consists of information provided by qualified experts in the chosen discipline. They also believe data obtained through the use of experts to be, “valid data and comparable to other data” (p. 21). They also emphasise how important it is to ensure that the experts are carefully selected and that every effort should be made to avoid bias.

In the case of black box testing, where the system is viewed entirely by examining the systems input and output characteristics, the evaluation is carried out by using the same interface as the end user (Hartmann, et al., 2004).

Tartir and Aspinar (2007) suggest that schema metrics could be used to address the quality of the design of an ontology.

Gangemi, Catenacci, Ciaramita and Lehmann (2006) identified three ontology evaluation measures as follows:

- Structural measures: Structural evaluation focuses on syntax (e.g. graph structure) used in formal semantics. The approach is to define a general function that enables the number of graph properties to be counted. This is an approach that is also advocated by Bourna and Ling (2004).These properties could include items such as depth and width of the graph, density or modularity.
- Functional measures: These measures are related to the intended use of an ontology and of its components.
- Usability-related measures: These measures depend on the level of annotation of the considered ontology.

Simulation-based analysis is an evaluation process in which simulation is the primary means of verifying and evaluating a system. When coupled with appropriate validation processes executed during the development of the system, the capabilities of a system can be ascertained. Simulation-based analysis is a widely used approach to evaluate systems and artefacts (Adler, Hothorn, & Lausen, 2004; Lian, Hu, & Shatz, 2008).

Kehagias, Papadimitriou, Hois, Tzovaras and Bateman (2008) believe that measures can be regarded as either internal or external, where internal measure are related to the internal organisation and external measures are concerned with the ultimate role of the system to service the needs of the target community.

- Internal measures identify the key measures and forms that can be used to determine whether the ontological framework has been constructed with appropriate semantic structures and which are relevant to the environment in which the system is being used.

- External measures ascertain what measures can be used to determine whether the semantic framework has the potential to deliver large amounts of interlinked information using semantic web technologies.

7.1.3 Constraints in the evaluation process

The project undertaken in this research entailed the design and development of a complex multi-layered structure based on ontological principles. The researcher manually populated the resulting system using information gathered from governmental sources. This information was primarily obtained using the Internet, but in the case of the Horizons Regional Council information was obtained from hard copy data provided by the Council employees. The instantiated information is not as complete as a commercial application as the resources available to the researcher were limited. This should not be seen as an impediment to the evaluation process as it is the effectiveness of the framework that is under investigation not the ability of the system to store and present all governmental information.

7.2 Evaluation Approaches

In this research, three different approaches were used to validate the truth of the hypothesis:

7. Expert judgement: A group of experts who have experience using and creating semantic environments were asked to critically comment on the quality and appropriateness of the framework.
8. Simulation-based analysis: Scenarios based on the use-case data was used to submit requests for information from the system that required the utilisation of the system's unique semantic features.
9. Structural evaluation: This approach analysed the ontology using well-defined schema and instance metrics.

Whilst the functionality of the system is not the prime focus of the evaluation process, it is nevertheless important. The semantic framework created in this thesis is based on a representative domain, from which information is garnered and subsequently instantiated into the ontology. To give credibility to the framework as a realistic and meaningful structure, being able to extract information from the ontology is a necessary but not a sufficient requirement. During the simulation-based analysis the functionality of the system to deliver information to the user in an efficient and effective way is observed and recorded.

7.3 Approach 1: Expert Judgement

7.3.1 Purpose and justification

The purpose of this approach is to gain the opinion of researchers and developers who have extensive experience in the application of semantic environments, and who can comment on the quality and appropriateness of the ontological framework used in this research.

It is possible to classify the purpose of this evaluation into two components; addressed here as questions:

- Can the designed framework be correctly described as being ontology-driven and has it been constructed using correctly formed semantic structures?
- Does the framework have the potential to contain a large amount of interlinked information, and could this information be disseminated to various stakeholders using web technologies?

The justification for seeking feedback from experts is based on a number of factors outlined in Section 7.1: Ontology Evaluation. From a verification perspective, confirming that the system has been constructed to a high standard and conforms to appropriate language and design specification is an appropriate evaluation approach (Gómez-Pérez, et al., 2004b; Strolf, et al., 2004). Similarly, drawing again from Gomez-Perez et al. (2004b) and Strolf et al. (2004) seeking the views of experts on establishing whether or not the ontological framework could deliver what is specified in the requirements specification and could be used for the purpose intended is a completely acceptable approach. This view is also expressed by Hartman et al. (2004) who are of the opinion that, after release of an ontology, it is highly acceptable for evaluation to be undertaken by experts. Gangemi et al. (2006) also suggest that applying structural measures is a desirable ontology evaluation approach. Continuing with the idea of structural evaluation, Kehagias et al. (2008) suggest that internal and external measures could both be applied.

7.3.2 Method

Step 1: Identify the key measures used to evaluate the system:

Using the classification system suggested by Kehagias et al. (2008), key measures are regarded as either internal or external, where internal measures are related to the internal organisation and external measures are concerned with the ultimate role of the system to service the needs of the target community.

Step 2: Identify the experts in the field:

Anderson, Sweeney, Willimas & Martin (2008) claim that when expert judgment is sought, “empirical evidence and theoretical arguments suggest that between 5 and 10 experts should be used” (p. 729). On this basis, it was considered appropriate to identify ten discipline experts in ontology and semantic networks to critically comment on the current system.

Step 3: Contact the experts and provide appropriate guidance and questionnaires:

The experts were advised that it was a two-stage process. In Stage 1, the experts would be asked to complete a five-point Likert scale questionnaire, and later, in Stage 2, the experts would have the opportunity to make additional observations about the semantic framework. To assist them in Stage 2, they would be provided with a summary of comments from panel members taken from the completed Stage 1 questionnaire, and be given the opportunity to add to their own earlier observations and those of others.

Step 4: Collect the data and analyse the results. Performed in Chapter 8: Data Collection and Analysis:

7.3.3 Step 1: Identify the key measures used to evaluate the system

An important stage in the ontology authoring process is to ensure that the chosen ontology structure and design specifications adhere to a set of common best practices (Kehagias, et al., 2008).

Although the authoring tools that have been used to develop this research ontology have features that provide some automatic checking of such things as logical consistency, subsumption, equivalence and instantiation checking, there is no certainty that the ontology has been properly constructed to produce valid results (Kehagias, et al., 2008).

Therefore, two types of measures were used. Internal measures are concerned with the internal organisation, naming conventions, representation and so on, whereas, external measures are concerned with the adoption of the system by the user community,

7.3.3.1 Internal Measures

Using the internal measure categories proposed by Kehagias et al. (2008) and described in Chapter 2, a subset of measures were identified. The layers proposed by the Kehagias et al. (2008) that have been retained are as follows:

- Lexical / Vocabulary layer: This layer is concerned with criteria associated with the syntactic elements of the ontology, such as the naming of elements, and consistency and correctness checking.
- Structural / architectural layer: The ontology's graphical structural elements are the subject of this layer, together with relationship richness, and reasoning.
- Representational / semantic layer: The criteria associated with the semantic elements of the ontology are considered in this layer.
- Internal: Data / Application layer: In this case it is the ontology's applicability to the chosen domain that is examined.

7.3.3.2 External Measures

- Standards layer: In this layer are the criteria associated with how well internationally accepted standards are adopted and followed by the developer during the design and construction process.
- Development layer: This layer is concerned with the appropriateness of the development tools used to design and construct the semantic environment.
- Usability layer: This layer focuses on the 'ease of use' of the application to potential users in the target domain.
- Effectiveness / efficiency / satisfaction layer: In this layer the usefulness of the artefact to transfer information to the target communities is assessed.

7.3.3.3 Key Design Science Guidelines

A list of design science guidelines proposed by Hevner et al. (2004) relevant to expert judgment evaluation is set out below:

- Design as an artefact: Has a viable artefact in the form of a construct, a model, a method, or an instantiation been created?
- Problem relevance: Has a technology-based solution to an important and relevant business problem been provided?
- Rigorous evaluation: Has the utility, quality, and efficacy of a design artefact been rigorously demonstrated via well-executed evaluation methods?

- Rigorous methods of construction and evaluation: Have rigorous methods been applied in both the construction and evaluation of the design artefact?

7.3.4 Step 2: Identify the experts in the field

Experts were chosen from those developers who were closely associated with the two ontology authoring tools: TopBraidComposer, and Protégé OWL. Another source of experts was academics who had either undertaken research in semantic environments or who had supervised senior students in semantic web development. Experts who had contributed to discussion boards were seen as another source.

A list of the experts' qualifications and designation is located in Appendix 11.2.1

7.3.5 Step 3: Contact the experts and provide appropriate guidance and questionnaires

Prior to the Stage 1: Questionnaire being distributed each of the experts was asked if they were able to contribute to the research process. They were advised that if they became members of the expert panel they would be given the opportunity to view the answers and observations of the other panel members and comment further if they so wished.

In the first instance, a list of questions was put together based on the classification system proposed by Kehagias et al. (2008) the purpose of which was to validate / evaluate the internal structure of the ontology which formed the central component of the e-government semantic environment. The questions were then placed in the Stage 1: Questionnaire. A Likert 5-point scheme was adopted. A covering letter explaining the evaluation process and outlining the experts' rights as participants was attached to the questionnaire prior to it being sent to the experts. Copies of this letter and questionnaire are located in Appendices 11.2.2 and 11.2.3 respectively.

Copies of the follow-up letter and Stage 2: Questionnaire are located in Appendices 11.2.4 and 11.2.5 respectively.

7.3.6 Step 4: Collect the data and analyse the results

The final step involving the collection of data and subsequent analysis is described in Chapter 8: Data Collection and Analysis

7.4 Approach 2: Simulation-based Analysis

7.4.1 Purpose and justification

According to Adler et al. (2004) and Lian et al. (2008), simulation-based analysis is a widely used and effective way of verifying and evaluating a system or artefact. Simulation-based analysis also fits very well with the findings of Strolf et al. (2004) who believe validation to be concerned with asking the question, “Is the system delivering what it is supposed to do?” Brank et al. (2005) also believe that using an ontology within an application-driven environment and examining its performance is an appropriate form of evaluation. In particular, Gomez et al. (2004b) believe it useful in evaluation to consider how effective a systems is in addressing the requirements specification and competency questions.

Gruninger and Fox (1995) claim that the development of an ontology is motivated by scenarios that surface when users and organisations are faced with issues that cannot be resolved adequately using existing systems. They believe that embedded within these informal scenarios are examples and queries that an ‘ideal’ ontology should support. Allinson (2011) considers a scenario to be a brief narrative that describes the hypothetical use of a system. Allinson (2011) goes on to propose that a scenario has the following features:

- The users of the system are identified and the role they perform.
- It provides a realistic yet fictional understanding of the constraints on the system in its attempt to deliver the desired outcomes.
- Provides a description of the context in which the user is working.
- Enables an assessment of the usefulness of the system.

Motivating scenarios are the source of queries that can be viewed as expressive requirements, which appear in the form of competency questions, derived from use cases, which the ontology must be able to answer (Michael Gruninger & Fox, 1995). According to Gruninger and Fox (1995) the links between the competency questions and the motivating scenario provide a series of test cases that can be used to validate an ontology. In such cases, the competency questions should be defined in such a way that higher level questions require the solution of lower level questions to be addressed first.

In this research, consideration of the motivating scenarios began the evaluation process. Based on the requirements generated by use cases obtained during the systems analysis phase informal competency questions were formed. This information was then used to create a series of test cases that reflected and exemplified the role and purpose of the semantic framework. These test cases consisted of a number of queries that were then used to validate the ontology using both TopBraid Composer and TopBraid Ensemble.

7.4.2 Method

Step 1: Identify the key measures used to evaluate the system.

Step 2: Identify the three target scenarios and associated test cases.

The scenarios used in this research are based on clusters obtained from the user demographics when gathering the use cases.

Step 3: Undertake the simulation.

Within this step, representative queries are identified and submitted to the ontology and the results observed and documented.

Step 4: Collect the data and analyse the results.

This step is performed in Chapter 8: Data Collection and Analysis.

7.4.3 Step 1: Identify the key measures used to evaluate the system

7.4.3.1 Simulation measures

The key measures are essentially based on whether or not the queries submitted to the semantic environment are successfully answered, and the process is effective and efficient.

7.4.3.2 Key Design Science Guidelines

The design science guidelines proposed by Hevner et al. (2004) that appear relevant to simulation based analysis are set out below:

- Design as an artefact: Has a viable artefact in the form of a construct, a model, a method, or an instantiation been created?
- Problem relevance: Has a technology-based solution to an important and relevant business problem been provided?
- Rigorous evaluation: Has the utility, quality, and efficacy of a design artefact been rigorously demonstrated via well-executed evaluation methods?

The most applicable for this evaluation exercise is last of the listed guidelines, which proposes that the utility, quality and efficacy of the design artefact should be rigorously demonstrated.

7.4.4 Step 2: Identify the three target scenarios and associated test cases.

For each scenario, test cases and associated queries were formed with the intention of demonstrating the depth and breadth of the knowledge within the ontology, and the ability of the querying tools to access the knowledge effectively and efficiently. The test cases used in this validation were:

- New Zealand Parliamentary information primarily associated with the roles of MPs and their affiliations;
- New Zealand’s national and local government electorates and regions; and,
- Publications related to environmental issues.

Two questions were presented in each test case / scenario. In each case, solutions to each query were obtained using both TopBraid Composer and TopBraid Ensemble. In fact, more than one solution was presented for each application to illustrate the versatility of the application and the innovative nature of the semantic ontology framework. The questions were composed from representative use cases that were obtained during the development process.

The list of queries submitted to the ontology and the semantic web environment is shown in Appendix 11.3.

7.4.5 Steps 3 and 4: Undertake the simulation and collect the data and analyse the results

These steps are performed in Chapter 8: Data Collection and Analysis.

7.5 Approach 3: Structural Evaluation

7.5.1 Purpose and justification

The use of ontology metrics to help assess the quality of an ontology is considered to be an important step in ontology evaluation (Garcia-Penalvo, Garcia, & Theron, 2011). This form of evaluation is of importance to developers as it may highlight components of the ontology that might need more development. It also provides some measure of the ontology’s usefulness if its reuse was being considered. Garcia-Penalvo, et al. (2011) state that, “metrics should always be taken into account when evaluating ontologies during the engineering and application processes” (p. 4318).

Garcia-Penalvo et al. (2011) believe ONTOMETRIC, OntoQA and Protégé to be the most important tools for measuring metrics with OWL ontologies. Of these three, OntoQA (Tartir & Arpinar, 2007) is seen to be the most important (Garcia-Penalvo, et al., 2011). In addition to the comments made by Garcia-Penalvo, et al. (2011) the decision to select OntoQA as the evaluation approach in this research is because it can be applied to populated ontologies and it is easy to understand the structure and nature of the various richness metrics.

7.5.1.1 OntoQA

Tartir and Aspinar (2007) in their discussion of OntoQA, place ontology evaluation metrics into two divisions, those associated with the structure of the ontology (schema metrics) and those that address the supporting semantics (instance metrics). The former are quantitative values that measure some feature of the ontology and require an analytical approach, whereas, an interpretive approach is required when semantic evaluation is being undertaken. Tartir and Aspinar (2007) suggest that visualisation techniques can be useful to the researcher when attempting to interpret semantic metrics.

Figure 7-1 shows the overall structure of OntoQA. The ontology is constructed and instantiated using metadata structures and data obtained from trusted sources. The OntoQA calculates a numeric value for each of the relevant schema and knowledge-base metrics, which are then used to evaluate the ontology.

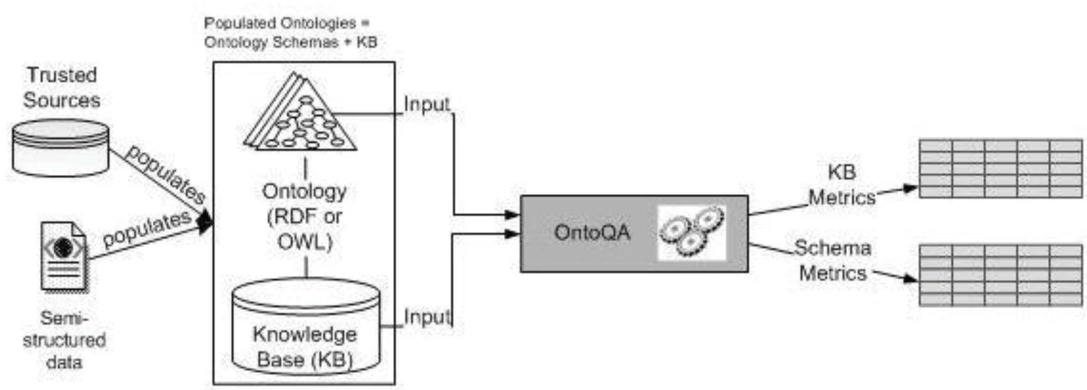


Figure 7-1: OntoQA architecture (Tartir & Arpinar, 2007).

In this research, the metrics were calculated manually as the researcher did not have access to the OntoQA tool. Another important factor to be considered is that the ontology is a prototype and it has not been fully populated with instance data. Similarly, not all concepts have been annotated and not all opportunities to add attribute properties have been taken. Because of these shortcomings, some of the OntoQA metrics, although useful, will require some care in their interpretation.

Schema metrics: Schema metrics address the design of the ontology. Essentially schema metrics provide an indication of the richness, width, depth, and inheritance of an ontology schema design. Schema metrics have the following features:

10. Relationship richness (RR): This metric reflects the proportion of properties in each class that is actually being used.
11. Attribute richness (AR): This measures the average number of attributes per class metric. This metric is not used in this evaluation due to limited number of annotations of classes and instances used in this research.
12. Inheritance Richness (IR): This measure describes the distribution of information across different levels of the ontology's inheritance tree.

Instance metrics (knowledge-base metrics): These metrics examine the placement of instance data and the effectiveness of the ontology to represent the knowledge modelled in the ontology. Instance metrics have the following features:

13. Class richness (CR): This measures the distribution of instances across classes.
14. Connectivity: This is defined as the number of instances of other classes that are connected to instances of the selected class.
15. Class importance (Imp): This measures the percentage of instances that belong to classes at the sub-tree rooted at the current class with respect to the total number of instances.
16. Inheritance richness (IR): This describes the distribution of information across different levels of the inheritance tree.
17. Class fullness: This metric is a measure of the actual number of instances compared with the expected number of instances. This metric is not considered because the researcher has populated the ontology manually from a representative set of data.
18. Readability (R): This is a measure of the existence of labels and annotations in the ontology. This metric is not included because the researcher deliberately chose not to annotate or label all classes, properties and instances as the focus of the research was more on the semantic framework and less on the details of each concept.

7.5.2 Method

The method follows the same process that was followed in the previous two approaches.

Step 1: Identify the key measures.

The metrics are those used by the OntoQA tool developed by Tartir and Aspinar (2007)

Step 2: Undertake the structural evaluation.

The evaluation is undertaken manually as access to the OntoQA tool is not available.

Step 3: Collect the data and analyse the results.

The data is collected and analysed as shown in Chapter 8: Data Collection and Analysis.

7.5.3 Step 1: Identify the key measures

The key measures adopted in this evaluation were based on those embedded within the OntoQA tool developed by Tartir and Aspinar (2007). These were divided into two divisions. Tartir and Aspinar (2007) use the following notation to expresses the metric definitions:

Main elements of the ontology schema:

- A set of classes, C.
  For example: Set of non-empty classes $C^{/}$
- A set of relationships, P.
  For example: Set of relationship between C_2 and C_1, is the set $P(C_1, C_2)$, where C_2 is the domain and C_1 is the range.
- An inheritance function, H^C.
  For example: $H^c(C_1,C_2)$ means C_1 is a subset of C_2
- A set of class attributes, Att.

Main elements of the ontology knowledgebase:

- A set of instances, I.
- A class instantiation function, inst(Ci).
- A relationship instantiation function, instr(Ii, Ii).

In the following example, the notation proposed by Tartir and Aspinar (2007) is adopted.

7.5.3.1 Key Schema Metrics

7.5.3.1.1 Relationship Richness:

Relationship richness, as proposed by Tartir and Aspinar (2007) is a schema metric, which measures the ratio of number of non-inherited properties (|P|), to the total number of relationships defined in the schema (|P| + |H|), where |H| represents the number of inherited relations.

The assumption is that an ontology that contains mainly inheritance properties is less rich than the one that has a larger proportion of non-inheritance properties.

$$RR = \frac{|P|}{|H| + |P|}$$

7.5.3.1.2 Inheritance Richness:

Inheritance richness measures the average number of sub-classes per class. In essence, this measures the distribution of information across different levels of ontology's inheritance tree. It is defined simply as the average number of subclasses per class.

$$IR = \frac{|subC|}{|C|}$$

Hence, a shallow (or horizontal) ontology would indicate a wide range of knowledge with a lower level of detail.

7.5.3.2 Key Instance Metrics

7.5.3.2.1 Class Richness:

Class metrics measure the distribution of instance over classes. Richness is defined as the ratio of the number of non-empty classes (classes with instances) $C^{/}$ to the total number of classes in the ontology.

$$CR = \frac{|C'|}{|C|}$$

If the knowledge base has a very low CR then it does not have sufficient data to justify the structure of the KB, whereas, if the CR were close to 1, it would indicate that the data in the KB represents a significant amount of the knowledge in the schema.

7.5.3.2.2 Connectivity:

This is defined as the number of instances of other classes that are connected to instances of the selected class (C_n). The sub-tree root classes would form the set $C(C_n)$

$$Cn = |I_j, P\left(I_i, I_j\right) \wedge I_i \in C_i(I)|$$

A class with a high C_n has a significant role in the ontology compared with one with a lower value. It can be represented graphically.

7.5.3.2.3 Class importance (Imp):

Essentially, this metric is concerned with the distribution of instances over classes. This measure is defined as the number of instances that belong to the sub-tree rooted C_i, compared to the total number of instances in the KB.

$$Imp = \frac{|C_i(I)|}{|I|}$$

This is a measure of the importance of the class. The higher the metric, the greater it's perceived importance.

7.5.3.2.4 Inheritance richness (IR):

This describes the distribution of information in the chosen sub-tree per class. It is defined as the average number of subclasses per class in the sub-tree.

$$IRc = \frac{\sum_{C_i \in C} |H^c(C_i, C_j|}{|C'|}$$

Classes in an ontology with a very specific domain will have a low IR_c, while a wide domain ontology will have a high value.

7.5.3.3 Key Design Science Measures

The design science guidelines and questions proposed by Hevner et al. (2004) that appear relevant to Structural Evaluation are shown below:

- Problem relevance: Has a technology-based solution to an important and relevant business problem been provided?
- Rigorous evaluation: Has the utility, quality, and efficacy of a design artefact been rigorously demonstrated via well-executed evaluation methods?

7.5.4 Steps 2 and 3: Undertake the structural evaluation, collect the data and analyse the results

The final two steps are performed in Chapter 8: Data Collection and Analysis

8 DATA COLLECTION AND ANALYSIS

In this chapter an analysis of the data collected from the three evaluation approaches, discussed and initiated in Chapter 7, is carried out. In the first evaluation approach, the feedback and comments received from the eight experts are gathered from the two questionnaires that were sent out. In Stage 1 the experts were asked to complete a five-point Likert scale questionnaire, and later, in Stage 2, the experts were provided, again in a five-point Likert scale questionnaire, a summary of comments and questions taken from the completed Stage 1 questionnaire and asked to submit their answers. Of the ten experts who were intitally approached, two could not make the commitment for the evaluation due to the other commitments. The second approach evaluates the ability of the ontology to adequately respond to queries based on the competency questions, and the third approach analyses the ontology using schema and instance metrics. The chapter concludes by combining the information from the three approaches and seeks to address the research question, making further reference to the design science research guidelines.

8.1 Approach 1: Expert Judgement

In this approach, the comments and opinions of the group of experts obtained using the survey questionnaires are collected and presented in summary and graphical forms. The Stage 1 data are analysed based on internal and external measures proposed by Kehagias et al. (2008). The researcher's responses to the experts' constructive comments are also given to illustrate the researcher's stance towards these comments and the amendments made to the ontology based on the experts' suggestions. A list of the experts' comments can be found in the Appendix 11.2.3.1.

In order to better summarise the Information gathered from the questionnaires the data has been placed into one of three categories: responses in support of the assertion stated in the questionnaire, responses not in support of the assertion, and a category for neutral responses.

8.1.1 Internal Measures

Question 1: Lexical and Vocabulary layer

This layer is concerned with the syntactic elements of the ontology. The assertions associated with Question 1 of the questionnaire are as follows:

1.1 The ontology has adopted internationally accepted naming conventions.

1.2 The ontology is well documented.

1.3 The ontology is logically defined.

1.4 The ontology is consistent (no contradictions).

1.5 The ontology is syntactically correct

Thirty-nine responses were collected from the eight experts in Question 1. The distribution of the responses is shown in Figure 8-1.

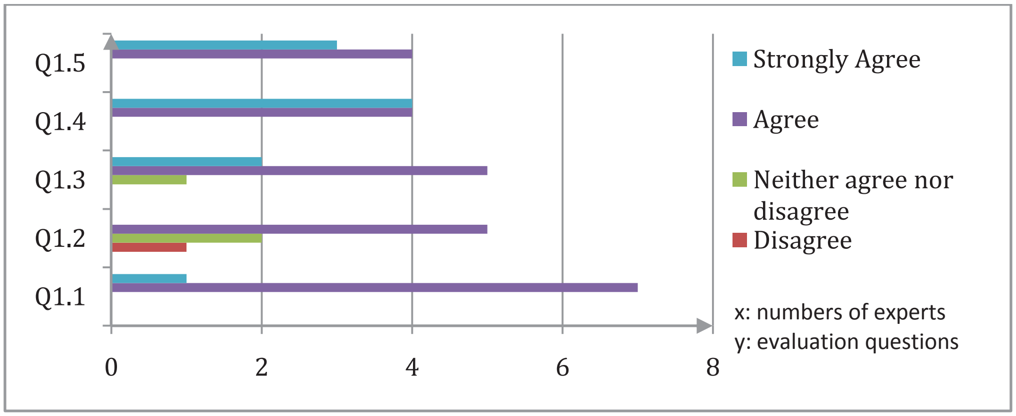


Figure 8-1 Distribution of responses for Question 1

Summary of the experts' responses

Table 8-1 Question 1: Distribution of responses:

Question	% of responses		
	In agreement	Neutral	In disagreement
Q1.1	100	0	
Q1.2	62.5	12.5	12.5
Q1.3	87.5	12.5	0
Q1.4	100	0	0
Q1.5	100	0	0
Question 1	89.7	7.7	2.6

Additional experts' comments

Constructive comments were obtained from several of the respondents.

The naming of some of the properties was too long and was not common practice. Researcher's response: This has been addressed, and both class and properties have been renamed in the ontology using Camel notation (Kehagias, et al., 2008).

Lack of documentation supporting the ontology structure and the meaning of several classes and properties. For example, it was recommended that the term 'rdfs:comment' be used to support the understanding of the terms and elements used/described in the ontology.

Researcher's response: There are thousands of concepts in the ontology and the researcher chose not to include `rdfs:comment` to describe every term that appeared in the ontology, as it was thought that it would be sufficient to provide a representative set.

It was suggested that the `rdfs:subPropertyOf` should be used more to group similar properties.

Researcher's response: The term 'sub-properties' was applied in some cases but it was found that it led to some inconsistency issues with the reasoner. To avoid these issues, the subProperty was not used in the ontology.

The suggestion was made of correcting the typos in naming the classes and properties.

Researcher's response: The typos have now been corrected in the ontology.

Summary

The overall percentage of responses in support of question 1 is a clear indication that the experts considered the Lexical and Vocabulary layer to have adopted recognised naming conventions, to be well document, logically defined and consistent.

However, it was clear that improvements could be made to the naming of properties, and, by implication, classes. This recommendation has been followed and the Camel notation has been adopted and the ontology updated.

There was also feedback given on the wider use of the statements, `rdfs:comment` and `rdfs:subPropertyOf`. The researcher is aware of these issues. In the case of `rdfs:comment`, due to the time considerations, the researcher chose to comment on a representative set of properties, classes and instances. In the case of `rdfs:subPropertyOf`, issues with the authoring tool limited its use. Later versions of the tool appear to have overcome this problem.

Question 2: Structural / architectural layer

The following assertions were put in Question 2:

2.1 Concepts and relationships within the ontology are highly connected.

2.2 The ontology has applied reasoning in a correct and useful way.

2.3 The ontology possesses a richness of relationships, attributes and inheritances.

Twenty-four responses were collected in Question 2. The distribution of the responses is shown in Figure 8-2.

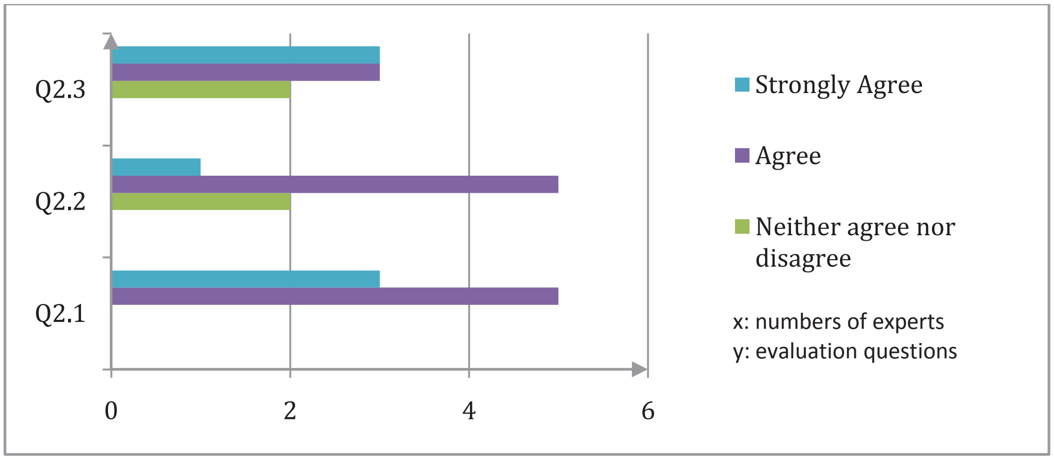


Figure 8-2 Distribution of responses for Question 2

Summary of the experts' responses

Table 8-2 Question 2: Distribution of responses:

Question	% of responses		
	In agreement	Neutral	In disagreement
Q2.1	100	0	0
Q2.2	75.0	25.0	0
Q2.3	75.0	25.0	0
Question 2	83.3	16.7	0

Additional experts' comments

Additional comments were received regarding the following issues:

- One expert felt that the assertion, "the concepts within the ontology are highly connected" was a bit vague, as the responder was not sure whether the quantity of the ontology concepts was to be taken into account.
- Another expert felt that not using `rdfs:subPropertyOf` affected the reasoning performance of the ontology, and limited the richness of the relationships, attributes and inheritances.

Summary

The high percentage of responses in support of the assertions, 83.3%, indicates that there was strong agreement among the experts that the structure of the concepts was well represented, and the interconnection within the concepts was well established. Most experts agreed that the reasoning was correct when running an inconsistency check, and the relationships, attributes and inheritances proved to be rich.

Question 3: Representational/semantic layer

The semantic elements of the ontology structure are evaluated in this question as it is concerned with how well the conceptual description has defined the ontology structure. The following assertions were put in Question 3:

3.1 Concepts and relationships within the ontology are highly connected.

3.2 The ontology system is prescriptive (tries to regulate how the world should be).

3.3 The ontology is consistent (no formal contradictions).

3.4 The ontology is comprehensive (extent of target domain it covered.)

3.5 The ontology has high granularity (fine grained versus coarse grained).

3.6 The ontology is expressive and explicit (suitable ontology languages are used).

3.7 The ontology is relevant (with regard to the application and possible users). There is a match between the formal and cognitive semantics in the ontology (semantic adequacy).

Fifty-two responses were collected in Question 3. The distribution for each of the questions is represented using a column chart as shown in Figure 8-3.

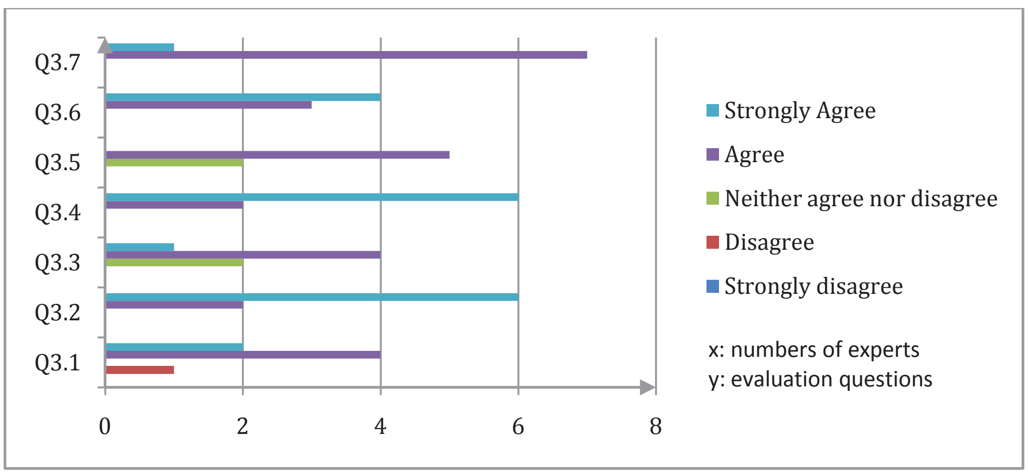


Figure 8-3 Distribution of responses for Question 3

Summary of the experts' responses

Table 8-3 Question 3: Distribution of responses:

Question	% of responses		
	In agreement	Neutral	In disagreement
Q3.1	85.7	0	14.3
Q3.2	100	0	0
Q3.3	71.4	28.6	0

Q3.4	100	0	0
Q3.5	71.4	28.6	0
Q3.6	100	0	0
Q3.7	100	0	0
Question 3	90.4	7.7	1.9

Additional experts' comments

Constructive recommendations were made by several of the experts.

1. It was suggested that some questions in the questionnaire needed a better description. It was suggested that this could be achieved by providing examples.
   Researcher's response to this recommendation: Using examples would have definitely helped the users better understand the assertion, and on reflection the questions could have been better framed.
2. In relation to Q3.3, one expert felt that it would be hard to judge whether this ontology could be extended.
   Researcher's response to this recommendation: The assertion might be better addressed if the domain area of the ontology had been better described.

Summary

The very high percentage of responses 81% agreed or strongly agreed with assertion that the ontology was consistent, comprehensive, highly granulated and expressive (Q3.2, Q3.3, Q3.4, Q3.5). The experts were also strongly of the opinion that the ontology is relevant and that there was a match between the formal and cognitive semantics in the ontology.

Question 4: Data/ application layer

The data and application layer is concerned with the ability of the ontology itself in representing the knowledge in a given domain. These following assertions were addressed in Question 4:

4.1 The query mechanisms are extensive. This issue concerns whether the theory associated with the ontology allows one to query the content.

4.2 The query mechanisms are easy to apply. This issue concerns whether the ontology framework enables one to apply the query in an easy manner.

4.3 The user is presented with a structured and appropriate interface that is structured with forms and windows.

4.4 The corpus of text represents the chosen domain well.

4.5 There is consistency between the text and the corpus terms.

Thirty-five responses were received for Question 4. A summary of the responses is displayed in Figure 8-4.

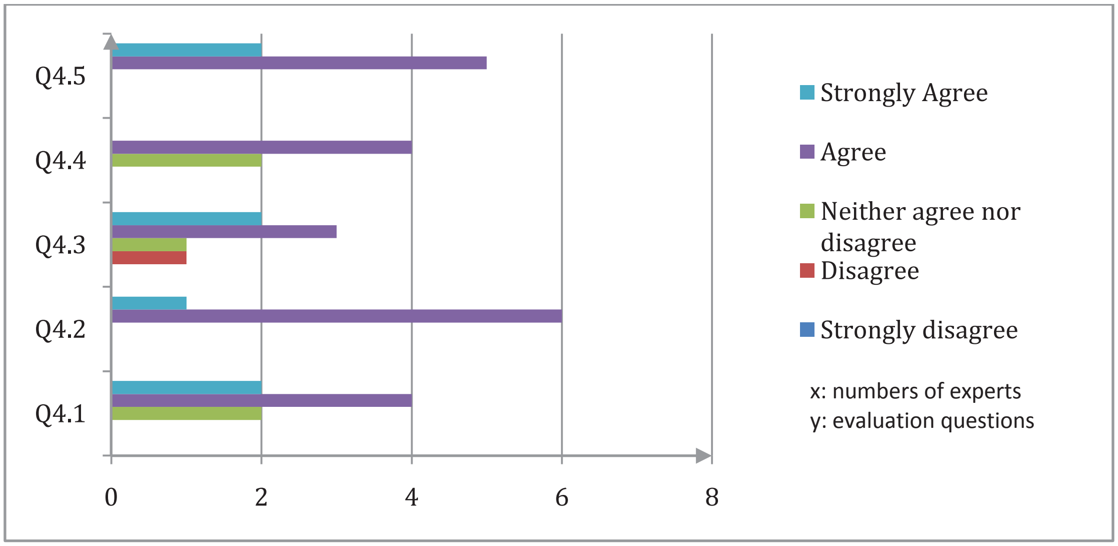


Figure 8-4 Distribution of responses for Question 4

Summary of the experts' responses

Table 8-4 Question 4: Distribution of responses:

Question	% of responses		
	In agreement	Neutral	In disagreement
Q4.1	75.0	25.0	0
Q4.2	100	0	0
Q4.3	71.4	14.3	14.3
Q4.4	66.7	33.3	0
Q4.5	100	0	0
Question 4	82.8	14.3	2.9

Additional experts' comments

Constructive recommendations were again received.

1. It was suggested that the interface and structure could be improved to better represent the information to the users.
   Researcher's response to the recommendation: In this research, the research's focus is not on the interface but on the semantic framework. However, the

comments are noted and that might be an area where further emphasis and research might be undertaken.

2. It was suggested that not using the `rdfs:subPropertyOf` had limited the use of the query facility.

   Researcher's response to this recommendation: The use of `rdfs:subPropertyOf` would definitely enhance the ability to query. However, as noted before, the researcher experienced some difficulty when carrying out consistency checking when sub-properties were used, and consequently avoided using them.

Summary

The overall response of 82.8% from the experts indicated strong support for the assertions in the questionnaire. This was noticeable with respect to the query mechanisms, which were employed in the ontology. There was some concern with the quality of the interface constructed in Composer, but overall the comments were very supportive. Comments from the experts advised the developer to make better use of the property `rdfs:subPropertyOf`.

8.1.2 External Measures

The external measurement of the ontology focuses on the usability of the external layer in representing the resulted ontologies. The two usability layers are evaluated in this section.

Question 5: Composer's usability layer.

TopBraid Composer usability layer evaluates the ontology's applicability to the chosen domain with the views of an OWL interface. The following issues were addressed in Question 5:

5.1 The query mechanisms are extensive.
5.2 The query mechanisms are easy to apply.
5.3 The interface is well constructed and appropriate.

Nineteen responses were collected for Question 5. Two responders did not address this part of the question. One of the respondents is the original developer of TopBraid Composer and he/she declined to answer issues addressed in Question 5 because of possible bias. The distribution for Question 5 responses is shown in Figure 8-5,

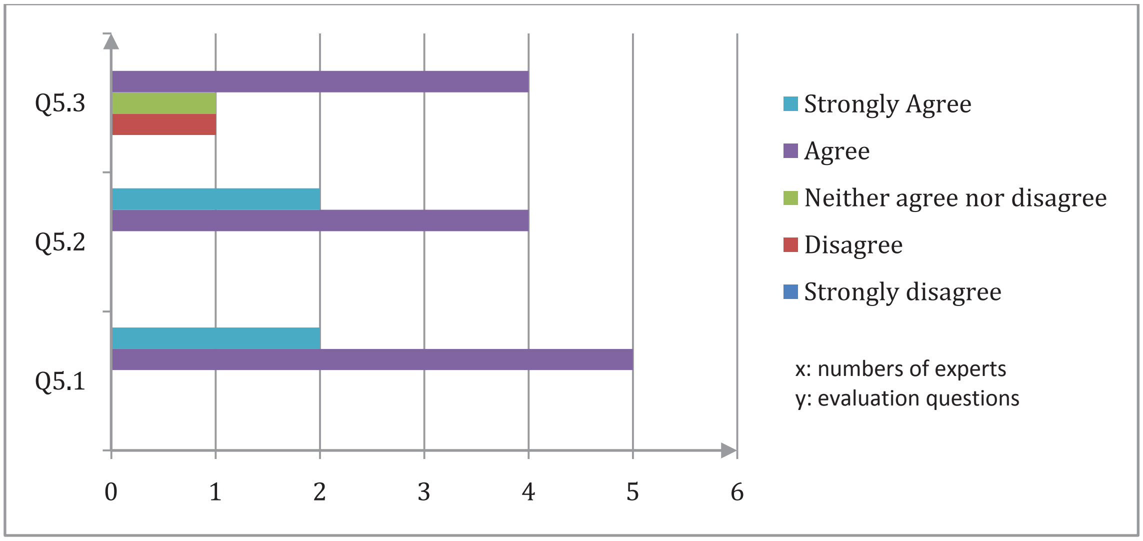


Figure 8-5 Distribution of responses for Question 5

Summary of the experts' responses

Table 8-5 Question 5: Distribution of responses:

Question	% of responses		
	In agreement	Neutral	In disagreement
Q5.1	100	0	0
Q5.2	100	0	0
Q5.3	66.7	16.7	16.7
Question 5	89.5	5.3	5.3

Additional experts' comments

Following constructive comment were gathered regarding Question 5.3:

1. The standalone interface to the ontology could be improved and better structured. It was felt that the interface would not present the information to possible users particularly well.

   Researcher's response to this recommendation: As mentioned before the interface, while important to illustrate that information in the ontology can be displayed in an interface, is not the focus of this research.

Summary

There was a very good overall positive response rate of 89.5% to questions relating to the Composer's usability layer. There was full agreement from the experts that the query mechanisms were both extensive and easy to apply. Despite the strong reservations of one expert, four experts felt the interface was well constructed and appropriate.

Question 6: Ensemble usability layer

TopBraid Ensemble usability layer evaluates the ontology's applicability to the chosen domain with the views of a web browser. The following issues were addressed in Question 6:

6.1 The web-query mechanisms are extensive.

6.2 The web-based query mechanisms are easy to apply.

6.3 The web interface is well structured and appropriate.

Eighteen responses were gathered for Question 6. Figure 8-6 shows a view for the distribution for all the responses.

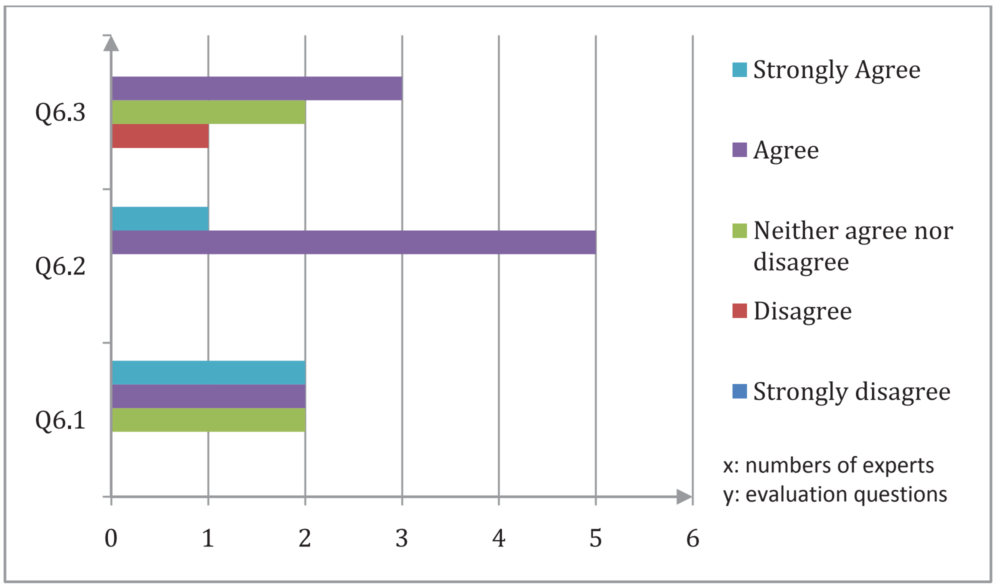


Figure 8-6 Distribution of responses for Question 6

Summary of the experts' responses

Table 8-6 Question 6: Distribution of responses:

Question	% of responses		
	In agreement	Neutral	In disagreement
Q6.1	66.7	33.3	0
Q6.2	100	0	0
Q6.3	50	33.3	16.7
Question 6	72.2	22.2	5.6

Expert commentary

Following comment were given by the experts regarding Question 6:

1. The web interface could be improved.

Researcher's response to the recommendation: As previously mentioned, the focus of the research is the design of the semantic framework; the interface is not the main focus.

2. One responder was unsure of the purpose of the application. The view was expressed that for people who have experience with TopBraid the interface is easy to understand, but others who do not have TopBraid experience the interface it is not very intuitive.

   Researcher's response to this recommendation: The comment made by the expert is understandable. Improvements to the interface would be required if the system were to be evaluated by 'real' users.

Summary

Eight experts considered the query mechanisms were both extensive and easy to apply when using the web browser. One person did not comment. With respect to interface, five either agreed or strongly agreed that the web interface was well structured and appropriate and one strongly disagreed.

8.1.3 Framework

In this research, a prototype representative semantic framework has been constructed describing New Zealand's parliament and some of the country's local government agencies. The reason for the evaluation of this framework is twofold, firstly, does the framework have the potential to effectively store and retrieve New Zealand-based information for its citizens, and secondly, and more importantly for the purpose of this research, is the semantic framework sufficiently robust to enable it to be used in other environments and jurisdictions?

These following assertions were addressed by the experts:

7.1 The current semantic framework has the potential to effectively store and retrieve information about the New Zealand parliament: its structure, its members and their roles

7.3 The current semantic framework has the potential to effectively store and retrieve integrated information relating to the internal management of a local government entity.

7.5 The current semantic framework has the potential to store and retrieve integrated information linking both local and national governmental information.

7.7 The current semantic framework has the potential to integrate information relating to environmental issues (such as water quality) to both regional and national government sources.

7.9 The current semantic framework has the potential to provide a more efficient, effective and richer source of integrated e-government information than traditional non-semantic government web sites.

Eighteen responses were collected for Question 7. Figure 8-7 displays the distribution of all the responses for Question 7.

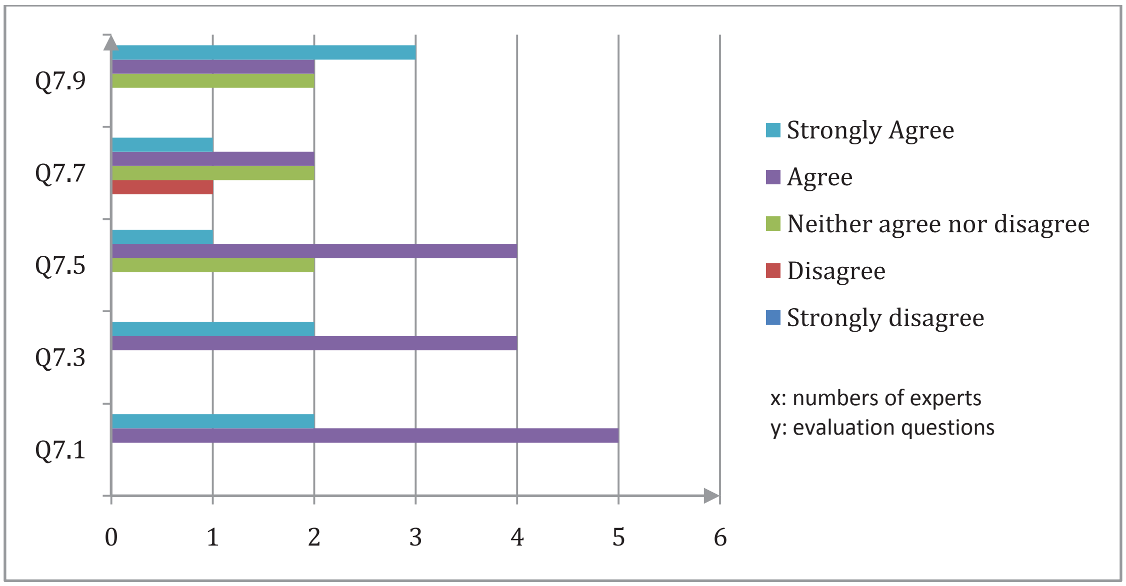


Figure 8-7 Distribution of responses for Question 7

Summary of the experts' responses

Table 8-7 Question 7: Distribution of responses:

Question	% of responses		
	In agreement	Neutral	In disagreement
Q7.1	100	0	0
Q7.3	100	0	0
Q7.5	71.4	28.6	0
Q7.7	50	33.3	16.7
Q7.9	71.4	28.6	0
Question 7	78.8	18.2	3.0

Expert commentary

Following comments were given by the experts for Question 7:

1. The use of existing vocabularies, such as ‘foaf:Person’, and linking with DBpedia will improve the links between data.

   Researcher’s response to the recommendation: It is a good suggestion to use ‘foaf:Person’ and ‘DBpedia’.

2. Remove unused namespace prefixes and define a prefix for your own file.

   Researcher’s response to the recommendation: researcher will use her own namespace prefixes in the ontology instead of using TopBraid’s.

3. Linking the existing data sources to the current ontology framework can perform better data integration.

   Researcher’s response to this recommendation: Data integration with the existing data resource was considered in the early stages of the research. However, the researcher was unable to find a governmental organisation who was prepared to expose their internal data to the researcher for a research purpose.

Summary

The analysis of the Stage 1 questionnaire suggested that all the respondents were of the opinion that the framework was able to store and retrieve information about the New Zealand parliament. There was also 100% agreement with the assertion that the ontology had the potential to store and retrieve integrated information relating to the internal management of both local government entities and the national government. There was less support for the assertion that it had the potential to combine both local and national government information; this suggests some disagreement in the possible linking of information relating to environmental issues from regional and national government sources.

Overall, experts were in agreement that the framework had the potential to provide an efficient, effective and rich source of integrated e-government information.

No Stage 2 questionnaires were returned. The questions were unlikely to have been relevant to the experts. Most indicated that they were extremely busy and it was difficult to fit the extra work into their schedules.

8.1.4 Approach 1: Analysis

General

In this approach, the framework was evaluated by seeking the views and comments from eight experts who have both extensive experience in ontology development and broad knowledge of the Semantic Web.

Summary

The experts agreed to the following:

- The ontology has adopted an appropriate naming convention and that the ontology is syntactically correct.
- The ontology has a well-defined structure, which shows that the relationship, attributes and inheritances have been developed in a rich manner.
- The ontology is consistent. It contains sufficient information to adequately reflect the target domains and the reality; proper language is applied to describe the ontology in expressive and explicit way; and, the ontology is properly structured to enable one to apply the query in an easy manner.
- The ontology has great potential to respond to queries using both the OWL interface and web-based interface.
- The current framework has the potential to contain a large amount of interlinked information, which could be disseminated to various stakeholders using web technologies.

Expert commentary

The experts commented in the following way:

- The ontology has a great potential for performing queries and showing the results within the chosen domain when using both the OWL interface and the web-based interface.
- Some of the property names could be shortened and follow a standard naming convention.
- The use of `rdfs:comment` was suggested to support the documentation and description of the concepts.
- The use of `rdfs:subPropertyOf` was suggested to improve reasoning performance.
- Examples should have been used in the questionnaires to help the evaluator better understand some of the questions in the survey.
- The web-based interface could be improved for better understanding and better information representation.

Based on these suggestions, the researcher has made some modifications to the ontology, which include shortening the properties' names, adopting the CamelBack notation, introducing "geo" standards to regulate the description of geographic information, and correcting the typos.

Despite the limitations of current ontology development tools deployed in this research, the researcher has attempted to address comments and suggestions made by the experts. In the case where there was limited ability in querying the web-interface application, the researcher explained that the focus was on the potential of the framework and not on the quality of the user interface. However, a limited evaluation of both the standalone and browser interfaces was performed in order to demonstrate that information contained in the ontology could be queried and retrieved.

Design Science

The relevant design science guidelines, discussed in Chapter 7.3.3.3, which were followed during Evaluation 1 are as follows:

- Design as an artefact: The experts endorsed the view that a viable artefact had been created and that it has been instantiated. This is evidenced by the strong supportive responses to the external measures, ‘Q5: Composer’s Usability Layer’ and ‘Q6: Ensemble’s Usability Layer’, which were 89% and 72.2% respectively.
- Problem relevance: The experts provided an overall supportive response rate of 78.8% to the question which sought comments on the potential of the artefact to provide a more efficient, effective and richer source of e-government information than traditional non-semantic government web sites. In so responding the experts gave support to the notion that a solution had been provided to an important and relevant business problem.
- Rigorous evaluation: The fact that the ontology has been put to a group of experts is evidence that the framework has been subjected to rigorous evaluation.
- Rigorous methods of construction and evaluation: The experts’ responses to the questions, Q1: Lexical and Vocabulary Layer, Q2: Structural and Architectural Layer, Q3: Representational and Semantic Layer, with 94.4%, 83.3%, 71.4% and 90.4% positive responses respectively, indicate very strongly that rigorous methods have been applied in both the construction and evaluation of the design artefact.

8.2 Approach 2: Simulation based analysis

The purpose of the second evaluation approach is to determine whether or not the ontology is able to meet the expectations of potential users as expressed in the use case scenarios. By examining the use cases and competency questions that were used to determine user requirements, three scenarios were formed, each of which represented a particular field of interest. Two queries were formed in each scenario and submitted to both the TopBraid ontology development environment and the TopBraid web-based interface application; the queries were executed using both TopBraid Composer (TBC) and TopBraid Ensemble (TBE).

In this section, details of the scenarios are described at the beginning of each scenario. A notation is used to classify the scenario, question, application and solution. For example "S2:Q1^{TBC}" Solution 1, in this document represents Solution 1, to Question 1, from Scenario 2, put to TopBraid Composer.

Scenario 1: Parliament and its members

Description of the Scenario

The scenario is bounded by the names and roles of democratically elected Members of the New Zealand Parliament.

Query 1

Identify those National Party electorate MPs who have ministerial roles and associate ministerial roles, and who are members of at least one select committee.

Solutions to Query 1

S1:Q1^{TBC}: Solution 1: Using Composer's SPARQL panel

How the SPARQL query was formed is shown in Table 8-8. The construct was developed statement by statement until the final form was obtained. Additional statements could be added to sort and remove duplicate solutions as mentioned in Chapter 4: Supporting languages, techniques and technologies. SPARQL statements are composed of triples.

Table 8-8: Scenario 1 – SPARQL Query 1 (Only the names of MPs selected).

S1:Q1:	Identify those National Party electorate MPs with a ministerial role and an associate ministerial role, and also membership of a select committee
<u>Steps</u>	<u>Query in SPARQL</u>
1. Identify all MPs	SELECT ?MPs WHERE{?MPs :isElectedElectorateMP ?GeneralElectoratePosition }
2. Identify all National Party Electorate MPs	SELECT ?MPs WHERE{?MPs :hasPoliticalParty :National_Party . ?MPs :isElectedElectorateMP ?GeneralElectoratePosition. ?GeneralElectoratePosition rdf:type :GeneralElectoratePosition

	}
3. Add the Ministerial Roles and Associate Ministerial Roles	SELECT ?MPs WHERE{?MPs :hasPoliticalParty :National_Party . ?MPs :isElectedElectorateMP ?GeneralElectoratePosition. ?GeneralElectoratePosition rdf:type :GeneralElectoratePosition . ?MPs :isAssignedParliamentaryMinisterialPortfolioRole ?MinisterialPortfolioRole . ?MPs :isAssignedParliamentaryAssociateMinisterialRole ?AssociateMinisterialRole }
1.4 Add membership of a Select Committee	SELECT DISTINCT?MPs WHERE{?MPs :hasPoliticalParty :National_Party . ?MPs :isElectedElectorateMP ?GeneralElectoratePosition. ?GeneralElectoratePosition rdf:type :GeneralElectoratePosition . ?MPs :isAssignedParliamentaryMinisterialPortfolioRole ?MinisterialPortfolioRole . ?MPs :isAssignedParliamentaryAssociateMinisterialRole ?AssociateMinisterialRole. ?MPs :isAssignedSelectCommitteeRole ?SelectCommitteeRole }

The complete query was then entered into the SPARQL panel as shown in Figure 8-8. When “Execute SPARQL” button was selected the results of the query were displayed in the Results panel, as shown in Figure 8-9.

Figure 8-8: TBC - Query Editor: Scenario 1 – Query 1 – Solution 1

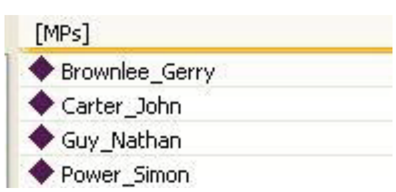


Figure 8-9: TBC – Result panel: Scenario 1 – Query 1 – Solution 1

The modification of the SELECT statement in the SPARQL query to include the names of the various committees resulted in the following output Figure 8-10.

[MPs]	MinisterialPortfolioRole	AssociateMinisterialRole	SelectCommitteeRole
Brownlee_Gerry	Minister_of_Energy_and_Resources	Associate_Minister_for_the_Rugby_Wo...	Select_Committee_Standing_Orders_M..
Brownlee_Gerry	Minister_of_Energy_and_Resources	Associate_Minister_for_the_Rugby_Wo...	Select_Committee_Privileges_Deputy_C.
Brownlee_Gerry	MInister_for_Economic_Development	Associate_Minister_for_the_Rugby_Wo...	Select_Committee_Standing_Orders_M..
Brownlee_Gerry	MInister_for_Economic_Development	Associate_Minister_for_the_Rugby_Wo...	Select_Committee_Privileges_Deputy_C.
Carter_John	Minister_for_Racing	Associate_Minister_of_Local_Government	Select_Committee_Auckland_Governan..
Carter_John	Minister_for_Racing	Associate_Minister_of_Local_Government	Select_Committee_Primary_Production_.
Carter_John	Minister_of_Civil_Defence	Associate_Minister_of_Local_Government	Select_Committee_Auckland_Governan..
Carter_John	Minister_of_Civil_Defence	Associate_Minister_of_Local_Government	Select_Committee_Primary_Production_.
Carter_John	Minister_for_Senior_Citizens	Associate_Minister_of_Local_Government	Select_Committee_Auckland_Governan..
Carter_John	Minister_for_Senior_Citizens	Associate_Minister_of_Local_Government	Select_Committee_Primary_Production_.
Guy_Nathan	Minister_of_Internal_Affairs	Associate_Minister_of_Justice	Select_Committee_Justice_and_Elector..
Power_Simon	Minister_of_State_Owned_Enterpr...	Associate_Minister_of_Finance	Select_Committee_Privileges_Member
Power_Simon	Minister_of_Justice	Associate_Minister_of_Finance	Select_Committee_Privileges_Member
Power_Simon	Minister_of_Commerce	Associate_Minister_of_Finance	Select_Committee_Privileges_Member

Figure 8-10: TBC – Results panel: Scenario 1 – Query 1 – Solution 1 (extended query)

S1:Q1^{TBC}: Solution 2: Using Composer's Graph panel

This solution uses the concept of 'Query by Example'. A node is identified which meets the required conditions described in the query, and all other nodes having the same combination of properties are automatically identified.

In Figure 8-11, MP "Carter John" was chosen as the initial node. Relations associated with ''Carter" were then displayed, and were the connected to the appropriate target nodes, such as "National Party", "Ministerial Portfolio", etc.

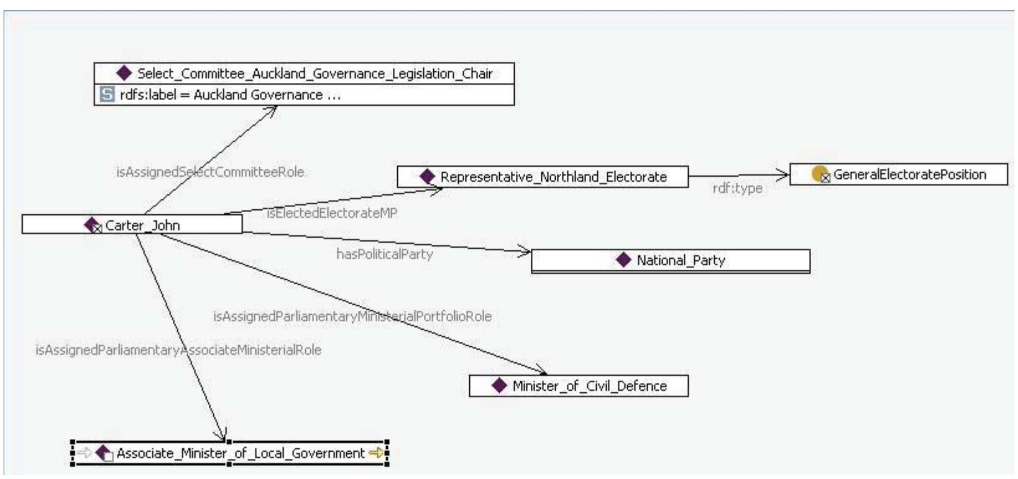


Figure 8-11: TBC - Graph panel: Scenario 1 – Query 1 – Solution 2

On selecting 'Generate SPARQL from the current graph', the SPARQL query was automatically generated as shown in the results panel automatically displayed the following output Figure 8-12.

[nzgovtmp]	namedindividual1	ministerialportfoliorole	namedindividual	namedindividual2
Brownlee_Gerry	Representative_Ilam_Electorate	Minister_of_Energy_and_R...	Select_Committee_Standing_O...	Associate_Minister_for_the_Rugby_...
Brownlee_Gerry	Representative_Ilam_Electorate	MInister_for_Economic_Dev...	Select_Committee_Standing_O...	Associate_Minister_for_the_Rugby_...
Brownlee_Gerry	Representative_Ilam_Electorate	Minister_of_Energy_and_R...	Select_Committee_Privileges_D...	Associate_Minister_for_the_Rugby_...
Brownlee_Gerry	Representative_Ilam_Electorate	MInister_for_Economic_Dev...	Select_Committee_Privileges_D...	Associate_Minister_for_the_Rugby_...
Carter_John	Representative_Northland_Elector...	Minister_for_Racing	Select_Committee_Primary_Pro...	Associate_Minister_of_Local_Govern...
Carter_John	Representative_Northland_Elector...	Minister_of_Civil_Defence	Select_Committee_Primary_Pro...	Associate_Minister_of_Local_Govern...
Carter_John	Representative_Northland_Elector...	Minister_for_Senior_Citizens	Select_Committee_Primary_Pro...	Associate_Minister_of_Local_Govern...
Carter_John	Representative_Northland_Elector...	Minister_for_Racing	Select_Committee_Auckland_G...	Associate_Minister_of_Local_Govern...
Carter_John	Representative_Northland_Elector...	Minister_of_Civil_Defence	Select_Committee_Auckland_G...	Associate_Minister_of_Local_Govern...
Carter_John	Representative_Northland_Elector...	Minister_for_Senior_Citizens	Select_Committee_Auckland_G...	Associate_Minister_of_Local_Govern...
Guy_Nathan	Representative_Otaki_Electorate	Minister_of_Internal_Affairs	Select_Committee_Justice_and...	Associate_Minister_of_Justice
Power_Simon	Representative_Rangitikei_Elector...	Minister_of_State_Owned_...	Select_Committee_Privileges_M...	Associate_Minister_of_Finance
Power_Simon	Representative_Rangitikei_Elector...	Minister_of_Justice	Select_Committee_Privileges_M...	Associate_Minister_of_Finance
Power_Simon	Representative_Rangitikei_Elector...	Minister_of_Commerce	Select_Committee_Privileges_M...	Associate_Minister_of_Finance

Figure 8-12: TBC – Result panel: Scenario 1 – Query 1 – Solution

S1:Q1^{TBE}: Solution 3: Using Ensemble's Graph Editor:

In this approach the node 'MPs' was selected and placed in the Graph Editor panel. By selecting the node, the "Incoming" list of triples and the "Outgoing" list of triples appeared in the panel. The 'Incoming' list displayed the triple where the node was the object of the triple, and the 'Outgoing' list displays the situation where the node was the subject. The links between MPs and its related triples was established step by step. Figure 8-13 shows the graph of the complete query. On submission of the query, the result was displayed in the Results Grid as shown in Figure 8-14 and the associated SPARQL query was automatically generated and displayed in the SPARQL Editor panel.

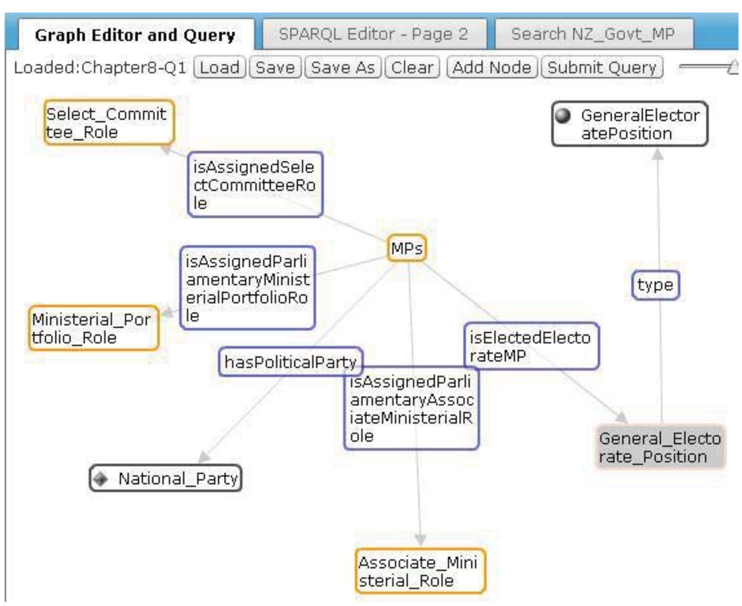


Figure 8-13: TBE - Graph Editor: Scenario 1 – Query 1 – Solution 3


Results Grid - MP | Gerry Brownlee | Green_Party | Load All

Loaded 14 results

MPs	Select Committee Role	Ministerial Portfolio Role	Associate Ministerial Role
John Carter	Auckland Governance Legi	Minister_for_Racing	Associate_Minister_of_Local_Government
John Carter	Auckland Governance Legi	Minister_of_Civil_Defence	Associate_Minister_of_Local_Government
John Carter	Auckland Governance Legi	Minister_for_Senior_Citizer	Associate_Minister_of_Local_Government
John Carter	Select_Committee_Primary	Minister_for_Racing	Associate_Minister_of_Local_Government
John Carter	Select_Committee_Primary	Minister_of_Civil_Defence	Associate_Minister_of_Local_Government
John Carter	Select_Committee_Primary	Minister_for_Senior_Citizer	Associate_Minister_of_Local_Government
Simon Power	Select_Committee_Privileg	Minister_of_State_Owned_	Associate_Minister_of_Finance
Simon Power	Select_Committee_Privileg	Minister_of_Justice	Associate_Minister_of_Finance
Simon Power	Select_Committee_Privileg	Minister_of_Commerce	Associate_Minister_of_Finance
Nathan Guy	Select_Committee_Justice_	Minister_of_Internal_Affairs	Associate_Minister_of_Justice
Gerry Brownlee	Member: Standing Orders	Minister_of_Energy_and_R	Associate_Minister_for_the_Rugby_World_Cup
Gerry Brownlee	Member: Standing Orders	MInister_for_Economic_Dev	Associate_Minister_for_the_Rugby_World_Cup
Gerry Brownlee	Select_Committee_Privileg	Minister_of_Energy_and_R	Associate_Minister_for_the_Rugby_World_Cup
Gerry Brownlee	Select_Committee_Privileg	MInister_for_Economic_Dev	Associate_Minister_for_the_Rugby_World_Cup

Figure 8-14: TBE – Results Grid: Scenario 1 – Query 1 – Solution 3

Additional Features:

The following shows how it is possible to gather additional information about a specific node. The Tree panel is used in tandem with the Results Grid or Search Form. In the following example, details of the MP – The Honourable Phil Goff are displayed. The following steps describe how this ontology was traversed:

1. The Class `NZ_Govt_MP` was selected in the Tree panel as shown in Figure 8-15.

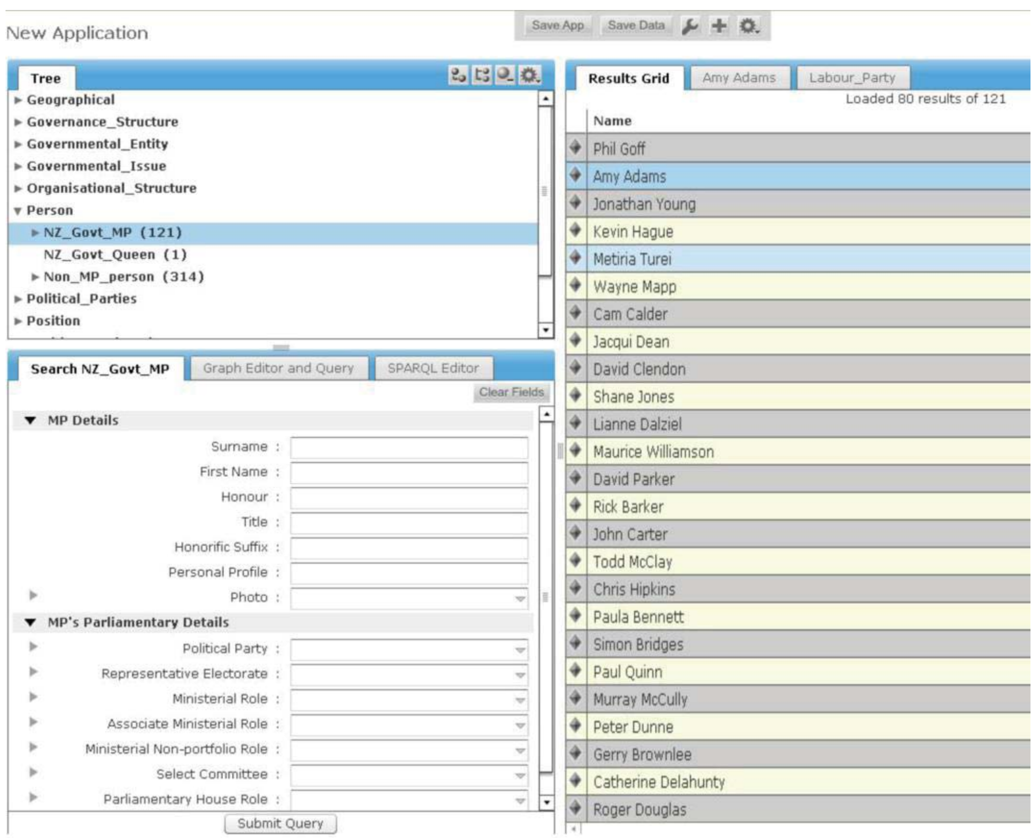


Figure 8-15: TBE – Tree panel and Results Grid: Shows the list of MPs

2. Phil Goff was selected in the Results panel. The result appeared in the Form panel Figure 8-16.

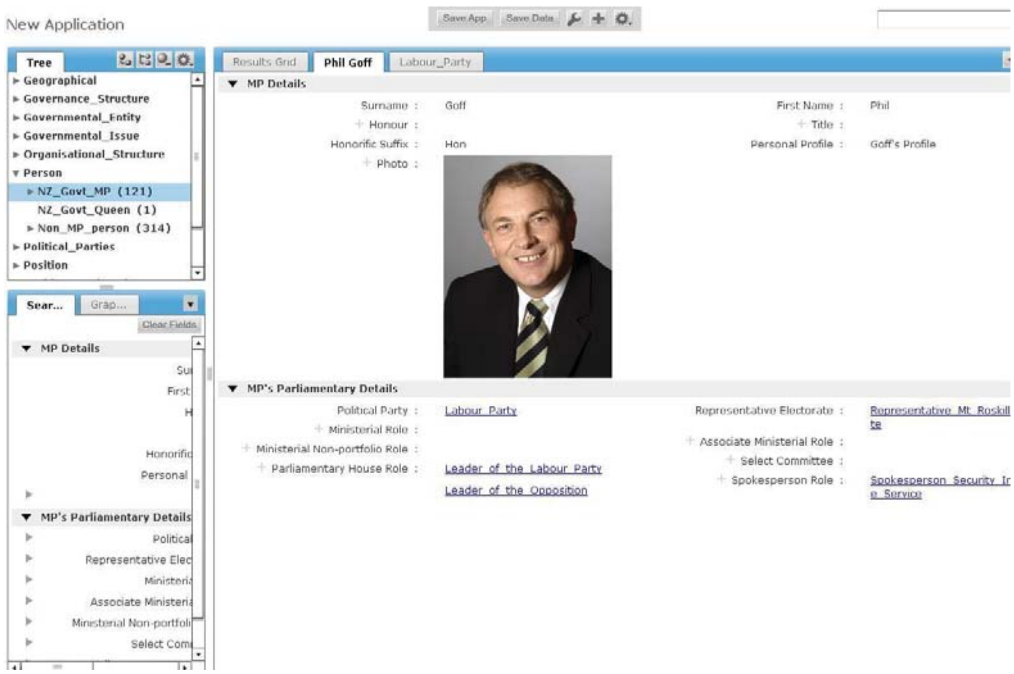


Figure 8-16: TBE - Form panel: Information relating to Honourable Phil Goff MP

Query 2

Identify those electorate MPs who are members of at least one select committee and who are members of an opposition party.

Solutions to Query 2

S1:Q2^{TBC}: Solution 1: Using Composer's SPARQL panel

The full query was compiled, as shown in Table 8-9. The query was then inserted into the Query Editor panel as shown in Figure 8-17.

Table 8-9: Scenario 1 – Query 2 – Formation of the SPARQL query

S1:Q2: Identify those electorate MPs and their role on Select Committees and who belong to an opposition party	
Steps	Query in SPARQL
1. Identify those MPs that are electorate representatives	SELECT ?MPs WHERE{?MPs :isElectedElectorateMP ?GeneralElectoratePosition. ?GeneralElectoratePosition rdf:type :GeneralElectoratePosition }

2. Add membership of a Select Committee	SELECT ?MPs WHERE{?MPs :isElectedElectorateMP ?GeneralElectoratePosition. ?GeneralElectoratePosition rdf:type :GeneralElectoratePosition } ?MPs :isAssignedSelectCommitteeRole ?SelectCommitteeRole }
3. Add belonging to an Opposition Party. Display the Party and Select Committee role.	SELECT DISTINCT ?MPs ?OppositionParties ?SelectCommitteeRole WHERE{?MPs :isElectedElectorateMP ?GeneralElectoratePosition. ?GeneralElectoratePosition rdf:type :GeneralElectoratePosition . ?MPs :isAssignedSelectCommitteeRole ?SelectCommitteeRole . ?MPs :hasPoliticalParty ?OppositionParties . ?OppositionParties rdf:type :OppositionParties }

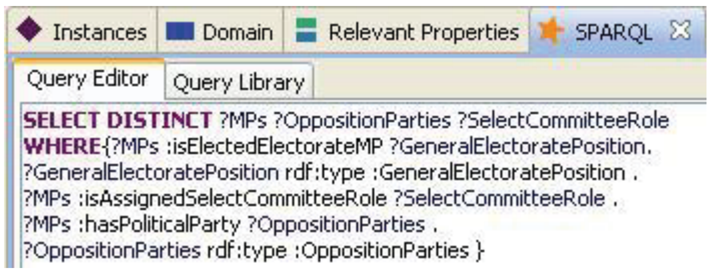
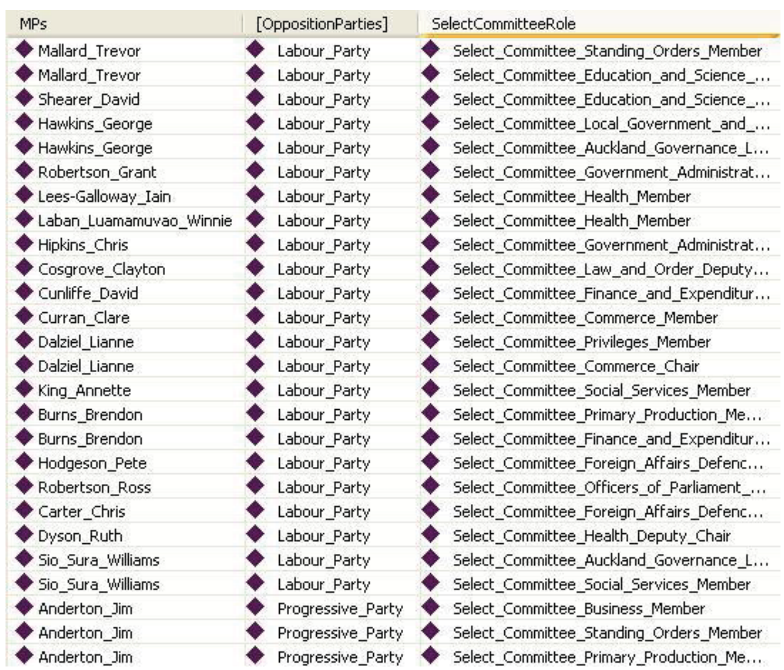


Figure 8-17: TBC – Query Editor: Scenario 1 – Query 2 – Solution 1

The result of the query was displayed in the Results panel as shown in Figure 8-18.



MPs	[OppositionParties]	SelectCommitteeRole
Mallard_Trevor	Labour_Party	Select_Committee_Standing_Orders_Member
Mallard_Trevor	Labour_Party	Select_Committee_Education_and_Science_...
Shearer_David	Labour_Party	Select_Committee_Education_and_Science_...
Hawkins_George	Labour_Party	Select_Committee_Local_Government_and_...
Hawkins_George	Labour_Party	Select_Committee_Auckland_Governance_L...
Robertson_Grant	Labour_Party	Select_Committee_Government_Administrat...
Lees-Galloway_Iain	Labour_Party	Select_Committee_Health_Member
Laban_Luamamuvao_Winnie	Labour_Party	Select_Committee_Health_Member
Hipkins_Chris	Labour_Party	Select_Committee_Government_Administrat...
Cosgrove_Clayton	Labour_Party	Select_Committee_Law_and_Order_Deputy...
Cunliffe_David	Labour_Party	Select_Committee_Finance_and_Expenditur...
Curran_Clare	Labour_Party	Select_Committee_Commerce_Member
Dalziel_Lianne	Labour_Party	Select_Committee_Privileges_Member
Dalziel_Lianne	Labour_Party	Select_Committee_Commerce_Chair
King_Annette	Labour_Party	Select_Committee_Social_Services_Member
Burns_Brendon	Labour_Party	Select_Committee_Primary_Production_Me...
Burns_Brendon	Labour_Party	Select_Committee_Finance_and_Expenditur...
Hodgeson_Pete	Labour_Party	Select_Committee_Foreign_Affairs_Defenc...
Robertson_Ross	Labour_Party	Select_Committee_Officers_of_Parliament_...
Carter_Chris	Labour_Party	Select_Committee_Foreign_Affairs_Defenc...
Dyson_Ruth	Labour_Party	Select_Committee_Health_Deputy_Chair
Sio_Sura_Williams	Labour_Party	Select_Committee_Auckland_Governance_L...
Sio_Sura_Williams	Labour_Party	Select_Committee_Social_Services_Member
Anderton_Jim	Progressive_Party	Select_Committee_Business_Member
Anderton_Jim	Progressive_Party	Select_Committee_Standing_Orders_Member
Anderton_Jim	Progressive_Party	Select_Committee_Primary_Production_Me...

Figure 8-18: TBC – Results panel: Scenario 1 – Query 2 – Solution 1

When the extra SPARQL statement, 'ORDER BY' was entered, the lists of names of the opposition parties appeared in alphabetical order.

S1:Q2[TBE]: Solution 2: Using Ensemble's Graph Editor:

The Graph Editor was used to create the query using 'MPs' as the initial node in the panel. Three strands of nodes were constructed linking 'MPs' to the nodes: 'General_Electorate_Position', 'Opposition_Parties', and 'Select_Committee_Role'. This is shown in Figure 8-19.

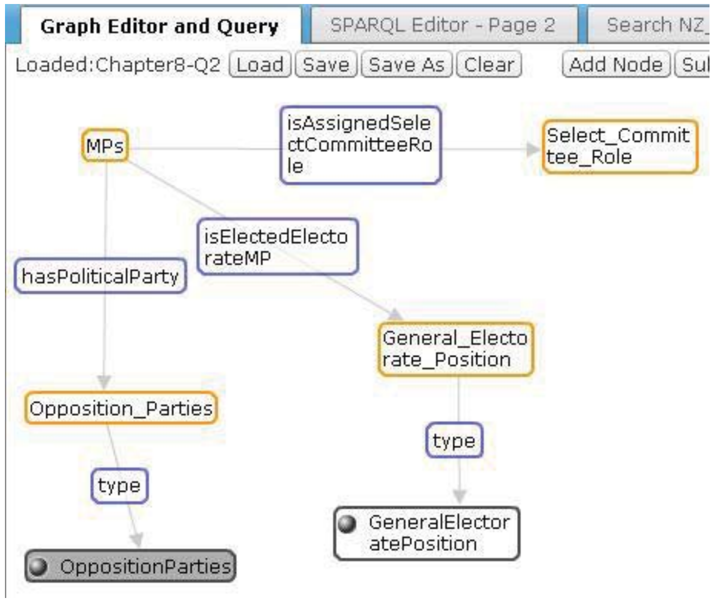


Figure 8-19: TBE – Graph Editor: Scenario 1 – Query 2 – Solution 2

On submission, the results of the query appeared in the Results Grid panel as shown in Figure 8-20, and the SPARQL code was automatically generated and appeared in the Query Editor panel as shown in Figure 8-21.

Results Grid - MP | Gerry Brownlee | Green_Party | Load All

Loaded 26 results

MPs	General Electorate Position	Opposition	Select Committee Role
Lianne Dalziel	Representative_Christchurch_East_Elec	Labour_Party	Select_Committee_Commerce_Chair
George Hawkins	Representative_Manurewa_Electorate	Labour_Party	Select_Committee_Local_Government_and
Sura Willam Sio	Representative_Mangere_Electorate	Labour_Party	Select_Committee_Auckland_Governance_
Annette King	Representative_Rongotai_Electorate	Labour_Party	Select_Committee_Social_Services_Membe
Chris Hipkins	Representative_Rimutaka_Electorate	Labour_Party	Select_Committee_Government_Administra
Lianne Dalziel	Representative_Christchurch_East_Elec	Labour_Party	Select_Committee_Privileges_Member
Grant Robertson	Representative_Wellington_Central_Ele	Labour_Party	Select_Committee_Government_Administra
Brendon Burns	Representative_Christchurch_Central_E	Labour_Party	Select_Committee_Finance_and_Expenditu
David Shearer	Representative_Mt_Albert_Electorate	Labour_Party	Select_Committee_Education_and_Science
George Hawkins	Representative_Manurewa_Electorate	Labour_Party	Select_Committee_Auckland_Governance_
Trevor Mallard	Representative_Hutt_South_Electorate	Labour_Party	Member: Standing Orders Committee
Pete Hodgeson	Representative_Dunedin_North_Elector	Labour_Party	Select_Committee_Foreign_Affairs_Defenc
Clare Curran	Representative_Dunedin_South_Electo	Labour_Party	Select_Committee_Commerce_Member
Sura Willam Sio	Representative_Mangere_Electorate	Labour_Party	Select_Committee_Social_Services_Membe
Ruth Dyson	Representative_Port_Hills_Electorate	Labour_Party	Select_Committee_Health_Deputy_Chair
Trevor Mallard	Representative_Hutt_South_Electorate	Labour_Party	Select_Committee_Education_and_Science
Clayton Cosgrove	Representative_Waimakariri_Electorate	Labour_Party	Select_Committee_Law_and_Order_Deput
Chris Carter	Representative_Te_Atatu_Electorate	Labour_Party	Select_Committee_Foreign_Affairs_Defenc
Luamamuvao Winnie Laban	Representative_Mana_Electorate	Labour_Party	Select_Committee_Health_Member
Brendon Burns	Representative_Christchurch_Central_E	Labour_Party	Select_Committee_Primary_Production_Me
David Cunliffe	Representative_New_Lynn_Electorate	Labour_Party	Select_Committee_Finance_and_Expenditu
Iain Lees-Galloway	Representative_Palmerston_North_Elec	Labour_Party	Select_Committee_Health_Member
Ross Robertson	Representative_Manukau_East_Elector	Labour_Party	Select_Committee_Officers_of_Parliament_
Jim Anderton	Representative_Wigram_Electorate	Progressive_P	Select_Committee_Primary_Production_Me
Jim Anderton	Representative_Wigram_Electorate	Progressive_P	Member: Standing Orders Committee
Jim Anderton	Representative_Wigram_Electorate	Progressive_P	Select_Committee_Business_Member

Figure 8-20: TBE - Results Grid: Scenario 1 – Query 2 Solution 2

Figure 8-21: TBE - Query Editor: Scenario 1 – Query 2 - Solution 2

Scenario 2: New Zealand's national and local government electorates and regions

Description of the Scenario

New Zealand's parliamentary electorates and local government electorates overlap. In the Auckland area there is a considerable overlap of electorates. This scenario and associated test case illustrates the level of overlap for Auckland City and throughout New Zealand.

Query 1

List all the general electorates (excludes Maori electorates) which are covered by the Auckland City area, and in addition, identify those MPs who represent these electorates.

Solutions to Query 1

S2:Q1[TBC]: Solution 1: Using Composer's SPARQL

How the SPARQL query is formed is shown in Table 8-10.

Table 8-10: Scenario 2 – Query 1

S2:Q1: List all the general electorates which are covered by the Auckland City area, and in addition identify those MPs who represent these electorates.	
Steps	**Query in SPARQL**
List all the Parliamentary General Electorate that is covered by Auckland City Area	**SELECT** ?ParliamentaryElectorate ?MPs **WHERE**{ :Auckland_City_Area :isRelatedToGeneralElectorate ?GeneralElectorateArea. ?GeneralElectorateArea :hasParliamentaryElectorate ?ParliamentaryElectorate. ?GeneralElectoratePosition :representsElectorate ?ParliamentaryElectorate. ?MPs :isElectedElectorateMP ?GeneralElectoratePosition. }

As shown in Scenario 1 – Solution 1, the SPARQL query was entered into Composer's Query Editor panel as shown in Figure 8-22.

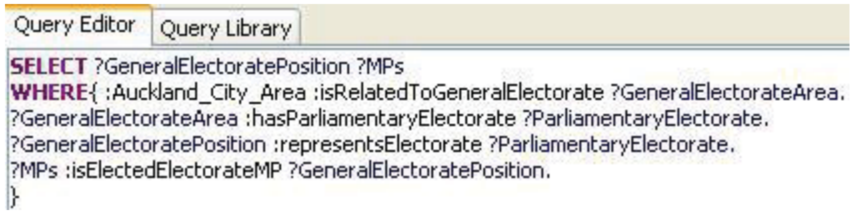
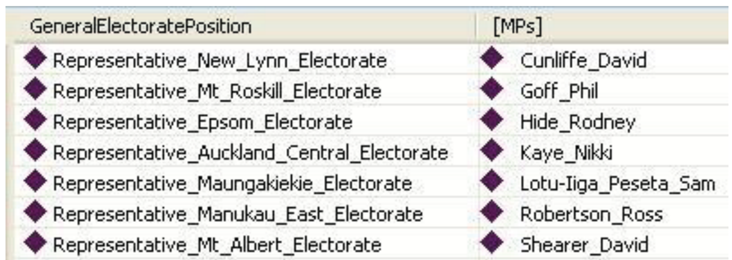


Figure 8-22: TBC - Query Editor: Scenario 2 – Query 1 – Solution 1

On submission of the query, the Results panel displayed the solution as shown in Figure 8-23.



GeneralElectoratePosition	[MPs]
Representative_New_Lynn_Electorate	Cunliffe_David
Representative_Mt_Roskill_Electorate	Goff_Phil
Representative_Epsom_Electorate	Hide_Rodney
Representative_Auckland_Central_Electorate	Kaye_Nikki
Representative_Maungakiekie_Electorate	Lotu-Iiga_Peseta_Sam
Representative_Manukau_East_Electorate	Robertson_Ross
Representative_Mt_Albert_Electorate	Shearer_David

Figure 8-23: TBC - Results panel: Scenario 2 – Query 1 – Solution 1

S2:Q1[TBE]: Solution 2: Using Ensemble's Graph Editor:

Commencing with the node class MP, the query was created within the Graph Editor and Query panel of TopBraid Ensemble. This followed the same procedure as demonstrated in Scenario 1 – Solution 3. The node 'MP' was chosen as the starting point and the entire query is developed triple by triple until all the desired nodes were identified as shown in Figure 8-24.

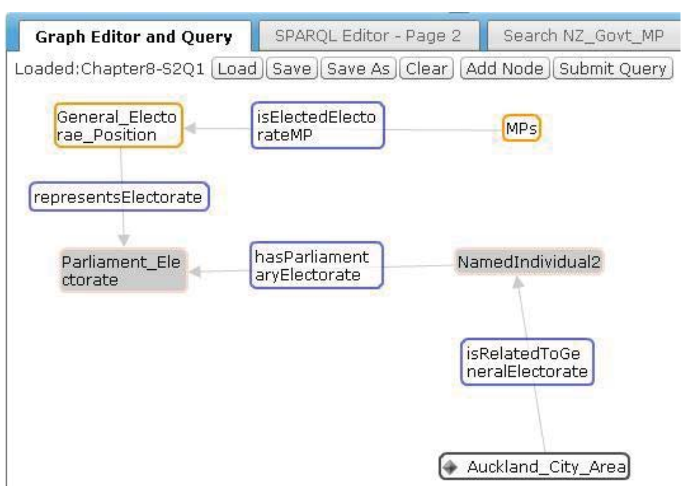


Figure 8-24: TBE - Graph Editor and Query: Scenario 2 – Query 1 – Solution 2

On submission of the query, the solution appeared in the Results Grid panel as shown in Figure 8-25, and the SPARQL code in the Graph Editor and Query panel as shown in Figure 8-26.

MPs	General Electorae Position
David Cunlffe	Representative_New_Lynn_Electorate
David Shearer	Representative_Mt_Albert_Electorate
Nikki Kaye	Representative_Auckland_Central_Electorate
Phil Goff	Representative_Mt_Roskill_Electorate
Rodney Hide	Representative_Epsom_Electorate
Ross Robertson	Representative_Manukau_East_Electorate
Sam Loto-Iiga Peseta	Representative_Maungakiekie_Electorate

Figure 8-25: Results Grid: Scenario 2 – Query 1 – Solution 2


```
SELECT ?MPs ?General_Electorae_Position
WHERE {
   ?MPs <http://www.topbraid/egovernment#isElectedElectorateMP> ?General_Electorae_Position .
   <http://www.topbraid/egovernment#Auckland_City_Area>
<http://www.topbraid/egovernment#isRelatedToGeneralElectorate> ?NamedIndividual2 .
   ?NamedIndividual2 <http://www.topbraid/egovernment#hasParliamentaryElectorate>
?Parliament_Electorate .
   ?General_Electorae_Position <http://www.topbraid/egovernment#representsElectorate>
?Parliament_Electorate .
}
```

Figure 8-26: TBE – Graph Editor and Query: Scenario 2 – Query 1 – Solution 2

Query 2

List the city councils and the general electorates that are located within their boundaries. Also include the names of the sitting MPs. This query explicitly excludes district or regional council regions. Note: Only the North Island city councils are considered as information relating to South Island cities has not been entered into the ontology.

Solutions to Query 2

S2:Q2^{TBC}: Solution 1: Using Composer's SPARQL panel

The SPARQL query is shown in Table 8-11.

Table 8-11: Scenario 2 – Query 2

S2:Q2: List all city councils and the general electorates that are located within their boundaries. Also include the names of the sitting MPs.	
<u>**Steps**</u>	<u>**Query in SPARQL**</u>

1. List the city councils and the areas in which they are located	**SELECT** ?CityCouncil ?CityCouncilArea **WHERE**{?CityCouncil :isLocatedIn ?CityCouncilArea. ?CityCouncil rdf:type :CityCouncil }
2. List the city councils with the areas in which they are located, and the general electorates.	**SELECT** ?CityCouncil ?GeneralElectorateArea **WHERE**{?CityCouncil :isLocatedIn ?CityCouncilArea. ?CityCouncil rdf:type :CityCouncil. ?CityCouncilArea :isRelatedToGeneralElectorate ?GeneralElectorateArea }
3. List the city councils with the areas in which they are located, and the general electorates and include the names of the sitting MPs.	**SELECT** ?CityCouncil ?GeneralElectorateArea ?MPs **WHERE**{?CityCouncil :isLocatedIn?CityCouncilArea. ?CityCouncil rdf:type :CityCouncil. ?CityCouncilArea :isRelatedToGeneralElectorate ?GeneralElectorateArea. ?GeneralElectorateArea :hasParliamentaryElectorate ?ParliamentaryElectorate. ?GeneralElectoratePosition :representsElectorate ?ParliamentaryElectorate. ?GeneralElectoratePosition :hasElectedElectorateMP ?MPs }

The SPARQL query was inserted into the Query Editor as shown in Figure 8-27:

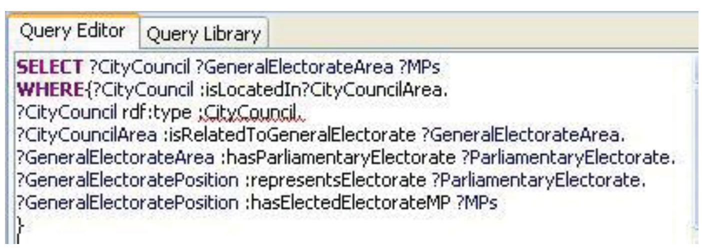


Figure 8-27: TBC - Query Editor: Scenario 2 – Query 2 – Solution 1

The result of the query appeared in Composer’s Results panel as shown in Figure 8-28.

[CityCouncil]	GeneralElectorateArea	MPs
Auckland_City_Council	Maungakiekie_Area	Lotu-Iiga_Peseta_Sam
Auckland_City_Council	New_Lynn_Area	Cunliffe_David
Auckland_City_Council	Mt_Albert_Area	Shearer_David
Auckland_City_Council	Epsom_Area	Hide_Rodney
Auckland_City_Council	Manukau_East_Area	Robertson_Ross
Auckland_City_Council	Mt_Roskill_Area	Goff_Phil
Auckland_City_Council	Auckland_Central_Area	Kaye_Nikki
Hamilton_City_Council	Hamilton_East_Area	Bennett_David
Lower_Hutt_City_Council	Ohariu_Area	Dunne_Peter
Lower_Hutt_City_Council	Hutt_South_Area	Mallard_Trevor
Lower_Hutt_City_Council	Rimutaka_Area	Hipkins_Chris
Manukau_City_Council	Papakura_Area	Collins_Judith
Manukau_City_Council	Botany_Area	Wong_Pansy
Manukau_City_Council	Hunua_Area	Hutchison_Paul
Manukau_City_Council	Manukau_East_Area	Robertson_Ross
Manukau_City_Council	Manurewa_Area	Hawkins_George
Manukau_City_Council	Mangere_Area	Sio_Sura_Williams
Napier_City_Council	Napier_Area	Tremain_Chris
North_Shore_City_Council	Northcote_Area	Coleman_Jonathan
North_Shore_City_Council	Helensville_Area	Key_John
North_Shore_City_Council	North_Shore_Area	Mapp_Wayne
North_Shore_City_Council	East_Coast_Bays_Area	McCully_Murray
Palmerston_North_City_Cou...	Palmerston_North_Area	Lees-Galloway_Iain
Palmerston_North_City_Cou...	Rangitikei_Area	Power_Simon
Porirua_City_Council	Mana_Area	Laban_Luamamuvao_Winnie
Tauranga_City_Council	Tauranga_Area	Bridges_Simon
Tauranga_City_Council	Bay_of_Plenty_Area	Ryall_Tony
Upper_Hutt_City_Council	Rimutaka_Area	Hipkins_Chris
Waitakere_City_Council	Te_Atatu_Area	Carter_Chris
Waitakere_City_Council	Helensville_Area	Key_John
Waitakere_City_Council	New_Lynn_Area	Cunliffe_David
Waitakere_City_Council	Waitakere_Area	Bennett_Paula
Wellington_City_Council	Ohariu_Area	Dunne_Peter
Wellington_City_Council	Mana_Area	Laban_Luamamuvao_Winnie
Wellington_City_Council	Rongotai_Area	King_Annette
Wellington_City_Council	Wellington_Central_Area	Robertson_Grant

Figure 8-28: TBC - Result panel: Query 2 – Scenario 2 – Solution 2 (North Island cities only)

S2:Q2^{TBE}: Solution 2: Using Ensemble's Graph Editor and Query panel

Again, the node MPs was chosen as the starting point. Following the same procedure as before, the entire query was developed triple by triple until all the desired nodes were included as shown in Figure 8-29.

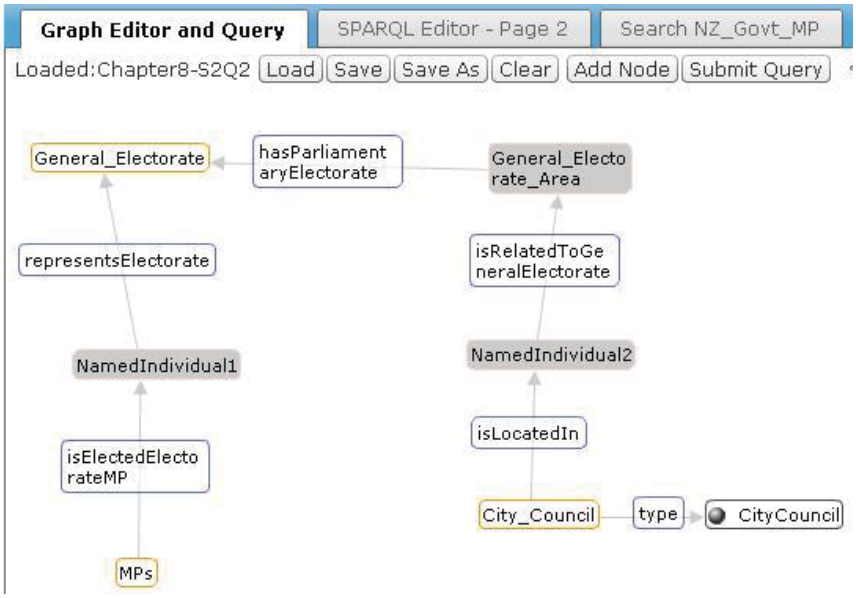


Figure 8-29: TBE - Graph Editor: Scenario 2 – Query 2 – Solution 2

On submitting the query, the result appeared in the Results Grid panel and a copy of the SPARQL query was automatically generated and displayed in the Graphic Editor panel, as shown in Figure 8-30 and Figure 8-31 respectively.

Results Grid - MP | Gerry Brownlee | Green_Party

Loaded 37 results

City Council	General Electorate	MPs
Auckland City Council	Manukau_East_Electorate	Ross Robertson
Auckland City Council	New_Lynn_Electorate	David Cunlffe
Auckland City Council	Mt_Albert_Electorate	David Shearer
Auckland City Council	Mt_Roskill_Electorate	Phil Goff
Auckland City Council	Maungakiekie_Electorate	Sam Loto-Iiga Peseta
Auckland City Council	Auckland_Central_Electorate	Nikki Kaye
Auckland City Council	Epsom_Electorate	Rodney Hide
Hamilton City Council	Hamilton_East_Electorate	David Bennett
Lower Hutt City Council	Rimutaka_Electorate	Chris Hipkins
Lower Hutt City Council	Hutt_South_Electorate	Trevor Mallard
Lower Hutt City Council	Ohariu_Electorate	Peter Dunne
Manukau City Council	Mangere_Electorate	Sura Willam Sio
Manukau City Council	Manurewa_Electorate	George Hawkins
Manukau City Council	Papakura_Electorate	Judith Collins
Manukau City Council	Hunua_Electorate	Paul Hutchison
Manukau City Council	Manukau_East_Electorate	Ross Robertson
Manukau City Council	Botany_Electorate	Pansy Wong
Manukau City Council	Pakuranga_Electorate	Maurice Williamson
Napier City Council	Napier_Electorate	Chris Tremain
North Shore City Council	Helensville_Electorate	John Key
North Shore City Council	East_Coast_Bays_Electorate	Murray McCully
North Shore City Council	Northcote_Electorate	Jonathan Coleman
North Shore City Council	North_Shore_Electorate	Wayne Mapp
Palmerston North City Co	Palmerston_North_Electorate	Iain Lees-Galloway
Palmerston North City Co	Rangitikei_Electorate	Simon Power
Porirua City Council	Mana_Electorate	Luamamuvao Winnie Laban
Tauranga City Council	Bay_of_Plenty_Electorate	Tony Ryall
Tauranga City Council	Tauranga_Electorate	Simon Bridges
Upper Hutt City Council	Rimutaka_Electorate	Chris Hipkins
Waitakere City Council	Helensville_Electorate	John Key
Waitakere City Council	New_Lynn_Electorate	David Cunlffe
Waitakere City Council	Te_Atatu_Electorate	Chris Carter

Figure 8-30: TBE - Results Grid: Scenario 2 – Query 2 – Solution 2 (North Island cities only)

Figure 8-31 TBE - Graph Editor and Query panel: Scenario 2 – Query 2 – Solution 2

Scenario 3: Find out publications related to environmental issues

Query 1

List the contact staff in Manawatu-Wanganui Regional Council who can provide customers with additional information on the Consent Submission Form.

Solutions to Query 1

S3:Q1^TBC: Solution 1: Using Composer's SPARQL panel:

The solution adopted the same approach as in scenarios 1 and 2; The SPARQL query was composed as shown in Table 8-12.

Table 8-12: Scenario 3 – Query 1

▪ List the contact staff in Manawatu-Wanganui Regional Council who can provide customers with additional information on the Consent Submission Form	
Steps	**Query in SPARQL**
1. List the consents planners and administration that can be contacted in the Regional Council for the Consents Submission Form	**SELECT** ?Staff ?Position **WHERE**{;Consents_Submission_Form :hasPublicationType :Consent. :Consent :hasContactPerson ?Position. ?Position :hasEmployedInLocalGovernment ?Staff }

The SPARQL query was entered into the Query Editor of TopBraid Composer as shown in Figure 8-32.

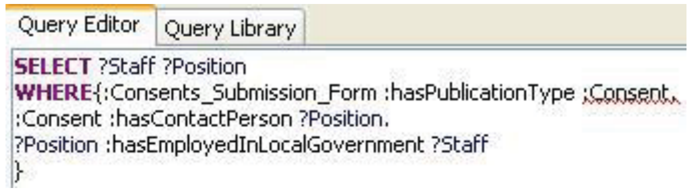
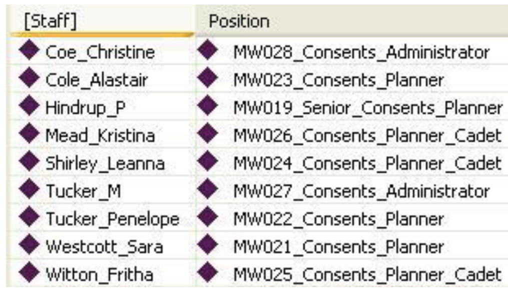


Figure 8-32: TBC - Query Editor: Scenario 3 – Query 1 – Solution 1

The results of the query appeared in the Results panel, as shown in Figure 8-33.



[Staff]	Position
Coe_Christine	MW028_Consents_Administrator
Cole_Alastair	MW023_Consents_Planner
Hindrup_P	MW019_Senior_Consents_Planner
Mead_Kristina	MW026_Consents_Planner_Cadet
Shirley_Leanna	MW024_Consents_Planner_Cadet
Tucker_M	MW027_Consents_Administrator
Tucker_Penelope	MW022_Consents_Planner
Westcott_Sara	MW021_Consents_Planner
Witton_Fritha	MW025_Consents_Planner_Cadet

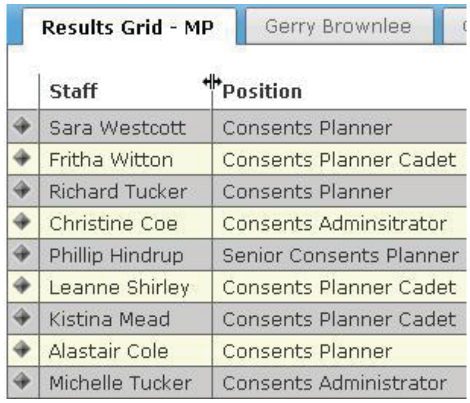
Figure 8-33: TBC - Results panel: Scenario 3 - Query 1 – Solution 1

S3:Q1[TBE]: Solution 2: Using Ensemble's Graph Editor panel:

The node 'Publication' was chosen as the starting point. The query was developed triple by triple until all the desired nodes were included as shown in Figure 8-34.

Figure 8-34: TBE - Graph Editor: Scenario 3 – Query 1 – Solution 2

On submission of the query, the results appeared in the Results Grid as shown in Figure 8-35, and the SPARQL query in the Ensemble's Graph Editor and Query panel as shown in Figure 8-36.



Staff	Position
Sara Westcott	Consents Planner
Fritha Witton	Consents Planner Cadet
Richard Tucker	Consents Planner
Christine Coe	Consents Adminsitrator
Phillip Hindrup	Senior Consents Planner
Leanne Shirley	Consents Planner Cadet
Kistina Mead	Consents Planner Cadet
Alastair Cole	Consents Planner
Michelle Tucker	Consents Administrator

Figure 8-35: TBE - Results Grid: Scenario 3 - Query 1 - Solution 2

Figure 8-36: TBE – Graph Editor and Query: Scenario 3 - Query 2 - Solution 2

Query 2

Find all the publications published by Ministry for the Environment with a publication date after 1st January 2002.

Solutions to Query 1

S3:Q2TBC: Solution 1: Using Composer's SPARQL panel:

The query was constructed step by step as shown in Table 8-13.

Table 8-13: Scenario 3 – Query 2

Find all the publications published by Ministry for the Environment with a publication date after the 1st January 2002	
Steps	**Query in SPARQL**

1. List the publications published by Ministry for the Environment.	**SELECT** ?publication ?date
	WHERE {
	?publication :isPublishedBy :Ministry_for_the_Environment;
	}

2. List the publications published by Ministry for the Environment with date after the 1st January 2002.	**SELECT** ?publication ?date
	WHERE {
	?publication :isPublishedBy :Ministry_for_the_Environment;
	dc:date ?date.
	FILTER (?date > "2002-01-01").
	}

The SPARQL query was entered into the Query Editor of TopBraid Composer as shown in Figure 8-37.

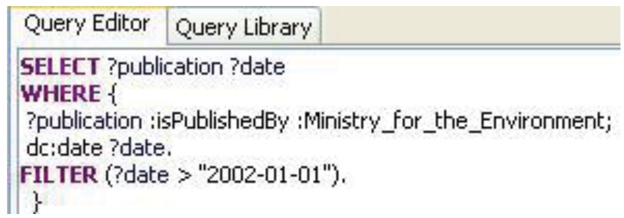


Figure 8-37 : TBC - Query Editor: Scenario 3 – Query 2 – Solution 1

The results of the query appear in the Results panel, as shown in Figure 8-38.

[publication]	date
A_Guide_to_the_Ministry_of_Health_Drinking-Water_Standa...	2008-06-01
A_Monitoring_and_Reporting_Strategy_for_the_Dairying_an...	2006-04-01
An_Assessment_of_Regional_Council_Water_Quality_ENZ07	2008-03-01
An_Introduction_to_Drinking_Water_Contaminates_Treatme...	2008-6-01
Dairying_and_Clean_Streams_Accord	2003-05-01
Economic_Instruments_for_Managing_Water_Quality_in_Ne...	2004-01-01
Environment_New_Zealand_2007	2007-01-01
Freshwater_for_the_Future	2006-04-01
Groundwater_Quality_in_New_Zealand_State_and_Trends_...	2007-08-01
Keeping_our_coastal_waters_clean	2004-01-01
Lake_Managers_Handbook_Fish_in_New_Zealand_Lakes	2002-06-01
Lake_Water_Quality_in_New_Zealand_Status_in_2006_and_...	2007-08-01
Microbiological_Water_Quality_Guidelines_for_Marine_and_F...	2003-06-01
Monitoring_of_freshwater_swimming_spots	2010-06-29
Our_Water_Groundwater_quality	2009-11-01
River_water_quality	2010-07-02
Snapshot_of_Water_Quality_in_New_Zealand	2006-11-01
State_and_Trends_in_the_National_River_Water_Quality_N...	2006-11-01
Water_Programme_of_Action_The_Effects_of_Rural_Land_...	2004-07-01

Figure 8-38 TBC - Results panel: Scenario 3 - Query 2 – Solution 1

S3:Q2^TBE: Solution 2: Using Ensemble's SPARQL Query Panel:

Due to the limitation of not being able to display the specific date in Ensemble's Graph Editor Panel, S3:Q2 can only be executed in Ensemble's SPARQL Query Panel.

The input for the SPARQL statement is shown in Figure 8-39, and the results of the query are shown in Figure 8-40.

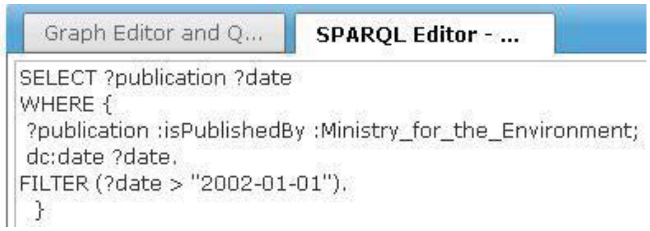


Figure 8-39: TBE – SPARQL Editor: Scenario 3 – Query 2

publication	date
Dairying_and_Clean_Streams_Accord	2003-05-01
Lake Water Quality in New Zealand: Status in 2006	2007-08-01
Environment New Zealand 2007	2007-01-01
Snapshot of Water Quality in New Zealand	2006-11-01
A Guide to the Ministry of Health Drinking-Water Sta	2008-06-01
Monitoring of freshwater swimming spots	2010-06-29
Freshwater for the Future	2006-04-01
A Monitoring and Reporting Strategy for the Dairyin	2006-04-01
Keeping our coastal waters clean	2004-01-01
An Introduction to Drinking Water Contaminates, Tr	2008-6-01
An Assessment of Regional Council Water Quality D	2008-03-01
Microbiological Water Quality Guidelines for Marine .	2003-06-01
River water quality	2010-07-02
Economic Instruments for Managing Water Quality i	2004-01-01
Groundwater Quality in New Zealand: State and Tre	2007-08-01
Lake Manager's Handbook: Fish in New Zealand La	2002-06-01
State and Trends in the National River Water Qualit	2006-11-01
Water Programme of Action: The Effects of Rural La	2004-07-01
Our Water: Groundwater quality	2009-11-01

Figure 8-40: TBE - Results Grid: Scenario 3 – Query 2

8.2.1 Approach 2: Analysis

General

In this approach the framework was evaluated by performing a number of simulations, which involved putting a number of queries to the ontology either directly or via a web interface. The queries were based on use cases and competency questions obtained during the development of the ontology, but those that were chosen were designed to fully test the environment by requiring solutions to complex queries. All the queries were successfully answered by the system. Furthermore, it was possible to provide solutions using a number of different approaches.

Summary

The success of the series of simulations demonstrated that the ontology framework is able to provide e-government information from a wide and connected group of public domains.

Design Science

The relevant design science guidelines for approach 2, as proposed by the researcher in Chapter 7.4.3.2, are as follows:

- Design as an artefact: The series of simulations and the successful outcomes to all the queries that were put to the ontology interface and the web-based interface have demonstrated that a viable artefact has been created and that it has been instantiated.
- Problem relevance: The ability of the ontology to deliver government information from several sources, such a NZ government information, local government information and information appertaining to environmental issues is evidence that the semantic environment has significant relevance to the e-government domain.
- Rigorous evaluation: Performing the set of simulations is a demonstration that the framework has been subjected to rigorous evaluation.

8.3 Approach 3: Structural evaluation

The metrics used in this evaluation are those proposed by Tartir and Aspinar (2007) and embedded in their ontology evaluation tool OntoQA.

8.3.1 Data collection

The following metrics were calculated using an Excel spreadsheet, a copy of which can be found in Appendix 11.4. The spreadsheet integrates the ontology's classes and properties enabling the components of the various metrics to be obtained and the metrics calculated.

8.3.1.1 Relationship Richness:

Relationship richness measures the ratio of number of non-inherited properties (|P|) to the total number of relationships defined in the schema (|P| + |H|), where |H| represents the number of inherited relations Tartir and Aspinar (2007). The assumption is that an ontology that contains mainly inheritance properties is less rich than the one that has a larger proportion of non-inheritance properties.

$$\mathrm{RR} = \frac{|\mathrm{P}|}{|\mathrm{H}| + |\mathrm{P}|}$$

$$\mathrm{RR} = \frac{16}{48 + 16} = 0.25$$

The value would have been higher had more sub-properties been defined in the ontology as suggested by the experts.

8.3.1.2 Inheritance Richness:

Inheritance richness measures the average number of sub-classes per class. In essence, this measures the distribution of information across different levels of ontology's inheritance tree. It is defined simply as the average number of subclasses per class.

$$IR = \frac{|subC|}{|C|}$$

$$IR = \frac{195}{194} = 1.01$$

The conclusion reached with this value, which is close to 1, indicates that the ontology would contain, if fully instantiated, a wide range of knowledge, albeit at a lower level of detail. This is to be expected in the case of an e-government ontology that provides information about the structure of government.

8.3.1.3 Key Instance Metrics

8.3.1.3.1 Class Richness:

Class metric measures the distribution of instance over classes. It is defined as the ratio of the number of non-empty classes (classes with instances) $C^{/}$ to the total number of classes in the ontology.

$$CR = \frac{|C'|}{|C|}$$

$$CR = \frac{85}{194} = 0.44$$

As the figure is low it would suggest that there is insufficient data to justify the structure of the knowledge base. However, because the ontology is a prototype, the number of non-empty classes is artificially low, as the researcher has chosen to limit the number of instantiations, focusing, for example, on the New Zealand parliamentary structure and the management structure of the Horizons Regional Council, and has ignored the other councils and associated environments. There is an expectation that a CR close to 1 would be achieved if the ontology were fully instantiated.

8.3.1.3.2 Connectivity:

This is defined as the number of instances of other classes that are connected to instances of the selected class (C_n). The sub-tree root classes would form the set $C(C_n)$.

$$Cn = |I_j, P(I_i, I_j) \wedge I_i \in C_i(I)|$$

The results of this metric for each of the sub-tree roots are shown in Figure 8-41.

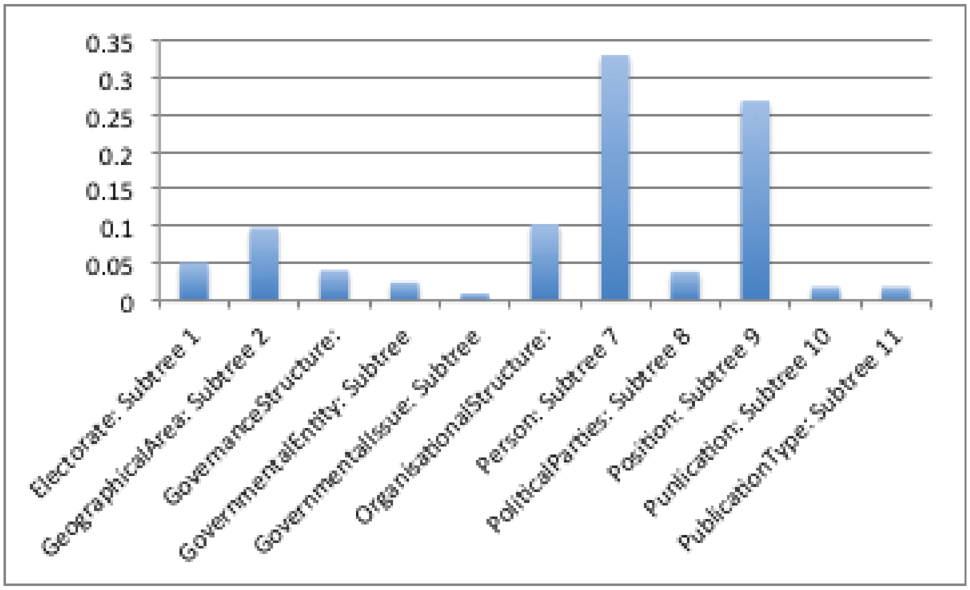


Figure 8-41: Connectivity metric: Sub-tree root classes

The sub-tree classes Person, Position and Organisational Structure are perceived to have a significant role in the ontology. This is not surprising given the focus of the ontology is to describe the person, roles and functions within the governmental entities.

8.3.1.3.3 Class importance (Imp):

Essentially, this metric is concerned with the distribution of instances over classes. This measure is defined as the number of instances that belong to the sub-tree rooted C_i, compared to the total number of instances in the KB.

$$Imp = \frac{|C_i(I)|}{|I|}$$

The results of this metric for each of the sub-tree roots are shown in Figure 8-42.

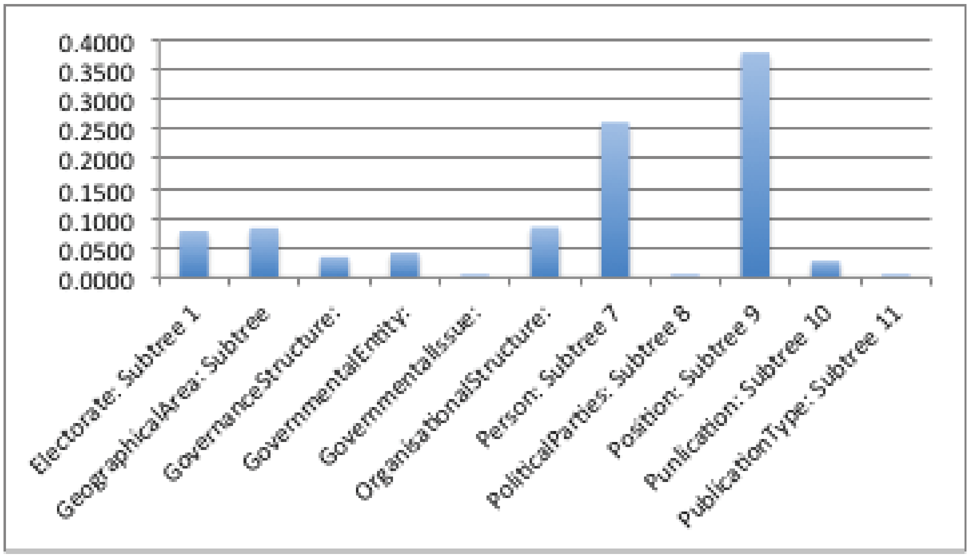


Figure 8-42: Class importance metric: Sub-tree root classes

In a sense, this metric reflects what has been found with the connectivity metric that the sub-tree classes that are perceived to be the most important are Person and Position and, to a lesser extent, Organisational Structure.

8.3.1.3.4 Inheritance richness (IR):

This describes the distribution of information in the chosen sub-tree per class. It is defined as the average number of subclasses per class in the sub-tree.

$$IRc = \frac{\sum_{C_i \in C} |H^c(C_i, C_j|}{|C'|}$$

$$IRc = \frac{183}{11} = 16.64$$

The high IR_c supports the notion that the e-government ontology in this study can be described as being a wide domain ontology.

8.3.2 Approach 3: Structural Evaluation

General

The two schema metrics suggested that the ontology contained a wide range of knowledge with possibly little detail. However, provided the developer increases the number of sub-properties, the richness of the schema would be enhanced.

In the case of the instance metrics the class richness in the prototype ontology was limited by the lack of instantiation within the wider ontology, particularly in the case of those empty classes associated with the governance and organisation structures of the councils and local authority administrations. This was not unexpected as the prototype was limited as instantiation was primary centralised in the `Person` and `Position` classes and not in a wider ontology. This view is supported by both the connectivity and class importance metrics, which identified the Person and Position classes as possibly the most important and those which possessed the greater connectivity. It would be a reasonable assumption that if all the local authority classes were instantiated, the class richness would be much improved.

Design Science

The relevant design science guidelines for approach 3, as proposed by the researcher in Chapter 7.5.3.3, are as follows:

- Problem relevance: The ontology metrics evaluation suggested that the ontology represents a wide domain ontology, however, it is limited by the lack of instantiation. It suggested that the richness of the ontology would be enhanaced by increasing number of sub-properties.
- Rigorous evaluation: The fact that the ontology has been evaluated by ontology metric is considered as one of the most important tools to to measure the ontology's usefulness and richness.

8.4 Overall summary

To conclude this chapter, the answer to the thesis research question is analysed by taking into consideration the results obtained from the three evaluation approaches undertaken in this study. In addition, a resolution is reached regarding whether the study can be regarded as design science research by making reference to several of the chapters in this thesis and to the results obtained from the study's three evaluation approaches.

8.4.1 Addressing the research question

By examining the results of the three evaluation approaches undertaken in this study, the researcher seeks to answer the research question, "Can a semantic framework be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?". To begin to answer this question, two sub-questions need to be addressed:

- Can the designed framework be correctly described as being ontology driven and has it been constructed using correctly formed semantic structures?
- Does the framework have the potential to contain a large amount of interlinked information, which could be disseminated to various stakeholders using web technologies?

Table 8-14 is used to assist in this analysis as it identifies the three evaluation approaches where the ontology-based and application-based features have been evaluated, thus permitting the use of triangulation.

Table 8-14: Distribution of evaluation components across the three approaches

Research Approach	Key measures	Ontology-based features			Application-based features				
		Accepted naming documented consistent	Connected reasoning richness	Semantic consistent Suitable	Richness	Query	Effectiveness efficiency	Interface Usability	Potential
Internal layers	Lexical Vocabulary	x							
	Structural Architectural		x						
	Representational Semantic			x				x	
	Data Application					x		x	
External layers	Composer usability					x		x	
	Browser usability					x		x	
Framework	NZ government, local and both								x
	Environmental issues								x
	Improve the delivery								x
2	Usability							x	
	Effectiveness Efficiency						x		
	Potential								x
3	Relationship richness		x						
	Inheritance richness		x						
	Class richness				x				
	Connectivity		x						
	Class importance				x				
	Inheritance richness				x				

8.4.1.1 Research Question Summary

The panel of experts in Approach 1 were in considerable agreement that the designed framework was correctly described using correctly formed semantic structures and that the underlying ontology was constructed using appropriate methods. The ontology was seen to be consistent and well connected. The experts felt that while the ontology had some reasoning power, it could be improved by increasing the number of sub-properties, and this would also lead to improvement in the richness of the framework. This view was supported by considering the results from Approach 3, which suggested that had more use been made of sub-properties, and had empty classes been instantiated the level of richness would have improved.

In Approach 1, the experts were strongly of the opinion that the semantic framework had the potential to provide a large amount of interlinked information, which could be disseminated to various stakeholders either directly using the OWL interface or through a web browser. The experts also agreed that the two interfaces provided the user with the opportunity to query the knowledge base in an effective and efficient manner. This perspective was also supported by the researcher’s own study in the Approach 2, where integrated information was delivered using a variety of query methods in an efficient and effective manner. The metrics gathered in Approach 3 indicated that the ontology was wide-based and if the ontology were fully instantiated, as it would be in a ‘real world’ situation, the class richness would be of sufficient level to conclude that the structure of the knowledge base would be justified.

From the evidence gained from the three evaluation approaches, it can be concluded that a semantic framework has been described and created in this thesis that will enable a foundation reference model to be established for the delivery of governmental information and services across the Internet.

Addressing the design science research question

By subjecting the activities performed in this study to the conceptual framework proposed by Hevner et al. (2004), the researcher has sought to demonstrate that the study has contributed to the field of design science research. The various points in this thesis where the guidelines are addressed are set out in Table 8-15.

Table 8-15: Distribution of Hevner et al. Guidelines across the thesis report.

		Hevner et al. (2004) Guidelines						
		Design as an artefact	Problem relevance	Rigorous evaluation	Contribution to the academic world	Rigorous methods of construction and evaluation	Design as a search process	Dissemination of the research finding
Chapter 2							x	
Supporting languages, techniques and technologies					x	x		
Chapters 5,6		x	x	x	x			
Chapter 8								
	Approach 1	x	x	x	x	x		
	Approach 2	x	x	x				
	Approach 3		x	x				
Workshops Presentation Thesis Report					x			x

8.4.1.2 Adherence to the design science guidelines

- Design as an artefact

"Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation" (Hevner, et al., 2004 p.83). Furthermore, Hevner's group defines IT artefacts as "constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems)." (Hevner, et al., 2004 p.83).

- Problem relevance

The objective of design-science research is to develop technology-based solutions to important and relevant business problems.

- Rigorous evaluation

The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods.

- Contribution to the academic world

Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies.

- Rigorous methods of construction and evaluation

Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.

- Design as a search process

The search for an effective artefact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.

- Dissemination of the research findings

The thesis will be placed in the Library at Massey University in New Zealand and will be made available to members of the public and to members of the academic or practitioners' community. In addition, a presentation of her study has been given to a workshop in Shanghai, China (Zhou, 2006), and doctoral presentations at Victoria University, Wellington, New Zealand and Massey University, Palmerston North, New Zealand. It is the researcher's belief that this guideline has been fulfilled.

8.4.1.3 Design Science Research Summary

Each of the Hevner et al. (2004) guidelines has been addressed and it can be concluded that there is sufficient evidence to support the notion that the study undertaken in this report can be described as design science research.

8.5 Validation, Verification and Generalisability

As was mentioned in Chapter 3, when undertaking case study research care must be taken to ensure that issues relating to validation, verification and generalisability are resolved or at the very least ameliorated. Similarly in research, particularly case study research, consideration needs to be given to subjectivity and ethics.

Validation and Generalisability

Paré and Yin (Paré, 2004; Yin, 2003) consider it important when using case study research to take into consideration all forms of validity: construct validity, internal validity, external validity and reliability.

Denzin and Yin (Denzin, 1984; Yin, 2003) suggest that gathering data from multiple sources is one way of addressing construct validity. With this in mind the researcher gathered use case data from several different user environments. According to Denzin (1984) methodological triangulation is another way to address construct validity. In this research methodological triangulation was achieved by adopting three different evaluation approaches. External validity, which is concerned with the degree to which the study results can be generalised to wider populations and contexts was considered and addressed during Evaluation 1. The experts were in almost unanimous agreement when responding to assertions related to the potential of the semantic framework beyond the domain of the current technology (Section 8.1.3). In addition, the conclusion reached in Section 8.4.1.3 that design science research had been performed is further evidence that external validity was achieved.

Verification

Gomez et al. (2004b) believe that verification refers to building the ontology correctly, such that the definitions embedded in the ontology are implemented in accordance with the requirements definition and associated competency questions.

Strolf et al. (2004) take a slightly extended view when they say that verification asks the following questions:

- Has the system been constructed correctly?
- Is the knowledge base complete?
- Does the inference engine manipulate the information properly?

Taking both these viewpoints into consideration, verification seeks to ensure that the system been constructed to a high standard and conforms to appropriate professional specifications, and meets the user group’s requirements.

Subjectivity and ethics

The researcher has been careful to ensure that subjectivity has been carefully monitored and addressed during data collection, evaluation and the report writing process as recommended by Guba and Lincoln (1981). In the case of data collection, the majority of users who provided information for the use cases were not known to the researcher, and while some use cases were not included in the three evaluation scenarios in Evaluation 2, the ones chosen were selected because they formed a coherent group. In Evaluation 1, the experts were chosen because they had either a fine academic record or considerable experience in semantic technologies; none of the experts was previously known to the researcher. The use of the OntoQA set of metrics and the evaluation questions in the Stage 1 questionnaire were selected by careful review of the literature (Sections 7.3.3 , 7.5.3). During the report writing phase the researcher has continued to seek advice from the thesis supervisors.

9 SUMMARY AND CONCLUSION

Information gathered in the literature review indicates that e-government is a domain that is dominated by semantic issues that can only be resolved by using software solutions such as the Semantic Web (Klischewski, 2003). Gruninger and Lee (2002) and Sabol and Mach (2006) take the view that e-government is an ideal domain in which to undertaken semantic technology research. Kavadias and Tambouris (2004) claim that the Semantic Web is underutilised and there are many question relating to technical and organisational issues that need to be resolved when developing semantic-based systems.

Building on this lack of certainty about the role of the Semantic Web and e-government, the motivation of this research is to add to the body of knowledge associated with the application of semantic technologies in the provision of government information across the Internet. In this context, this research is concerned with the question as to whether an e-government semantic framework can be designed, developed and implemented such that it can be used to describe governmental structures, and deliver associated governmental information to stakeholders using an Internet browser. Research in this area would be expected to add to the body of knowledge associated with the design and construction of an innovative semantic framework in the delivery, but not exclusively, of governmental information through a query-driven web browser.

Research strategy and the role of design science research in this study were discussed in Chapters 1 and 3. In the following two sections, 9.1:Research Process and 9.2: Design Science Research, the roles these two concepts play in this study are summarised.

9.1 Summary and Conclusion of the research process

9.1.1 Summary: Research process

In this summary of the research process, reference is made to Chapter 1, Figure 1.1, where milestones were identified to indicate the objective of each sub-section of the research design:

1. Objective 1: To define the domain and scope of the study, and to ascertain the most appropriate research philosophy, research methodology and methods to be used.

2. Objective 2: To create and instantiate the semantic framework, which syntactically and semantically describes the e-government ontology.

3. Objective 3: To create an interactive web interface to enable a user to traverse and query the ontology.

4. Objective 4: To evaluate the semantic framework.

5. Objective 5: To analyse the results of the evaluation of the framework and make concluding comments describing the overall research process.

9.1.1.1 Objective 1a: To define the domain and scope of the study

To reach the stated objective the following supporting activities were undertaken, as shown in Figure 9-1.

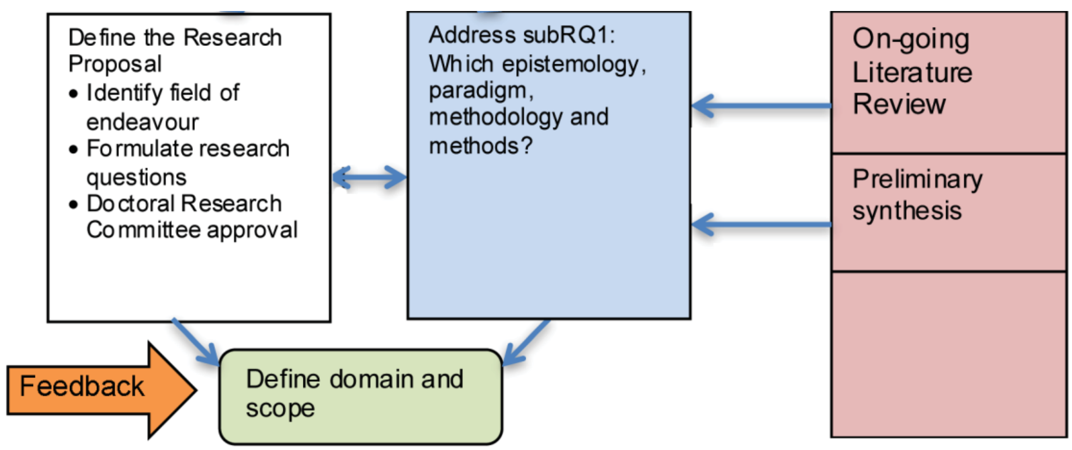


Figure 9-1: Achieving objective 1

Define the research proposal

As discussed in the introduction to this chapter, the overall field of endeavour was seen to be the complementary interaction between semantic technologies and the provision of government information and services across the Internet. Information gathered from the literature review supports the view that active research in design, construction and evaluation of e-government-based semantic artefacts is part of the research currently underway by the international e-government community.

To narrow the domain of interest down to a more manageable size in this research the New Zealand Parliament and local government entities were collectively chosen as the representative domain. The justification, again discussed in the literature review, being that the systems and processes used by New Zealand governmental entities are similar to those to be found in many other countries. The domain was further refined to embrace four interconnected sub-domains: New Zealand parliament, local authority councils in New Zealand, New Zealand geographical areas, and publications related to the New Zealand environment.

9.1.1.2 Objective 1b: to ascertain the most appropriate research philosophy, research methodology and methods to be used

As discussed in Chapter 3, an application driven research approach (Abecker, et al., 2006) was adopted in this research to examine the feasibility that e-government information could be adequately described by a semantic framework, and that information subsequently stored within the semantically described knowledge base could be delivered across the Internet to the public and other stakeholders. This approach led to the following thesis research question:

> *Can a semantic framework be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?*

In order to research, study and evaluate the effectiveness of such a semantic framework, it was first necessary to design, develop and construct it. As discussed in Chapter 3, this led to the following research sub-questions:

- Which epistemology, research paradigm, methodology and research methods should be adopted?
- What semantic tools and languages are required to design the framework and construct the semantic model?
- What design and construction methods are required to build the semantic framework?
- What authoring tools are required to create and instantiate the semantic environment?
- What authoring tools are required to create a query driven semantic web portal?
- What methods are to be used to validate and evaluate the semantic environment?

Address research sub-question 1

Which epistemology, research paradigm, methodology and research methods should be adopted?

In Chapter 3, the approach suggested by Crotty (1998) led to the identification of the epistemology, paradigm, methodology and methods applicable to this research. The result of this investigation led to the following conclusions:

- Philosophy of science was chosen as the epistemology.
- Design science research paradigm was selected, as the research examines the role of the artefact, its design and the way the design process enfolds in a real-world environment.
- An embedded case study was chosen as the research methodology, as the study is concerned with a bounded system, where the research process is documented (Yin, 2003), and includes both interpretivist and positivist methods of analysis (Scholz & Tietje, 2002; Yin, 2003).
- Three research methods were adopted in the research; expert judgement, where experts are invited to comment on the validity and potential of the semantic framework; simulation analysis, where the researcher seeks to demonstrate the utility of the semantic framework; and, in the third approach, schema and instance metrics are used to determine various levels of richness of the semantic environment.

The importance of design science research to this study was also discussed in Chapter 3, which led to the adoption of design science guidelines proposed by Hevner et al. (2004) and which are referenced throughout each stage of the research process. The role of design science research is summarised in Section 9.2.1 .

Prior to moving on to the next objective, the research proposal was presented to other senior research students, visiting experts and PhD supervisors. Advice was received regarding the scope of the research in particular about the level of detail that would be required to make the study meaningful. The use of design science research was discussed and supported as it was claimed at the meeting that it was a research approach that was being actively promoted by information systems researchers.

9.1.1.3 Objective 2: To create and instantiate the semantic framework, which syntactically and semantically describes the e-government ontology

This objective was addressed in Chapter 4. The role of semantic languages, authoring tools and ontology development methodologies in the creations of semantic frameworks was obtained from the literature review. This was supplemented with information provided by discussion group contributors and staff from local government agencies. This process is graphically illustrated in Figure 9-2.

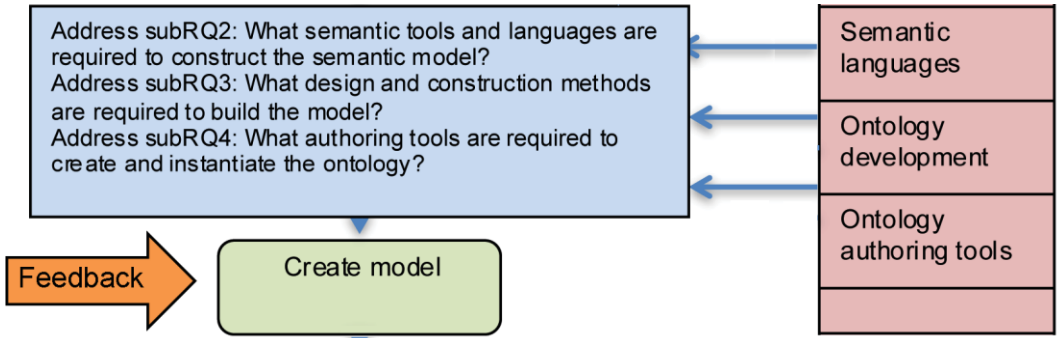


Figure 9-2: Achieving objective 2

Address research sub-question 2

- What semantic tools and languages are required to design the framework and construct the semantic model?

The choice and feature of the semantic languages adopted in this research was discussed in detail in Chapter 4. The languages chosen were essentially those recommended by the World Wide Web Consortium in 2004 and illustrated in the Berners-Lee's (2009) Semantic Stack. The semantic languages were RDF, RDS(S), OWL and SPARQL. OWL DL was selected as the most appropriate OWL language as it was claimed that it had more expressive constructs than OWL Lite, and offered predictable reasoning support unlike OWL Full. OWL DL version 2 was also adopted over OWL1.1 as Patel-Schneider et al. (2008) found that it had fewer shortcomings. The fact that these set of languages were sufficient to implement the construction of the semantic framework created in this study support the view that the set of language was appropriate.

Address research sub-question 3

- What design and construction methods are required to build the semantic framework?

In the literature review, the approach proposed by Noy and McGuinness (2005) was considered to be most appropriate for this type of development. In Chapter 5, the researcher added an extra step to the development process to accommodate the information obtained by using use cases. The process was described in detail in Chapter 5 and includes the steps:

1. A determination of the domain and scope of the ontology.
   Information extracted from use cases was used as to create sets competency questions. These questions, as recommended by Gruninger and Fox (1995), were then used to scope each of the sub-domains from which the overall domain and scope of the sematic framework was determined.

2. The consideration of similar ontologies with the possibility of either importing or adapting an existing ontology.
   No comparable e-government ontology was found; however, FOAF and Dublin Core ontologies were seen as possibly important to enable the naming of universally known concepts.
3. The enumeration of important concepts and items.
   To assist in the definition of classes and properties nine top-level entities were identified together with related sub-classes.
4. The definition of classes and their hierarchy in the ontology.
   In this step each of the classes and sub-classes identified in Step 3, was placed in a class hierarchy.
5. Definition of properties connecting classes and concepts.
   Using object and datatype properties the internal structure of the ontology was defined.
6. Definition of property facets to restrict and control relationships.
   Property restriction value, cardinality, functional and inverse functional were placed on the properties.
7. Undertake the instantiation of the ontology.
   Information gathered from national and local government web sites and other sources such as regional authority management structures was used to manually instantiate the ontology. Over 2000 instances were added.

Address research sub-question 4

What authoring tools are required to create and instantiate the semantic environment?

An extensive review of prospective authoring tools capable of creating and instantiating semantic frameworks was undertaken in Chapter 4. The review identified a list of essential features that ontology-authoring tools should posses:

- All languages identified in the Semantic Stack are required to be supported.
- Enable property types to be created and attached to classes.
- Class and property restrictions to be present.
- Querying languages such as SPARQL to be supported.
- Integrated reasoner support.
- Open source as opposed to expensive commercial product.
- Have actively supported user-discussion groups and tutorials.

Protégé-OWL was chosen because it possessed all of these qualities and was widely accepted by the professional user community.

Aspects of this process were documented and compared with the design science research guidelines proposed by Hevner et al. (2004). These aspects are discussed in 9.2.1.

Prior to moving onto the next objective, the researcher secured feedback from senior research students, visiting experts and PhD supervisors, members of staff from Horizons Regional Council and at the Asia Pacifica E-Government Workshop (APEGW). Towards the end of the study amendments were made to the model based on comments received from the expert group during the evaluation of the semantic framework. These amendments were primarily concerned with the Camelback notation, more use of sub-properties, and the import of Dublic Core and FOAF ontologies.

9.1.1.4 Objective 3: To create an interactive web interface to enable a user to traverse and query the ontology.

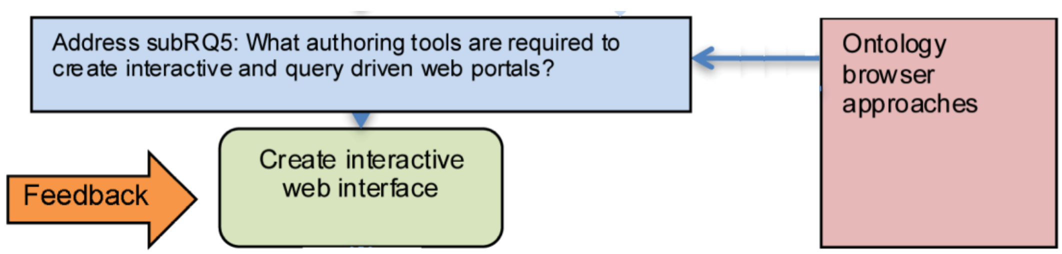


Figure 9-3: Achieving objective 3

Address research sub-question 5

What authoring tools are required to create a query-driven semantic web portal?

The answer to this sub-question was comprehensively canvassed in Chapter 4. TopBraid Ensemble was chosen from a list of tools identified by the World Wide Web Consortium (W3C) (2010b) and the organisation SemanticWeb.com (2010), namely, Web-Protégé, Ontofly, TopBraid Ensemble, Neologism and Knoodl. The application chosen to construct the interface was TopBraid Ensemble. The reason for this choice was that the application enables the user to traverse semantic models using trees, grids, search forms, maps and graphs. Popup dialog boxes, multi-page views and SPARQL query forms were other features that contributed to the decision.

Browser interface construction

The portal construction approach adopted used in this project was based on TopBraid's Application Development Quickstart Guide (TopQuadrant, 2010). The following process was followed:

1. Construct the ontology.
   This was achieved in Objective 2.

2. Create a 'mock-up' interface to the ontology.
   A sketch of the interface was made assuming information based on use case scenarios and competency questions. It was expected that the contents would include search and query capabilities.

3. Create new ontology application.
   When executed a blank form appeared on the monitor and access to a list of interface components using a pull-down menu was provided.

4. Identify the key domains (pages) in the ontology.
   The multiple pages option was chose. The purpose was to make it possible for the user to jump to different starting point in the framework to begin a search, therefore saving search time. This also ensured that the interface was not too cluttered as information was distributed across several pages. In this interface, four pages were used. In the first page the entire class structure of the ontology was made available in the Tree panel. In the second page, the Tree panel displayed all Person sub-classes. The third provided electorate information and in the last page environmental publication information. Essentially, using the Page concept allows the user to jump to a specific point in the ontology and traverse the ontology from that point.

5. Identify the ontology's components.
   Each page was a separate development activity. The page was constructed by placing the components in the pattern described in 'mock-up' diagram.

6. Configure the components.
   Post and listening events were used to configure the components to permit connectivity between various classes and instances.

7. Test the application.
   The interface was tested to ensure that the interface permitted the user to traverse the knowledge base or search using SPARQL,

Aspects of this process were documented and compared with the design science research guidelines proposed by Hevner et al. (2004). These are discussed in 9.2.1.

Feedback was received from a doctoral workshop held at Victoria University in Wellington, New Zealand, and from the expert group during the evaluation of the semantic framework. The general tone of the feedback was that while the interface was intriguing and the query mechanism were impressive, the interface was not user friendly. There was agreement that the portal did allow the user to search and query in a way quite different from usual portal, and that was of significant value.

9.1.1.5 Objective 4: To evaluate the semantic framework

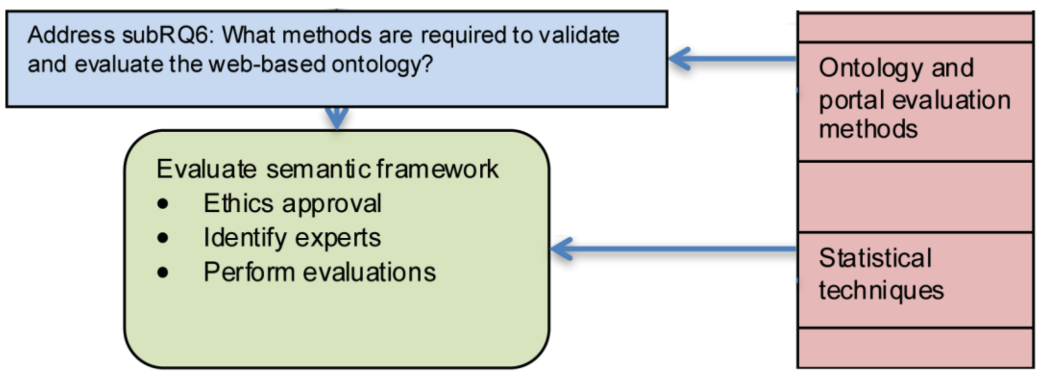


Figure 9-4: Achieving objective 4

Address research sub-question 6.

What methods are to be used to validate and evaluate the semantic environment?

Evaluation methods were discussed in the literature review, Chapter 3, and in considerably more detail in Chapter 7. The focus of evaluation in this research was a combination of three approaches: expert judgment, simulation-based analysis, and structural evaluation.

Approach 1: Expert judgement:

The semantic framework developed in this research was presented to experts and the experts were asked, using a 5-point Likert-based questionnaire, to critically comment on the quality and appropriateness of the framework. The questions in the questionnaire were divided into three groups based on a proposal by Kehagias et al. (2008) and described in Chapters 2 and 7:

- Internal measures: This measure is concerned with elements associated with the ontology's syntax, structure, semantics, including its applicability to the chosen domain.

- External measures: This measure focuses on the use of internationally accepted standards of design and construction, appropriateness of the development tools and the ease of use of the application.
- Semantic framework: This measure seeks to establish the potential of the ontology as an e-government application in both a standalone environment and via a web interface.

To undertake the evaluation the researcher selected eight internationally respected experts who had extensive knowledge related to the design and development of semantic environments to participate in the evaluation. The experts were also encouraged to expand on their answers to the questions put in the questionnaire. A follow-up questionnaire was sent to experts, which sought clarification of what had been previously obtained. None of the experts responded to the follow-up questionnaire

Approach 2: Simulation-based analysis.

This approach, advocated by Adler et al. (2004), Lian et al. (2008), Strolf et al. (2004), Brank et al. (2005) and Gomez-Perez et al. (2004b), and described in Chapter 7, involved submitting queries direct to the standalone ontology or via a web browser interface, based on use case scenarios and competency questions. The ability of the semantic environment to deliver accurate and timely responses was a measure of the environment's efficiency and effectiveness.

Approach 3: Structural evaluation.

- The richness of information contained within the internal structure of the e-government ontology was assessed by using metrics based on the OntoQA tool (Tartir & Arpinar, 2007). This method required statistics to be extracted from a three dimensional matrix consisting of classes, properties and instances.

Again, aspects of this process were documented and compared with the design science research guidelines proposed by Hevner et al. (2004). These are discussed in Section 9.2 of this chapter.

9.1.1.6 Objective 4: To analyse the results of the evaluation of the framework and make concluding comments describing the overall research process.

The research question posed in this study is:

> *Can a semantic framework be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?*

To begin to answer this question two implied sub-questions were addressed:

1. *Can the designed framework be correctly described as being ontology-driven and has it been constructed using correctly formed semantic structures?*

In relation to the ontology's internal measures the results of the evaluation were extremely positive. Experts were in strong agreement that the framework was correctly described using correctly formed semantic structures and that the underlying ontology was constructed using appropriate methods. A similar view was expressed by the experts with respect to the consistency of the ontology and the level of connectivity. This view was in agreement with the results obtained from the structural richness metrics analysis. The experts were also of the opinion that the semantic structures within the ontology were correctly formed.

One expert felt that the reasoning power of the ontology could have been improved using sub-properties and that the naming of some of the properties and classes could have been better. The researcher subsequently addressed these shortcomings, and in the case of the naming issues the Camelback notation was enforced.

There was strong agreement between the experts that the semantic framework had been well designed and constructed, although one expert strongly disagreed with this assertion. However, in terms of the query and research features, the experts agreed that they were extensive and easy to apply.

2. *Does the framework have the potential to contain a large amount of interlinked information, which could be disseminated to various stakeholders using web technologies?*

The experts were strongly in agreement that the semantic framework had the potential to connect a large amount of information and distribute it to stakeholders either directly through the OWL-DL interface or through a web browser. Evaluation using simulation-based analysis supported the experts' viewpoint in that all queries based on use case scenarios and competency questions that were submitted to the ontology, either in the standalone mode or via a standard web browser, were fully answered.

9.1.2 Conclusion: Research Question

The motivation for this research, as described Section 1.5 embraces two concepts. In the first instance, it can be said that this research has added to the body of knowledge associated with the application of semantic technologies in the provision of government information across the Internet. This viewpoint is embedded in the research question, “Can a semantic framework be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?”

Secondly, this research has aimed to add to the body of knowledge associated with design science research. In this case, this is measured by how closely the research outputs have followed the design science research guidelines proposed by Hevner et al. (2004). The former is discussed in this sub-section and the latter in sub-section 9.2.2.

In this research a semantic framework was designed and constructed to allow selected e-government information to be semantically described and enable that information to be extracted and displayed using a standalone environment or by using a standard web browser. While the focus of this framework has been set within the New Zealand context, the intention is that the basic ideas and concepts that underpin this particular framework could be implemented in other jurisdictions.

Other possibilities exist regarding the use of this ontology, for example, taking the semantic description of the management structure of the Horizons Regional Council as a template, it would be possible to model similar management structures in both public and private organisations. In fact, the framework has the potential to include information beyond the governmental domain. Information could be described connecting for example, district health boards, police divisions, and Maori organisations.

In addition, the design and development processes described in this thesis have the potential to support other developers and researchers who seek to construct semantic frameworks in this and other fields of endeavour.

9.2 Design Science Research

9.2.1 Summary: Design science research process

During project the researcher has kept in focus on the need to adhere to the seven established guidelines (Hevner et al. (2004) so that it could be claimed that design science research had been performed. With this objective in mind, each of the seven guidelines are addressed as follows:

1. *Design as an artefact*: “Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation” Hevner et al. (2004, p. 83).

In chapter 5, the construction of a semantic framework is described. The framework is considered to be innovative and imaginative as it meets the needs of the research community. For example, applying use case scenarios to the Noy and McGuinness’s (2001) approach resulted in a successful construction of the ontology. The framework shows that it was possible to connect administrative, geographical, environmental information and governance structures in the same semantic framework. This suggests the possibility of including other national agencies and organisations such as police divisions and health authorities.

The interface, as described in Chapter 6, provides useful information to the research community as it shows that by applying a systematic and structured approach it is possible to construct an interface that allows the user to traverse the knowledge base hierarchically, graphically or using a query language.

As outlined in Chapter 8, the experts who have evaluated the semantic framework are of the opinion that a viable artefact has been created and that it has been successfully instantiated as a prototype. This is evidenced by the strongly supportive responses to the external measures and by the series of successful simulations performed by the researcher both by querying the ontology directly, and by using the web-based interface.

2. *Problem relevance:* “The objective of design-science research is to develop technology-based solutions to important and relevant business problems” Hevner et al. (2004, p. 83).

The information gathered in the literature review quite clearly indicates that the public worldwide is demanding that governmental organisations should provide services and information in a more coherent and integrated way.

In Chapters 5 and 6, a prototype e-government ontology was developed that uses a browser interface to deliver government information in an effective and efficient manner to a wide range of users.

The evaluation experts in this study have stated quite comprehensively that this semantic environment has the potential to provide an innovative technology-based solution that will meet the expectations of future users of e-government services.

3. *Rigorous evaluation:* “The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods” Hevner et al. (2004, p. 83).

Chapter 4 described a comprehensive and rigorous review process undertaken in this research to identify the most appropriate set of semantic languages and authoring tools to construct the semantic artefact, and in Chapter 6, the utility of the interface was demonstrated.

The group of experts rigorously evaluated the semantic framework and judged it to have been constructed using appropriate design and construction methods. The experts also evaluated the browser interface and while some felt it was not particularly user-friendly they did agree that the ontology did not contain any technical errors and it did provide a more integrated and rich environment compared with current web portals. The extensive simulation exercise demonstrated that the ontology adequately reflected users’ requirements by providing numerous solutions to queries based on use cases.

4. *Contribution to the academic world*: “Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies” Hevner et al. (2004, p. 83).

The review semantic languages and authoring tools in Chapter 4 provided clear and verifiable contributions in the selection and use of authoring tool in the design and development of semantic artefacts. In a similar way, the adopted design science research methodology, described in in Chapter 3, and the construction of the ontology and browser interface described in detail in Chapters 5 and 6 would be useful for other developers who are considering similar or comparable projects.

5. *Rigorous methods of construction and evaluation*: “Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact ” Hevner et al. (2004, p. 83).

As demonstrated in Chapters 4, 5, 6 and 7, care was taken to ensure that rigorous and internationally accepted methods were used in the construction and evaluation of the artefacts. As mentioned in Section 9.1.1.5 Objective 4, the experts’ extremely positive responses to the questions relating to the ontology’s lexical and vocabulary layer, structural and architectural layer and the representational and semantic layer indicate very strongly that rigorous methods been applied in both the construction and evaluation of the design artefact.

6. *Design as a search process.* “The search for an effective artefact requires utilizing available means to reach desired ends while satisfying laws in the problem environment” Hevner et al. (2004, p. 83).

As shown in the literature review and in the chapters concerned with the artefact construction, a deep and serious search regime was followed to identify relevant and informative publications contributed by experienced and knowledgeable authors relating to the concepts involved in the construction of the artefact.

7. *Dissemination of the research finding.* The last guideline addresses the importance that the work be published in both the academic community and in the practitioner’s community Hevner et al. (2004, p. 83).

The thesis will be placed in the Library at Massey University in New Zealand and will be made available to any member of the public and to members of the academic or practitioners’ community. In addition, findings of this research have been presented at a workshop in Shanghai, China (Zhou, 2006), and during doctoral student presentations at Victoria University, Wellington, New Zealand and Massey University, Palmerston North, New Zealand.

9.2.2 Conclusion: Design science research process

The literature review supported the need for applied ‘real-world’ research in semantic technologies to gain a better understanding of the potential of semantic technologies not from a design and construction process but its applicability in business and commercial environments. This research, where a semantic framework and associated ontology have been created, care has been taken to ensure that the processes that were followed were in alignment with design science guidelines proposed by Hevner et al. (2004). In adopting this approach there is a strong evidence that all the conditions of design science research have been satisfied and that new knowledge about the design and construction of a semantic artefact has been acquired. Evidence has been accumulated in all aspects of the development process.

The knowledge that has been acquired will not only be useful for researchers and developers who are involved in e-government projects but will also be useful in other projects involving the construction of other forms of semantic artefacts, as most, if not all, of the processes involved in the construction of the artefact are generic in nature.

9.3 Strengths of the research

This research has contributed to the existing knowledge in four different ways. Firstly, it has demonstrated that using a design science based, mixed method, embedded, multidimensional case study approach is an appropriate research approach to investigate the design and construction of a semantic frameworks. In turn, this has demonstrated that use of expert judgement, simulation-based analysis and schema richness metrics provide a comprehensive and complementary set of evaluation tools to assess the quality and usefulness of a semantic framework. Secondly, the answers to the research sub-questions provide potential researchers with useful insights into the characteristics of semantic languages, authoring tools and ontology construction methods. Thirdly, the research provides support for those researchers who wish to employ design science research guidelines to ensure their research can be fully recognised by the professional and research communities. Lastly, the use of a representative e-government domain and gathering data from real world sources can lead to beneficial results that can be generalised to other e-government domains and situations.

9.3.1 Research methodology

The design science based, mixed method, embedded, multidimensional case study approach has provided an interesting and detailed in-depth study of the design and construction of a semantic framework based on a representative e-government domain. The success of the research confirms the views expressed by Abecker et al. (2006) that useful research can be achieved by using real-world situations to undertake application driven research within the e-government domain. The collection of data using three completely different perspectives contributed to triangulation in the research and provided a better understanding of the potential of the semantic technologies in the delivery of e-government information to the wider community. In the first approach, experts were asked to critically comment on the quality and appropriateness of the semantic framework. Simulation based analysis performed by the researcher was undertaken in the second approach to assess the ability of the system to successfully answer queries based on use case scenarios. In the third approach richness metrics were calculated that provided some measure of the quality of the structural schema of the semantic framework.

9.3.2 Design Science Research Paradigm

Undertaking this research under the design science research paradigm has revealed a number of extremely useful outcomes. In particular, focussing on the seven design science guidelines (Hevner, et al., 2004) ensured greater control over the design and development processes when creating a semantic artefact. The process engendered considerable self-reflection in the behaviour of the researcher / developer and as a result a better understanding of the design and development process has followed.

Issues that arise in the use of case studies are primarily associated with validation, verification, generalisability and bias. Experts were asked to comment on these issues.

9.3.3 Validation and verification

The experts agreed in their evaluation of the semantic artefact that the three elements of validation proposed by Strolf et al. (2004) had been satisfactorily addressed and that the ontology was compliant with the researcher's perception of the real world (Gómez-Pérez, et al., 2004b). In addition, the extensive simulation exercise demonstrated that the ontology adequately reflected users' requirements by providing numerous solutions to queries based on use cases.

Similarly from a verification perspective, it was the view of the experts that the semantic artefact had been constructed correctly and the inference engine manipulated the information properly as required in the definition proposed by Strolf et al. (2004). The knowledge base was not complete as would be expected in a completely verified model, but as mentioned in the literature review, the constructed model was essentially a prototype artefact, and there was no expectation that it would be fully instantiated or that the interface to the standalone configuration or the web-based configuration would be more than functional. Compensating for the lack on instantiation when calculating the richness metric there was a clear expectation that the model could be viewed as complete as far as Strolf et al. (2004) definition was concerned. Of what was available for the experts to view, the experts were of the opinion that the artefact was verified.

9.3.4 Triangulation and generalisability

Three separate approaches were adopted during the evaluation of the artefact. Some of the results of the evaluation refer to two or more approaches, therefore supporting the concept of triangulation. In the context of verification and validation both draw on results obtained from two or more of the evaluation approaches adopted in this research.

There is reasonable evidence to show that the results of this research can be generalised to other research endeavours. In the first instance, the knowledge gained by adopting a design science approach to answering the research sub-questions would be relevant to many studies involving the design and construction of a technology-driven semantic artefact. Given the similarity of the role and structure of New Zealand governmental entities to other worldwide jurisdictions, and the universal demands by the international community for richer and more integrated information from their government departments, the likelihood of generalising these research findings is good.

9.3.5 Researcher's bias

There were a number of occasions during the research where researcher's bias could have been introduced, for example:

- Selection of the representative domain:
  The choice of domain was completely at the discretion of the researcher. However, in a small city as Palmerston North there is every likelihood that you will engage in research with people you know. In order manage this situation the researcher adopted a professional work ethic when discussing matters relating to this research.
- Choice of semantic languages, authoring tools, method of construction:
  As was clearly demonstrated in the review that the choice of languages was not an issue, given that almost all ontology languages are represented in the Semantic Stack (2009). The choice of the technologies as well as the method of construction was driven in part by the researcher's prior experience with authoring tools and systems development approaches. However, a very exhaustive review of those issues was taken by the researcher to ensure the best and most appropriate technologies were used.
- Choice of user, use cases and competency questions:
  This area was where the most likely where bias would be generated. To overcome this critical issue the researcher adopted a highly ethical approach to the situation to limit its effects. When gathering use cases the researcher first approached members of staff at Horizons Regional Council, who in turn suggested people in the wider community who might be interested.
- Selection of experts:
  Experts were chosen who had considerable expertise in semantic frameworks and artefacts, were academically well respected, and were not personally known to the researcher.

9.4 Limitations of the research

The limitations of the research are set out below:

- A relatively small group of users contributed to the research and their areas of interest were not necessarily representative of the wide community. This has had some effect on the generalisability of the research. However, the views that they expressed will resonate with people in other locations and overseas. In essence the research is about the ability of the semantic framework being able to describe e-government data irrespective of its form. To have compensated for this limitation would have required a sophisticated survey to have been performed prior to the commencement of the development process. This was impractical given the constraints with time and resources.

- Not having fully instantiated the knowledge base resulted in some of the structural and instance metrics giving low results. Nevertheless, the indications from the metrics evaluation indicated the framework would be able to effectively describe a wide range of governmental information. To have addressed this limitation would have required the researcher to narrow the scope of the domain, or increase the level of instantiation. The latter would have required huge amount of resources, which would not appear sensible given that this was an unfunded research project. To have limited the scope would have affected the potential use of the artefact.
- From a research perspective it is imperative that a distinction is made between a prototype artefact deployed in this research to a commercial product. Muller and Thoring (2011) claim a product artefact is a product that is already in use; from a research perspective it can be used for experiments and analysis and can be subjected to evaluation. A prototype artefact, such as the one produced in this study, is essentially incomplete and is used to gain feedback from possible stakeholders concerning the overall concept, design and construction methods used, and thereby gain a view of its potential in the commercial or business environment. Such an artefact lacks the sophistication and depth expected of a full blown product, and in this research that is evidenced by the lack of instantiation and the shortcoming of the web interface, where the emphasis is on functionality rather than usability, as commented upon by several of the experts.
- The semantic framework was instantiated manually by the researcher using date collected primarily from the Internet. This takes away from the ontology one of its main capabilities in that it is digitally capable of integrating data. The researcher was unable to find a government agency who was willing and able to participate in this study. The researcher successfully imported data from a MySQL database to the ontology but there were no real benefits as the researcher had to instantiate the relational database. The research also extracted government publication from the National Archives into an Excel file

and successfully imported into the ontology. Neither of these two activities was included in this report.

9.5 Recommendation for future research

The research undertaken in this thesis offers opportunities for further investigation, as mentioned in some of the examples listed below:

- Automatically integrating information from several semantically driven sources of government information and the possibility of doing that on demand. To provide a wider range of integrated semantic e-government service, the ontology has to be able to digitally integrate data from a wide range of government sources. To do that on demand rather than build a complete semantic database would be the most interesting research approach. Research into the use of ontologies in medical informatics is well documented but the literature has little e-government research using semantic technologies in New Zealand.
- Identify new approaches in the design and usability of semantic web browser interfaces, particularly the use of query languages and graphical tools. The literature found little evidence of research into the design and use of query-driven interfaces such as that used in this research. The evaluation of this project by the experts strongly indicated a user-friendly yet powerful interface would be very welcome.
- Explore the use of semantic artefacts to describe management information between and within a large organisation, such as the military, research institutes and information-rich companies where there is perceived interconnectivity between the various groups and staff. As discussed in this report the European Commission is now promoting the *Cloud4SOA* initiative (FP7). How such a semantic framework in New Zealand would operate and how it would advantage New Zealand would be a wonderful research project.

9.6 What has been gained from the research?

The researcher has gained many skills and abilities from this research study:

- The skills associated with creating a literature such as organising, synthesizing and summarising into what is known and what is not known, identify areas of controversy and formulate questions that need further research.
- Understanding the process of research.

- Knowing the different types of research methodologies and methods, and how to apply them in a given problem situation.
- Acquired a lot of knowledge and expertise is using complex computer software.
- Using interviewing skills.
- Acquiring patience, discipline and dealing with both disappointment and elation

9.7 Summary of the conclusions

This research provided a representative semantic framework for investigating the design and construction of an innovative artefact in the form of a semantic framework. The artefact has been instantiated with sufficient information to demonstrate that it is capable of delivering integrated governmental information both in a stand-alone mode and via a web browser. Embracing a design science approach the research describes in detail how a technology-driven artefact can be designed, constructed and deployed.

It is possible to answer in the affirmative that a semantic framework can be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet. It is also possible to assert that there is sufficient evidence to support the notion that the study undertaken in this report can be described as design science research.

It is also confirmed in this study that a semantic framework can be described and created in order to establish a foundation reference model for the subsequent delivery of governmental information and services across the Internet?

This research makes a useful contribution to the body of knowledge associated with the development and use of semantic frameworks in describing government information. Researchers and developers will also benefit from the description of the construction and development of the artefact.

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11 APPENDICES

11.1 Systems Development

11.1.1 Use case template

Topic: ………………………………

Name of user: ………………………………

Date information obtained: ………………………………

Question user would like to put to the knowledge base: [ ]

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

The content of the answer the user would like to obtain and the likely source of such content if known.

Answer content		Source if known[1]	
1.	…………………………………………	1.	………………………
	…………………………………………		………………………
2.	…………………………………………	2.	………………………
	…………………………………………		………………………
3.	…………………………………………	3.	………………………
	…………………………………………		………………………
4.	…………………………………………	4.	………………………
	…………………………………………		………………………
5.	…………………………………………	5.	………………………
	…………………………………………		………………………
6.	…………………………………………	6.	………………………

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11.1.2 Summary of use cases

Target user groups	User ID	Date obtained	Questions Users would like to know from the system
Farmers	F01 F02	27/4/08	The regulations on the water takes in the Manawatu-Wanganui Region
	F01	27/4/08	Water quality standards for the Manawatu-Wanganui Region
	F02 F03 F04 F05	27/4/08	Consent Forms
	F02 F03	27/4/08	Stuff to contact in Horizons Regional Council for applying the consents
	F04	27/4/08	The water allocation framework (includes the information about water management zone and the minimum flow in each monitoring site)
	F05	27/4/08	Guideline for discharge of wastewater in the Manawatu-Wanganui Region
Users who are interested in the structure of the New Zealand Parliament, and MP's responsibilities and roles	I01 I02 I03 I04 I05 I06	15/7/08	MPs and their membership of political parties.
	I02 I03 I04 I06	15/7/08	Find out information about MPs of National Party. For example find out the National Party members who take the both ministerial portfolio role and the associate ministerial role.
	I01 I02 I03 I04	15/7/08	Find out information about MPs of Labour Party. For example find out the Labour Party members who also take the role of the Select Committee.
	I01 I02 I03 I04 I05	15/7/08	Find out the relationship between the General Electorates and the geographic boundary of City/District. For example, find out the City/District area that fall within the boundary of Palmerston North General Electorate and it's related MP.
	I01	15/7/08	Find out the information about MPs that are members of the current Government

	I02 I03 I04 I05 I06		parties. For example, find out information about MPs who are the members of Government Parties with the General Electorates they represent and any government roles took by them.
	I01 I02 I03 I04 I05 I06	15/7/08	Find out the information about MPs that are members of the Oppositional parties. For example, find out information about MPs who are the members of Oppositional Parties with the General Electorates they represent and any government roles took by them.
Staff members of local government authorities who are interested in the roles colleagues and councillors play in their organisation	H01 H02 H03 H04 H05 H06	20/9/08	Find out the relationships among the Local Government Organisation's positions, such as find out the positions report to the Chief Executive Officer in Horizons Regional Council.
	H01 H02 H03 H04 H05	20/9/08	Find out the staff who has been assigned to a particular position in the Local Government Organisation. For example, find out the name of the staff who has been assigned to the position of Group Manager of Regional Planning and Regulatory Horizons Regional Council.
	H01 H02 H03 H05 H06	20/9/08	Find out the duty for a particular position in the Local Government Organisation. For example, find out the positions and staff members who are responsible for Consent matters in Horizons Regional Council.
	H01 H02 H03 H04 H05 H06	20/9/08	Find out the links between the staff and the position in the Local Government Organisation. For example, find out the staff members who report to the Senior Consents Planner in Horizons Regional Council.
Users who are interested in New Zealand environmental issues	E01 E02 E03 E04	5/11/08	Find out the environmental documents about standards, guidelines, regulations and laws, technical reports. For example find out the related documents about drinking water standards.
	E01	5/11/08	Find out the environmental documents that are published by a specific organisation within a certain timeline. For example, find

	E03 E04		out the regulations and laws about water quality issues that published by the Ministry for the Environment before 1st August 2008.
Members of the rural community who would like more information about the roles councillors play on the regional council.	R01 R02 R03 R05	12/11/08	Find out the person who have been elected with the position in the Local Government and are assigned with the Local Government Role. For example, find out the person who have been elected as the Palmerston North City Councillor and are assigned for the Palmerston North City Council Committee role.
	R02 R04 R05	12/11/08	Find out the members for a specific committee in the Local Government. For example, list the members for Environmental Committee in Manawatu-Wanganui Regional Council.
	R01 R02 R03 R04 R5	12/11/08	Find out all the people elected as the representative for Local Government position. For example list all the people and the wards they represent as the representative for Palmerston North City Council.

11.2 Evaluation 1: Expert Judgement

11.2.1 Experts General Information

This section contains some brief information of the student/researcher being interviewed in this research process.

Expert 1 – University Professor - USA

Field of expertise/ interest: Application of contexts in leaning systems, mobile technologies in education, educational multimedia, exploratory learning, simulation-based systems, intelligent & adaptive learning/ tutoring, teaching styles, web-based teaching & learning.

Expert 2 – Topbraid Developer

Field of expertise/ interest: developing new technologies in the fields of Semantic Web and ontology modelling.

Expert 3 – Senior Lecturer

Field of expertise/ interest: Health informatics, electronic medical records, object-object analysis, and distributed systems design.

Expert 4 – Protégé Consultant

Field of expertise/ interest: Enterprise Architecture, Information Architecture, Data Architecture, Ontology, Semantic Technology, Meta Data Management, Master Data Management.

Expert 5 – University Professor – United Kingdom

Field of expertise/ interest: OWL, Semantic Web, Java, OO, knowledge representation, software engineering, rdf, web, html, xhtml, css, xml. He has been a developer on several piece of software including Protégé OWL.

Expert 6 – PhD student - China

Field of expertise/ interest: Previously in computer science, different programming languages, information storages, and many more.

Expert 7 – University Professor - Greece

Field of expertise/ interest: Participation to 61 Research and Development Projects. His main research interests are in the areas of Technology Enhanced Learning and Semantics.

Expert 8 – University Professor – New Zealand

Field of expertise/ interest: Health Informatics and e-health, Ontologies and the Semantic Web and ubiquitous computing and the developing world.

Low risk Notification

MASSEY UNIVERSITY

15 April 2010

Jia Zhou
7 Cramer Place
PALMERSTON NORTH

Dear Jia

Re: Ontology Drive Semantic Web-Based Solution to e-Government Services in New Zealand

Thank you for your Low Risk Notification which was received on 8 April 2010.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

> *"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*
>
> *If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail humanethics@massey.ac.nz".*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

J. O'Neill

John G O'Neill (Professor)
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

cc Dr Dick Whiddett
Department of Management
PN214

Assoc Prof Kinshuk
Department of Management
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Mr Barry Jackson
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Massey University Human Ethics Committee
Accredited by the Health Research Council

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11.2.2 Stage 1: Accompanying letter

Dear Expert:

I am a student at Massey University, Palmerston North, studying for my PhD in Management. My research aims at developing, testing and evaluating an ontology-enabled web-based public service environment that is consistent with the New Zealand's e-government initiative. As part of the research evaluation, I'd like the critical comments from discipline experts on the semantic framework I have developed. The project needs to be viewed as a prototype and is not fully instantiated, so the focus is not so much on functionality of the ontology but on the semantic framework itself.

The project is based on the New Zealand parliamentary and local government systems. The domain of the research encompasses:

- The New Zealand Parliament structure, MPs, and their roles.
- Horizons Regional Council Management structure, staff and their roles.
- Environment Issues (water) within the Manawatu-Wanganui Region.

These domains have been placed in a wider context of local and national government.

The validation I have in mind is a two-stage approach. During the first approach, the experts are advised that the process involves their completing a questionnaire. A five-point Likert scale is used, but the participants have the opportunity to make additional observations about the semantic framework. During the second approach, the initial feedback from the experts will be analysed and a summary of the comments made by the panel members will return to the panel member for their further deliberations and comments.

A copy of the ontology will send to the experts once they have committed to the evaluating of the ontology. Experts will require access to TopBraid Composer and Ensemble. For those who don't have access to TopBraid Composer and Ensemble, a 30 days trial version of Maestro Editions can be downloaded from TopQuadrant's website:

http://topquadrant.com/products/TB_download.html .

I would greatly appreciate it if you could assist in this investigation by completing the accompanying questionnaire.

You have the right to:

- decline to participate;
- refuse to answer any particular questions;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the findings of the study when it is concluded.

Please do not hesitate to contact myself or my supervisors if you have any questions about this study at the addresses below:

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This project has been assessed by the Massey University Human Ethics Committee as a low risk investigation. If you have any concerns about the ethics of this research, please contact Dr John G O'Neill, Chair, Massey University Campus Human Ethics Committee: PN telephone 06 350 5799 x 8635, email: humanethicspn@massey.ac.nz

We hope that the aspirations of this research have become clear to you, and that the time required to complete the survey will be worth your while. Thank you for taking the time to read this information.

Instructions for completing the questionnaire can be found on the form itself. The questionnaire and the ontology are enclosed in this email in two separate files. We would appreciate it if you would complete the questionnaire and return it to Jia Zhou, preferably within the next week. You may at any time withdraw from the evaluation process.

Sincerely yours,

Jia Zhou

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Massey University
Palmerston North
Phone: 06 350 5799 x 7753
Email: j.c.zhou@massey.ac.nz

11.2.3 Stage 1: Questionnaire

Expert Panel Questionnaire						
Please rate the following assertions by ticking the appropriate box. If you wish to clarify your answer or make additional comments please use the comment(s) box. If you feel that other assertions should have been put please insert in Part 2 of the questionnaire together with your rating.						
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Internal Layers						
1	**Internal: Lexical / Vocabulary layer** Syntactic elements of the ontology					
1.1	The ontology has adopted internationally accepted naming conventions.	1			4	
1.2	The ontology is well documented.		1	2	2	
1.3	The ontology is logically defined.				3	2
1.4	The ontology is consistent. (no contradictions)				2	3
1.5	The ontology is syntactically correct.				1	3
1.6	Additional comment(s) • Some property names and domains are too long, which is not regarded as common practice and is inconsistence. • Lack of support documentation about the domain knowledge. • It is suggested to introduce the sub-property to group similar properties similar to the class hierarchy.					
2	**Internal: Structural / architectural layer** Graphical and structural elements. Relationship, richness and reasoning.					
2.1	Concepts within the ontology are highly connected.				3	2
2.2	The ontology has applied reasoning in a correct and useful manner.			1	3	1
2.3	The ontology possesses a richness of relationships, attributes and inheritances.			2	2	1
2.4	Additional comment(s) The recommendations for this question are similar with question 1 that the ontology system should introduce some sub-properties and more descriptions about the domain knowledge.					
3	**Internal: Representational / semantic layer** Semantic elements of the ontology.					
3.1	The ontology is prescriptive (tries to regulate how the world should be)		1		2	1
3.2	The ontology is consistent (no formal contradictions)				1	4
3.3	The ontology is comprehensive. (extent of target domain covered)			1	2	1
3.4	The ontology has high granularity. (fine-grained versus loose grained					5
3.5	The ontology is expressive and explicit. (suitable ontology language used)			1	3	
3.6	The ontology is relevant. (with regard to the application and possible users)				1	3
3.7	There is a match between the formal and cognitive semantics in the ontology (semantic adequacy)				4	1

3.8	Additional comment(s) • It’s hard to judge 3.3 – this could of course be extended infinitively. • Question 3.4 and 3.7 needs a better description, an example could be added and will be useful for explaining better the user’s input expected.					
4	**Internal: Data / Application layer** Ontology's applicability to the chosen domain.					
4.1	The query mechanisms are extensive.			1	3	1
4.2	The query mechanisms are easy to apply.				3	1
4.3	The user is presented with a structured and appropriate interface (forms and windows)		1		2	1
4.4	The corpus of text is representative of the chosen domain.			1	2	
4.5	There is congruency between the ontology and the corpus terms.				3	1
4.6	Additional comment(s) • The interface could be improved and better structured, since there are difficulties with the current interface and the way the information is presented to the user. • Lack of “rdfs:subPropertyOf” limits queries.					

External Layers						
5	**External: Composer usability layer** Ontology's applicability to the chosen domain. Viewed by means of an OWL interface.					
5.1	The query mechanisms are extensive.				5	2
5.2	The query mechanisms are easy to apply.				4	2
5.3	The interface is well constructed and appropriate.		1	1	4	
5.4	Additional comment(s) • The interface could be improved and better structured, since there are difficulties with the current interface and the way the information is presented to the user. • As the original developer of TBC, the responder feels it’s too biased to answer any of these questions.					
6	**External: Ensemble usability layer** Ontology's applicability to the chosen domain. Viewed by means of a Web Browser.					
6.1	The web-based query mechanisms are extensive.			2	2	2
6.2	The web-based query mechanisms are easy to apply.				5	1
6.3	The web interface is well structured and appropriate.		1	2	3	
6.4	Additional comment(s) • The web interface could be improved and better structured, since there are difficulties with the current web interface and the way the information is presented to the user. • The responder is not sure what the application was designed for: people who have experience in TopBraid, the interface is easy to understand, people who don’t have TopBraid experience TopBraid experience, it is not very intuitive. • The original developer of TBC doesn’t want to answer the question as the bias might occurred.					

Framework						
7	The current semantic framework embodied in the ontology is a prototype and there is a belief that there are a number of opportunities to build on the existing framework and make it more useful and effective. In this section the potential of the framework is the focus of the assertions.					
7.1	The current semantic framework has the potential to effectively store and retrieve information about the New Zealand Parliament: its structure, its members and their roles.				5	2
7.2	Additional comment(s) One major thing that is missing is to turn this into Linked Data. This means that you should try to reuse existing vocabularies, at least link to them. For example make :Person owl:equivalentClass foaf:Person, and add links to DBpedia resources via owl:sameAs or rdfs:seeAlso. Syntactically, you should also remove unused namespace prefixes (detail) and also define a prefix for your own file. This makes it easier for people who import your file to use your ontology consistently.					
7.3	The current semantic framework has the potential to effectively store and retrieve integrated information relating to the internal management of a local government entity.				4	2
7.4	Additional comment(s) One major application area of such things is usually data integration. So you would need to evaluate your schema with existing data sources. For example, find a spreadsheet that lists all universities of NZ. Then try to automatically establish links between the unis and the political entity that manages them. The question here is to figure out whether it is easy for the people who manage the uni database to link to your central ontology so that everyone has benefits.					
7.5	The current semantic framework has the potential to store and retrieve integrated information linking both local and national governmental information.			2	4	1
7.6	Additional comment(s)					
7.7	The current semantic framework has the potential to integrate information relating to environmental issues (such as water quality) to both regional and national government sources.		1	2	2	1
7.8	Additional comment(s)					
7.9	The current semantic framework has the potential to provide a more efficient, effective and richer source of integrated e-government information than traditional non-semantic government web sites.			2	2	3
7.10	Additional comment(s)					

Part 2 of the questionnaire

In this part of the questionnaire the respondent (expert) is asked to add up to four assertions they would like to have been put in Part 1 but were omitted.

Additional assertions proposed by the expert (up to 4)	Research use only				
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

A1	**Expert assertion 1**					
A 1.1	Add Assertion 1 here The ontology must be able to be understood by stakeholders					1
A 1.1	Comments in support of Assertion 1					
A2	**Expert assertion 2**					
A 2.1	Add Assertion 2 here Rules in the ontology must be shown to be correct in terms of legislation.					1
A 2.2	Comments in support of Assertion 2 Any decision making should be legally supportable.					
A3	**Expert assertion 3**					
A 3.1	Add Assertion 3 here					
A 3.2	Comments in support of Assertion 3					
A4	**Expert assertion 4**					
A 4.1	Add Assertion 4 here					
A 4.2	Comments in support of Assertion 4					

Part 2 of the questionnaire

In this part of the questionnaire the respondent (expert) is asked to add up to four assertions they would like to have been put in Part 1 but were omitted.

Additional assertions proposed by the expert (up to 4)					Research use only
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

A1	**Expert assertion 1**					
A 1.1	Add Assertion 1 here The ontology must be able to be understood by stakeholders					1
A 1.1	Comments in support of Assertion 1					
A2	**Expert assertion 2**					
A 2.1	Add Assertion 2 here Rules in the ontology must be shown to be correct in terms of legislation.					1
A 2.2	Comments in support of Assertion 2 Any decision making should be legally supportable.					
A3	**Expert assertion 3**					
A 3.1	Add Assertion 3 here					
A 3.2	Comments in support of Assertion 3					
A4	**Expert assertion 4**					
A 4.1	Add Assertion 4 here					
A 4.2	Comments in support of Assertion 4					

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11.2.3.1 Stage 2: Feedback on Stage 1

Question 1: Internal: Lexical / Vocabulary layer Syntactic elements of the ontology 87% of the responses posed agree and strongly regarding the lexical and vocabulary of the ontology. Comments were obtained from several of the respondents:

19. The naming convention for some of the properties is too long and is not suggested as the common practice.

    Researcher's response to the comment: The problem with the naming issue has largely been addressed in the most current ontology to make sure the naming convention is consistency in the ontology. This is ongoing.
20. Lack of documentation in supporting the ontology structure and meaning of the classes and properties, such as it is recommended to use the "rdfs:comment" to support the understanding of the terms and elements used/described in the ontology.

    Researcher's response to the comment: More "rdfs:comment" have been used in the current ontology framework to support the meaning of the terms and structure of the ontology, however, the researcher hasn't used the "rdfs:comment" to describe every term that appears in the ontology. This is ongoing.
21. The use of "rdfs:subPropertyOf:" is suggested to introduced in the ontology to group similar properties.

    Researcher's response to the comment: the use of "sub-properties had been applied in an earlier version of the ontology. However, some issues occurred when using the software particularly when checking consistency, and in some cases it caused problems with forms particularly when observing data in the browser. To avoid these issues, the "subproperties" wasn't used in the ontology. This topic is being reviewed.
22. The suggestion is made of correcting the typos in naming the classes and properties.

    Researcher's response to the comment: The typos are currently being corrected in the ontology.

Question 2: **Internal: Structural / architectural layer** Graphical and structural elements. Relationship, richness and reasoning.

83% of the responses posed agree and strongly agree regarding the structural and architectural layer of the ontology. Constructive comments were obtained from several of the respondents:

- The question about “the concepts within the ontology are highly connected” is bit vague, as the responder is not sure whether the quantity of the ontology concepts is taking account.

  Researcher’s response to the comment: Agreed.

- The lack of using “rdfs:subPropertyOf” has affected the performance of reasoning and richness of the relationships, attributes and inheritances.

  Researcher’s response to the comment: The reason for not applying “rdfs:subPropertyOf” was mentioned in the summary of Question 1.

Question 3: **Internal: Representational / semantic layer** Semantic elements of the ontology.

90% of the responders gave positive selections towards the semantic layer of the ontology. Constructive recommendations have been suggested by some of the experts, they are:

1. Some questions [in the questionnaire] needed a better description, this could be done by illustrating with examples to help the users’ input for these questions.

   Researcher’s response to this recommendation: Agreed.
2. Issue Q3.3 is hard to judge as the ontology could be extended infinitively.

   Researcher’s response to this recommendation: The issue might be addressed better by specifying the domain area.

Question 4: **Internal: Data / Application layer** Ontology's applicability to the chosen domain.

83% of the responders gave positive selection towards the applicability to the chosen domain. Constructive recommendations are made regarding to the rest of the issues:

1. It is suggested that the interface could be improved and better structured to better represent the information to the users.

   Researcher’s response to the recommendation: Agreed. The structure and design of the forms and queries are based on my ability to use the TopBraid Composer’s development interface. In this research, the research’s focus is the ontological design of the framework, the interface is not the main focus. However, as time permits the researcher will seek to improve the interface.
2. The recommendation about the query mechanisms is the lack of using “rdf:subProperty” limits the query extensibility.

   Researcher’s response to this recommendation: The use of “rdf:subProperty” will definitely enhance the ability of query, the reason for not using the subPropety was explained in Question 1)

Question 5: **External: Composer usability layer** Ontology's applicability to the chosen domain. Viewed by means of an OWL interface

89% of the responders gave positive selections towards ontology's applicability to the chosen domain. Constructive comment is gathered regarding Question 5:

1. The TopBraid Composer could be improved and better structured; the current interface is not able to well represent the information to the users
   Researcher's response to this recommendation: See the researcher's response in Question 4).

Question 6: **External: Ensemble usability layer** Ontology's applicability to the chosen domain. Viewed by means of a Web Browser.

72% of the responders gave positive responses toward ontology's applicability to the chosen domain that is viewed by a web-based interface. Constructive comment is gathered as follow:

1. The web interface could be improved for better understanding and better information representation to the users.
   Researcher's response to the recommendation: The structure and design of the forms and queries are based on the TopBraid Ensemble web-based interface. I am not sure that the problem lies with TopBraid but with my own ability to use it wisely and effectively. I am also sure that in the future tools such as TopBraid will enable users to be more creative and imaginative. As mentioned before, the research's focus is the ontological design framework, the interface is not the main focus.
2. One responder is not sure what the application was designed for: People who have experience in TopBraid would find the interface easy to understand, whereas people who don't have TopBraid experience would not find it very intuitive.
   Researcher's response to this recommendation: I appreciate this comment made by the experts, If looking from a user's perspective, it will be useful to have users evaluate the system, but in this research the emphasis has been place more on the potential of the framework than the quality of the user interface, however, through the mechanism of the adoption of use cases approach in the requirement and analysis phase of the development, a limited opportunity to evaluate the interface from a usability perspective is provided in this research. The experts were not aware that the 'Expert Questionnaire Evaluation" was only one of three evaluation activities that were undertaken by the researcher. For example, the second involved the ability of the system to

deliver results base on a number of user-based scenarios, and the third evaluation method involved the calculation of a number of usability metrics. Perhaps providing this information would have been useful to the experts.

Question 7: Framework

79% of the responders gave positive responses toward ontology's applicability to the chosen domain that is viewed by a web-based interface. Constructive comments gathered:

1. The use of existing vocabularies, such as use "foaf:Person", and linking with DBpedia would improve the links between different sources of metadata
   Researcher's response to the recommendation: It is a good suggestion to make. The researcher has since introduced DBpedia in one or two cases (MPs), and is considering where to use "foaf:Person". In the original design, the researcher placed little emphasis of attributes of 'Person". However, adding this facility would be a trivial matter, and would generate some benefits. Dublin core was already implemented.
2. Remove unused namespace prefixes and define a prefix for your own file.
   Researcher's response to the recommendation: Researcher will use her own namespace prefixes in the ontology instead of using TopBraid's.
3. Data integration can be done by linking the existing data source with the current ontology framework.
   Researcher's response to the recommendation: Data integration with the existing data resource was considered in the early stage of the research, however, it became unrealistic as no organisations would expose their internal data for a research purpose. The problem was exacerbated as I was working alone and not in a recognised research group, linked to say, a government agency. However, a dummy source were created, based on MySQL, and instantiated with representative data, was tested and found that it could be successfully integrated with my ontology. Perhaps I should have included this in the ontology. Similarly, files from the Library of New Zealand containing environmental data, were downloaded and imported via an Excel spreadsheet into a separate ontology but this was not shown on the ontology.

11.2.4 Stage 2: Accompanying letter

Dear experts,

My name is Jia Zhou from Massey University, New Zealand. Thanks a lot for your efforts in supporting me with Stage 1 of my evaluation survey for my E-government ontology early this year. Due to some personal reasons the project has been delayed for some time, however, I have recently come back to my project and I have summarized the survey results and comments I received from all the experts in Stage 1. You will find a summary of the results and comments in the attached document.

As requested, some experts proposed additional assertions they thought could have been put in Part 1. I'm sending you these experts' assertions as a supplement of the questionnaires to evaluate the ontology structural. It is hoped that you have time to answer these questions. I apologize for leaving this analysis for such a long time and that may pose some difficulties for you to look at my system again. If you have any difficulties and problems with the survey please let me know.

I would appreciate it greatly if you could send me your feedback for the supplementary questions at the end of this document within 2-3 weeks as I'm trying to catch up with my schedule to meet the deadline for my thesis submission.

I would greatly appreciate it if you could assist in this investigation by completing the accompanying Stage 2 questionnaire.

You have the right to:

- decline to participate;
- refuse to answer any particular questions;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the findings of the study when it is concluded.

Please do not hesitate to contact my supervisors or myself if you have any questions about this study at the addresses below:

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11.2.5 Stage 2: Questionnaire: Evaluating the New Zealand e-government ontology framework

The supplementary assertions added from Part 1

In the Stage 1 Questionnaire, the respondents (experts) were asked to add up to four assertions that they would like to have seen placed in Part 1. Overall there were six suggested assertions; these are shown below. Please complete the form and return to me.

Additional assertions proposed by the experts		Research use only				
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
A1	**Added Expert assertion 1**					
A 1.1	The ontology must be able to be understood by stakeholders	☐	☐	☐	☐	☐
A 1.1	Comments in support of Assertion 1					
A2	**Added Expert assertion 2**					
A 2.1	Rules in the ontology must be shown to be correct in terms of legislation.	☐	☐	☐	☐	☐
A 2.2	Comments in support of Assertion 2					
A3	**Added Expert assertion 3**					
A 3.1	The structure of the ontology is sensible.	☐	☐	☐	☐	☐
A 3.2	Comments in support of Assertion 3					
A4	**Added Expert assertion 4**					
A 4.1	The use case is well defined.	☐	☐	☐	☐	☐

A 4.2	Comments in support of Assertion 4					

A5	**Added Expert assertion 5**					
A 5.1	Full use of language expressivity is necessary for the domain.	☐	☐	☐	☐	☐
A 5.2	Comments in support of Assertion 5					
A6	**Expert assertion 6**					
A 6.1	There are gaps in the areas of coverage.	☐	☐	☐	☐	☐
A 6.2	Comments in support of Assertion 6					

11.2.6 Summary table

No responses were received from the experts. Experts did respond by e-mail and said that due to pressure of work and time constraints that they would not respond to the Stage 2 Questionnaire

11.3 Evaluation 2: Simulation-based Analysis

Queries put to the ontology

Scenario 1:

Identify those National Party electorate MPs who have ministerial roles and associate ministerial roles, and who are members of at least one select committee.

Identify those electorate MPs who are members of at least one select committee and who are members of an opposition party.

Scenario 2:

List all the general electorates (excludes Maori electorates) which are covered by the Auckland City area, and in addition, identify those MPs who represent these electorates.

List the city councils and the general electorates that are located within their boundaries. Also include the names of the sitting MPs. This query explicitly excludes district or regional council regions.

Scenario 3:

List the contact staff in Manawatu-Wanganui Regional Council who can provide customers with additional information on the Consent Submission Form.

Find all the publications published by Ministry for the Environment with a publication date after 1st January 2002.

11.4 Evaluation 3 – Structural Evaluation

Table 11-1: Ontology classes, properties and instantiations (one of four)

Class Domain			Properties	Class Range					Instances	|P|	|H|	|C|	|subC|	|SubC| /subtree	#instances subtree
				Thing								1	12		
					Electorate				1			1	3		
ParliamentaryElectorateArea GeneralElectoratePosition			hasParliamentaryElectorate representsElectorate			ParliamentaryElectorate					2	1	2		
	63						GeneralElectorate		63			1			
	7						MaoriElectorate		7			1			
CityAndDistrictArea			hasCityOrDistrictElectorate			CityAndDistrictElectorate					1	1	2		
	16						CityElectorate		16			1			
	58						DistrictElectorate		58			1			
						AuthorityElectorate			1			1	2		
TerritorialAuthorityArea	12		hasTerritorialAuthorityElectorate				TerritorialAuthorityElectorate		12		1	1			
UnitaryAuthorityArea	4	160	hasUnitaryAuthorityElectorate				UnitaryAuthorityElectorate		4			1		9	162
GovernmentalEntity			isLocatedIn		GeographicalArea				1		1	1	5		
						PoliceDistrictArea			12			1			
						RegionalAuthorityArea						1	2		
CityAndDistrictArea CityAndDistrictArea	99		isCoveredByTerritorialGovernanceArea isPartiallyCoveredByTerritorialAuthorityArea				TerritorialAuthorityArea		12	3		1			
TerritorialAuthorityElectorate			isLocatedInTerritorialAuthorityArea												
UnitaryAuthorityElectorate			isLocatedInUnitaryAuthorityArea				UnitaryAuthorityArea		4			1			
ParliamentaryElectorate			isLocatedInParliamentaryElectorateArea			ParliamentaryElectorateArea			0		1	1	2		
CityAndDistrictrea	16		isRelatedToGeneralElectorate				GeneralElectorateArea		63	1		1			
CityAndDistrictArea	7 7		isRelatedToMaoriElecorate				MaoriElectorateArea		7	1		1			
						HospitalBoardArea						1			
CityAndDistrictArea TerritorialAuthorityArea GeneralElectorateArea	58 63		isLocatedInCityAndDistrictArea hasPartiallyCoversCityAndDistrictCouncilArea isRelatedToCityAndDistrictCouncilArea			CityAndDistrictArea					3	1	2		
							CityCouncilArea		16			1			
	58	308					DistrictCouncilArea		58			1		11	173
GovernmentalEntity	77		hasGovernanceStructure		GovernanceStructure						1	1	2		
AssignedLGRole LocalGovernmentGovernanceStructure NonMPPerson AssignedLGRole LocalGovernmentGovernanceStructure			isAssignedGovernanceGroup isPartOfGovernanceGroup isCouncillorFor isAssignedGovernanceGroup hasSubGovernanceGroup			LocalGovernmentGovernanceStructure			0		5	1	14		
							AucklandRCGovernanceStructure		1			1			
							BayOfPlentyRCGovernanceStructure		1			1			
							CanterburyRCGovernanceStructure		1			1			
							HawkesBayRCGovernanceStructure		1			1			
							ManawatuDCGovernanceStructure		1			1	1		
	11							Elected	11						
	7							Assigned				1			
							ManawatuWanganuiRCGovernanceStructure					1	1		
	12							Elected	12						
	0							Assigned				1			
							NorthlandRCGovernanceStructure		1			1			
							OtagoRCGovernanceStructure		1			1			
							PNCityGovernanceStructure		1			1	1		
	16							Elected	16						
	4							Assigned				1			
							SouthlandRCGovernanceStructure		1			1			
							TaranakiRCGovernanceStructure		1			1			
							WaikatoRCGovernanceStructure		1			1			
							WellingtonRCGovernanceStructure		1			1			
							WestCoastRCGovernanceStructure		1			1			
						NZParliamentaryStructure			1			1	2		
							Other					1			
		127					SelectCommittee		18			1		21	71

Table 11-2: Ontology classes, properties and instantiations (two of four)

GovernanceStructure OrganisationalStructure			isGovernanceStructureOf isManagementStructure		GovernmentalEntity						2	1	2		
	3					NationalGovernment			1			1			
						LocalGovernment			0			1	3		
	19						CityCouncil		16			1			
	18						DistrictCouncil		58			1			
	37	77					RegionalCouncil		12			1		5	87
					GovernmentalIssue				0			1	1		
Publication			isRelatedToGovernmentIssue			EnvironmentalIssues			0		1	1	2		
	11						LandIssue		1			1			
	18	29					WaterIssue		2			1		3	3
GovernmentalEntity Publication	58 16		hasManagementStructure isPublishedBy		OrganisationalStructure						2	1	3		
LocalGovernmentOrganisationalStructur e LocalGovernmentOrganisationalStructur e LGOrganisationalPosition			hasSubOrganisationalGroup isPartOfOrganisationalGroup isAssignedOrganisationalGroup			LocalGovernmentOrganisationalStructure			1		3	1	15		
	1						AucklandRCOrganisationalStructure		1			1			
	1						BayOfPlentyRCOrganisationalStructure		1			1			
	1						CanterburyRCOrganisationalStructure		1			1			
	1						HawkesBayRCOrganisationalStructure		1			1	1		
	0							HawkesBayRCDepartment	4			1			
	1						ManawatuDCOrganisationalStructure		1			1			
	2						ManawatuWanganuiRCOrganisationalStructure		1			1	8		
	8							MWCommunicationsAndPromotions	3			1			
	25							MWCorporateAndGovernanceSuppo	4			1			
	52							MWEnvironmentalManagementGp	13			1			
	12							MWFinanceAndAccountsGp	4			1			
	35							MWOperationsGp	10			1			
	38							MWRegionalPlanningGp	4			1			
	45							MWRegionalServicesGp	11			1			
	12							ManawatuWanganuiRCGroups	7			1			
	1						NorthlandRCOrganisationalStructure		1			1			
	1						OtagoRCOrganisationalStructure		1			1			
	1						PNCCCityOrganisationalStructure		1			1			
	2						RuapehuDCOrganisationStructure		1			1	1		
	4							RuapehuDCGroups	4			1			
	1						SouthlandRCOrganisationalStructure		1			1			
	1						TaranakiRCOrganisationalStructure		1			1			
	1						WaikatoRCOrganisationalStructure		1			1			
	1						WellingtonRCOrganisationalStructure		1			1			
	1						WestCoastRCOrganisationalStructure		1			1			
	1					NZGovernmentOrganisationalStructure			1			1	1		
							NewZealandStateServices		8			1	7		
								CrownEntityClass	4			1			
								NonPublicServiceDepartmentClass	6			1			
								OtherCompanyClass	1			1			
								ParliamentaryOfficesClass	3			1			
								PublicFinanceActFourthScheduleOrg	16			1			
								PublicServiceDepartmentClass	36			1			
								StateOwnedEnterprisesClass	19			1			
		323				OrganisationsAndInstitutes			2			1		36	176

Table 11-3: Ontology classes, properties and instantiations (three of four)

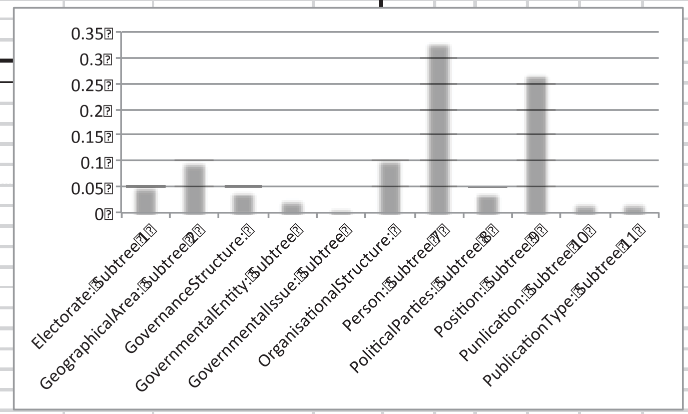
PublicationType	11		hasContactPerson		Position							1	1	6		
						GovernancePosition				1			1	1		
							AssignedGovernancePosition			1			1			
						LGGovernancePosition							1	2		
LocalGovernmentGovernanceStructure NonMPPerson			hasAssignedGovernancePosition isAssignedLocalGovernanceRole				AssignedLGRole					2	1	8		
	0							AssignedHorowhenuaDCRole					1			
	0							AssignedManawatuDCRole					1			
	7							AssignedMWGovernanceRole		7			1			
	4							AssignedPNCCGovernanceRole		4			1			
								AssignedRangitikeiDCRole					1			
								AssignedRuapehuDCRole					1			
								AssignedTararuaDCRole					1			
								AssignedWanganuiDCRole					1			
NonMPPerson			isElectedCouncillor				ElectedLGPosition					1	1	8		
	0							ElectedHorowhenuaDCPosition					1			
	12							ElectedMWPosition		12			1			
	11							ElectedManawatuDCPosition		11			1			
	16							ElectedPNCCPosition		16			1			
	0							ElectedRangitikeiDCPosition					1			
	0							ElectedRuapehuDCPosition					1			
	0							ElectedTararuaDCPosition					1			
	0							ElectedWanganuiDCPosition					1			
LocalGovernmentOrganisationalStructure LGOrganisationalPosition NonMPPerson LGOrganisationalPosition			has AssignedOrganisationalPosition isManager isEmployedInLocalGovernment hasManager			LGOrganisationalPosition						4	1	8		
	0						HorowhenuaDCStaffPosition						1			
	227						MWStaffPosition			227			1			
	0						ManawatuDCStaffPosition						1			
	0						PNCCStaffPosition						1			
	0						RangitikeiDCStaffPosition						1			
	5						RuapehuDCStaffPosiiton			5			1			
	0						TararuaDCStaffPosition						1			
	0						WanganuiDCStaffPosition						1			
						NZGovtOrganisationalPositon							1	1		
NonMPPerson	3		isEmployedNZGovernment				NZGovtStaffPosition			3		1	1			
						NZParliament							1			
						NZParliamentaryPosition							1	2		
							AssignedNZParliamentaryRole						1	7		
NZGovtMP	23		isAssignedParliamentaryAssociateMinisterialRole					AssociateMinisterialRole		23	5		1			
NZGovtMP	15		isAssignedParliamentaryMinisterailNonPortfolioRole					MinisterialNonPortfolioRole		15			1			
NZGovtMP	63		isAssignedPar;liamentaryMinisterialPortfolioRole					MinisterialPortfolioRole		64			1			
NZGovtMP	23		isAssignedParliamentaryHouseRole					ParliamentHouseRole		23			1			
NZGovtMP	63		isAssignedSelectCommitteeRole					SelectCommitteeRole		64			1			
								ShadowMinisterialRole					1	2		
	24								ShadowOtherResponsi	24			1			
	70								ShadowPortfolio	70			1			
NZGovtMP	144		isAssignedSpokespersonRole					SpokespersonRole		144	1		1			
							ElectedNZParliamentPosition						1	3		
NZGovtMP	63		isElectectedElectorateMP					GeneralElectoratePosition		63	1		1			
NZGovtMP	7		isElectectedElectorateMP					MaoriElectoratePosition		7	1		1			
NZGovtMP	52	843	isElectedListMP					NZParliamentListPosition		1	1		1		48	785
OrganisationalStructure			hasProducedPublication		Publication							1	1	3		
	37					NZOrganisationalPublication				37			1			
	2					NZGovernmentOrganisationalPublication				2			1			
						LocalGovernmentPublication							1	2		
	0						HawkesBayRCPublication						1			
	19	58					ManawatuWanganuiRCPublication			19			1		5	58
Publication	58	58	hasPublicationType		PublicationType					8	1		1		0	8
GeographicalArea	1	1	hasLocation		SpatialThing					1	1		1	1		
	3142	3142				Point							1		1	
											|P|	|H|	|C|	|subC|		
			159							2074	16	48	196	195	183	2073
										C/						
									Non empty	85						

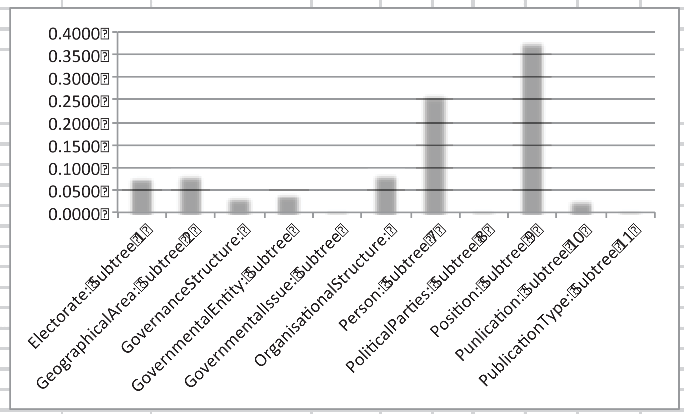
Table 11-4: Ontology classes, properties and instantiations (four of four)

					Person								1	3		
NonMPPerson NZGovtStaffPosition MWStafPosition LocalGovernmentGovernanceStructure ElectedLGPosition			hasAssignedLocalGovernanceRole hasEmploymentInNZGovernment hasEmploymentInLocalGovernment hasCouncillor hasElectedCouncillor			NonMPPerson				314		5	1	2		
							Employment						1	2		
	226							MWStaffMember					1			
								NZGovtStaffMember					1			
							Governance						1	3		
	24							MWCouncilMember					1			
	22							ManawatuCouncilMember					1			
	36							PNCCouncilMember					1			
AssociateMinisterialRole PoliticalParties ParliamentaryHouseRole or SelectCommitteeRole MinisterialNonPortfolioRole MinisterialPortfolioRole SelectCommitteeRole GeneralElectoratePosition or Maori ElectoratePosition SpokespersonRole NZParliamentListPosition			hasAssignedParliamentaryAssociateMinisterialRole hasPartyMember hasParliamentaryHouseRole hasAssignedParliamentaryMinisterialNonPortfolioRole hasAssignedParliamentaryMinisterialRole hasAssignedSelectCommitteeRole hasElectedElectorateMP hasAssignedSpokespersonRole hasElectedListMP			NZGovt MP				121		9	1	12		
							ExecutiveCouncilMember						1			
	8						NZGovtElectorateActMP						1			
	113						NZGovtElectorateLabourMP						1			
	33						NZGovtElectorateMaoriMP						1			
	219						NZGovtElectorateNationalMP						1			
	8						NZGovtElectorateProgressiveMP						1			
	13						NZGovtElectorateUnitedFutureMP						1			
	26						NZGovtListActMP						1			
	73						NZGovtListGreenMP						1			
	152						NZGovtListLabourMP						1			
	83						NZGovtListNationalMP						1			
							SelectCommitteeMember						1	18		
								SCBusinessMember					1			
								SCCommerceMember					1			
								SCEducationAndScienceMember					1			
								SCFinanceAndExpenditureMember					1			
								SCForeignAffairsDefenceAndTradeMember					1			
								SCGovernmentAdministrationMember					1			
								SCHealthMember					1			
								SCJusticeAndElectoralMember					1			
								SCLawAndOrderMember					1			
								SCLocalGovernmentAndEnvironmentMember					1			
								SCMaoriAffairsMember					1			
								SCOfficersOfParliamentMember					1			
								SCPrimaryProductionMember					1			
								SCPrivilegesMember					1			
								SCRegulationsReviewMember					1			
								SCSocialServicesMember					1			
								SCStandingOrdersMember					1			
								SCTransportAndIndustrialRelationsMember					1			
						NZGovtQueen				1			1			
		1036	hasImage		An object property but with no stated range within the ontology.					106					40	542
NZGovtMP			hasPoliticalParty		PoliticalParties							1	1	4		
	0					NonParliamentaryParties				1			1			
	58					GovernmentParty				1			1			
	53					OppositionParties				3			1			
	11	122				OppositionProvideConfidenceAndSupply				3			1		4	8

Table 11-5: Ontology instance metrics – Connectivity and Class Importance

Schema Metrics		
Relationship Richness:	|P|	16
	|H|	48
	RR	0.25
Inheritance Richness (Schema)	|subC|	195
	|C|	196
	IRs	0.9949
Instance Metrics		
Class Richness	|C/|	85
	|C|	196
	CR	0.43367
Connectivity		
Electorate: Subtree 1	160	0.05094
GeographicalArea: Subtree 2	308	0.09806
GovernanceStructure: Subtree 3	127	0.04043
GovernmentalEntity: Subtree 4	77	0.02451
GovernmentalIssue: Subtree 5	29	0.00923
OrganisationalStructure: Subtree 6	323	0.10283
Person: Subtree 7	1036	0.32983
PoliticalParties: Subtree 8	122	0.03884
Position: Subtree 9	843	0.26839
Punlication: Subtree 10	58	0.01847
PublicationType: Subtree 11	58	0.01847
Tota lNumber	3141	1
Class Importance	#Subtree instances	Imp
Electorate: Subtree 1	162	0.0781
GeographicalArea: Subtree 2	173	0.0835
GovernanceStructure: Subtree 3	71	0.0342
GovernmentalEntity: Subtree 4	87	0.0420
GovernmentalIssue: Subtree 5	3	0.0014
OrganisationalStructure: Subtree 6	176	0.0849
Person: Subtree 7	542	0.2615
PoliticalParties: Subtree 8	8	0.0039
Position: Subtree 9	785	0.3787
Punlication: Subtree 10	58	0.0280
PublicationType: Subtree 11	8	0.0039
Total number of instances	2073	1
Cohesion		
	Coh	
	#classes	183
Inheritance Richness	#Subtree	11
	Iri	16.6364





In the caculation of the metrics reference to the 'GeogrpahicalArea' has been excluded

11.5 E-Government ontology

11.5.1 Classes

Table 11-6: List of classes in the E-Government ontology (one of two)

- Thing (1 + 3994)
  - Electorate (1 + 164)
    - AuthorityElectorate (1 + 16)
      - TerritorialAuthorityElectorate (12)
      - UnitaryAuthorityElectorate (4)
    - CityAndDistrictElectorate (0 + 74)
      - CityElectorate (16)
      - DistrictElectorate (58)
    - ParliamentaryElectorate (0 + 73)
      - GeneralElectorate (66)
      - MaoriElectorate (7)
  - GeographicalArea (1 + 173)
    - CityAndDistrictArea (0 + 74)
      - CityCouncilArea (16)
      - DistrictCouncilArea (58)
    - HospitalBoardArea
    - ParliamentaryElectorateArea (0 + 71)
      - GeneralElectorateArea (64)
      - MaoriElectorateArea (7)
    - PoliceDistrictArea (12)
    - RegionalAuthorityArea (0 + 16)
      - TerritorialAuthorityArea (12)
      - UnitaryAuthorityArea (4)

- Electorate (1 + 164)
- GeographicalArea (1 + 173)
- GovernanceStructure (0 + 45)
- GovernmentalEntity (0 + 87)
  - LocalGovernment (0 + 86)
    - CityCouncil (16)
    - DistrictCouncil (58)
    - RegionalCouncil (12)
  - NationalGovernment (1)
- GovernmentalIssue (0 + 2)
  - EnvironmentalIssues (0 + 2)
    - LandIssue
    - WaterIssue (2)

- GovernanceStructure (0 + 45)
  - LocalGovernmentGovernanceStructure (0 + 26)
    - AucklandRCGovernanceStructure (1)
    - BayOfPlentyRCGovernanceStructure (1)
    - CanterburyRCGovernanceStructure (1)
    - HawkesBayRCGovernanceStructure (1)
    - LowerHuttCityGovernanceStructure (1)
    - ManawatuDCGovernanceStructure (1)
      - ManawatuDCCommittee
    - ManawatuWanganuiRCGovernanceStructure (1 + 5)
      - MWRCCommittee (5)
    - NorthlandRCGovernanceStructure (1)
    - OtagoRCGovernanceStructure (1)
    - PNCityGovernanceStructure (1 + 6)
      - PNCCCommittee (6)
    - SouthlandRCGovernanceStructure (1)
    - TaranakiRCGovernanceStructure (1)
    - WaikatoRCGovernanceStructure (1)
    - WellingtonRCGovernanceStructure (1)
    - WestCoastRCGovernanceStructure (1)
  - NZParliamentaryStructure (1 + 18)
    - Other
    - SelectCommittee (18)

- OrganisationalStructure (0 + 176)
  - LocalGovernmentOrganisationalStructure (1 + 79)
    - AucklandRCOrganisationalStructure (1)
    - BayOfPlentyRCOrganisationalStructure (1)
      - CanterburyRCOrganisationalStructure_1
    - CanterburyRCOrganisationalStructure (1)
      - CanterburyRCOrganisationalStructure_1
    - HawkesBayRCOrganisationalStructure (1 + 4)
      - CanterburyRCOrganisationalStructure_1
      - HawkesBayRCDepartment (4)
        - CanterburyRCOrganisationalStructure_1
    - ManawatuDCOrganisationalStructure (1)
      - CanterburyRCOrganisationalStructure_1
    - ManawatuWanganuiRCOrganisationalStructure (1 + 56)
      - CanterburyRCOrganisationalStructure_1
      - Communications and Promotions Group (3)
        - CanterburyRCOrganisationalStructure_1
      - Corporate and Governance Support Group (4)
        - CanterburyRCOrganisationalStructure_1
      - Finance and Accounts Group (4)
      - ManawatuWanganuiRCGroup (7)
      - MWEnvironmentalManagementGp (13)
        - CanterburyRCOrganisationalStructure_1
      - Operations Group (10)
      - Regional Planning Group (4)
      - Regional Services Group (11)
    - NorthlandRCOrganisationalStructure (1)
    - OtagoRCOrganisationalStructure (1)
    - PNCCCityOrganisationalStructure (1)
    - RuapehuDCOrganisationStructure (1 + 4)
      - RuapehuDCGroups (4)
    - SouthlandRCOrganisationalStructure (1)
    - TaranakiRCOrganisational_Structure (1)
    - WaikatoRCOrganisationalStructure (1)
    - WellingtonRCOrganisationalStructure (1)
    - WestCoastRCOrganisationalStructure (1)
  - NZGovernmentOrganisationalStructure (1 + 93)
    - NewZealandStateServices (8 + 85)
      - CrownEntityClass (4)
      - NonPublicServiceDepartmentClass (6)
      - OtherCompanyClass (1)
      - ParliamentaryOfficesClass (3)
      - PublicFinanceActFourthScheduleOrganisationsClass (16)
      - PublicServiceDepartmentClass (36)
      - StateOwnedEnterprisesClass (19)
  - Organisations_and_Institutes (2)

Table 11-7: List of classes in the E-Government ontology (two of two)

- Person (0 + 436)
  - NonMPPerson (314)
    - Employment
      - MWStaffMember
      - NZGovtStaffMember
    - Governance
      - ManawatuCouncilMember
      - MWCouncilMember
      - PNCCouncilMember
  - NZGovtMP (121)
    - ExecutiveCouncilMember
    - NZGovtElectorateActMP
    - NZGovtElectorateLabourMP
    - NZGovtElectorateMaoriMP
    - NZGovtElectorateNationalMP
    - NZGovtElectorateProgressiveMP
    - NZGovtElectorateUnitedFutureMP
    - NZGovtListActMP
    - NZGovtListGreenMP
    - NZGovtListLabourMP
    - NZGovtListNationalMP
    - SelectCommitteeMember
      - SCBusinessMember
      - SCCommerceMember
      - SCEducationAndScienceMember
      - SCFinanceAndExpenditureMember
      - SCForeignAffairsDefenceAndTradeMember
      - SCGovernmentAdministrationMember
      - SCHealthMember
      - SCJusticeAndElectoralMember
      - SCLawAndOrderMember
      - SCLocalGovernmentAndEnvironmentMember
      - SCMaoriAffairsMember
      - SCOfficersOfParliamentMember
      - SCPrimaryProducitionMember
      - SCPrivilegesMember
      - SCRegulationsReviewMember
      - SCSocialServicesMember
      - SCStandingOrdersMember
      - SCTransportAndIndustrialRelationsMember
  - NZGovtQueen (1)
- PoliticalParty (0 + 8)
  - GovernmentParty (1)
  - NonParliamentaryPartY (1)
  - OppositionPartY (3)
  - OppositionProvideConfidenceAndSupply (3)

- Position (0 + 785)
  - GovernancePosition (1 + 1)
    - AssignedGovernancePosition (1)
  - LG_Governance_Position (0 + 50)
    - AssignedLGRole (0 + 11)
      - AssignedHorowhenuaDCRole
      - AssignedManawatuDCRole
      - AssignedMWGovernanceRole (7)
      - AssignedPNCCGovernanceRole (4)
      - AssignedRangitikeiDCRole
      - AssignedRuapehuDCRole
      - AssignedTararuaDCRole
      - AssignedWanganuiDCRole
    - ElectedLGPosition (0 + 39)
      - ElectedHorowhenuaDCPosition
      - ElectedManawatuDCPosition (11)
      - ElectedMWPosition (12)
      - ElectedPNCCPosition (16)
      - ElectedRangitikeiDCPosition
      - ElectedRuapehuDCPosition
      - ElectedTararuaDCPosition
      - ElectedWanganuiDCPosition
  - LGOrganisationalPosition (0 + 232)
    - HorowhenuaDCStaffPosition
    - ManawatuDCStaffPosition
    - MWStaffPosition (227)
    - PNCCStaffPosition
    - RangitikeiDCStaffPosition
    - RuapehuDCStaffPosiiton (5)
    - TararuaDCStaffPosition
    - WanganuiDCStaffPosition
  - NZGovtOrganisationalPositon (0 + 3)
    - NZGovtStaffPosition (3)
  - NZParliament
  - NZParliamentaryPosition (0 + 498)
    - AssignedNZParliamentaryRole (0 + 427)
      - AssociateMinisterialRole (23)
      - Deputy Speaker [SpokespersonRole] (144)
      - MinisterialNonPortfolioRole (15)
      - MinisterialPortfolioRole (64)
      - ParliamentHouseRole (23)
      - Select_Committee_Role (64)
      - ShadowMinisterialRole (0 + 94)
        - ShadowOtherResponsibilityRole (24)
        - ShadowPortfolioRole (70)
    - ElectedNZParliamentPosition (0 + 71)
      - GeneralElectoratePosition (63)
      - MaoriElectoratePosition (7)
      - NZParliamentListPosition (1)
- Publication (0 + 58)
  - Local_Government_Publications (0 + 19)
    - Hawkes_Bay_RC_Publication
    - Manawatu_Wanganui_RC_Publication (19)
  - NZ_Government_Organisational_Publications (37)
  - NZ_Oranisational_Publications (2)
- PublicationType (8)

11.5.2 List of Properties

Table 11-8: List of properties in the E-Government ontology (one of two)

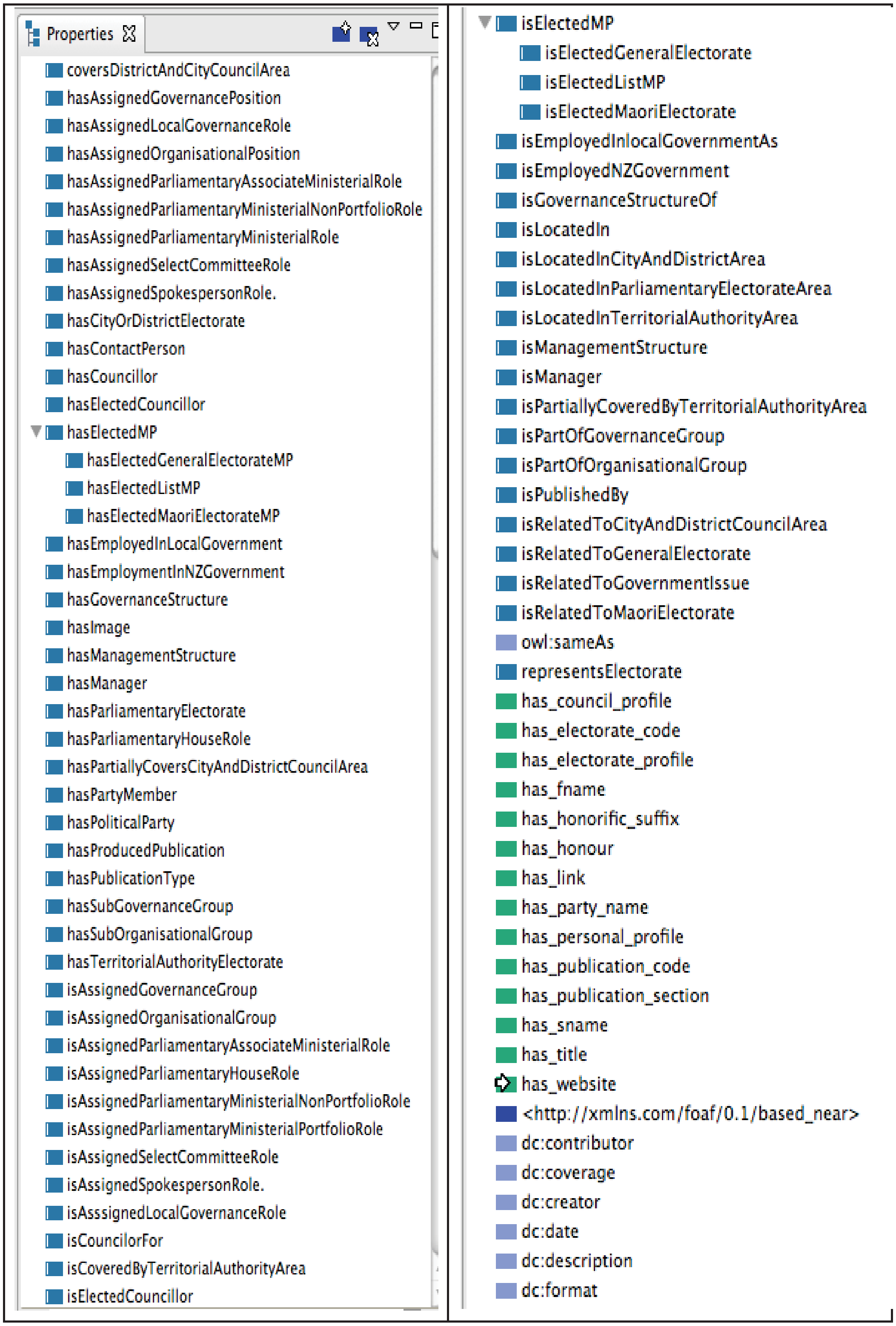


Table 11-9: List of properties in the E-Government ontology (two of two)