HIPPOCRATIC DATA SHARING IN E-GOVERNMENT SPACE WITH CONTRACT MANAGEMENT

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HIPPOCRATIC DATA SHARING IN E-GOVERNMENT SPACE WITH CONTRACT MANAGEMENT

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Dedication

This dissertation is dedicated to my dear sweet little angel:

Tanvi Aiyadurai

She is my motivation, inspiration and the liveliness.

Acknowledgement

To my supervisors Professor Dr. O. O Olugbara and Professor Dr. Thiruthlall Nepal, I have been eternally grateful for your leadership, patience, critique, motivation and valuable inputs in my research work. I appreciate your expertise, wisdom, cheerful encouragement and vast research knowledge that came in handy towards shaping this research. I am always motivated with your positive energy.

To my family for tolerating me and supporting me during the course of study.

Declaration

I, Yoganand Aiyadurai, hereby declare that the dissertation submitted for the degree Master in Information Technology at the Department of Information Technology, Faculty of Information Technology at Durban University of Technology, Durban South Africa, is my original work and has not been previously submitted to any other institution of higher learning by other persons or myself. I further declare that all the sources cited and quoted have been acknowledged accordingly by means of a list of references and footnotes.

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List of Abbreviations

B2G	Business-to-government
DBA	Database Administrator
DIG	Data Integration Gateway
DHA	Department of Home Affairs
DSR	Design science research
DUT	Durban University of Technology
G2B	Government-to-Business
G2C	Government-to-Citizens
G2E	Government-to-Employee
G2G	Government-to-Government
G2N	Government-to-Non-profit
G2P	Government-to-Public
HDBs	Hippocratic databases
ICT	Information communication technology
IDABC	Interoperable Delivery of European e-Government Services to public Administrations, Businesses and Citizens
IDC	Industrial Development Corporation
IIS	Internet Information Server
IOW	Inter organizational workflow
N2G	Non-profit-to-Government
OCL	Object constraint language
SAPS	South Africa Police Service
SDSR	Soft design science research
SQL CE	Structured Query Language Compact Edition
TCP	Transmission Control Protocol
UML	Unified modelling language
WAS	Windows Application Service
WCF	Windows Communication Foundation

Artefacts

The Data Integration Gateway (DIG) system prototype is deployed on the web for evaluation and demo purposes. This prototype is awaiting for patent from Durban University of Technology (DUT). The URL details and the login details are provided below:

DIG system URL: http://yogiaiyadurai-001-site1/

Login details

a) Global Admin (Role: Data contract authorizer)
   User name - globaladmin
   Password - Globaladmin15$%

b) Department Admin (Role: Data contract manager)
   - Metro department admin
     User name - metroadmin
     Password - Metroadmin15$%
   - SAPS department admin
     User name - sapsadmin
     Password - Sapsadmin15$%
   - Home Affairs department admin
     User name – homeaffairsadmin
     Password - Homeaffairsadmin15$%

c) Department User (Role: Data contract visualizer)
   User name – deptuser1
   Password – Deptuser115$%

Abstract

The research reported in this dissertation focuses on seamless data sharing in e-government space because of the intrinsic complexity, disparity and heterogeneity of government information systems as well as the need to improve government service delivery. The often observed bureaucracy in government processes, especially when verifying information, coupled with the high interdependency of government departments and diversity in government operations has made it difficult to improve government service delivery efficiency. These challenges raise the need to find better ways to seamlessly share data between government to citizens, government to businesses, government to suppliers and government to public institutions. Obviously, efficient automatic data sharing is an important phenomenon that contributes to improvements in communication, collaboration, interaction and efficiency in the service delivery process because it reduces information verification time and improves reliability of information.

The general applications of data sharing systems become perceptible in institutions such as banks and government establishments where information verification is highly necessary in the process of service delivery. Data sharing usually occurs between a data holder and a data requester when copies of authorized data are transported from the source databases to the requester. This data sharing process should guarantee a high level of privacy because of the confidential nature of certain data. A data integration gateway (DIG) is being proposed in this research as a methodological solution to seamlessly share data in e-government space, using Hippocratic database principles to enforce data privacy.

The DIG system is a centralized web application that utilizes a lightweight database within the government data centre to hold information on data contracts, data sources, connection strings and data destinations. The data sharing policies are stated as contracts and once indentures on how to share data are established between different data publishers, it is possible to ensure a seamless integration of data from different sources using the DIG application being proposed in this dissertation. The application is malleable to support the sharing of publisher data that are stored in any kind of database. The proposed DIG application promises to reduce costs of system maintenance and improve service delivery efficiency without any change to the existing hardware infrastructure and information systems residing within different government departments.

CHAPTER 1 : INTRODUCTION

Data sharing is an important phenomenon that allows for disparate and heterogeneous information systems to effectively communicate supported by seamless transportation of data from sources to the target destinations. It is the ability to distribute data resources that are stored in one or more disparate data servers in the network to multiple applications or users. Data sharing is a key concept in 'open government' initiatives. Such initiatives inspire governments to share their data thereby forming a shared environment and encouraging innovation regarding provision of improved services for citizens and society. An effective form of data sharing can transform government into a smart-government. The industrial development corporation (IDC) defines smart government as "the implementation of a set of business processes and underlying information communication technology capabilities that enable a seamless flow of information (data) across government agencies and programmes to become intuitive in providing high quality of information and citizen services, increase efficiency, transparency and openness across all government programmes and activity domains" (Rubel 2011). The first important mission for the success of smart government is to share government data with citizens, which is called government-to-citizens (G2C) sharing (Choi *et al.* 2013). In general, governments collect huge volumes of data items such as demographic, asset ownership, criminality, health, financial and traffic data and store them in their information systems or store them as manual documents, depending on the situation. The sharing of government collected data in an unprecedented manner may create innovative products and services for citizens, businesses and governments (Choi *et al.* 2013).

Automatic sharing of data is particularly useful in a complex e-government space to improve efficiency of service delivery. In this dissertation, an e-government space is defined as a multidimensional virtual ecosystem of data sources, information systems, data providers and data consumers where different dimensions represent the diverse automated resources and functions of government. An example of an e-government space is the virtual space of automated resources and functions of two government departments, South Africa Police Service (SAPS) and Department of Home Affairs (DHA). The virtual space spanned by SAPS and DHA completely describes the automated resources and functions of these two departments together with how these functions and resources are shared in relation to external agencies. Data sharing places a huge demand on data security or privacy because of the confidentiality of different kinds of data that are kept in such a virtual space.

There are many existing techniques for ensuring that data are kept secure, prominent amongst these being cryptography and secured network channels. While these traditional techniques provide acceptable solutions to data security problems to a certain extent, they can still be compromised because of the impossibility to achieve 100% security in real life. In addition, these techniques provide little confidence to data providers because resource providers are not directly involved in the data security process. It is prudent therefore to provide several layers of data security to increase the confidence level of data publishers or owners in e-government space.

In recent times, researchers have proposed a set of Hippocratic database principles as a way of securely managing disclosure of privately owned data (Massacci *et al.* 2006). The attractiveness of the Hippocratic database principles is that they guarantee respect of privacy principles in data management. This research reports on a Data Integration Gateway (DIG) which is based on Hippocratic database principles to improve and speed up the delivery process of government services through seamless sharing of data. The idea of a DIG as proposed in this research is motivated by the elementary principles of the Hippocratic oath that apply to information systems to afford data security by applying privacy and confidentiality principles (Agrawal *et al.* 2002; Azemovic 2012). The very factor that makes the internet a powerful medium for seamless sharing of personal data has also led to criticism over the loss and violation of privacy (Kim and Kim 2010). The research community must therefore be concerned with the great challenges of open data, big data, and the reliability of stored data and fool proof computing when designing new information systems. There must be no compromise with the security and privacy features of those information systems. The security and privacy must also be simple enough so that they are easily understood by an average user (Bernat *et al.* 2003). The maintenance of privacy controls becomes more complex across diverse distributed and heterogeneous systems that differ in operating systems and requirements where data security policy is often overlooked (Skinner and Chang 2006).

The focus of this research is on using the Hippocratic database principles to achieve seamless data sharing within the e-government space. The rapid advancement in information technology directed to the incorporation of computers with telecommunication gadgets in government institutions and private sectors has made it possible to improve the government service delivery process. Governments across the world have shown a willingness to reap the power of information communication technology for providing improved service delivery and to improve the effectiveness, responsibility and ease of service access along with

increased openness and transparency in government actions (Choudrie *et al.* 2005). The use of information communication technology, particularly the internet, to transform government processes is often called e-government, which is a multi-faced and varied field that must be carefully managed and supported by the government. The field of e-government is a concept that is ever changing and improving with the availability of new technologies and emerging challenges. Taking into cognisance the variety of solutions needed to implement seamless e-government, a general solution to fulfil all the requirements of seamless e-government and to come up with a common work process is very difficult to achieve. The essential elements of e-government are the following (Heeks 2001; Mkude *et al.* 2014; Grundén 2012):

a) E-administration – this solution is for refining the existing process or methods in government that can lead to reduced costs, improved performance and empowerment of strategic decision making.
b) E-service – this solution is for linking the government with the citizens, wherein the government consults with the citizens to support democracy and help improve the efficiency of public services.
c) E-society – all the entities within society such as business, citizens, private sectors and communities are connected together to work better outside the limitations of the government.

The accomplishments in e-government can be measured on the basis of effective collaboration between different sectors of government departments, businesses and citizens (Jaeger and Thompson 2003). The different types of collaborations often associated with e-government that can bring about significant opportunities to governments, citizens, businesses, employees, non-profit organisations and social-political organisations are the following (Yanqing 2011):

a) Government-to-government (G2G) – this involves communication and internal exchange of resources between government departments through an online platform to create an obvious impact on efficiency and effectiveness of service delivery.
b) Government-to-business (G2B) – this involves the electronic transaction activities such as e-procurement of goods and services between government departments and businesses.
c) Business-to-government (B2G) – this involves online transaction initiatives such as e-procurement and development of an e-marketplace for government purchases and procurement of tenders for sales of goods and services.

d) Government-to-citizen (G2C) – this involves offering public services online through electronic service delivery to increase the accessibility of citizens who consume those government services.
e) Citizen-to-government (C2G) – this involves online business transactions such as tax payment, issuance of certificates, renewing of motor driving license that citizens can initiate to engage directly with government.
f) Government-to-employee (G2E) – this involves online initiatives that will facilitate the management of the civil service and internal communication with government and its employees to make e-career applications and processing systems paperless in e-office.
g) Government-to-non-profit (G2N) – this involves online information communication services provided by the government to non-profit organizations, political parties, legislatures and social organizations.
h) Non-profit-to-government (N2G) – this involves online exchange of information communication services between non-profit organizations, political parties, legislatures and social organizations and government.

The collaborative sharing of data in e-government space can be appositely classified as a new type of e-government called government-to-public (G2P) sharing (Choi *et al.* 2013). The G2P sharing paradigm advocates for openness to receive data or information pertaining to citizens and share them in a timely manner amongst government agencies that need those data or information towards enhancing the efficiency of public service delivery. This also facilitates the creation of integrated personalized services that can be delivered to citizens anywhere, anytime and to any device, transcending space, time and device differences. This would sustain the smart-government development, allowing different types of data and information sharing environments. However, provision of secure and trusted data in information sharing is the utmost critical issues that will prevent leakage of secret and sensitive information (Choi *et al.* 2013).

The study reported in this dissertation contributes to one of the four central research questions in e-government, which is how decentralized government operations can be seamlessly integrated (Scholl and Klischewski 2007). Moreover, the research concretely fits into three research themes, namely information quality, data privacy and personal identity as well as crossing borders that require governance proficiencies as identified in the eGovRTD 2020 project (Wimmer *et al.* 2008).

1.1 Problem Statement

Although e-government offers several opportunities such as increasing efficiency in streamlining government procedures, refining internal communication and to provide better customer services, it is still facing many challenges, including value realisation (Juell-Skielse and Perjons, 2010), multi-technological chaos (Rosengren and Ohlsson, 2011), privacy, security and disparities in computer access (Yang, 2011). In the context of South Africa, the current huge concern for the government is the disconnected resources and operations of various government departments. All the departments have their own internal information systems catering for their own immediate needs without considering the future needs of data sharing that can facilitate improved service delivery. Departments are not seamlessly connected but instead are operating in silos. The automation of government activities in a silo brings in danger and other challenges as governments cannot consolidate and standardize their operations, preventing governments from reducing costs of maintaining their information systems. Governments can massively reduce costs, time and effort needed for running the operations of their information systems by promoting merging, elimination of duplication and normalization of information systems through the process of secure data or information sharing. The freed up resources can then be used for other useful projects that may benefit society at large (Cowell and Martin 2003).

The Department of Public Service and Administration of the Republic of South Africa has mentioned that the greatest hurdle is to upgrade the existing information systems across government departments and to use cloud computing and web technologies at different levels and for different processes. This change will enable the government to reduce the costs of system maintenance and will pave the path for integrated e-government (DPSA 2014). The following issues, therefore must be adequately tackled (Lofstedt 2012; Cordella 2013; Linders 2012):

a) The speed of service delivery process must be at acceptable levels.
b) Reducing costs of the infrastructure changes by using the existing infrastructure when the changeover happens.
c) The latest and most efficient technology must be used to fulfil government mandates.
d) Develop a vision of a connected government and use information technology to support government objectives and a broader development agenda.

e) Document, re-engineer and streamline administrative and business processes to deliver simpler, more effective services to citizens, businesses and other stakeholders, thereby contributing to the strategic objective of customer service improvement.
f) Develop and implement immediate and interim measures to support effective and secure information technology environment for governments.
g) Build the institutional arrangements and governance in which an effective team is supported to realize much needed transformation and the building of a secure, cost effective and aligned information technology capability on behalf of the state.
h) Redefine, rebuild and reinvent an information technology model for government or single public service.

Any two separate government institutions willing to collaborate effectively must define a common process, policies and outline the workflow. The inter-organizational workflow (IOW) is a framework used by most organizations to support effective collaboration between the varied and distributed business processes of diverse organizations to achieve a shared goal. The management of the diverse organizations is the ultimate problem in the IOW and remains the main reason for the failure in many e-government projects. In addition, numerous other problems related to e-government still exist, such as self-motivated work space, committed environment, semantic data interoperability and technical interoperability. The information systems within the government space also face two major problems, which are technological interoperability and data heterogeneity (Chaabane *et al.*). Hopefully, seamless data sharing mechanisms in e-government space can help to address the challenges of effective collaboration, openness, and transparency and information quality.

1.2 Research Question

The intrinsic problems hindering effective interaction between government departments or their information systems can be adequately resolved through a seamless data sharing mechanism. As a result, arising from the problem statement is the following research question being pursued in this study:

- How should data be seamlessly shared in e-government space such that privacy of an individual or an organisation is not overly compromised?

1.3 Research Goal and Objectives

Stemming from the research question enunciated, the overarching aim of this study is to create a web application, is based on Hippocratic database principles, to support seamless sharing of data in e-government space. The study at hand is guided by the following research objectives:

a) To enable seamless data sharing across diverse government departments without any changes to the existing system infrastructure.
b) To control the volume of data sharing more securely across government departments using a coherent contract management technique implemented according to Hippocratic database principles.
c) To reduce the time delay often experienced during cross verification of data involved in government services.
d) To maintain a high level of consistency when data are shared across government departments.
e) To eliminate the storage of duplicate data across government departments by sharing the data from the source of truth.

1.4 Research Methods

The methodology of this study is primarily "soft design science research" (SDSR). The goal of design science research (DSR) is to solve important business problems by creating and developing good solutions using the latest information communication technology. The DSR depends on the use of demanding methods to build and evaluate a design artefact (Hevner and Chatterjee 2010). The creation of a lighter approach to DSR to address the important business problems was suggested (Baskerville *et al.* 2009). Soft system methodology (SSM) is an outstanding system science method to tackle the social-technical complications facing an organisation. The SDSR methodology combines the principles from SSM with DSR to provide a design thinking methodology to solve real world problems using good technology. SDSR provides the possibilities to create new ways to progress and advance organisations related to humans and to coherently tackle socioeconomic issues. SDSR enables the process of developing solutions by following through the phases of design, implementation and evaluation of a technological artefact. It enables identification and delineation of a specific problem to solve. The problem must be articulated as a specific set of system requirements.

The requirements for the precise problem defined are then abstracted and converted into a general problem with a technical, procedural and social dimensions. A common solution design or a class of solutions for the general problem is then derived through systems thinking and concretely expressed in terms of the general requirements. The general design requirements are then compared with the precise problem for fitness. In this activity, the precise problem has to be re-articulated in terms of the general requirements. A declarative search is thereafter made for the particular components that will deliver a workable instance of a realistic solution to the general requirements. An instance of the specific solution is constructed, evaluated and deployed in the social system setting (Baskerville *et al.* 2009). Crucial to the application of SDSR methodology in this study is the adoption of the unified modelling language (UML) as a useful tool to support the modelling, visualisation and representation of the components of DIG artefact being proposed. The UML helps to facilitate different modelling activities of SDSR and DSR, such as exploration for general components of a solution, together with ability to express the functionalities of the artefact using imperative logic. The UML through its object constraint language (OCL) expressions offers the capability of imperative logic to express constraints of the DIG application.

1.5 Study Scope

This research was motivated by the experiences faced by the citizens when accessing the services of South African government departments. With the e-skills Colab at Durban University of Technology behind the motivation of this research study, a cost effective DIG solution is proposed to enable seamless data sharing between government departments that will help to speed up government services without any changes to the government infrastructure. The significance of the study is geared towards improving the service delivery of South African government departments. The systematic documentation of the research process, implementation of the proposed DIG application and results of the evaluation of the study will greatly contribute to the information technology and e-government knowledge domains. In particular, the significance of this study, is to deliver the services of the government faster by eliminating the waiting period for data verification across inter departments within the government space.

The scope of the research study at hand is limited to the government departments within South Africa. The prototype DIG application for this case study is designed to solve the process of current data sharing within government departments, which currently are

mainly a manual process and time consuming. However, the DIG application has a wider usefulness and can be used by any organization that wants to speed up their process of data sharing in the most secure way with data contract agreements.

1.6 Contributions

This research proposes the development of a lightweight data integration gateway (DIG), which is a web application that can be used to facilitate seamless sharing of data maintained by different disparate and heterogeneous information systems. The proposed DIG application satisfies the following requirements:

a) Convenient – the language based on contract management policy borrowed from Hippocratic database principles for specifying data of interest is intuitive, simple and user friendly.
b) Preservation – enforcing data privacy policies through a set of contract agreement policies that do not require any change to the current database systems managing the source databases.
c) Persistency – data privacy policies could be created, stored and can be managed as contracts in an external database that is private to the gateway.
d) Protection – contents of source databases are not altered, no data write access given to the gateway and data read by the gateway from the source databases are not stored in the database maintained by the gateway, but such data are delivered to the requesters as portable files.

The potency of the Hippocratic data sharing approach being proposed in this study is built on two technical properties. Firstly, it supports field and record level data privacy enforcement policies. Secondly, it allows full use of the standard structured query language (SQL) query capabilities to express policies for seamless data sharing. In more detail, the contributions of the research reported in this dissertation are:

a) The investigation of an approach for a seamless Hippocratic sharing of data maintained by different heterogeneous information systems with specific reference to e-government space.
b) The examination of several implementation issues of a seamless Hippocratic data sharing technique, including secure metadata storage, efficient query formulation policies and data structure for the storage of contract information.

c) The experimental evaluation of the proposed application shows that the data sharing approach has low overheads and speeds up data sharing and information verification time.

The original research reported in this dissertation piggybacks on a number of existing techniques and principles to evolve DIG for a seamless sharing of data with focus on e-government space. However, the proposed application has a much wider spectrum of applications. A growing range of possible application areas are in content management applications, customer/consumer support services, e-commerce and e-education which require intensive levels of data privacy. Many such applications may use security policies to seamlessly access control data and eliminate duplication of data. The dissemination of the results of this research will definitely contribute to knowledge sharing in the e-government field.

1.7 Synopsis

Chapter 1 of this dissertation introduces the background to the research and discusses the need for data sharing across government departments with particular reference to the South Africa scenario. In addition, the context of the problem domain, the research question that guides the study, the goals and objectives of the study, the research methods used, the scope of this study and decisive contributions of the study are clearly delineated in this chapter.

Chapter 2 comprehensively discusses the related literature on e-government, data sharing and Hippocratic data contract. Chapter 3 provides the systematic documentation of the research design and holistic approach that is followed in modelling the proposed prototype application for the Hippocratic data sharing management within the e-government space. This chapter also unpacks the theoretical foundation that guided the research and how the soft design science research methodology was systematically followed in designing the prototype data sharing application being proposed in this study. Chapter 4 presents the implementation of the prototype data sharing application and discusses the evaluation of the artefacts in addressing the research problem. Chapter 5 discusses the results, presents the reflection of the researcher and concludes with recommendations for further research.

CHAPTER 2: LITERATURE OVERVIEW

This chapter focuses on providing a rigorous and structured overview of relevant literature with regard to their coverage of description of e-government, opportunities for e-government, challenges in e-government, growth stages of e-government, the state of e-government in developing countries, technology adoption for data sharing in government departments and e-government data sharing models.

2.1 Definition of e-Government

There exists numerous e-government definitions in the literature, but they are all associated with the use of information communication technology (ICT), mainly the internet, to transform, re-engineer, improve or enhance government business processes. The term "information communication technology" covers internet technologies, internet applications, internet services and internet based components that are needed to execute business solutions more effectively and more efficiently. Sinawong (2008) states e-government as the use of ICT, particularly the internet, as media to achieve a better government that delivers improved public services and enhances internal department works in a more useful, customer oriented and cost effective manner. Yanqing (2011) states that e-government is the use of ICT to improve government processes and re-engineer government services. Fang (2002) defines e-government as the innovative use of ICT to provide more convenient access to government information and services, making government services accessible from anywhere anytime. This in turn improves the quality, reduces time delay and encourages more participation between the government and citizens. Nkwe (2012) argues that ICT has changed the way human activities are performed in different sectors around the world. Yanqing (2011) states that implementing e-government crosses many service delivery, legislative, digital divide, privacy, public access, and information security issues.

In general, governments across the world see ICT as a protagonist for government reform because their aspiration is to improve the welfare of citizens and to deliver quality services that add value to the citizens. Private companies have adopted ICT quickly and

across the spectrum to do their daily business more efficiently. Information communication technology has also changed the way governments deliver services to their citizens and businesses as well as how they communicate and interact with people who need government services. A visit to government departments is a not a pleasant experience as the services offered by government is characterised by a lot of paperwork with the intrinsic manual process, long queues for each section of services, inadequate spaces and a lot of frustrations related to inefficient services. The transition around the world to using ICT for government service delivery has provoked citizens to demand better services from the government. The public sector and governments are under heavy pressure to deliver the services at the needed time and with high quality. Citizens and business organisations prefer engaging government services without having to physically go to the government departments. Governments are doing their best to tackle these expectations by reforming and re-engineering the existing government processes and translating them to ICT automated processes.

2.2 Opportunities for E-government

The effective application of e-government to fulfil the aspirations of citizens and businesses is the cardinal motive of governments across the world. Governments are putting a strong effort on using ICT to redefine, re-engineer and reorganise public services to better serve their citizens. ICT provides efficient resources and a platform for data sharing, information dissemination and communication, which are the key functionalities needed for effective public participation in government. In order to seamlessly integrate all the information systems in the government departments to support massive citizen's participation in government activities, the existing work processes which brought about e-government in the first place must be improved, redesigned or re-engineered. The government process redesign opens up new possibilities for information availability, communications possibility, seamless services to its citizens and good planning process through the use of e-government (Bhattacharya *et al.* 2012). The assurance of E-government is to make the government more responsive, efficient, legitimate and transparent, which is a technical, economic and social problem.

Ndou (2004) pointed out a long time ago that government and the public have realized the several opportunities offered by ICT to fulfil the insatiable demands of citizens. ICT in government reforms have great potential to provide better services to the citizens and can increase government efficiency by enabling the restructuring of the existing process in the

government. The challenge of e-government is how to help facilitate citizens-to-government interactivity and make service delivery more efficient by allowing data or information sharing. Moreover, the current structure of government departments and their information systems are disparate and filled with virtual boundaries, making it difficult to achieve effective data sharing with minimum costs. The challenge of inter-organizational or inter-department data sharing has given rise to organizational boundaries. Data sharing overcoming cross-boundary in terms of departments and integrating them has been long identified as major enablers for improving government departments and organizational efficiency (Thakur and Singh 2012). The government of any nation can achieve healthier strategic decisions and better-quality problem solving techniques when its departments have aggregated data and knowledge sharing across boundaries (Mohammed *et al.* 2012).

Researching the significance of inter-department data sharing, vertical and horizontal directions data sharing have been identified and a theoretical framework for understanding the boundaries in data sharing initiatives has been defined (Thakur and Singh 2012). The integration of various information systems inside and across external organizational boundaries remains costly and time-consuming (Mohammed *et al.* 2012). This is because of heterogeneity of computing environments involved and a shortage of technical infrastructure in the public sector. The growing cooperation of organizations has resulted in the need to share data more effectively. The sharing of information is still affected by privacy concerns, organizational structure and technical issues, which have to be taken into account (Asogwa 2013). The existing literature studies have identified a host of opportunities that e-government offers, including the following:

a) **To increase efficiency by streamlining the business process**: implementing e-government could decrease the number of stages involved in tedious business processes and functions that are currently manual. This saves effort and time and reduces the pressure around government offices (Ndou 2004; Almarabeh and AbuAli 2010; Singh and Karaulia 2011).
b) **To improving internal communication**: using ICT to connect within local government can be made easier. Tracking of the events and programme happening in each department is easier. Head of the department can keep the executives up-to-date with regular communications and emails (Almarabeh and AbuAli 2010; Singh and Karaulia 2011).
c) **To providing better customer service**: giving self-service access to information via the internet can definitely improve citizen's access to government services.

Technologies like automated telephone systems can improve citizen services (Ndou 2004; Singh and Karaulia 2011).

d) **To keep pace with citizen expectation:** society is being moved to the latest technologies, citizens and business are working electronically and therefore they expect the same from their local government (Singh and Karaulia 2011).

e) **Sharing data constantly and consistently:** data sharing leads to transparency, openness, anticorruption and accountability as citizens participate in decision making with the government based on information at their disposal. Government will be run by the people because individuals are well informed about government activities (Ndou 2004; Singh and Karaulia 2011).

f) **Reducing cost or increasing revenue:** implementing e-government leads to centralizing government information systems and removes duplication of information and processes, thereby reducing cost and increasing government's revenue (Singh and Karaulia 2011)(Singh and Karaulia 2011).

g) **Restructuring of administrative process:** moving to e-government changes the way government interacts with citizens, business and other governments. This requires the restructuring of internal and external administrative processes so that they are more efficient (Singh and Karaulia 2011).

h) **Data and process standardization:** when data sharing is enabled with the implementation of government processes then most of the processes and formats of protocol used can be standardized across government departments (Hwang *et al.* 2004).

i) **Clearly defined authority and responsibility of users:** the users of e-government are accountable and responsible for the outcome of the services. This speeds up the service delivery process from the government end (Hwang *et al.* 2004).

j) **High security:** security and privacy are the key feature of e-government. Centralized systems within government data centers and secure access to government information increases the security of the systems and data when compared to the decentralized systems without e-government (Hwang *et al.* 2004).

k) **Decreasing corruption:** every service from every government department do exactly as per the rules and processes defined (Almarabeh and AbuAli 2010).

l) **Trust building:** e-government systems build trust between the government and the citizens by prompt, efficient, secure, cost effective service delivery from the government (Almarabeh and AbuAli 2010).

2.3 Challenges of E-government

Although e-government offers several opportunities for transforming government operations, there are still huge challenges. In the context of South Africa for an instance, the characteristics and challenges of data sharing amongst governments seem to be similar among all government departments. Although each government department has a centralised computing system for data storage and retrieval, the operation of departmental data is vertical integration between the head office and its regional or suburb offices. There is no provisioning of services that request for intra data sharing across different government departments that are disparately distributed. The current process of data sharing in many government departments in South Africa is still a manual process, which is very time consuming and prone to errors. The various studies from different government departments have identified environment, external and internal factors as hindering the process of data sharing in government departments (Davison *et al.* 2005; Kasim 2008; Tsai *et al.* 2009). Even though the internet infrastructure in South Africa ranks highly, this infrastructure is not used much. To overcome the infrastructure and the application upgrade challenges to use the latest internet technologies will take a long time. The fastest way to implement and enable data sharing amongst government departments, which is the motivation for this research, is to use the existing infrastructure and still provide for data sharing.

As the internet is linking the vast majority of people together, the advancement of e-government represents government's reaction to the shifting world of information technology (Xu, W and Zhou 2008). With the e-government initiative the traditional government can tackle the traditional problems of government services, using the latest internet technologies and modern communication devices. This initiative will enable government to transform to e-government, but comes with many challenges that must be taken into account to accommodate the difficult relationships between government and its constituencies to enable transaction interaction and the delivery of government services (Wang and Hou 2010). The literature has identified a number of common challenges facing e-government across the world, including the following:

a) **Technological and infrastructure development:** implementation of the latest hardware technologies to accommodate modern internet and web technologies. This is a very costly transformation from traditional government to e-government

(Reffat 2003; Hwang et al. 2004; Ndou 2004; Sinawong 2008; Xu, W and Zhou 2008; Khan et al. 2010; Wang and Hou 2010; Dawes et al. 2012).

b) **Security:** security is costly and must be adequately addressed in the design phase of e-government. Security leads to trust, which is a vital component of e-government (Reffat 2003; Sinawong 2008; Xu, W and Zhou 2008; Yanqing 2011).

c) **Interoperability:** the ability to make systems and organizations work together seamlessly to enable data sharing and a comprehensive overhaul over the legacy systems is crucial for success of e-government (Reffat 2003; Almarabeh and AbuAli 2010).

d) **Privacy:** protecting the privacy of citizens' personal data and government department' private information, while enabling data sharing, is an important consideration for successful e-government (Reffat 2003; Sinawong 2008; Yanqing 2011).

e) **Digital divide**: this refers to the gap between people who have access to the internet and those who do not. Without internet the people cannot access the data, information or services which the government wants the citizens, business and government to access (Reffat 2003; Xu, W and Zhou 2008; Sang *et al.* 2009; Khan *et al.* 2010; Yanqing 2011).

f) **Transparency:** the lack of transparency between government and people prevents the public form actively participating in government decision making process (Reffat 2003; Ndou 2004; Almarabeh and AbuAli 2010).

g) **Web based service delivery:** the establishment of a secure e-government infrastructure and web based service delivery can be consider a difficult task because of the unavailability of technical personnel (Juell-Skielse and Perjons 2009).

h) **Awareness of potential costs:** lack of awareness of the potential cost of e-government amongst e-government practitioners can lead to implementation failure (Sinawong 2008; Dawes *et al.* 2012).

i) **Leadership and management factor:** political leadership with a clear vision is vital to ensure the successful implementation of e-government and efficient change management processes (Hwang *et al.* 2004; Ndou 2004; Sinawong 2008; Sang *et al.* 2009; Yanqing 2011; Dawes *et al.* 2012).

j) **Legal substructure:** the laws and regulation required to permit and to support the move to e-government are often not promulgated in many countries (Reffat 2003; Hwang *et al.* 2004; Xu, W and Zhou 2008; Sang *et al.* 2009).

k) **Institutional infrastructure:** e-government can only progress if there are institutions capable of supporting and implementing the technology at low cost (Sang *et al.* 2009; Khan *et al.* 2010).

l) **Low human capital index:** absence of ICT literacy skills and lack of readiness of local content and national language versions of government websites is a serious challenge (Ndou 2004; Khan *et al.* 2010).

m) **Trust:** e-government systems must be built and installed with trust from agencies across governments, business, Non-Governmental Organisations (NGOs) and citizens. They are the end users and their buy-in is a must to make the e-government systems successful (Almarabeh and AbuAli 2010).

2.4 Growth Stages of E-government

The original research reported in this dissertation has classified the growth stages of e-government into inception, maturity and innovation based on decades of advancement in ICT.

2.4.1 Inception Stage

During the periods of 1990 to 1999, the implementation of e-government made significant interaction between government employees and their departments easier. Computing technologies such as minicomputers, mainframe computers and desktop computers were predominantly used to automate the business processes of government. Meanwhile, the service subscribers or citizens faced difficulty in accessing services mainly because of interdependency between various government departments. There was considerable delay in the verification of data or information pertaining to a subscriber when more than one government department had to be consulted. Figure 2.1 portrays this scenario, wherein high communication latency can be observed between service providers and service subscribers, but there was low communication latency between government departments. This was due to the fact that individual service subscribers had to physically visit each government department for a service subscription process to be successfully completed. The inception

stage can be likened to the first generation e-government, which is more about computing adoption by government for business process automation.

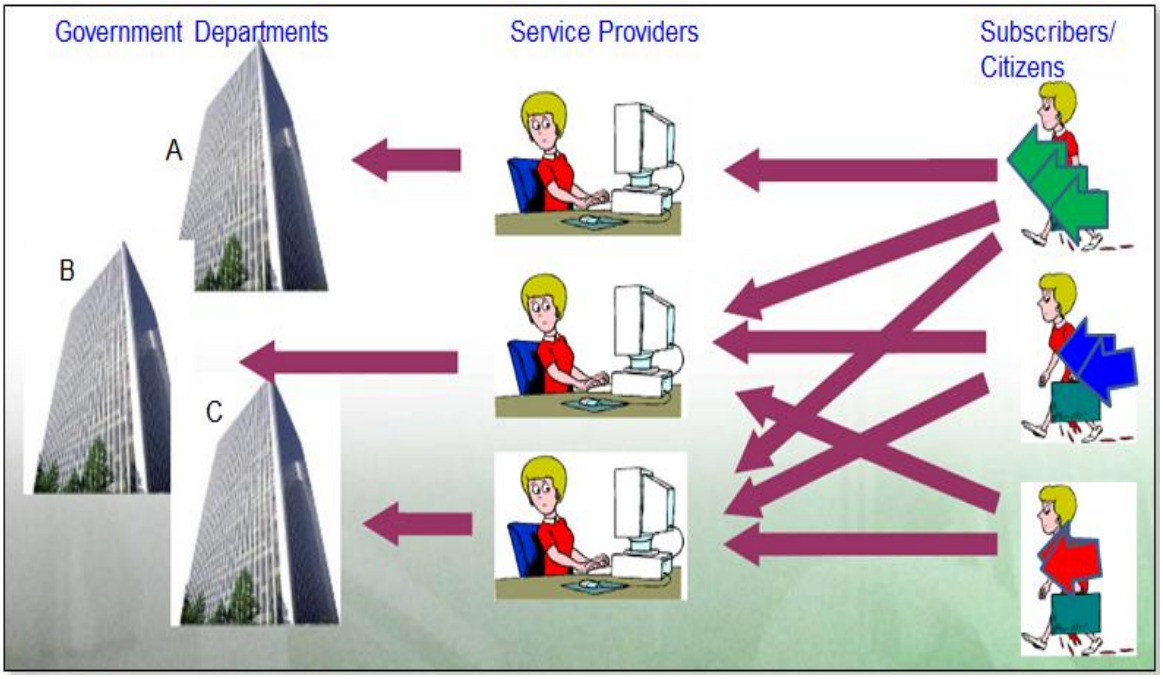

Figure 2.1: E-Government reforms at the inception stage (1990-99)
(Tallo 2013)

2.4.2 Maturity Stage

The advancement in e-government technology from 2000 to 2010 made the interaction between government employees and subscribers easier. This was the period of electronic transformation of government business processes. During the period, the world experienced massive applications of computing power through the emergence of the internet and web applications to offer government services online. The maturity stage can be likened to second generation e-government in which technology enabled government transformation into subscriber-centric and integrated government. The subscribers could access services within a particular government department without feeling the interdependency that exists across diverse government departments. However, as shown in Figure 2.2, this improvement in service delivery does not eliminate the complication in the interaction between service providers and government departments, making service delivery inefficient. This was because of high interdependency between government departments and inability of different government information systems to seamlessly interoperate and share subscriber data effectively (Tallo 2013).

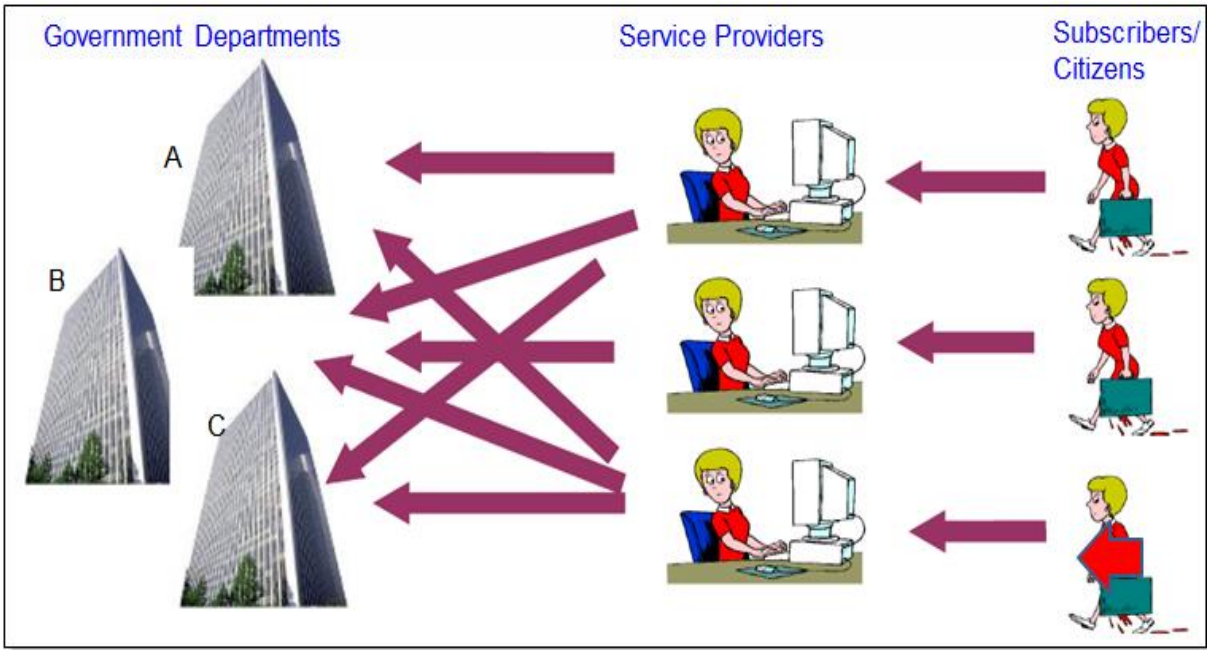

Figure 2.2: E-Government reforms at the maturity stage (2000-2010)
(Tallo 2013)

2.4.3 Innovation Stage

The current e-government vision for 2011-2020 is to solve data interoperability problems to improve efficiency in service delivery. The period 2011-2020 is regarded as an innovation stage of e-government or third generation e-government where technology will enable government transformation into smart government. During this period computing power, such as cloud computing, mobile devices, smart televisions, sensor and wireless devices, mobile networks and phatic technology will be used to transform government processes that allow citizens and civil society to co-create with government. Phatic technology is any kind of technology such as social media – Facebook, LinkedIn, Twitter and WhatsApp – that facilitate communication, content sharing, collaboration and interaction amongst people. The use of big data analytics, which is the discovery and communication of meaningful patterns in data, will drive government policy action, facilitate effective communications, rapid transaction execution and improve service delivery. There will be openness, transparency, accountability, innovative services, data privacy and massive availability of information for knowledge creation and knowledge transfer. Governments across the world will able to provide service bundles for governmental one-stop-shop to their subscribers as an effective

way of improving service delivery (Linders 2012). The one-stop-shop service allows subscribers to get everything they need in just one stop without any officialdom.

This new version of innovation in government offers the reward that efficient interaction between subscribers and government departments will be facilitated by web, internet, cloud and mobile phones using a central government gateway. The central gateway will absorb all the convoluted interactions using a mobile cloud service technology to deliver real-time innovative services to subscribers (Tallo 2013). Figure 2.3 portrays this innovation in e-government business processes.

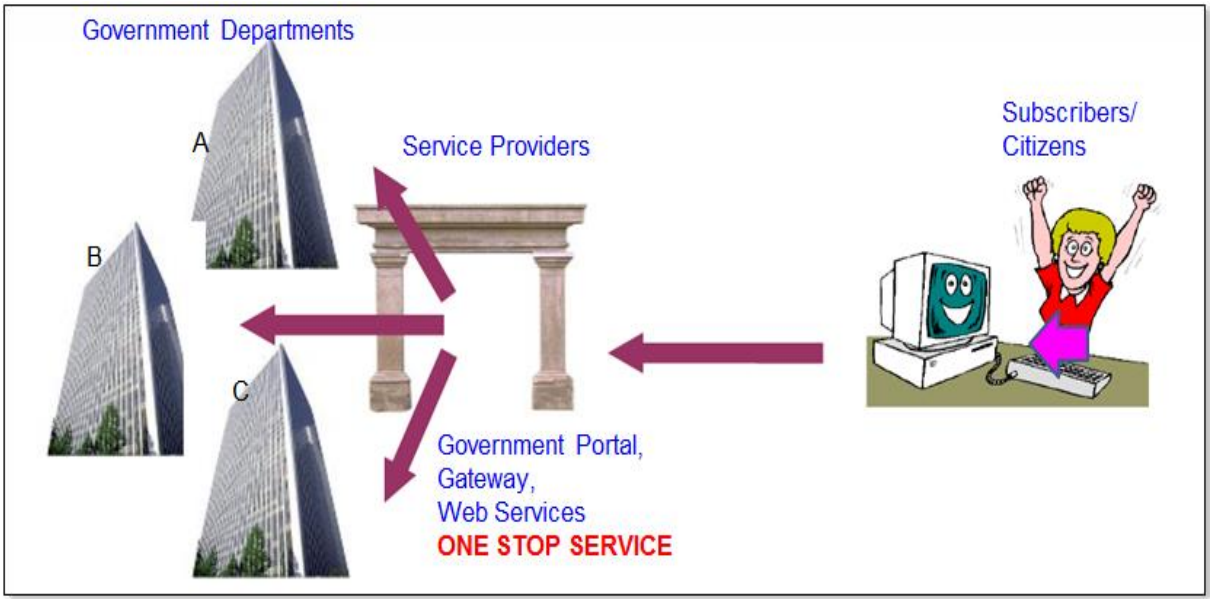

Figure 2.3: E-Government reforms at the innovation stage (2011-2020)
(Tallo 2013)

The research reported in this dissertation purports to lay a solid foundation for smart government and can be classified as contributing to the innovative stage of e-government. This research proposes Hippocratic data sharing management in e-government space in order to significantly contribute to the future e-government vision. The Hippocratic data sharing mechanism requires a data sharing contract to be established between government departments that want to participate in the data sharing process. This implies that any information that is required by a subscriber would automatically be sent to the target source which is the publisher, provided that information resides elsewhere centrally within the e-government space and the subscriber can access the data by contract. In the context of this research, a contract denotes the specification of rules or policies governing data disclosure. A particular government department or an institution, for example, adopts a data disclosure

contract to specify who is allowed to access what data and for what purpose data may be disallowed to each recipient (Agarwal 2012). The contracts are expressed in a simple and understandable privacy language.

2.5 State of e-Government Development in Developing Countries

Implementing e-government to fulfil the needs and aspiration of citizens and business are the main motive of governments across the world. Governments are putting strong efforts into redefining and reorganizing public services for the benefits of their citizens. With e-government, data sharing and easy communication is made possible, which are the key functionalities needed for public participation in government. In order to facilitate seamless integration of all the systems in the government departments, the existing work process must be improved and redesigned. This required redesign opens up possibilities of achieving information availability, effective communications and good planning processes. The key emphasis of e-government across countries is to provide seamless services to its citizens (Bhattacharya *et al.* 2012).

Many developed countries of the world have successfully implemented e-government which is making an impact on, and changing the lives of, their citizens. There are a lot of case studies that illustrate this direction. The IDABC (Interoperable Delivery of European e-Government Services to public Administrations, Businesses and Citizens), which is the European Union Program that promotes the correct use of ICT for cross-border services in Europe (IDABC 2009). There is also the IBM Smarter Government initiative that promotes collaboration from the local council to international level in the United States of America.

When we compare the countries in the Africa in terms of their state of e-government development, against the rest of the world, it can be stated without any doubt that African nations have to go a long way to achieve the full benefits of e-government implementation. There are several challenges in African countries such as scarcity of internet access, lack of proper internet infrastructure, lack of transparency and accountability in government, that are hindering e-government development.

Mutula (2008) points out that from an African perspective, finding a precise status of e-government implemented in sub-Saharan Africa is difficult because the majority of case studies conducted on e-government do not fully cover each and every country in the designated location. Thakur and Singh (2012) state that in recent years there has been increased pressure from citizens and business on governments to deliver quality services that

are more efficient, reliable, convenient and faster. The applications, systems and platforms designed to fulfil the requirements of quality services are referred to as e-government. E-government services are being provided by connecting the government, citizens and business, but the availability of such services are few and expensive. Due to this reason citizens are raising their anger and are demanding improved service levels. In order to achieve government-centric services, they must be developed to fulfil citizen led initiatives.

Heeks (2001) reiterates that e-government programmes in South Africa are usually implemented by following the top-down approach. This approach focuses on management ideas and therefore the requirements of the citizens are not as much in focus as they should be. In order to provide a robust and better public service delivery, good and smooth communication between the government and citizens is a must. E-government platforms in developing countries provide an excellent channel for communication between government stakeholders and the public in real time. E-communications have become gradually more essential for interacting, communicating and exchanging data/information in the workplace. Many of the organizations are dispersed and are geographically isolated, so e-communication is a can solve inherent communication problems (Abodohoui *et al.*, 2014).

Rorissa *et al.* (2011) benchmarked e-government development in a sample of sub-Saharan government websites. They placed Algeria, Angola, Benin, Botswana and Burkina Faso as the top 5 countries with developed e-government. South Africa was placed in the 49th position out of 58 countries. The research work at the Waseda University for nine years monitored and surveyed the development of e-government worldwide and has scored Singapore, Finland and USA as the top countries that are well developed in e-government amongst the 55 countries that were studied. Figure 2.4 shows this result of e-government development ranking, where it can be seen that only four Africa countries featured in the raking. South Africa was ranked 36, followed by Nigeria (ranked 47), then Egypt (ranked 48) and Tunisia (ranked 53).

No	Final Rankings	Score
1	**Singapore**	**94.00**
2	**Finland**	**93.18**
3	**USA**	**93.12**
4	**Korea**	**92.29**
5	**UK**	**88.76**
6	**Japan**	**88.30**
7	**Sweden**	**87.80**
8	**Denmark**	**83.52**
8	**Taiwan**	**83.52**
10	**Netherlands**	**82.54**
11	**Australia**	**82.10**
12	Canada	81.78
13	Switzerland	81.33
14	Germany	80.08
15	Italy	79.11
16	New Zealand	77.29
17	Norway	75.53
18	Belgium	72.01
19	Estonia	71.76
20	France	69.49
20	Thailand	69.49
22	Portugal	69.11
23	Turkey	67.10
24	Malaysia	66.26
25	Hong Kong	66.12
26	Spain	65.89
27	China	65.69
28	Mexico	64.24
29	UAE	63.34
30	India	62.77
31	Brunei	60.89
32	Israel	60.25
33	Brazil	59.88
34	Russia	59.32
35	Macau	58.65
36	South Africa	57.77
37	Vietnam	55.42
38	Czech	55.06
39	Chile	54.87
40	Indonesia	53.05
41	Philippines	50.88
42	Romania	49.72
43	Argentina	49.23
44	Pakistan	47.25
45	Venezuela	47.20
46	Peru	46.56
47	Nigeria	45.20
48	Egypt	44.11
49	Kazakhstan	37.27
50	Georgia	34.98
51	Cambodia	33.52
52	Fuji	32.65
53	Tunisia	31.33
54	Iran	30.77
55	Uzbekistan	30.35

Figure 2.4: Waseda University E-Government world ranking 2013 (de Jager and van Reijswoud 2008)

In many developing countries of the world, government is redesigned by two types of emerging trends. The top most trend is decentralized, hierarchical and vertical government systems to the polycentric networks of governance, built on horizontal integration between different departments and multifaceted societies. The next change is the introduction to ICT that is targeted at transforming the delivery of public services. The e-governance concept is a merger of these two trends (de Jager and van Reijswoud 2008).

Heeks (2001) mentioned three separate, but interconnected practical domains of e-governance (Figure 2.5) that when implementing e-government must be carefully considered and proper analysis must be done to avoid the overlap and duplication of their functionalities. These domains are:

a) E-Administration – improving the business processes of government using ICT.
b) E-Services: connecting individual citizens with their governments using ICT.
c) E-Society: building interactions with and within civil society using ICT.

Figure 2.5: Overlapping of e-governance
(Heeks 2001)

The governments in developing countries are under intense pressure to review and update their business processes (Jager *et al.* 2008). The developed countries that have implemented e-government are asking the developing countries to support decentralization, decrease corruption, increase transparency and to participate in the global digital information sharing. The private sectors in the developing countries are demanding additional openness and are keen to participate in open and transparent relationships with the governments. The citizens of these countries are demanding faster and better services and are demanding to extend the government services to rural areas. (Beynon-Davies 2007) states that over the last few years, many deficiencies are present in the current documented formations of e-government. Moreover, the majority of them are around the lack of holistic conception that takes into consideration, the full socio-technical environment of the government processes.

E-government therefore must solve the complex societal problems taking the technical and process change. Beynon-Davies (2007) presents a number of metal models that are organised around the vertical dimension that considers the aspects of infrastructure, which are made up of human activity infrastructure long with the informatics infrastructure. The horizontal dimensions use e-government business models, which are G2B, G2C and C2C and the value creating system (VCS) that supports the human activity. Figure 2.6 shows the human activity infrastructure of the e-government model where all human activity system in internal and external value chains will depend on information systems for effective, robust and efficient collaboration and harmonization of activities.

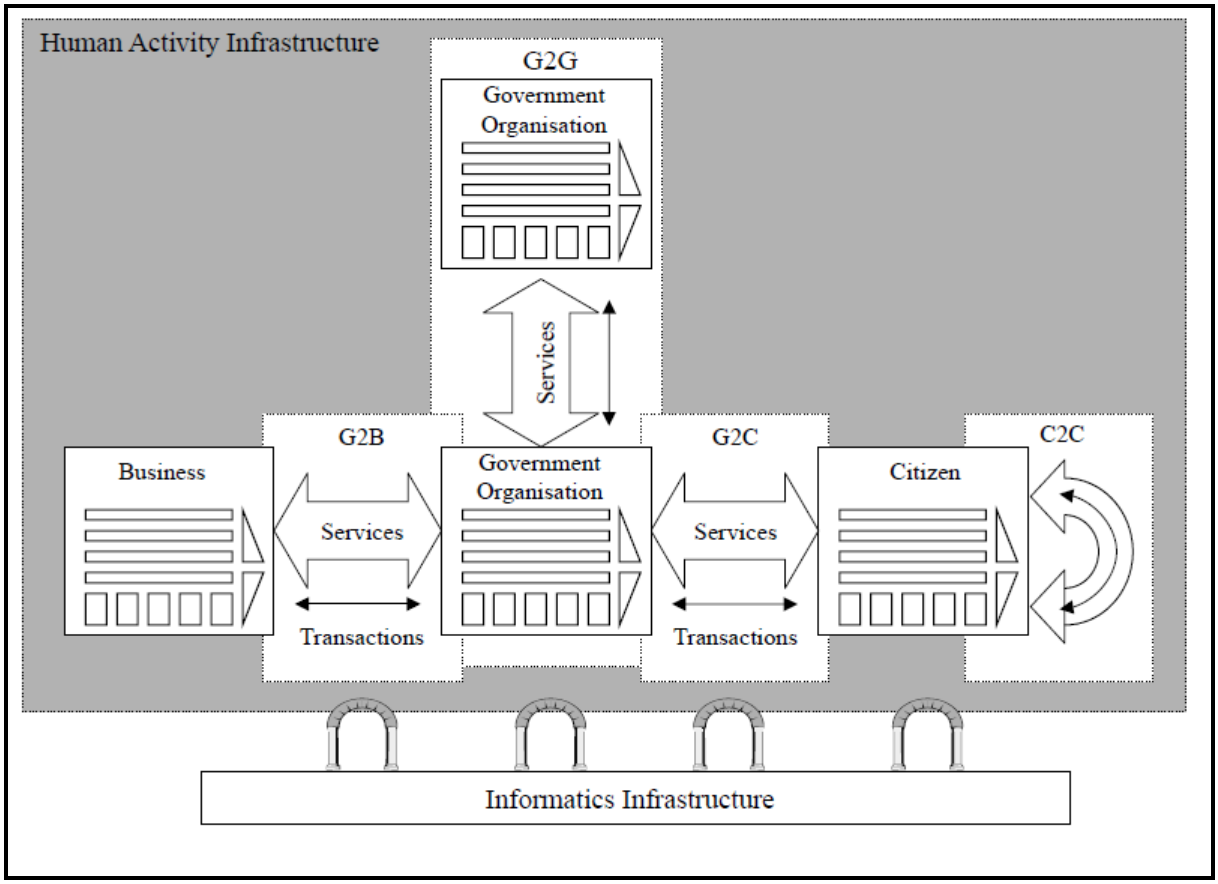

Figure 2.6: Human activity infrastructure of e-government model (Beynon-Davies 2007)

Davison *et al.* (2005) illustrated a transition model for the conversion from government to e-government and the steps needed in this process. The purpose of their model was to provide a guide for governments to clearly understand the motivations for the need of e-government, and to avoid any possible problems during the transition. They stated that in traditional government the perception of the government is a slow-moving and delayed administration, resisting to change with new technology, inconvenient and confusing process. In this type of government the citizens and business involve with the government in numerous areas, but because of the lengthy process and absence of new technology, a vast amount of paperwork is created. The early adoption of internet technologies promotes the automation of the existing government process with less redesign and innovation. The authors also stated that a good e-government characteristics should be openness, clearness of purpose and immediate responsiveness to its citizens along with its internal efficiency and effectiveness. Hence, they proposed the e-government maturity model and the strategic transformation to e-government (Figure 2.7). The mature e-government is recognised by the high levels of competence, performance and includes data sharing across government

departments and units that will help to reduce process times within the workflow of each government department.

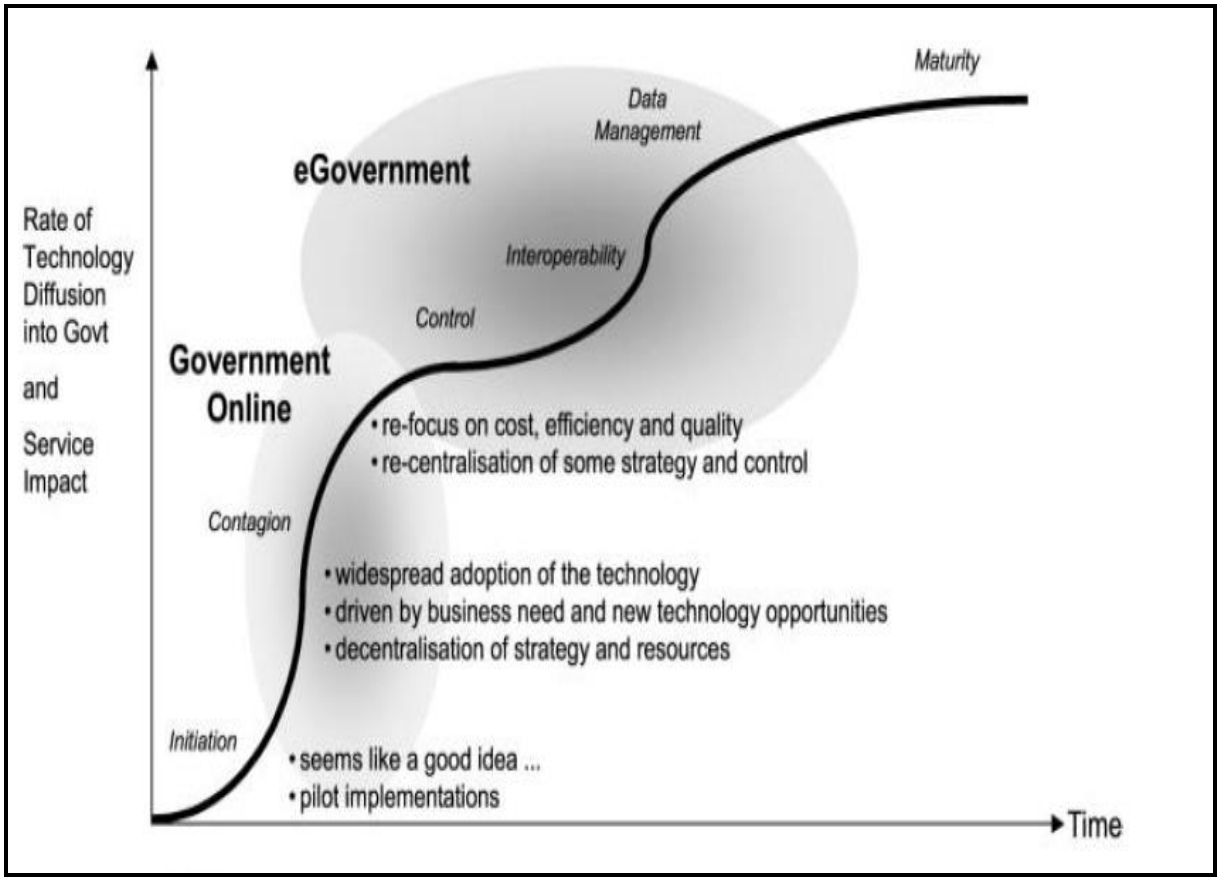

Figure 2.7: E-government maturity model
(Davison et al. 2005)

Sahraoui (2007) addresses the high failure rates of e-governments in developing countries because of the presence of a "design-reality-gap" where e-government programs did not mirror the reality of government. Sahraoui's view is that e-government should improve the activities and services of government by making government services more accessible, effective and accountable. When government services are delivered online via e-government to citizens, efficiency is achieved. The governance model of e-government increases the participation of the citizens in the affairs of their government. Sahraoui (2007) therefore proposes the e-inclusion model of the governance, which should be a stage of e-government adoption. This stage demands that all citizens within the government should have equal access and opportunity to the mechanics of service delivery from the government. Equal opportunity is achieved through a partnership between the government, the private sector and civil society. Figure 2.8 shows the e-inclusion model, which can be useful only

when political, economic, technological and social barriers are removed and access to e-government opportunities is equitable.

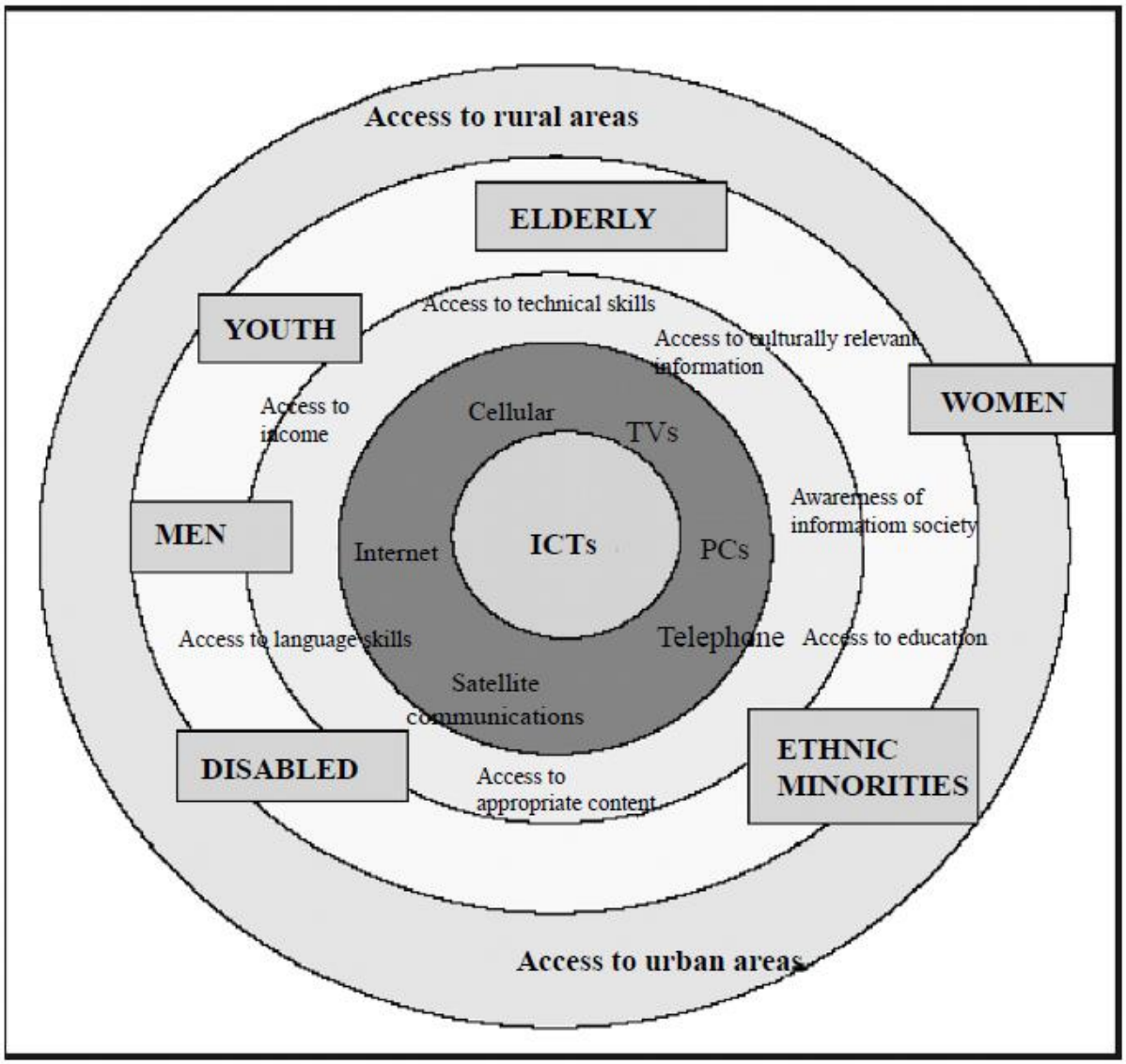

Figure 2.8: Model of e-inclusion
(Sahraoui 2007)

Chun *et al.* (2012) state that interactions occur within and across G2G, G2B, G2C and between international governments in a still and dynamic fashion. The collaboration from the interactions therefore increases the effectiveness of government by inspiring partnerships, participation and engagements across government. They pointed out that the motivations of e-government collaborations between G2G, G2B and G2C may differ and are made up of diverse motivational forces that drives collaborative e-government (Figure 2.9). The value-driven forces shape the governments to deliver better decision making skills and increases better service provisioning and to achieve domain specific goals. The main benefits of

collaborative government is the sharing of data or information that permits a smooth process design and that offers better and timely services for its citizens. The collaborative e-government applies collective intelligence for innovative solutions to the problems as well as offer a shared governance that adopts the trust and confidence of citizens in government.

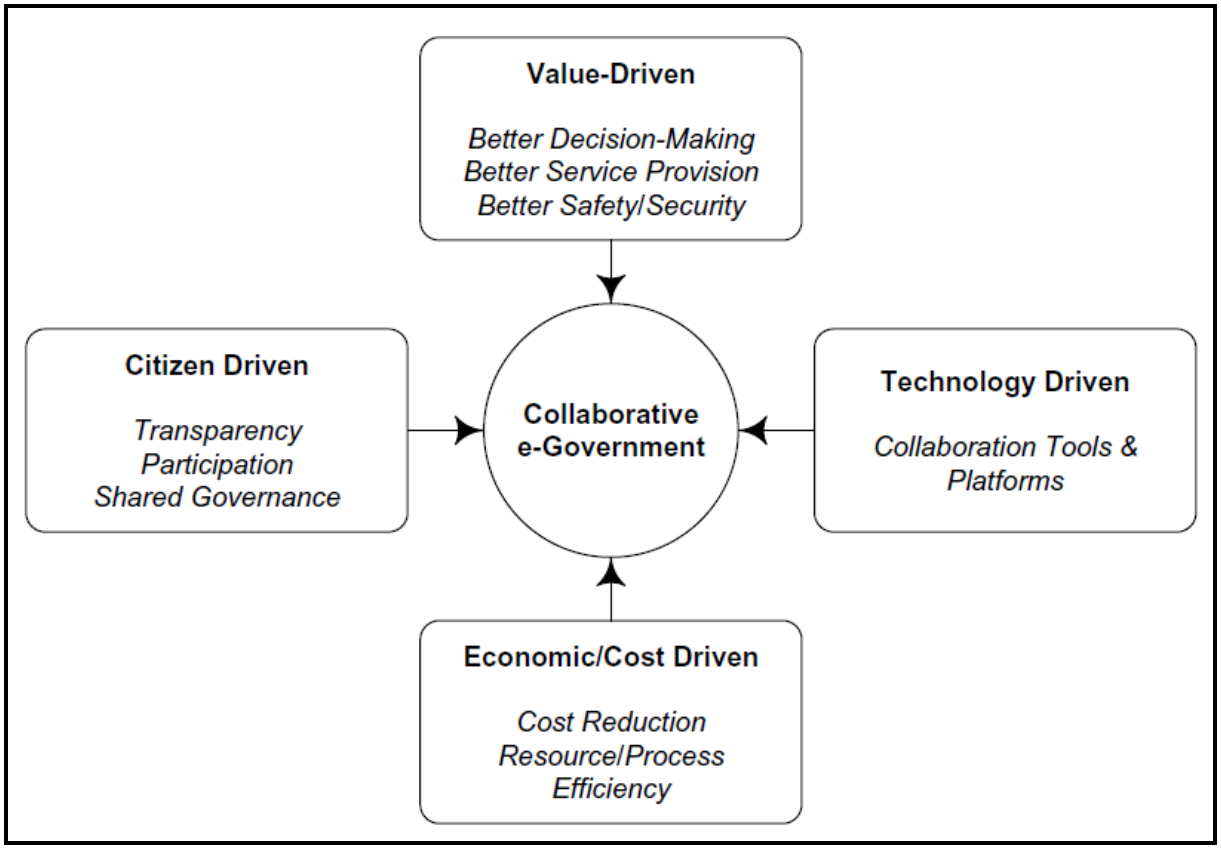

Figure 2.9: Collaborative e-government forces
(Chun et al. 2012)

Chen *et al.* (2011) argues that many of the recent studies shows indifference between the e-government models and e-government advancement around the world. Many of the models were developed for the improvement and understanding of e-government in the last decade. Chen *et al.* (2011), therefore, suggested a three-dimensional model for e-government advancement for better administration and improved service delivery. This three-dimensional model proposes that taking ICT alone will not attain the best result for the quality and service. The other four factors in the e-government development, which are effectiveness, appropriate functionality, governance and capability of the applications with respect to the efficiency and quality and the applications themselves must play a vital role in the accomplishment of e-government implementation (Chen *et al.* 2011).

2.6 Rationale for E-Government Data Sharing

Previous authors have argued that information communication technology (ICT) has dramatically changed the way human activities are performed in different sectors around the world (Fang, 2002; Ndou, 2004; Nkwe, 2012). Private companies have embraced ICT to deliver improved services. ICT has changed, tremendously, the way governments deliver the services to their citizens and businesses as well as how they communicate and interact with the people needing government services using a technology called e-government. The governments in many developing countries are striving to improve the welfare of citizens and to deliver quality services that add value to the citizens. However, many services offered by governments are still associated with a lot of paperwork coupled with manual processes, long queues for each section of service, inadequate spaces and a lot of frustrations related to inefficient services. The public sector and the governments are under intense pressure to deliver services at the needed time and with high quality. Citizens and business preferably want services without physically going to government departments. Governments are doing their best to tackle the demands of citizens by reforming and re-engineering the existing government processes and translating these processes into automated ICT solutions.

E-government has a great potential to provide improved government services to the citizens and can increase efficiency by restructuring the existing process in government departments. However, the actual challenge of e-government is how to help facilitate citizen to government interaction and to make service delivery more efficient. Data/information sharing can be helpful in speeding government service provisioning, but the current structure of government departments and their information systems are disparate and distributed with virtual boundaries, which make it more difficult to achieve effective data sharing with minimum costs. The challenge of inter-organizational or inter-department data sharing has given rise to organizational boundaries. Data sharing can be useful in overcoming barriers of cross-boundary because integrating government departments has been long identified as a major enabler for improving organizational efficiency (Thakur and Singh 2012). Governments can also achieve healthier strategic decisions and better-quality problem solving techniques when their departments have aggregated data and knowledge sharing mechanisms (Mohammed *et al.* 2012).

Researching the significance of inter-department data sharing (Thakur and Singh 2012) identified vertical and horizontal directions for data sharing and they defined a theoretical framework for understanding boundaries in data sharing initiatives. The integration of various information systems inside and external to organizational boundaries remains costly and time-consuming (Mohammed *et al.* 2012). This is because of heterogeneity of computing environments involved and a shortage of technical infrastructure in the public sector, which is a real challenge. The growing cooperation of organizations has resulted in the need to share data more effectively. The sharing of information is still affected by privacy concerns, organizational structure and technical issues, which have to be taken into account (Asogwa 2013). Data sharing across government sectors and departments forms an important component of e-communication system. de Jager and van Reijswoud (2008) point out several advantages of e-communications amongst which are the following:

a) Cooperation between teams and collaborative teamwork.
b) A complicated business process that can be solved.
c) Rapid communication with the administration and stakeholders.
d) Cost effective communication as traditional process like postage usage, telephony and travel expenses are eliminated.
e) Due to openness the complex layers of management are reduced.
f) Instant accessibility to information makes strategic decision making easier and faster.
g) Contributes to improved public administration performance.
h) A red-tape orientation in organizations is removed.

2.7 Barriers to E-Government Data Sharing

From a review of the literature it is evident that are many challenges and difficulties to be faced while implementing e-government. The important factors that indicate the success or the failure of e-government acceptance may vary according to the location of the country and its local context. The barriers facing successful e-government data sharing were identified to include lack of good ICT infrastructure, lack of good digital security and privacy issues (Lofstedt 2012). Privacy of data/information and digital security is a very severe technical barrier that was identified by many of the researchers and this serious concern was mentioned in many journals of e-government implementation (Ostberg 2010). The barriers in developing countries are much more than ICT and e-government implementation. The basic needs for the citizens and the control of corruption, poverty eradication, increasing the literacy levels,

upskilling the poor ICT skills and the technical ability and solving the power crisis are other barriers that must be resolved before looking at e-government data sharing in developing countries (de Jager and van Reijswoud 2008; Al-Rashidi 2013). The barriers to efficient e-government that can hamper effective data sharing as identified by Lofstedt (2012) are as follows:

a) No strong ICT hardware and software Infrastructure.
b) No proper project planning and inadequate knowledge about e-government program.
c) Absence or shortage of security and privacy of data and information.
d) Nonexistence of capable and skilled workforce.
e) The cultural difference within the government and across departments.
f) Good guidance from the leaders and poor management support.
g) Absence of well-defined policies and guideline for e-usage.
h) Lack of partnership with 3rd party service providers.
i) Deficiency of proper strategic plans.
j) Resistance from the entities involved in e-government to change to change over to e-systems.
k) Unavailability of financial funding and resources.

Table 2.1 summarizes the barriers to inter-organisational data sharing as pointed out by (Debnath *et al.* 2008).

Table 2.1: Barriers to inter-organisational data sharing

(Debnath *et al.* 2008)

Barriers	**Details**
Institutional culture issues	The issues related to ideological, technical complexity, politics, history, ideology, muscle power and even location falls under this category.
Conflicting priorities among participating organizations	Different data standards, leadership issues, hardware equipment, department's interest and different levels of training are part of this category.
Absence of resources	Deficiency of skilled human and latest technical resources.
Poor implementation of standards	Difference with data definitions, data formats and data models across the organisations.
Overheads of coordination	Expenses encountered while coordinating activities across different organizations.

2.8 E-Government Data Sharing Models

Makedon *et al.* (2003) proposed a negotiation-based data sharing system called SCENS (Secure Content Exchange Negotiation System). The SCENS was developed at Dartmouth College which is a multi-layer scalable system that brings guarantee to transaction safety using several security mechanisms. The system was based on a metadata with varied information and was then applied to a number of various domains. They proved that with vulnerable and disseminated information, government users may bring an agreement on the conditions of data/information sharing by negotiation.

Liu and Chetal (2005) suggested an interest based trust model and data sharing protocol to solve the difficultly of data/information sharing between government organizations. The proposed protocol integrated a varied range of information rules and policies, along with trust negotiation during information exchange. The added policies made the parties who are interested in sharing data to be dependent upon each other. The protocol was implemented using the latest internet technology of XML web services. The implementation is suited for the Federal Enterprise Architecture (FEA) reference models and can be integrated into the e-government systems.

Ager *et al.* (2006) developed a set of policy based technologies to enable data/information sharing across government departments easy without negotiating individual privacy or information security. The model design consists of line-grained access controls that support filter semantics for complex policy condition. A policy ability assists to consolidate information from multiple sources to the source's original disclosure policies. Creation of a department that allows departments to apply item-level security arrangements and disclosure policies. The auditing of histroy of each information accessed in the system is also avaliable. The auditing method screens information derivations along the time to support the evaluation of information quality. The ultimate goal was to offer the possibility of solving major information sharing problems in government departments and to offer direction for the expansion of upcoming government owned insformation systems.

Sandhu *et al.* (2006) projected the ways where recent Trusted Computing (TC) technologies can help in secure data/information sharing, compared to those not offering pre-TC technology. The Policy, Enforcement and Implementation (PEI) framework produced by them highlights three distinct layers at which security policy and design decisions need to be made. The PEI framework made possible to evaluate in detail, the potential TC applications for secure information sharing in their upcoming work.

Fan and Zhang (2007) had presented a conceptual model for data/information exchange in digital government infrastructure. They found out that the Government-Government (G2G) information sharing model will assist in the understanding of G2G information sharing and can assist decision makers in making decisions with regards to G2G information sharing. Fan and Zhang tested the conceptual model with the purpose of finding the factors that influence electronic (or digital) government information sharing. The model was highlighted via a case study under the Chinese government system.

Headayetullah and Pradhan (2009) proposed a protocol for sharing data securely across different government agencies for the main motive of streamlining government services. This protocol was proficient and innovative for trust-based data sharing, exchange of confidential information amongst government intelligence agencies across national and international boundaries using public key encryption. The protocol uses MD5 algorithm for data integrity and public key across cryptosystem for confidentiality and authentication and complex mapping for agency identification. The protocol supports privacy protection and information sharing with possible restrictions based on the trust level maintained between the donor and the receiver of information. The protocol ensures secure and streamlined information/data sharing within government intelligence agencies to avoid threatening activities.

Oberholzer *et al.* (2012) presented a Hippocratic privacy protection framework (HPP) which is based on the concept of privacy contract. This prototype was used for protecting personal information in cooperate organisations, which are becoming increasingly concerned. Decision criteria that are needed for privacy protection are very complex. A classic problem in this context concerns about giving the individuals an improved control over their personal information, and at the same time allows the organisation to process its transactions based on the same personalised information. A prototype of the HPP framework was built to serve as a proof of concept in order to demonstrate the developed HPP framework becomes applicable and therefore serve as an efficacious model for solving privacy problems. With this prototype, the HPP framework afforded individuals more control over their personal information.

2.9 Literature Summary

The chief motive of this research study is to come up with a data sharing working prototype system for e-government that can enable data sharing with data contract management as a

practical implementation tool for security and privacy protection. The development of the framework underlying the development of data sharing system was inspired by the following models.

a) Hippocratic privacy protection framework (HPP) by Oberholzer *et al.* (2012) – decision criteria that are needed for protecting privacy and control over personal information when sharing information.
b) Policy based technologies model by Ager *et al.* (2006) – consolidation of information from multiple sources across departments, subjected to the source's original disclosure policies.
c) Sharing secure information between protocol by Headayetullah and Pradha (2009) – trust-based information sharing protocol that can provide secure exchange of information, with authentication and encryption.
d) Policy based technologies to enable information sharing by Ager *et al.* (2006) – auditing method that traces information changes over time along with consolidation of information from multiple sources across departments, subject to the source's original disclosure policies with.

The potential merits of using the Data Sharing Gateway (DIG) originating from this research study as a proof-of-concept formalism are the following:

a) The DIG enables both the column and row level privacy protection of information that can be implemented through the data contracts.
b) The DIG model is a lightweight web application framework that can connect to any type of database to enable information sharing.
c) The DIG model can be implemented within governments to enable data sharing, without any changes to the existing hardware infrastructure and the software applications.

The common goals of all the data sharing models as uncovered from the literature in the course of this study are the following:

a) To enable seamless information sharing in government, private or corporate departments.
b) To seamlessly implement trust and security policies using trusted computing technologies.
c) To seamlessly integrate security and privacy related policies with data sharing protocols.

In this chapter of the dissertation, the researcher found it expedient to conclude with a succinct summary of e-government models and problems solved in related studies (Table 2.2).

Table 2.2: Summary of Related e-Government Model

E-government model description	Problem Addresses
SCENS: Secure Content Exchange Negotiation System proposed by Makedon *et al.* (2003), is a multi-layered saleable systems that brings surety to transactions safety.	Content Exchange Negotiation System that distributed the information to government users based on the condition of sharing information.
Government (G2G) information exchange in electronic government infrastructure using information sharing conceptual model by Fan and Zhang (2007)	Government-Government (G2G) information/data sharing in e-government, assistance in framing decisions.
Sandhu *et al.* (2006) projected methods using recent computing technologies and how it can assist with the secure information sharing, compared against those that did not offer pre-TC technology.	PEI framework with policy, enforcement, and implementation models. The framework helped identifying possible TC applications that can support secure information sharing.
Ager *et al.* (2006) developed a group of policy based technologies that enable information sharing across government agencies without negotiating individual privacy and information security.	Line-grained access controls, A adhesive policy ability that supports joining of information from multiple sources from the source's original disclosure policies, disclosure policies, item level security classification, and auditing method that keeps track of information derivations over time, addressed key information sharing problems in government agencies.
Liu and Chetal (2005) suggested an innovative information sharing protocol and interest based trust model to resolve the issue of information sharing across government agencies.	Integration of wide range of information policies with trust negotiation, sharing data to be interdependent upon each other, XML Web Services, for digital government.
Oberholzer *et al.* (2012) presented a Hippocratic privacy protection framework (HPP) that is based on the concept of privacy contracting.	Prototype for protecting personal information to cooperate organisations, decision criteria needed for privacy protection, better control over their personal information allowing process of transaction, efficacious model for solving privacy problems.
Headayetullah and Pradhan (2009) proposed a protocol capable of sharing secure information between different government organisations for the purpose of streamlining government services.	Using the MD5 algorithm for data integrity, public key in cryptosystem for secrecy and authentication, complex mapping for agency identification, privacy preference and information sharing based on trust level, trust based protocol for sharing top secret information among government intelligence agencies.

CHAPTER 3 : STUDY METHODOLOGY

This study proposes to use the design science approach to construct and develop a data sharing application technology that is focused on values and principles of Hippocratic database technology for managing disclosure data that can be incorporated into e-government space. The task of safeguarding privacy in the latest information system is vital for system users. The conventional method taken is to apply privacy policies at the application level by issuing queries on the database thereby retrieving the result. The application then scans the record set and then filters restricted information. But, this method leads to privacy beaches when the same method is applied at the cell level. The use, trust and confidence of system users depend heavily on the degree of privacy provided by the system and its platform. The answer for the above-mentioned problems could be found when using Hippocratic database principles.

3.1 Design Science Research

The research discipline of information systems comprises behavioural science research (BSR) and design science research (DSR), which are complementary paradigms with the intention of addressing the fundamental problems that face the productive application of information technology (Hevner and Chatterjee 2010; Olugbara and Ndhlovu 2014). The goal of BSR is truth and the goal of DSR is to seek and stretch the boundaries of human and organizational proficiencies by constructing new and innovative artefacts. Truth tells a design whereas utility informs theory that leads to where truth can be combined into the design (von Alan *et al.* 2004). BSR is concerned with underlying theories that provide insights and inform researchers about interactions amongst people, technology and organizations. On the other hand, DSR addresses the fundamental problems of people and organizations through the construction, utilization, and evaluation of artefacts, or systems that provide the utility to transform an existing situation into a more preferred one (Olugbara and Ndhlovu 2014).

DSR enables the evaluation of the capabilities of the intended user, which will be the government employees providing government services to the citizens, business or to other government departments. This evaluation allows for the understanding of how government departments process their data sharing and those services demanding data sharing capability

from other departments and to discover those factors that delay the process of data sharing. It can be therefore concluded that the DSR method supports the realization of the research goals and objectives that were put forward in this study. In the present research study, the DSR method was applied to study how government departments in South Africa conduct their daily business transactions, as well as to construct and evaluate the suitability of a Data Integration Gateway (DIG) for Hippocratic data sharing in e-government space.

The modelling of a software artefact called DIG serves as a proof of concept of this study. The object constraint language (OCL) and unified modelling language (UML) serve as useful modelling tools in the application of DSR. The UML is widely accepted by industry and academics for formal modelling and specification of software systems. It offers a standard method to visualize the design of a software system. The OCL is a formal system specification language within UML for defining the well-formed constraints and queries for UML and OMG related meta models. It extends the UML by adding precise semantics to visualize UML models. A modeller from a modelling approach must combine illustrative and formal languages. Within the UML, the OCL is an additional language for UML. The OCL is a universal standard for adding expressions that increase important information to object oriented models. The DIG system is an innovative system, so UML and OCL are used (Oberholzer *et al.* 2012). OCL has the features of a formal language, modelling language and an expressive language that depend on the defined UML data types and thus contains some facets of UML.

The DSR is a set of analytical and synthetic techniques for carrying out research in information systems. DSR involves the creation of new knowledge through the design of innovative artefacts. The analysis of the usage of such artefacts helps to understand and improve the behaviour of features of information systems (Vaishnavi *et al.* 2004). These artefacts enable individuals to implement information processing capabilities that move organizations to achieve a set of desired goals (Baskerville *et al.* 2009). This study follows the cognitive process (Figure 3.1) of the DSR model proposed by Vaishnavi *et al.* (2004). The cognitive process groups the process steps into three groups, which are the abduction, the deduction and the reflection abstraction.

In the cognitive process of DSR, the research begins by identifying the problem to solve, which is also the awareness of the problem. Suggestions are made for the identified problem such as how the problem should be solved and what resources are needed to solve the problem. The problem solutions are drawn from the existing body of knowledge and an effort is made to solving the problem creatively. The solution or group of solutions, which could be

an initial design, is constructed from the need requirements, followed by the design specification and an artefact is developed. The partially or fully developed artefact is then evaluated by comparing the functional requirements. This is an iterative phase where the evaluation can go back to the development phase, suggestion phase and awareness of problem phase. The flow from partial completion, going back to the awareness of the problem is represented as the circumscription phase. The creative cognitive process of abstraction and reflection are used in the conclusion phase, which specifies the termination of the research cycle.

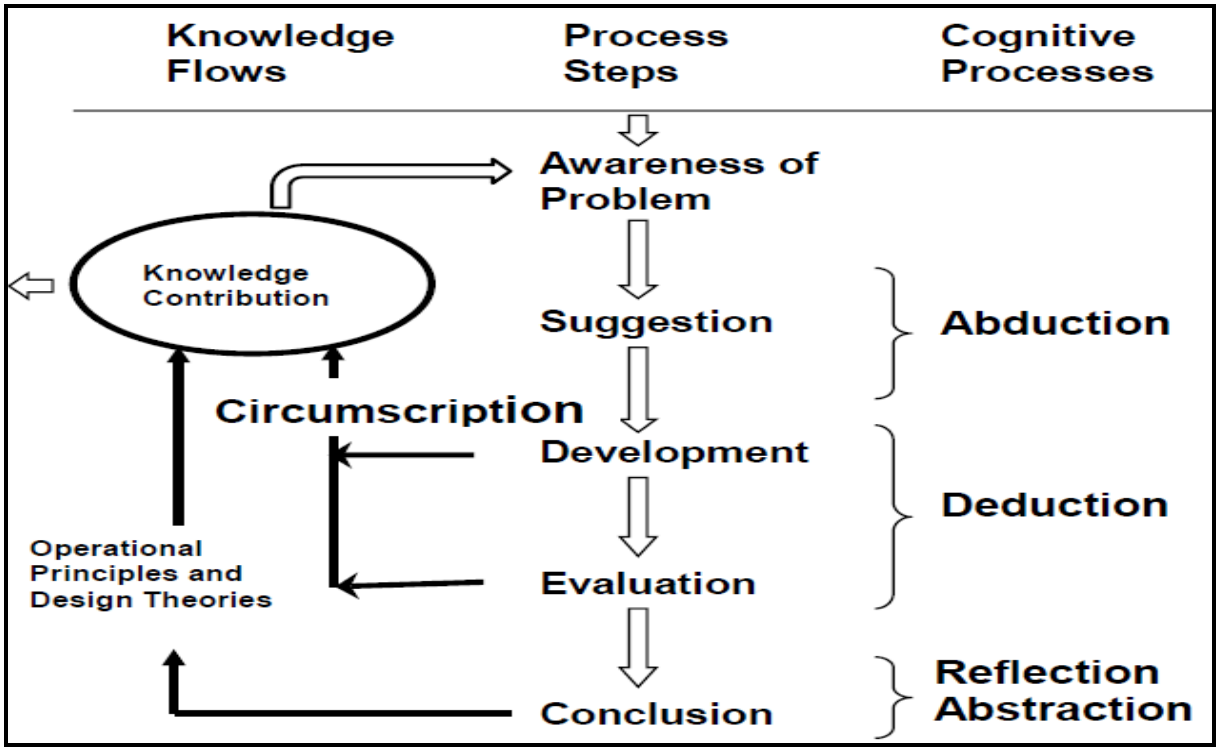

Figure 3.1 Design science research cycle (Vaishnavi et al. 2004)

The functional requirements for solving the problem of data sharing across government departments were deduced from preliminary interactions with two South Africa government departments, namely the Home Affairs (HA) and the South African Police Service (SAPS) located in Durban of the KwaZulu-Natal province. The researcher examined several official documents from both departments and interviewed staff from these departments were also the end users, to pinpoint the research problem and to provide the system requirements. Context-free interviews were used to gather the function requirements of the DIG application. The use of context-free questions by the interviewer helped to avoid prejudicing the response (Escalona and Koch 2004). The context-free interviews were then

analysed, brainstormed and converted into functional system requirements. The functional requirements are necessary attributes in a system development lifecycle, which are narratives that identify the capabilities, characteristics or quality factors of a system in order for the system to give value and utility to end users (Sheikh *et al.* 2014). Some service quality assessment models such as the analytic Kano model (Xu, Q *et al.* 2009) specifically suggest early involvement of end users in functional requirements satisfaction measurement.

This study uses the DSR model (Vaishnavi *et al.* 2004; Baskerville *et al.* 2009) to map the process steps involved in the development of the DIG system. The research problem was tackled by following the phases as guided by the soft DSR methodology (Baskerville *et al.* 2009):

a) Awareness of the problem:
    - Data sharing between government departments was identified as a major problem for the slow delivery of public services.
    - Data sharing must be enabled to use the existing government databases and infrastructures within each department and the devised solution must be cost effective.
    - Data sharing within departments is considered highly confidential and is secured within a department. Strict process, policies and rules are followed when sharing data within government departments.

b) Suggestions:
    - The design of data sharing can be applied to any organization and for any departments other than government organization. However, the confidentiality of data is maintained through contracts or agreements of what must be shared, and how and when the sharing should take place between the parties involved in the transaction.
    - A centralised web application or an external agent system that can be used by all departments for data sharing could ensure data security.
    - A lightweight web application using ASP.net web technology and a lightweight database using SQL compact edition could be more suited to create a workable instance of a solution that solves the data sharing research problem.

c) Development:

- The DIG functional requirements specification was written using UML-OCL modelling language.
- The DIG system prototype was developed using visual studio 2010 IDE, SQL CE database and test driven development methodology.

d) Evaluation:

- The evaluation of the DIG system was verified by test driven development and manual system by the testers verifying against the functional requirements specification.

e) Conclusion:

- The DIG system developed in the research study is a workable, tested and deployable solution that could be deployed to any government departments that want to implement information sharing.

3.2 Hippocratic Data Sharing

Data or information sharing among governments and citizens are vital to any country for speeding up the administration process (Harvey and Tulloch (2006). The government of any country can become inefficient if the communication amongst the citizens and the government breaks down abruptly because society can become unstable. Using the latest technologies for communication, the connection between government and citizens can be drastically improved. This communication problem between citizens and governments can be better managed if the country is small, but for countries with large geographical areas and massive populations management is very challenging. In some countries, there is a wide gap between the rich and the poor communities and without efficient communication systems the government is unable to effectively handle a good administrative system and the government can lose control. Ndou (2004) states that fast development in information communication technology (ICT) leads to widespread opportunities for proficient service delivery. Even with the current advancement in technology that is secure and robust, most of the government sectors have not fully explored the sharing of data methods because of the fear of data

sniffing or data leaks across the wires, when information is shared data out of the departments.

The main competency which is needed for one-stop, connected, smart and networked government that rapidly responds to vast needs of inter- and intra-departmental or organizational needs for cross-national or inter-national needs are services such as data sharing. However, to develop such proficient solution is very challenging and requires the government to coordinate policies, share strategies and implement common frameworks across its departments (Ebrahim and Irani 2005). Shared data services have been indicated as a way of enhancing services to improve the efficiency of the service delivery and yet the implementation of shared data services has proved to be difficult because of the operating environments.

This research study originated from the identification of a research problem in the government sector, regarding data sharing between government departments towards improving service delivery. The sharing of data between government departments hypothesizes the research problem as the central point of research and initiation of the research process. The requirement of the main research problem is to search for a technological solution framework that can effectively support data sharing amongst the diverse government departments to ensure high level security and privacy. A more demanding aspect of the solution is that data sharing must be possible without any massive changes to the existing infrastructure and software applications. A holistic solution to these challenges is the DIG, which is based on Hippocratic database principles. From a government point of view, data will normally be published as a general privacy policy stating how the data will be shared by departments.

In order to publish a common privacy policy, we propose customised and an interactive manner of data sharing using the DIG system, with which the government departments can connect and maintain its data contract policies. Primarily, the department DIG administrator with other stakeholders of the department has to define all the data contracts and publications in the DIG system so that the transactions and the data items that are needed by every transaction can be processed into important information. The department DIG administrator must also define the purpose of sharing data for each transaction and data item and to whom the data should be shared. In addition, the definition of data contracts follows the Hippocratic principles, which is applied to data to be shared and restricting sensitive data.

The concept of Hippocratic databases (HDBs) was encouraged by the elementary principles of Hippocratic oaths for the sole purpose of conserving secrecy and privacy in information systems. HDBs contains a class of database system that accepts responsibility for managing the security and privacy of data/information without hindering disclosure and legitimate use (Grandison *et al.,* 2008). HDBs guarantees to give authorization only to authorized individuals and grants, direct access to sensitive data and that any revelation of the data is only for used for authentic purposes. They empower individuals to consent to specific uses and disclosures of their data and to verify the enterprise's compliance with its privacy policies (Grandison *et al.,* 2008). HDBs use analytics and advanced data sharing methods to enable enterprises to gain maximum value from data without negotiating individual privacy or security.

The Hippocratic principles are implemented through the platform for privacy preservation and role base access control model (Crépin *et al.* 2008). The DIG system implements the ten Hippocratic principles, which are the following:

a) Purpose specification – the donor must know the purpose of sharing or restricting the sensitive data stored in a database relation.
b) Consent – the donor must give informed consent to the data collected.
c) Restricted collection – indicates the minimal data collection required for the understanding of the purposes.
d) Restricted use – this principle enforces policies on the database to use the gathered data merely for a specific purpose.
e) Restricted disclosure – a database has to transfer the stored data just for the intended purpose, with the donor's approval.
f) Limited retention – information is available until the purpose of the utilization.
g) Accurateness – the accuracy of the data has to be enforced.
h) Safety – the safety of the data stored must be guaranteed.
i) Openness – all data are accessible which are shared.
j) Compliance – the donor of the data can at any point of time, verify the above principles are respected.

3.3 Modelling of Data Sharing Gateway System

The main research aim of this study was to create a framework for data sharing across government departments. The objective of this phase of modelling a data sharing gateway

was to understand the problem domain and constraints of the intended users. The understanding of government department's data sharing and the requirements gathering for the DIG system was accomplished using the PaJMa model proposed by Chun *et al.* (2010). The PaJMa model for structured approach to requirement gathering was originally generated in the development of health information systems. For this research study and for the development of the DIG system the, PaJMa model suited very well. The PaJMa model increases the level of details in the requirements with the inclusion of non-functional requirements, along with the identification of required practices, policies and metrics for the requirements needed for the system. Chun *et al.* (2010) state that there are two type of requirements that must be collected for a system development. These are functional and non-functional requirements. The functional requirements are visible to the end user and the user interacts with the system using the implemented function in the system. These functions must be performed by the information system to capture and retain the user input into the system. The world of information system depends on the scope of the information system and this scope is defined through the functional requirements. The information system must contain another type of requirement which is known as internal requirements for the system or the non-functional requirements. The system's internal requirements also known as non-functional necessities are invisible to the end user and these are the functions that are internal to the information system. This collection of features or software program requirements define in what way the software program belonging to the information system must perform. The collection of software program requirements is comprised of numerous governmental or organizational structural processes, rules and policy based constraints that the information system should strictly adhere to.

3.3.1 Objectives of the DIG Framework

The information gathered during the interactions with different government departments and government service providers was for the development of a framework for information sharing between government departments. The focus was primarily on the research problem needs, not necessarily on any particular technology. The exercise in this research study leads to the discovery of critical business processes and system requirements within the government sector. The objectives of developing the robust framework for data sharing between government departments are as follows.

a) To understand how the government services are delivered and the factors hindering the speedy delivery to its citizens and businesses.
b) To implement a prototype system that enables government information sharing securely between its departments through a web application with easy to use interfaces.
c) To evaluate the efficacy of the implemented system for the government to share information faster and securely between its departments.

In this phase of the DSR process, the objectives of the proposed DIG framework for data sharing among government departments were identified and prioritized accordingly. The high level framework for the DIG system is presented in Figure 3.2. The UML sequence diagram for government inter-departmental communication based on the current scenario is presented in Figure 3.3 and the UML sequence diagram for the government inter-department communication after the implementation of the DIG system is presented in Figure 3.4.

3.3.2 High Level DIG Architecture

Figure 3.2 illustrates the high level technical architecture of the DIG system with the various components on each system layer. The high level architecture shares the deployment and the installation of software and hardware needed as well as the relationship among DIG system components. The technical architecture of the DIG system is a web application (cloud based) that resides within the government data centre to optimize the effort of delivering an instance of the system to different government service providers. The DIG system is a 3-tier architecture consisting of a lightweight Structured Query Language (SQL) Compact Edition (CE) database, the middle service layer and the front-end interface which is a Silverlight web application. Silverlight technology is a powerful development tool for designing and creating appealing and interactive user experiences for mobile and web applications, and this technology is supported by .NET framework from Microsoft. The layers of the DIG architecture are the presentation layer, which is the User Interface (UI) layer, the business logic layer and the data layer. The API layers talk to the Hippocratic data contract database via the Hippocratic data contract database engine. The view data contract API uses the Hippocratic data contract translation engine to formulate the data contract details and then connects to the remote/intra department database to fetch the data thereby enabling data interoperability across diverse government departments.

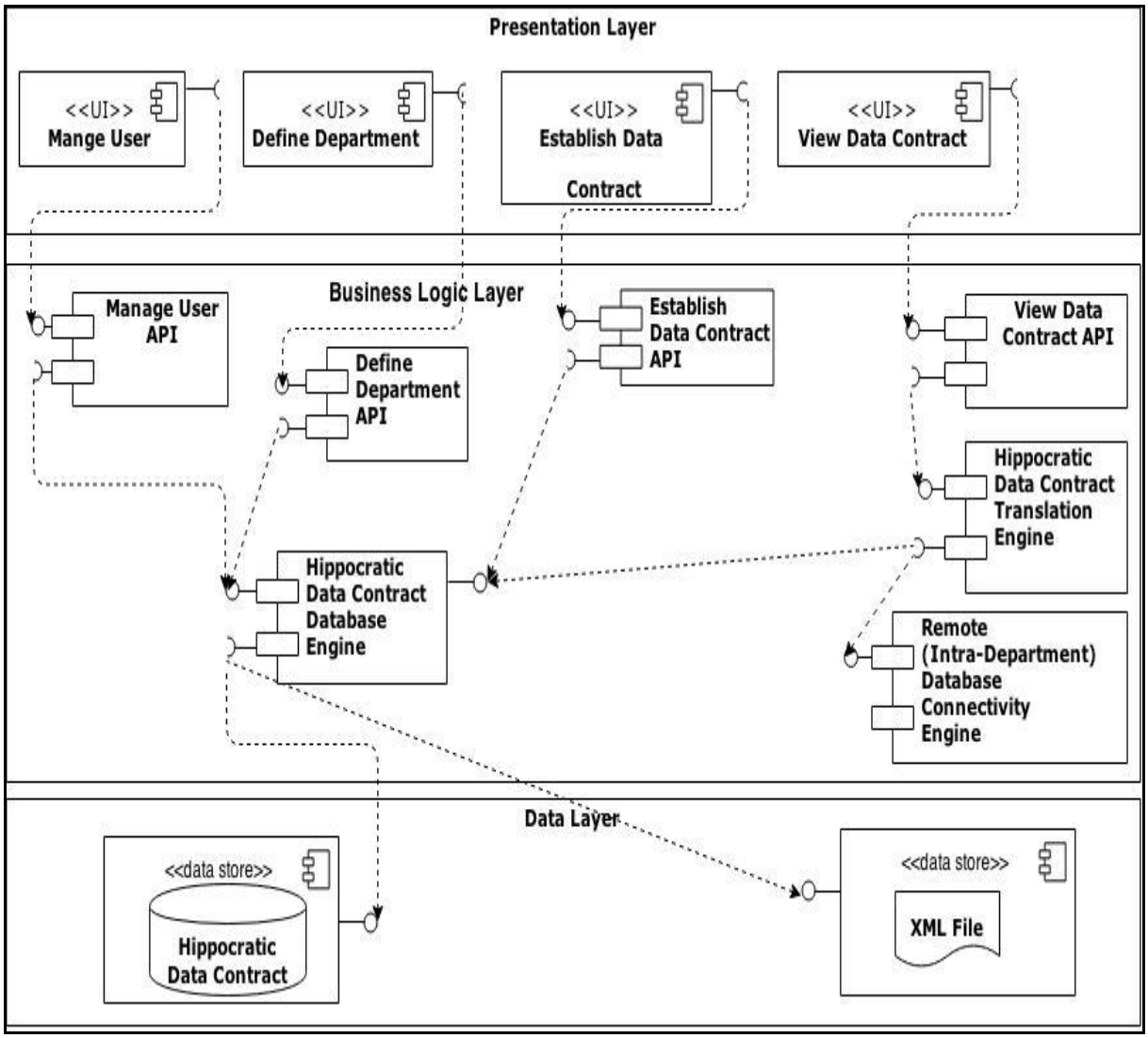

Figure 3.2: DIG system architecture

3.3.3 Managing Hippocratic Data Contract Policy

From a government department point of view, an assigned department's Hippocratic data contract administrator of the DIG system will normally publish a Hippocratic data contract policy stating how the government department will handle the department's information that they wish to share. For publishing a general Hippocratic data contract policy, we put forward a customised and an interactive solution using which a government department can create and manage its Hippocratic data contracts. The department's Hippocratic data contract administrator defines all the transactions and data items that are needed for the Hippocratic data contract via the DIG system. Once the Hippocratic data contract is added, the chief

Hippocratic data contract administrator verifies the Hippocratic data contract and approves the publication.

Creation of the Hippocratic data contract metadata is made up of an automated script that is run by the database administrator (DBA). The automated script installs the needed relational tables and the prerequisite (master data) on the database used by the DIG system. Any new metadata can be added on demand through the DIG system.

The features of the DIG system are represented using OCL. Using OCL we overcome the limitations of UML when defining the detailed features of the DIG system design (Cabot *et al.* 2012).

3.3.3.1 Manage Users

The context presented below inserts a new transaction in the user table in the DIG system database. The user details will then be used to log into the DIG system.

context Transaction::addUser(
newUserId: Integer,
newUserName: String,
newPassword: String,
newRoleId: integer,
newIsAdmin: Boolean,
newIsLocked: Boolean,
newLoginExpiryDate: Date,
newEmailAddress: String,
newDepartmentID: Integer): Transaction
inv: self.User.UserId → isUnique(UserId)
def: newIsAdmin: Boolean = false
newIsLocked: Boolean = false
newLoginExpiryDate: Date = 365 days + sysdate
pre: self.transaction → excludes(newUserId)
post: self.transaction → includes(newUserId)

3.3.3.2 Mange Departments

The context presented below confirms a new transaction is added to the department table in the DIG system database. The department details will be used by the DIG system for participation in the data sharing.

context Transaction::addDepartment(
newDepartmentId: Integer,
newDepartmentName: String,
newLocation: String,
newFunction: String): Transaction
inv: self. Department.DepartmentId → isUnique(DepartmentId)
pre: self.transaction → excludes(newDepartmentID)
post: self.transaction → includes(newDepartmentID)

3.3.3.3 Manage Database Connections

The context presented below confirms a new transaction is added to the database connection table in the DIG system database. The database connection details will be used by the DIG system to connect to the remote databases in other departments and thus will enable data sharing across departments.

context Transaction::addDatabaseConnection(
newDatabaseConnectionId: Integer,
newDatabaseServerName: String,
newDatabaseName: String,
newDatabaseLoginName: String,
new.DatabasePassword: String,
new.DatabaseConnectionString:String): Transaction
inv: self.DatabaseConnection.DatabaseConnectionID
→ isUnique(DatabaseConnectionID)
pre: self.transaction → excludes(newDepartmentID)
post: self.transaction → includes(newDepartmentID)

3.3.3.4 Manage Publications

The context presented below ensures a new transaction is added to the database publication table in the DIG system database. The publication details will be used by the DIG system to create the data contracts to share the data that will be accessed by the authorised DIG system.

context Transaction::addPublication(
newPublicationId: Integer,
newPublicationName: String,
newPublicationDataTable: String,
newAvaliableFields: String,
new.RestrictedFields: String,
new.DataFilter: String,
newDepartmentId:Integer): Transaction
inv: self. Publication.PublicationID → isUnique(PublicationID)
pre: self.transaction → excludes(newPublicationID)
post: self.transaction → includes(newPublicationID)

3.3.3.5 Manage Data Contracts

The context presented below confirms the addition of a new transaction the data contract table in the DIG system database. The data contract details will be used by the DIG system to access the published data by the departments to enable data sharing across government departments.

context Transaction::addDataContract(
newDataContractId: Integer,
newPublicationId: Integer,
newDataContractName: String,
newDataContractTable: String,
newDataContractFields: String,
newDataContractTableFilter: String,
newDatabaseConnection: String,
newDataContractIsApproved:Boolean): Transaction

inv: self. DataContract.DataContractId → isUnique(DataContractId)

pre: self.transaction → excludes(newDataContractId)

post: self.transaction → includes(newDataContractId)

3.3.3.6 Manage Department Data Contract Access

The context presented below ensures an addition data to the department data contract access table in the DIG system database. The department data contract access details will be used by the DIG system to grant access to the data contracts to the users belonging to the assigned departments.

context Transaction::addDepartmentDataContractAccess(
newDataContractId: Integer,
newDepartmentId:Integer): Transaction

inv: self.DepartmentDataContractAccess.DataContractIdDepartmentId
→ isUnique(DataContractId, DepartmentId)

3.3.3.7 Manage Audit Logs

The context presented below ensures that a new transaction is added to the audit log table in the DIG system database. The audit log details is used by the administrator to monitor and to check the activities of the DIG system.

context Transaction::addAuditLog(
newAuditLogId: Integer,
newUserName: String,
newSessionStartTime: Datetime,
newSessionEndTime: Datetime,
newModuleName: String,
newRole: String,
newAuditDate: DateTime,
newFunctionAccessed:String): Transaction

inv: self.AuditLog.AuditId → isUnique(AuditLogId)

pre: self.transaction → excludes(newAuditLogId)

newSessionStartTime:Datetime = sysdatetime

post: self.transaction → includes(newAuditLogId)

newSessionEndTime:Datetime = sysdatetime

3.3.3.8 Approve a Data Contract

The below presented context describes the process to activate a data contract.

context DataContract::approve(cDataContractId:Integer): Boolean
inv: self. references.verified = true
pre: self. DataContractIsApproved = false
post: self. DataContractIsApproved = true

3.3.4 Sequence Diagram for Inter Department Communication

The UML sequence diagrams for inter departmental communication between the DHA and SAPS branch office are explained in this section.

3.3.4.1 Current Scenario

Government departs can be integrated in two ways for efficient communication, namely, vertical and horizontal integration. Escalona and Koch (2004) defined vertical integration as local and central governments that are integrated and therefore they can share functions and services. Horizontal integration is the integration of government across all sectors that can exchange functions and services. The application systems and the central database for each department in most countries are vertically integrated. The government database of each department resides at the government data centre. For example, all government offices belonging to one department, irrespective of the location can access its own central database. As shown in Figure 3.3, the DHA department across the country cannot directly access the fingerprint data from SAPS for ID process of any person irrespective of the location. Similarly, the SAPS department that generates fingerprint data cannot access the data required to verify the fingerprint request that resides in the DHA department directly even

from the same location. The request for accessing fingerprint data has to go through the head offices of DHA and SAPS from the local SAPS office. This is the cardinal cause of service bureaucracy and delay in the current processes because the client has to wait for approval until the data are verified. This process of client data verification takes up to two or three weeks. Figure 3.3 shows the sequence diagram that models the interactions between the objects of DIG system and the time ordering of those objects. The sequence diagram shows the inter-department set up for four objects which are:

- Branch office Home Affairs
- Head office Home Affairs
- Head office SAPS
- Branch office SAPS

The head office of each administration has a centralized database and the branch office reads and writes data to the centralized database. Branch offices of different administrations can't directly access each other's head office data, thereby making data sharing difficult. The request for data from one branch office to another head office is a 4 step process. For example, as shown in the sequence diagram, if branch office Home Affairs needs any data from head office SAPS then the sequence of the process is:

- The Home Affairs branch office requests the needed info from SAPS head office to its own head office.
- The Home Affairs head office forwards this request to the SAPS head office.
- The SAPS head office returns the data to Home Affairs head office.
- The Home Affairs head office, then forwards the needed data to Home Affairs branch office.

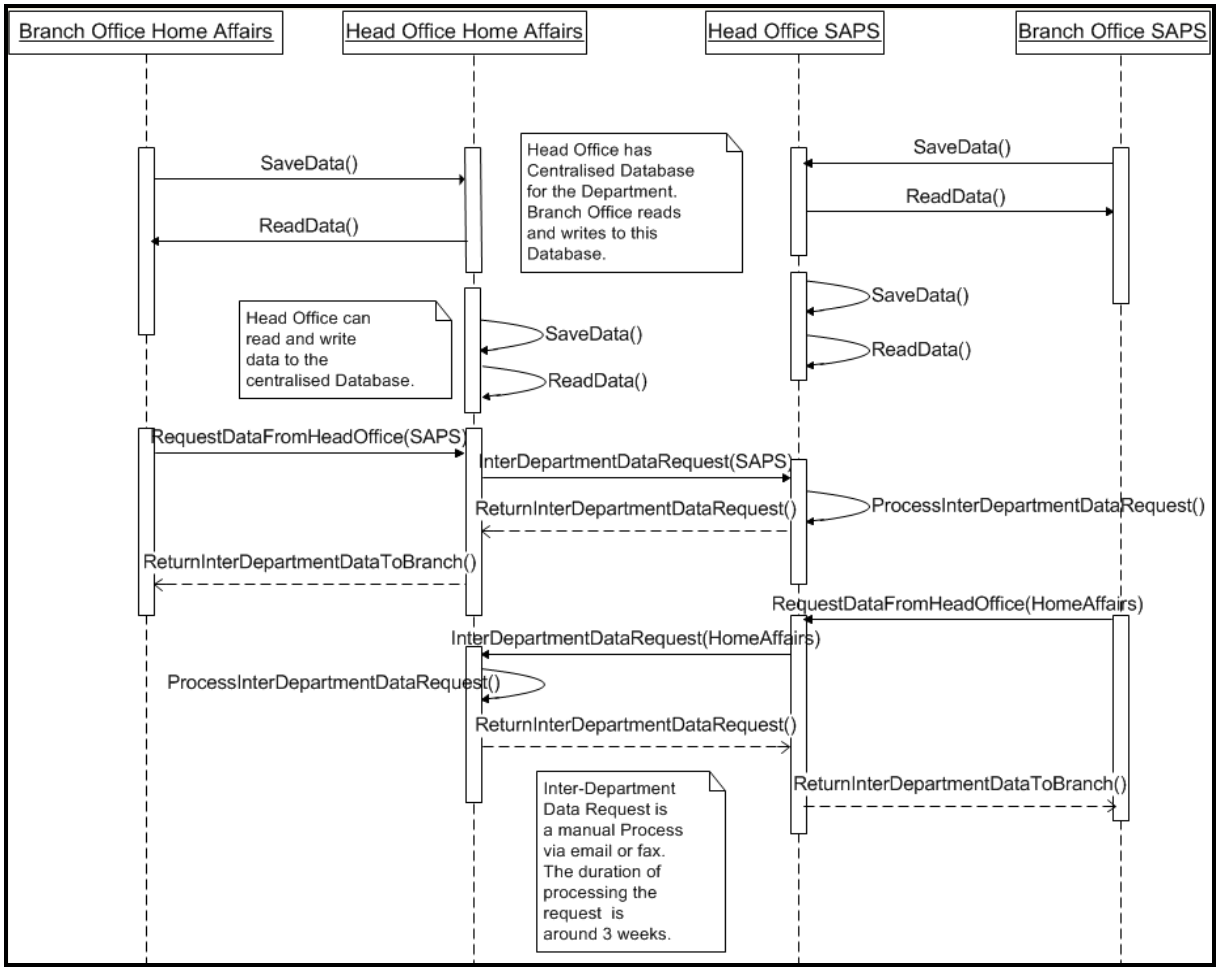

Figure 3.3: UML sequence diagram for inter department communication current scenario

3.3.4.2 Future Scenario with DIG system

The implementation and deployment of the DIG system can provide a direct interaction between the Home Affairs branch office and SAPS head office as shown in Figure 3.4. Similarly, the SAPS branch office can access data from the Home Affairs head office thereby enabling inter-departmental communication.

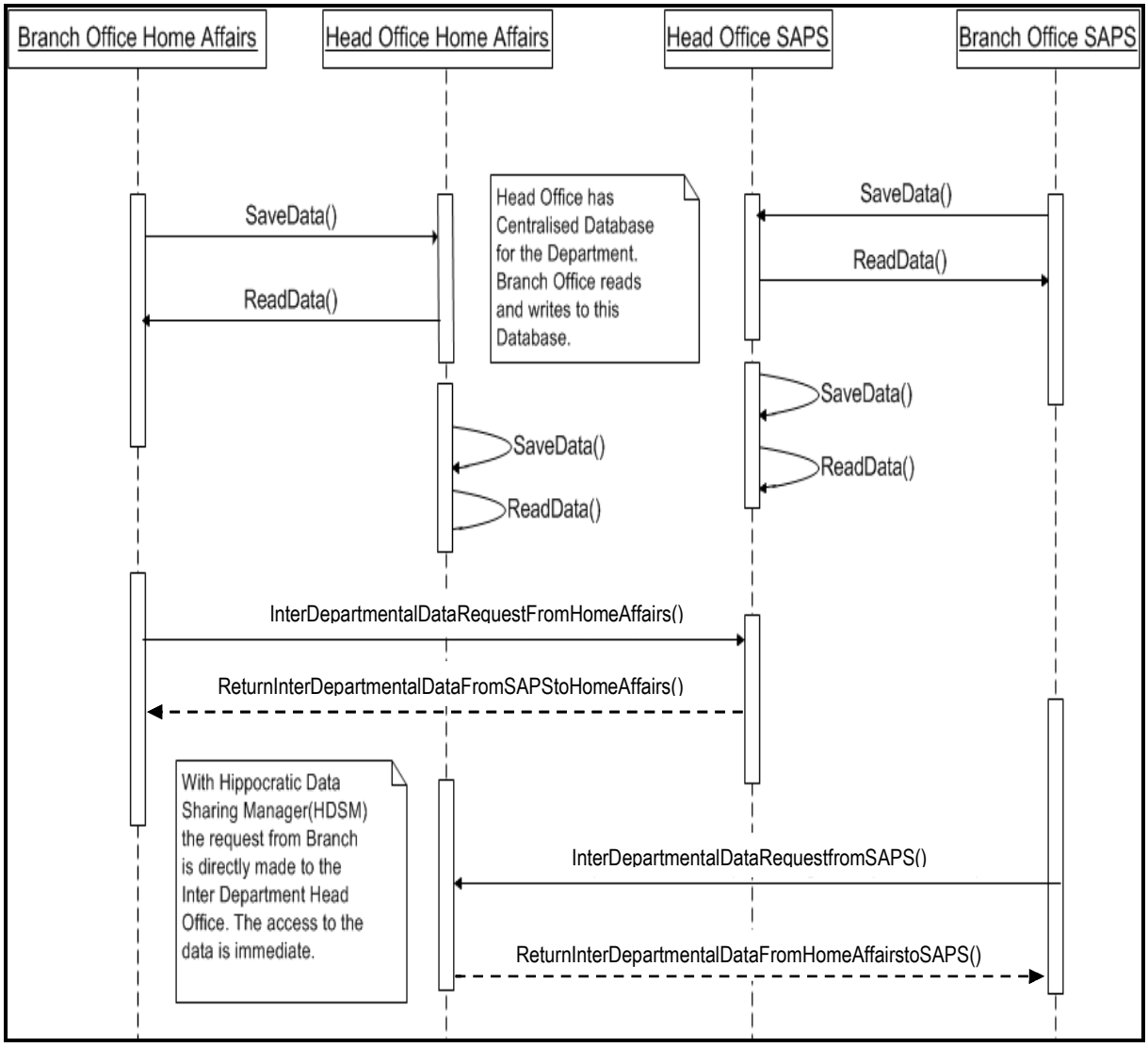

Figure 3.4: UML sequence diagram for inter department communication with DIG

3.3.5 Meta Model Class Diagram for the DIG System

The UML class diagram and sequence diagrams are used to convert the knowledge model into a specification model. All object classes and their relationships that are deduced from UML models are implemented to give the software components of the system. The DIG system presents eight classes and the relationships between the classes in the DIG system are represented in the UML model. The interpretations of the six DIG relationships that exist between classes are described as follows.

- R1 – One department can have access to more than one data contract.
- R2 – One department can have more than one user.
- R3 – One publication can have more than one data contract.
- R4 – Only one view can exist from one data contract.

- R5 – One department can have more than one publication.

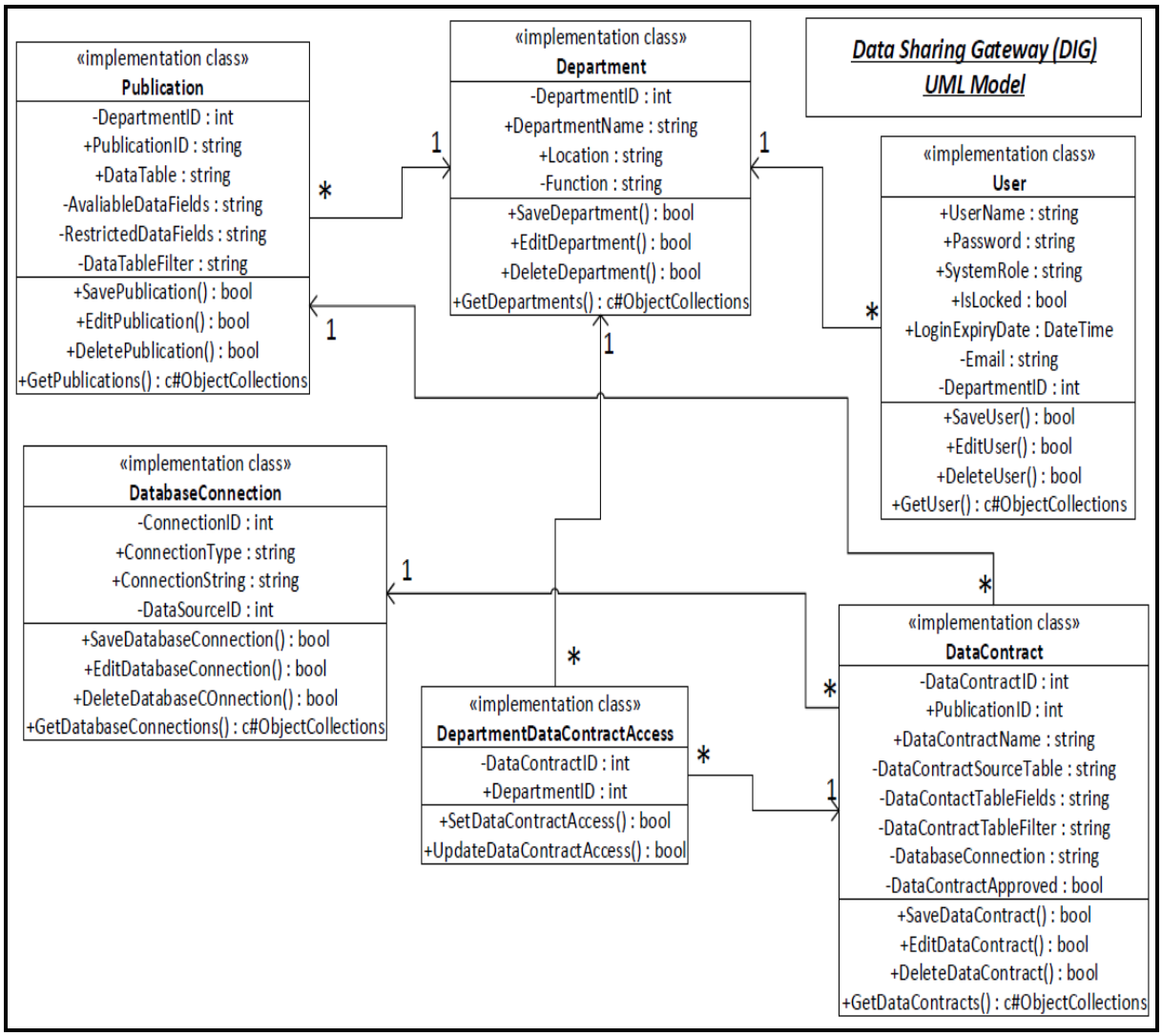

Figure 3.5: Data sharing gateway – UML meta model

3.3.6 Use Case Diagram for the DIG System

The relationship between the actors, functionality and the boundaries of the DIG prototype system are shown by use cases. Escalona and Koch (2004) state that use case diagrams show visually the functionality of the DIG prototype system. The use case diagrams of a system and the relationship between the entities provides a great understanding of the system. The high level functional requirements needed for the system as expected by the user can be derived from the use case diagram. Figure 3.6 represents the use case diagram for the DIG system.

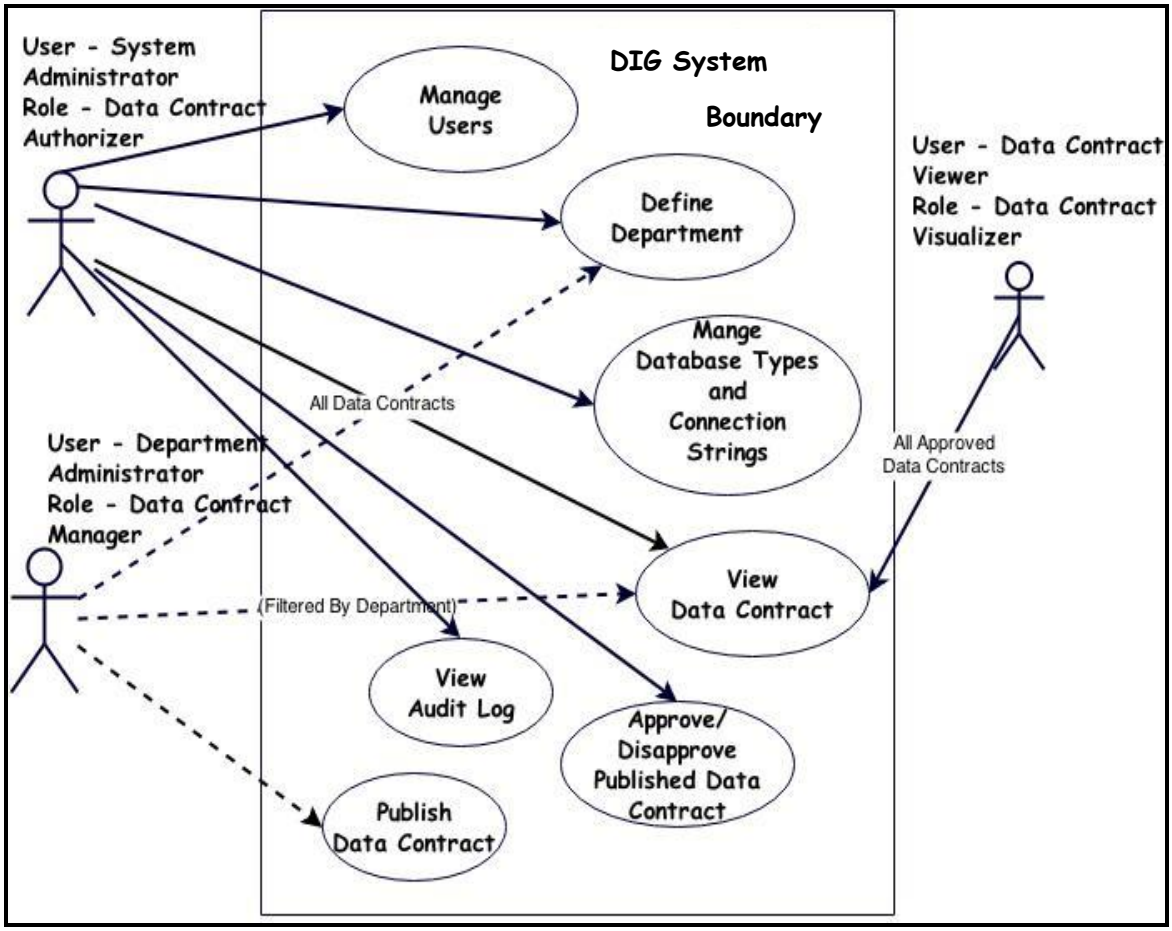

Figure 3.6: Use case diagram for the DIG system

The functional requirements shown in Figure 3.6 have to be prototyped at this stage using the DSR method. The users of the prototype and their roles (Salunke *et al.* 2013) are shown in Table 3.1 and the main functions of the DIG system prototype are represented in Table 3.2.

Table 3.1: Role and responsibility of the users

User	Role and Responsibility
DIG System Administrator	Data Contract Authorizer. This user is the overall administrator of the system.
Department Administrator	Data Contract Manger. This user created the data contract of his department.
Data Contract Viewer	Data Contract Visualizer. This user is the end user who accesses the data contract as defined by the system.

Table 3.2: Functions needed for the prototype development

Function	Description
Manage Users	This function created users who can access the system. The sub functions like locking the user, changing password and setting up the expiry of the logins forms the part of this function.
Define Department	This function creates departments that wish to participate in the information sharing using the system.
Manage Database Types and Connection strings	This function defines the database type and the connection string needed by the system. The database types in each department may be diverse that the system should support.
View Data Contract	This function allows the authorised users to view the defined data contract across the government departments.
Approve/Disapprove Published Data Contract	This function allows the DIG system administrator to approve or disapprove the data contracts. Only the approved data contract can be accessed by the authorized users.
View Audit Log	This function enables the DIG system administrator to view the activities done on the system.

The specification documentation involves the conversion of the UML use case diagrams showed in Figure 3.6 into a prototype system. The prototype system for data sharing across government departments requires the implementation of these specifications, which must be then be coded to realise the DIG system (Satzinger *et al.* 2004). Figure 3.5 represents the UML class diagram (meta model) for the DIG system, which is the static structure of classes and the relationship between them such as association, inheritance, aggression and dependency.

3.3.7 Hippocratic Model on which the research is premised

Padma et al. (2009) demonstrated a Hippocratic postgreSQL architecture, which used an extended SQL command along with the privacy facilities from both a terminal-based interface and a web-based healthcare application. The Hippocratic postgreSQL architecture is based on three key principles which are:

a) Privacy Policy Management – This feature requires extending the primary table with an additional attribute that specifies the current policy associated with each data owner.
b) Integrated Limited Disclosure – This feature ensures that any database access complies with the active privacy policies stored in the 'Privacy policy metadata' tables and the owner preferences.
c) Integrated Limited Retention: This feature allows the data to be retained only as long as necessary for the fulfillment of the purposes for which it was collected.

The DIG web application implements these key principles of the Hippocratic postgreSQL model in the core data sharing engine to successfully enable secure data sharing across the government departments using data contracts.

3.3.8 Prototype Evaluation

For the DSR study, the evaluation phase allows for testing Fan and Zhang (of the efficacy of the soft DSR artefact in addressing the problem in the context in which it was established (Crépin *et al.* 2008). The evaluation criteria and the limitation of the evaluation of the DIG system is described in the evaluation phase in Chapter 4 of this dissertation. The relevance and merits of the DIG system that will help seamless data sharing between government departments is proved by the evaluation results. The stress is on demonstrating that the DSR and this research study will produce a purposeful DIG system and a useful framework that could solve real life problems in real situations (Wang and Hou 2010).

3.3.9 Dissemination

The dissemination phase focuses on communicating the extent to which the implementation of the DIG system has addressed the research problem. The research problem is the entry point, therefore the results of the research should clearly communicate if the research problem was solved and the research objectives fulfilled. Additionally, the contributions of the DSR artefact as it relates to the DIG system will be communicated to the relevant knowledge domains. DSR not only focuses on producing innovative systems, but also on how these systems will benefit those who will use them (Wang and Hou 2010). Hence the research study should clearly provide contributions and disseminate them accordingly (Crépin *et al.* 2008). The research results, its contribution and the scope for further study are discussed in Chapter 5.

3.9 Limitations

The popularity of the DSR research paradigm compared to other research paradigms in information systems is low, but it is a valuable approach in information systems research. Sahraoui (2007) states that there has been a slow adaptation and distribution of DSR in the information system discipline in the last 15 years. The existing knowledge may be inadequate

for design purposes and therefore can force software designers to depend on intuition, experience and experimentation approaches (Hevner *et al* 2004; Ellis and Levy 2010) to produce innovative artefacts. This is why this study augments DSR with modelling tools and languages such as UML and OCL. According to Crépin *et al.* (2008) one of the major challenges of DSR is the overemphasis on the technological artefacts with the failure to preserve an adequate theory base. These results are well-made artefacts that are not useful in real life. Other challenges are related to the DSR solving a particular problem and applicable only in the context of that problem (Hevner and Chatterjee 2010). For example, a model that solves a particular problem in large organization may not necessarily be applicable to address similar programs in small unstructured organizations (Juell-Skielse and Perjons 2009).

In this research study, the research method was a synergy between the DSR paradigm and guidance from theoretical practices such as problem based research and contextual research to get an in depth knowledge of the problem domain and setting of the intended DIG system. This study does not justify the role of DSR in information system research, but merely adopted it to shape the research study to produce reliable results and to follow an accepted research method that involved thoroughness in the development and evaluation of the DIG system. The lightweight web application framework could be criticized as a product of software development exercise because both DSR and software development produces software artefacts. The DSR process requires the use of rigorous accepted methods, empirically testing of the artefact and communicating the results to contribute to the body of knowledge (Sahraoui 2007; Crépin *et al.* 2008).

CHAPTER 4: PROTOTYPE SYSTEM EVALUATION

This chapter presents the prototype system evaluation of the Data Integration Gateway (DIG) following design science research and Hippocratic database principles. The DIG application facilitates seamless data sharing across different departments. The integration process pulls data from different sources defined by data sharing contracts into a coherent view delivered to the recipient. The purpose of conducting the DIG prototype system evaluation is to legitimize the concrete idea behind its proposal. The DIG application proposes a central web application framework that is accessible to different government departments that wish to participate in data sharing collaboration. The prototype application is compatible with different browsers and when invoked it connects to the backend database server that hosts the DIG database. In addition, the DIG application offers the definition of data contracts that apply the Hippocratic principles before data sharing can occur. The proposed approach for data sharing between government departments takes place in real-time, whereas currently the processing time of data requests by government departments can be anywhere from a few hours to a few days depending on the transaction.

The implementation of the different components of the DIG application is discussed in order to provide a clear view of the system evaluation task. This will be followed by the introduction of the evaluation procedure, the presentation of evaluation metrics and information on the evaluators. Simple scenarios are used to illustrate the efficacy of the application. The evaluation covers the functions needed to seamlessly share data amongst the government departments in a secure way using Hippocratic principles to enforce security policies.

4.1 Prototype Implementation

This section presents the discussion on the implementation of the web application framework called DIG in order to provide a proof of concept through a real life prototype system implementation. The prototype system in action demonstrates the relevance of data sharing in the e-government space. The prime goal of this research was to develop a central lightweight web application framework for enabling seamless data sharing amongst government departments in order to speed up the service delivery process. The varied functions provided

by the DIG application could be used by different government departments and can be coherently integrated into their service delivery process. If any service is dependent on data from any other government department, the DIG application can pull the data from that source in real time. This mechanism reduces the time waiting to get the needed information from other departments, which in turn speeds up the service delivery process of government.

The DIG prototype system provides the related management functionalities such as managing user login, database connection, defining department, data contract, data contract authorization and data contract visualization. The DIG application merely serves as a channel for exchanging data reliably between government departments. An inherent merit of the application is that no data from government departments are stored anywhere in the DIG application. The DIG application only stores the authorized user and data contract information for accounting purpose. Another potential merit of the prototype system is that it is relatively easy to use and it accommodates basic users with low literacy levels. Users can easily view the data exchanged using the data visualization function and skilled users who can manage the data contract and other administrative functions can find the system appealing.

The design of the prototype system took into cognisance the context of the working environment of government departments, data ownership, data security, and hardware infrastructure and software technology constraints. The system aims to improve efficiency in delivering government services, foster accountability, minimize duplication of data across government departments and promote openness and transparency in government departments when it comes to efficient service delivery process. The implementation of the DIG application is through the design science approach, incorporating Hippocratic database principles to enforce data security. The application is cloud enabled because its database server resides on the cloud to be able to hold huge volumes of data as often experienced in government space.

Cloud computing has been defined as the aggregation of computing utility and software services located in data centres offsite where the applications are delivered over the internet as needed (Fernando *et al.* 2013). Cloud computing is the latest computing paradigm that adds capabilities to conventional computer without the need of investing in new hardware or infrastructure, licensing a new software, or having to train the system user. Cloud computing provides shared online business applications that can be accessed using a web browser or any other client devices, that runs the software and data stored on the shared web/database servers. Cloud computing extends the functionalities of web applications into

services. A web application is a distributed client-server system. The web application uses, a web browser which provides the user interface. The server and client exchange messages using the HTTP/HTPPS request and response protocols (Rewatkar and Lanjewar 2010).

In this study the front-end of the DIG application was implemented using the Microsoft Silverlight technology and framework for Windows Communication Foundation (WCF) (MicrosoftDeveloperNetwork 2014a; MicrosoftDeveloperNetwork. 2014b). The Silverlight technology is a cross-platform, cross-device and cross-browser plugin technology for providing the next generation of ".NET" framework based rich interactive and user experiences applications for the Web (LI *et al.* 2009). The WCF is Microsoft's unified computer programming model for creating and building a rapid service oriented applications (McMurtry *et al.* 2006; Skonnard 2006). The back-end database was implemented using the Microsoft Structured Query Language Compact Edition (SQL CE) lightweight database technology. Microsoft SQL CE is a database engine designed for mobile and embedded applications that run efficiently and that require less resources (Seshadri and Garrett 2000).

In the DIG application, the mechanism for sending and receiving data from the server to the client is handled through the WCF services. The applications, build with WCF can communicate across the web and the enterprise applications (Meier *et al.* 2009). The WCF is the layer between the Silverlight client application and the SQL CE database server (Kamran and Haas 2011). The WCF service works asynchronously and supports all type of protocols, namely named pipes, Microsoft Message Queuing (MSMQ), http/https, Transmission Control Protocol (TCP) and it can be hosted on self-hosting applications, Internet Information Server (IIS) and Windows Application Service (WAS). As already emphasised, the definition of the data contract defined in the DIG system does not store any data from government departments. The data contract only stores the necessary information to fetch the data from the publisher and seamlessly transport the data to the subscriber and the necessary security as well as connection information. So the lightweight SQL CE database with the WCF services fits in appropriately as technologies that can handle the data contract needed by the DIG system.

4.2 Evaluation Components

This section provides a description of the components of the DIG application that were evaluated in this study following the DSR approach. The DSR evaluation process focuses on the validity of a system in regard to changing the user requirements to preferred states. The

DIG application may be deemed inappropriate when it does not present any real value for practical usage. However, the application may be regarded as complete and effective when it satisfies the intended requirements within the constraints of the problem being solved. The DSR evaluation process can be carried out in two main forms, namely, a naturalist and an artificial setting evaluation (Olugbara and Ndhlovu 2014). An artificial evaluation is conducted in a non-realistic setting and uses methods such as laboratory experiments and simulations (Baskerville *et al.* 2009). A laboratory evaluation allows for more control over the testing scheme and reduces the costs of experimentation. However, it lacks the pragmatism of user interaction because it does not simulate the real context of users and lacks the desired ecological validity of user settings (Kallio and Kaikkonen 2005). A naturalistic evaluation involves observing the performance of a system in a real user setting and engages the actual users in identifying real system problems.

The literature posits that a system can be evaluated from an ex-ante and/or ex-post perspective. An ex-ante perspective means system evaluation prior to implementation and ex-post perspectives means system evaluation after implementation (Baskerville *et al.* 2009). Evaluation of the DIG application follows an ex-post naturalist pattern, using DSR principles to explore how real users react to the application in a natural context (Helfert and Donnellan, 2012). By considering all the above arguments, the DIG application was evaluated by observing its actual operation in a field experiment. This approach allowed for the acceptance of all the complexities of human behaviour in real life settings, against specified evaluation methods and realistic expectations (Baskerville *et al.* 2009). The choice of the right evaluation method was critical for research of this nature and was influenced by the fact that real users are from varied contextual backgrounds and settings. This made it, therefore, imperative to establish the validity of the evaluation in a user context (Cleven *et al.* 2009). The ex-post naturalist evaluation was conducted on the basis of different system components. A component wise evaluation offers an advantage over a whole system evaluation because it allows each important aspect of the application to be fully comprehended and validated against its functional requirements. The ".net" framework and the Silverlight design patterns (El-Bakry and Mastorakis 2009) helped to provide simple and easily accessible system component workflows.-

4.2.1 Manage Login

The DIG system requires users from participating departments to register with user names and passwords for authentication purposes. A user authentication is required for the DIG system users to gain access for using the application on their web browsers as shown in Figure 4.1. This is the fundamental requirement of most web applications to allow user access by authorization. The application will then authenticate the user and load the main interface of the application to allow the department user to perform specific data integration transactions such as viewing or defining a data contract. The system allows the user to complete as many transactions as possible without delays and deviation from transactions to enable data integration.

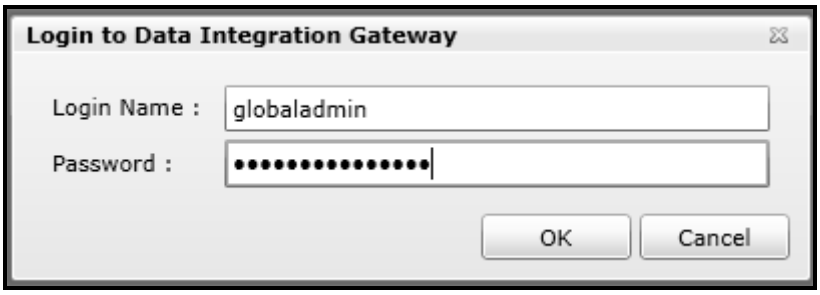

Figure 4.1: "DIG Login" screen

The user with a data contract authorization role can manage the logins for the DIG application. It is possible to use the "Manage Login" component to "Create Login", "Edit Login" and "Delete Login" for a user as shown in Figure 4.2. This figure portrays the main components of the DIG application such as "Manage Login", "Define Department", "Manage Connection Strings", "Authorise Contract" and "View Audit Log".

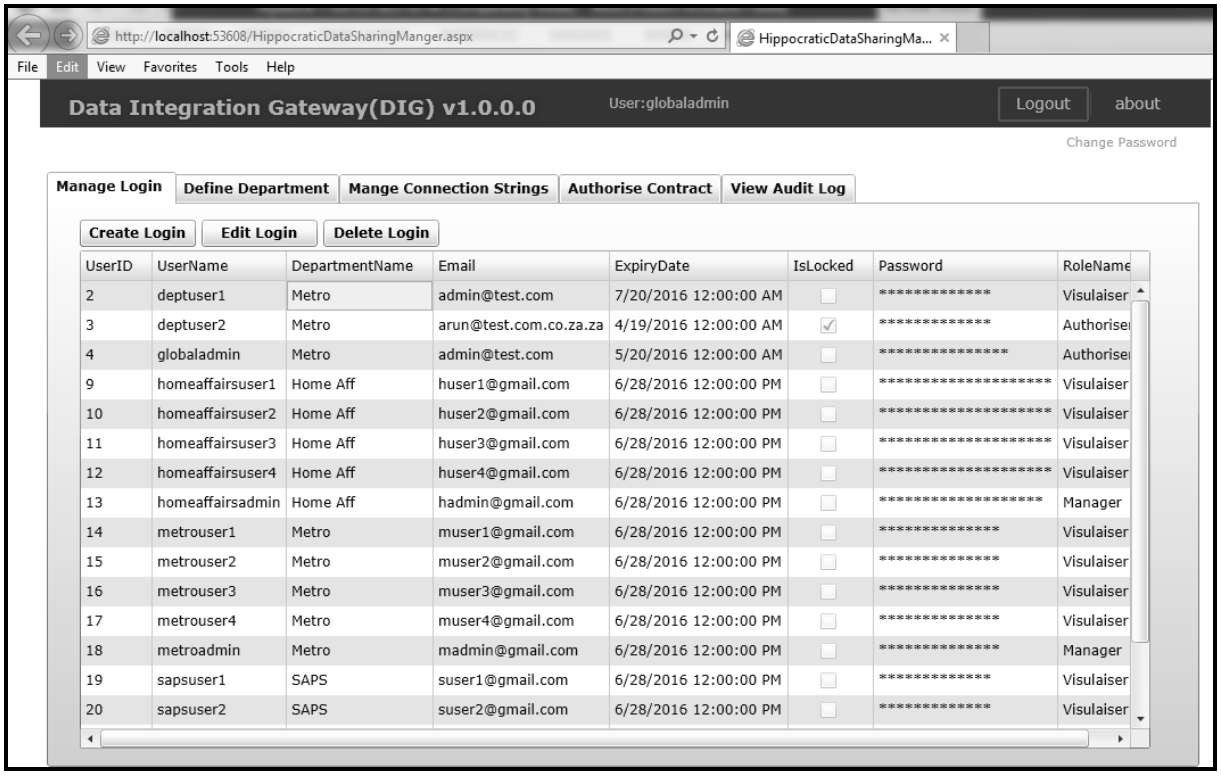

Figure 4.2: "Manage Login" screen

The "Create Login" or "Edit Login" components pop up a similar screen that allows for the required input to be captured and saved. The required inputs such as user name, secret password, expiry date for the login to the DIG system, the user role, email address and department that are required areas are shown in Figure 4.3.

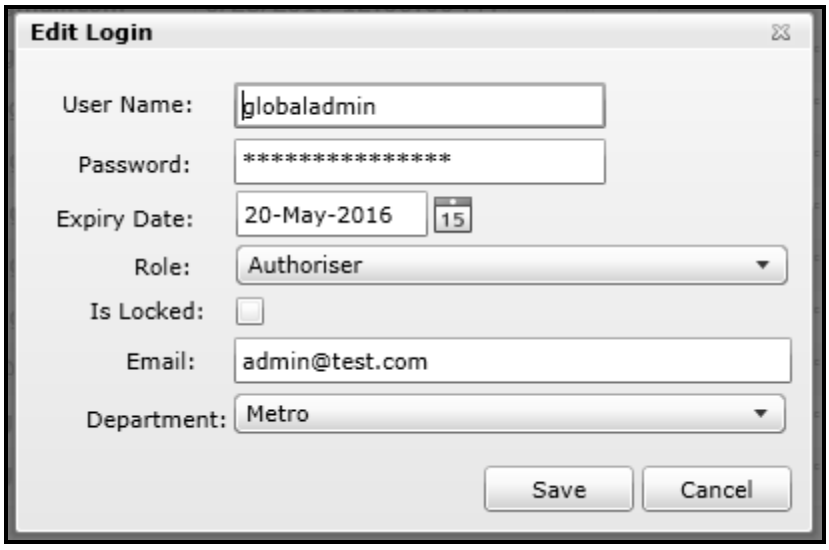

Figure 4.3: "Create Login" or "Edit Login" screens are similar to each other

4.2.2 Define Department

The administrator can “Create Department”, “Edit Department” and “Delete Department” according to the departments that wish to participate in the data sharing collaboration using the DIG system. The information such as department ID (unique identifier for a department), department name, department function and location are captured and stored in the DIG application as shown in Figure 4.4.

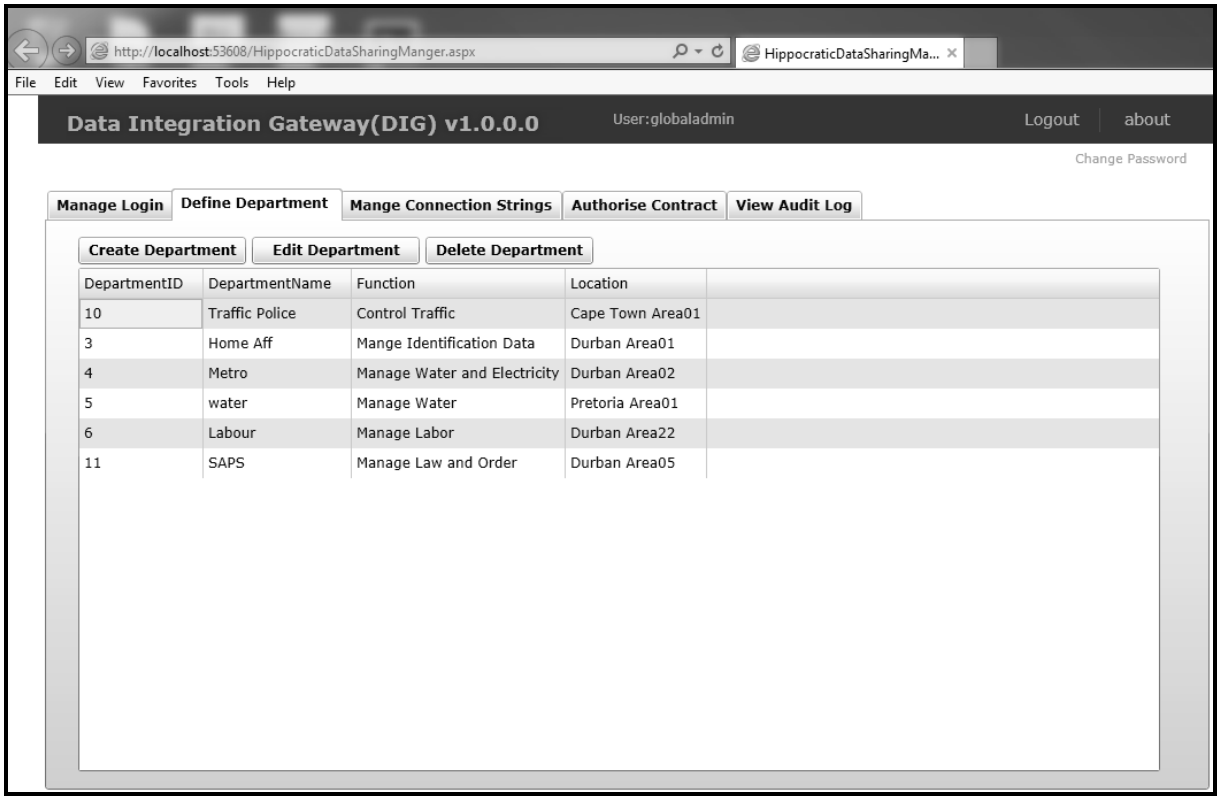

Figure 4.4: “Define Department” screen

The department’s system administrator can edit the department details that are defined by the DIG system administrator if needed. The “Define Department” component also allows the department administrator to publish the data contracts for the department using the “Create Publication” functionality as shown in Figure 4.5.

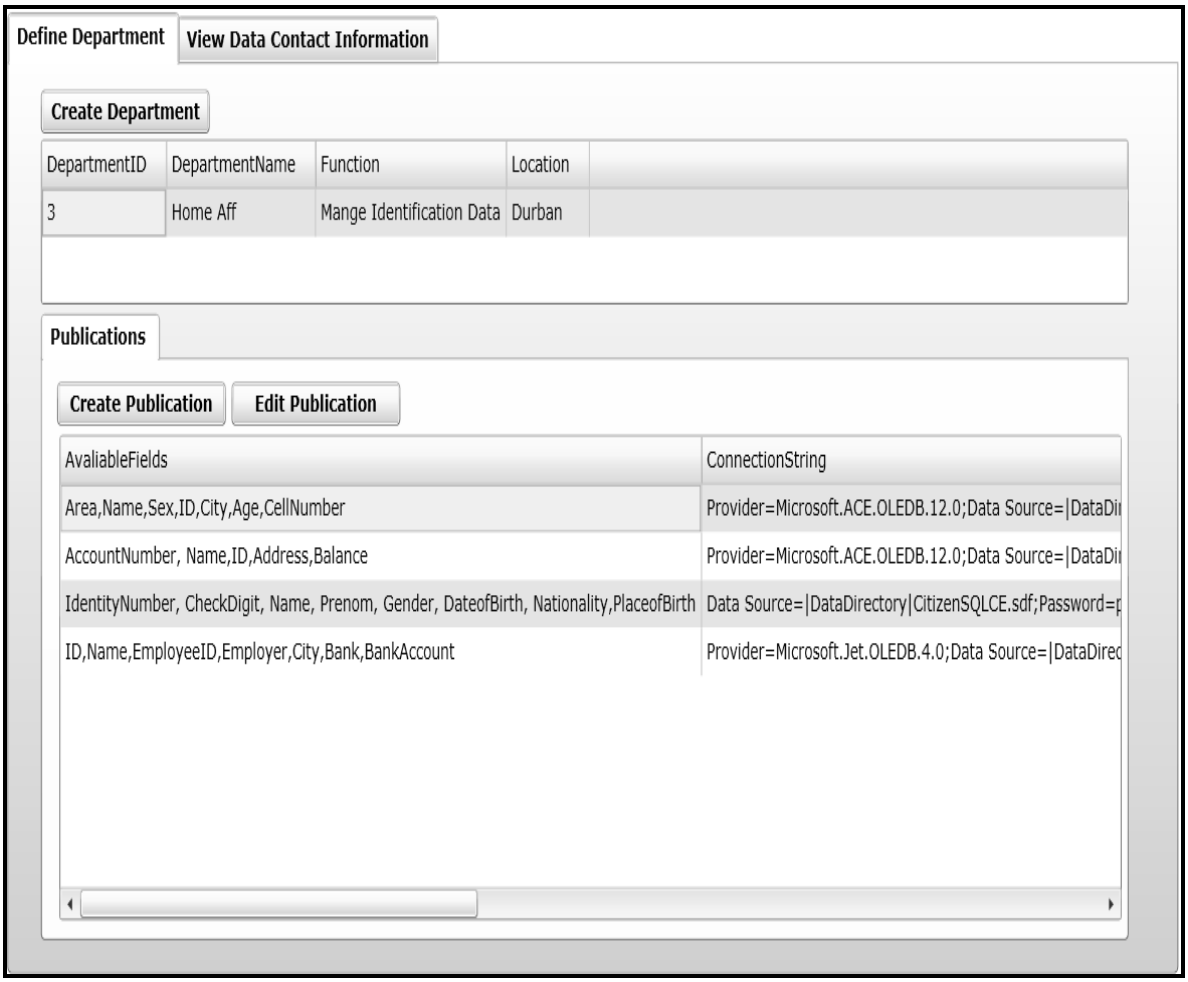

Figure 4.5: "Create Department" screen

The department system administrator can create the data contract and publish it to facilitate data sharing transactions using the "Create Publication" functionality as shown in Figure 4.5. This functionality allows the administrator to test the connection using the "Test Connection" function and to verify the validity of the publication before publishing it to the DIG system. The preview of the data that will be shared is also supported using the "Data Preview" function. The DIG system will enable the "Data Preview" when the test connection verifies the connection for valid publication data, as shown in Figure 4.6.

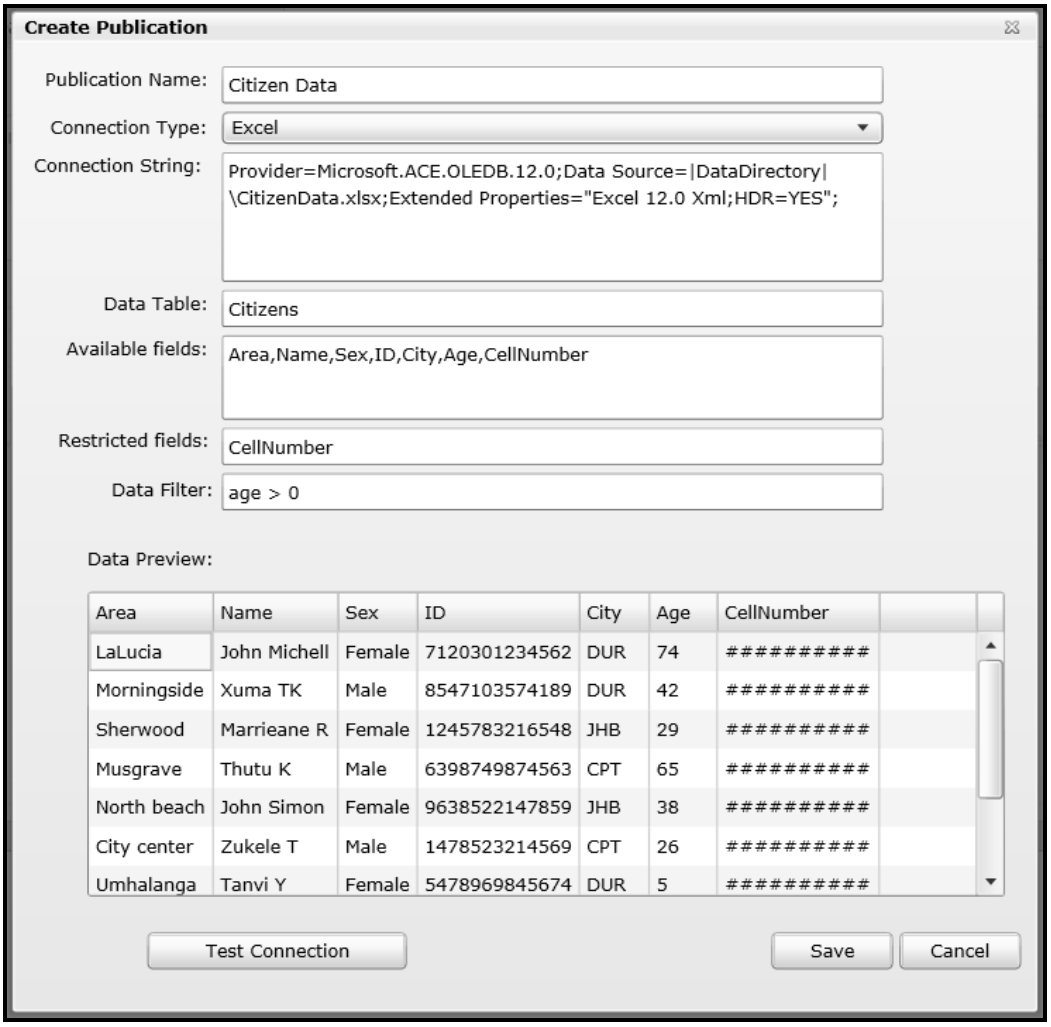

Figure 4.6: "Create Publication" contract screen

The "View Data contract information" functionality of the "Define Department" component of DIG application is accessible to "Data Contract Manager" role specified by the system. If the user has only "Data Contract Visualizer" role then the user can access the "View Data Contract Information" screen only. This screen shows all the data contracts approved by the DIG system administrator and to the data contracts to which the Data Contract Visualizer" role has access to as shown in Figure 4.7.

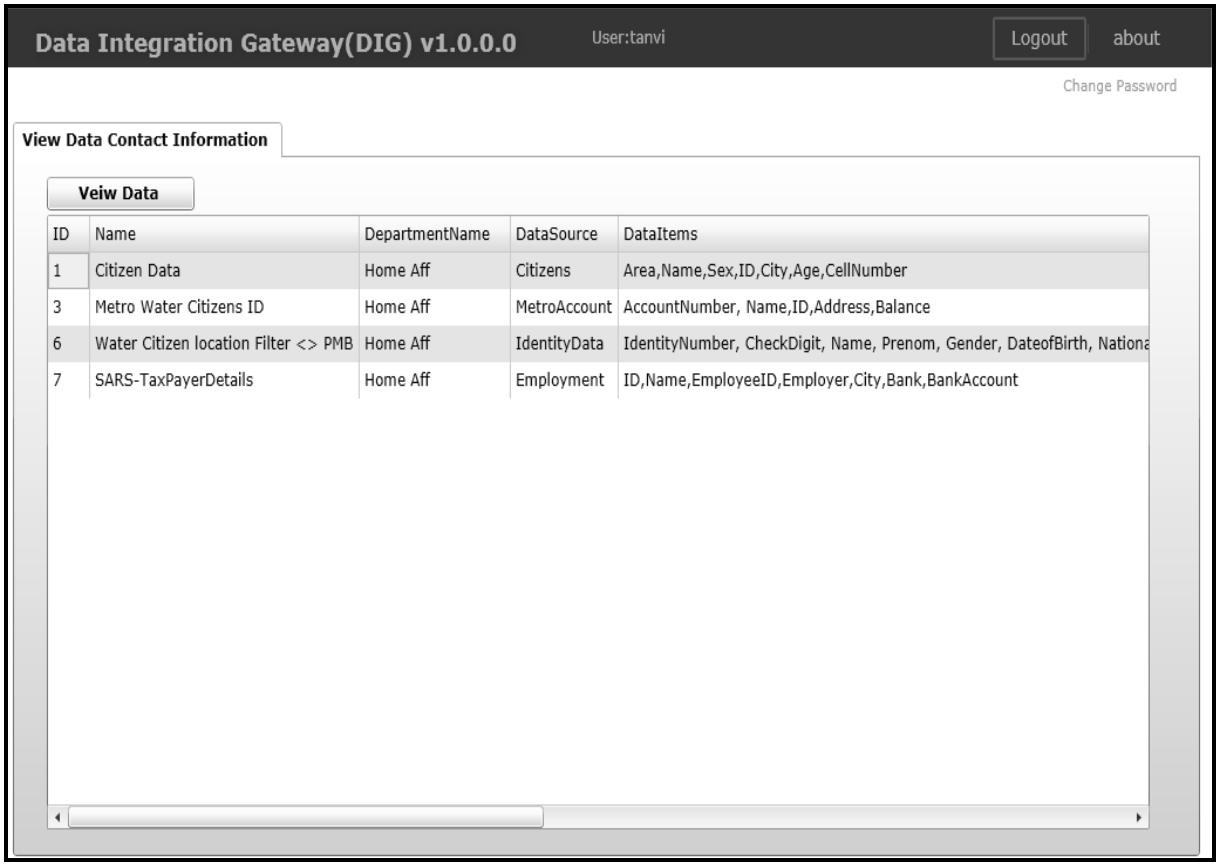

Figure 4.7: "View Data Contract Information" screen

Selecting the data contract and then clicking on the "View Data" button brings up the data contract preview screen shown in Figure 4.8. The "View Data Contracts" screen has a print preview tab where you can preview the data before printing. This screen also has a data filter text box where data can be filtered before printing.

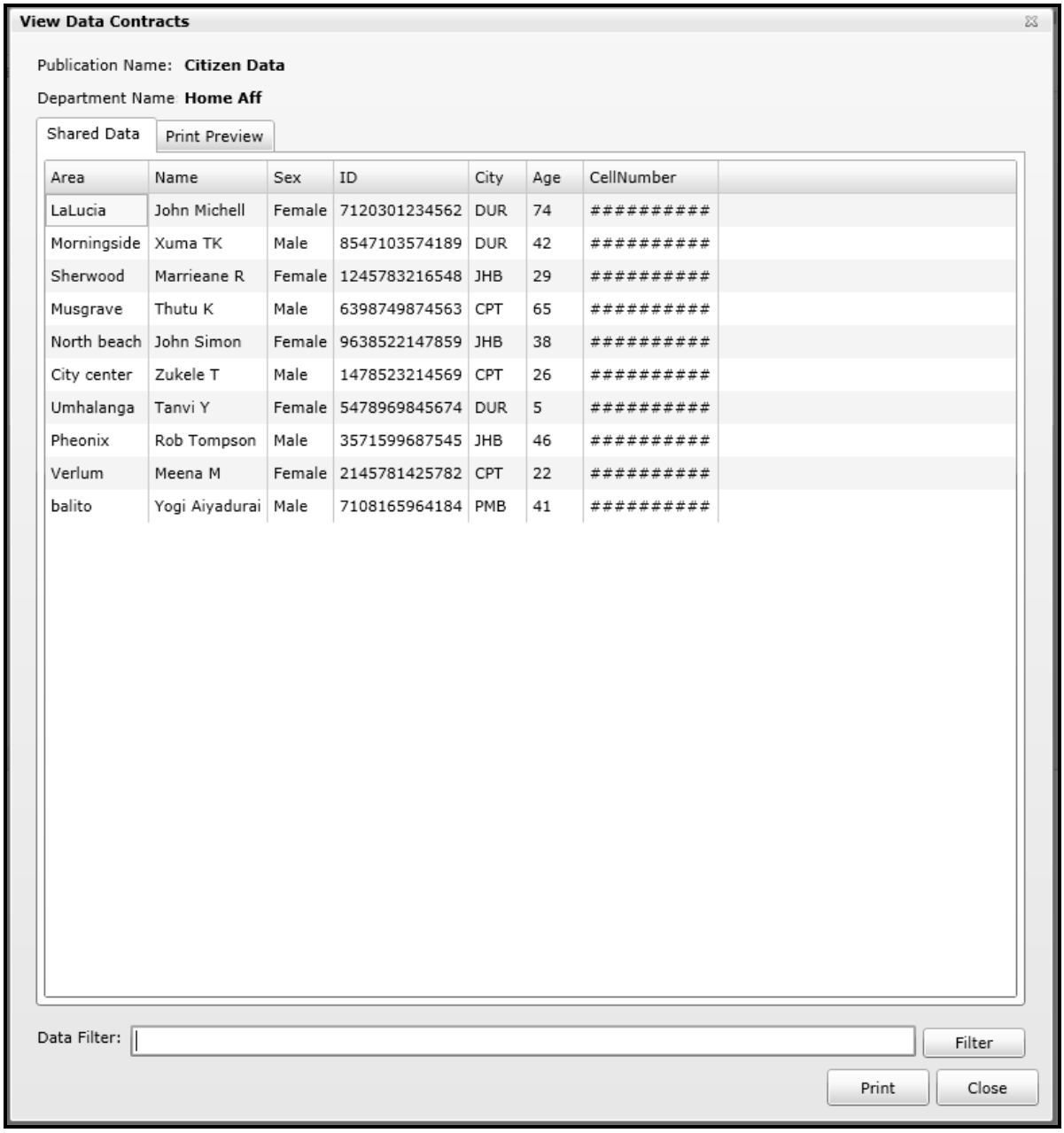

Figure 4.8: "View Data" screen

4.2.3 Manage Connection String

The user with the role of "Data Contract Authoriser" who is the DIG system administrator of the DIG system can define the type of databases that the DIG system can support (Figure 4.9) along with its corresponding connection strings (Figure 4.10). The connecting string formats will be later used when defining the data contracts by the department system administrator.

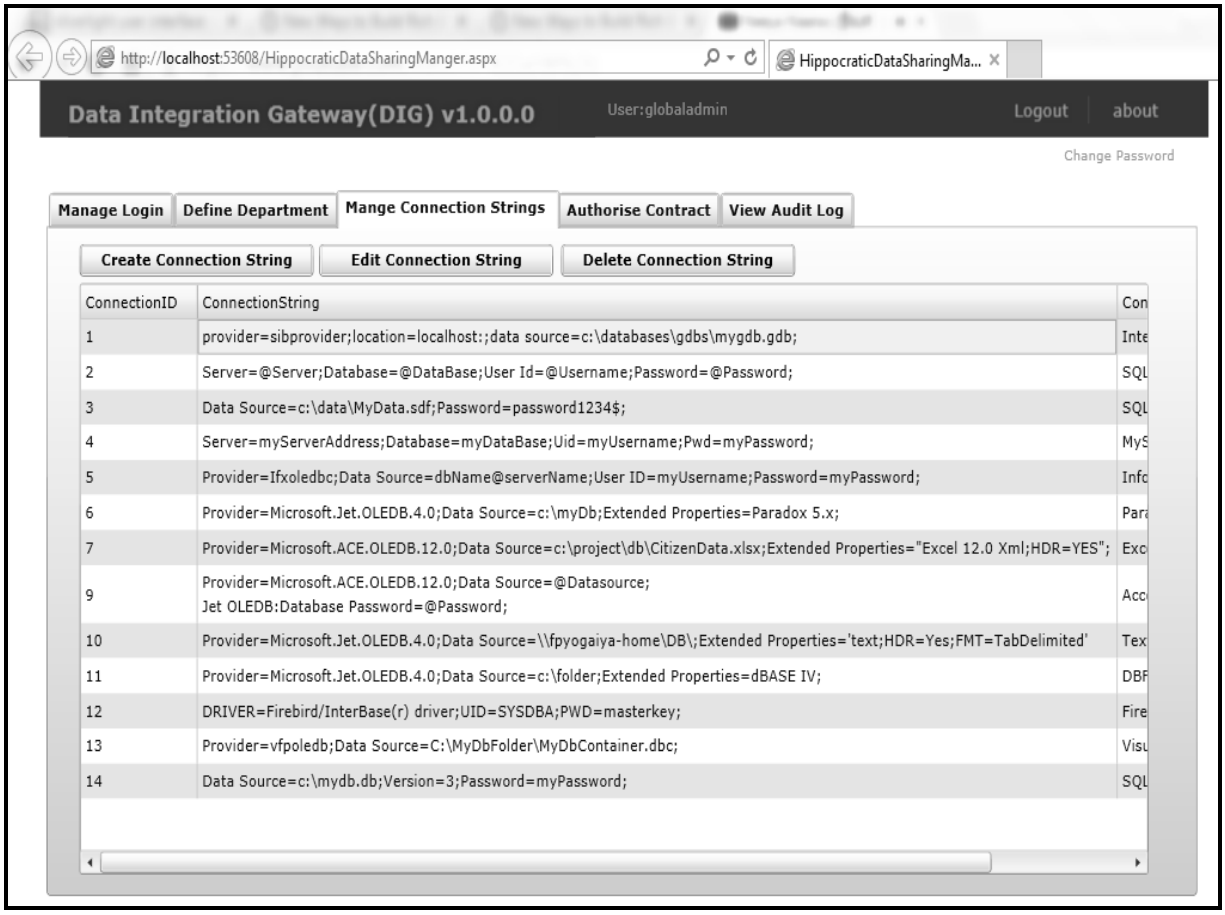

Figure 4.9: "Manage Connection String" screen

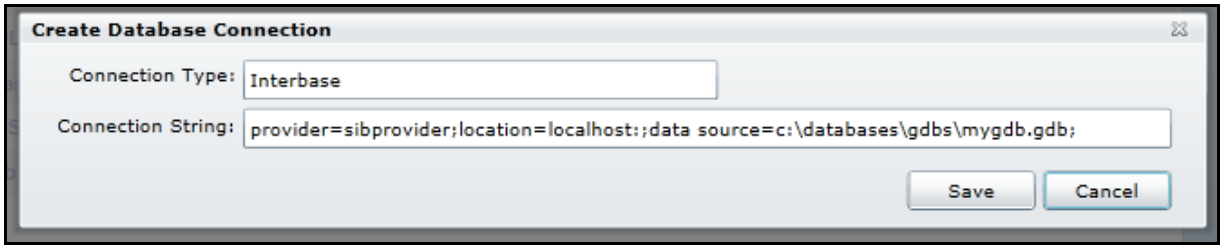

Figure 4.10: "Create Connection String" screen

4.2.4 Authorise Contract

The DIG system administrator can "Approve" or "DisApprove" the published data contracts by the department administrator using authorise contract functionality. Only the approved data contracts will be visible to the users with the "Data Contract Visualiser" role. This mechanism enforces security control at multiple levels, including who has access to create data contracts and who has access to approve the sharing of the published data contracts. Figure 4.11 shows the data contract authorisation screen.

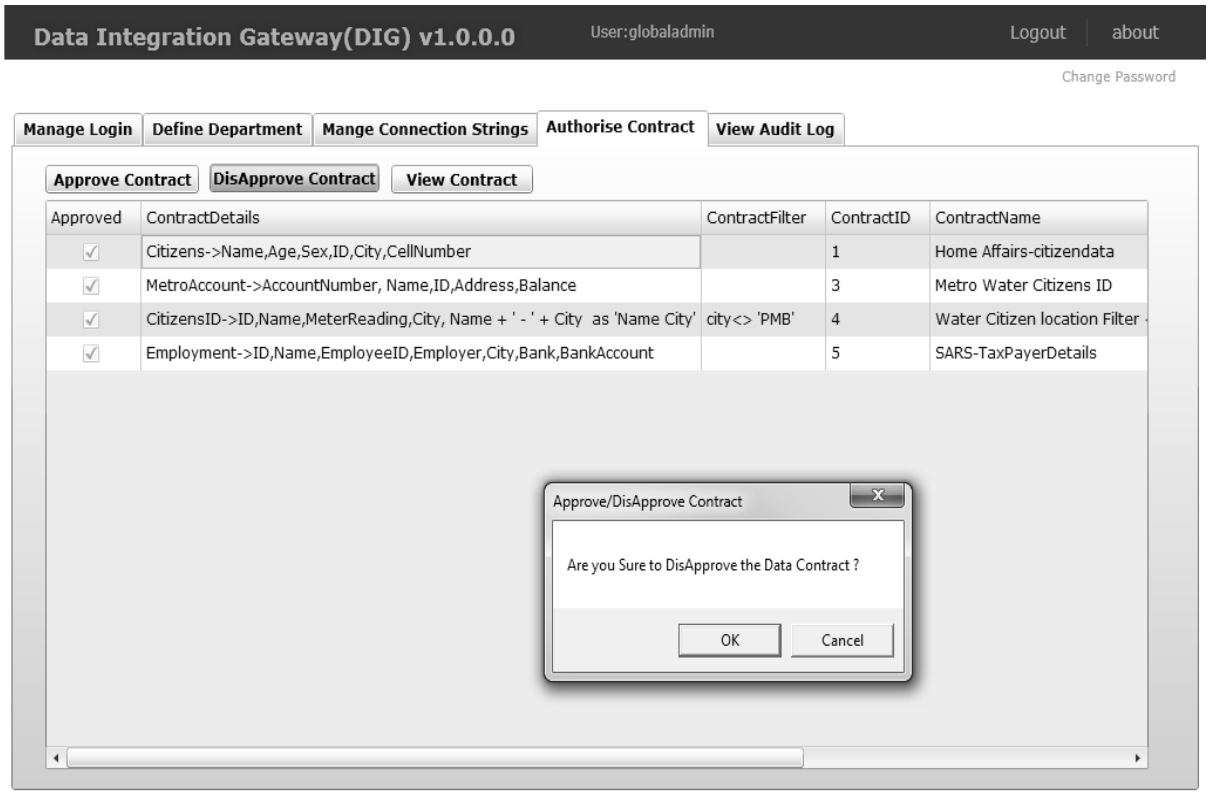

Figure 4.11: "Authorise Contract" screen

4.2.5 View Audit Log

The DIG system administrator can check the activities on the DIG system using the "View Audit Log" function as shown in Figure 4.12.

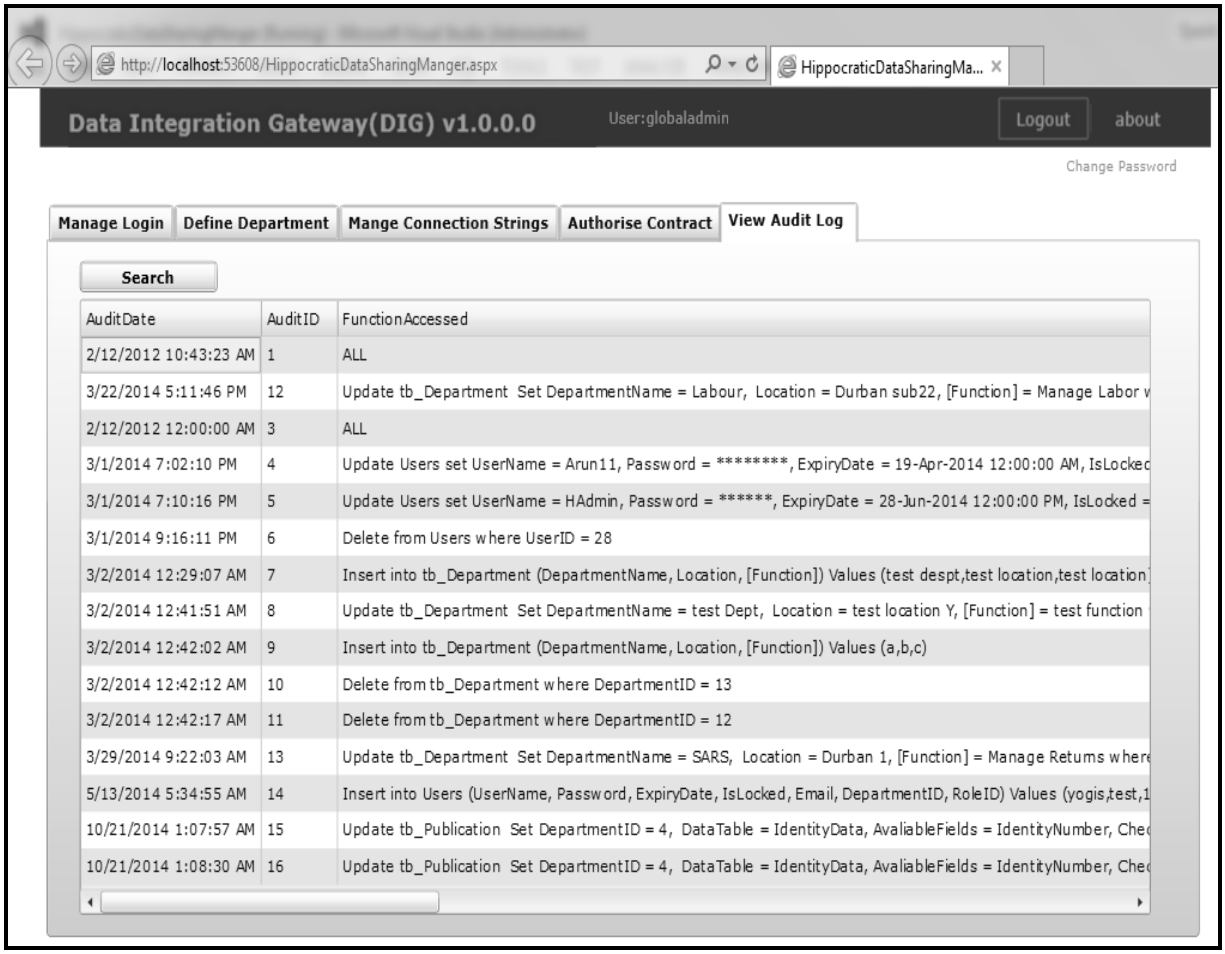

Figure 4.12: "View Audit Log" screen

The DIG system administrator can also search for a specific audit log using the "Search Audit Log" function. This function allows the DIG system administrator to search for a date range or for a specific text value as shown in Figure 4.13.

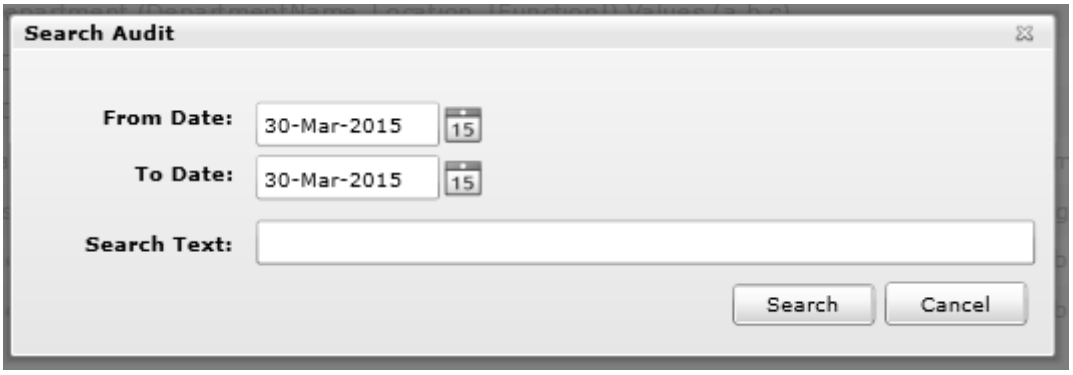

Figure 4.13: "Search Audit Log" screen

4.3 Evaluation Constructs

The evaluation of the performance of the DIG application is based on user interaction and system usability constructs, which are two important measures for system evaluation (Harrison *et al.* 2013; Olugbara *et al.* 2010; Zaharias and Poylymenakou 2009; Johnson and Yang 2009; Theofanos and Scholtz 2005; Scholtz and Consolvo 2004). Interaction is defined as how evaluators and systems function cooperatively taking into account that devices in the computing environment can be more dynamic than static (Scholtz and Consolvo 2004). Usability is the level to which a system can be used by users to achieve the needed goals with satisfaction , efficiency and effectiveness in a definite context of use (Nayebi *et al.* 2012). The success of application of the DIG system focuses on the overall user experience during the interactions and evaluations.

The ability of the system evaluators to correctly respond to the measurable statements was measured using a five-point Likert scale. A response score of 5 indicates “strongly agree”, and a response score 1 indicates “strongly disagree”. An average response score of 2 indicates “disagree”, a response score of 3 indicates “somewhat agree” and a response score of 4 indicates “agree”. Table 4.1 shows the constructs with their corresponding evaluation statements or measures.

Table 4.1: DIG system evaluation constructs and statements

o.	Description of Interaction Statement
01	I am able to access the system only when my details are correctly specified.
02	I am allowed to log into the system with password validations and the system logs me out after the task is complete, if I do not explicitly log out.
03	Only the Users that have been authorised can access the published in for.
04	The system speed and response to fetch the data contract data is satisfactory.
05	The system responded to the specified login authorization and the data contracts linked to the user and department.
06	The system exposes only the published data based on the available and restricted data fields from the data source.
07	Auditing is enabled for monitoring, in compliance with Hippocratic principles and privacy policies covering security and privacy.
08	The system tracks all the accessed data for what purpose and by whom, the time of access and the changes made.
	Description of Usability Statement
09	I understand the information required of me to access the system.
10	The system maintaining my privacy preferences.
11	The system only publishes only the information that I allow.
12	The system allows the publishing of my information only when authorised.
13	Once the data content is published, the data contract cannot be altered. Data contract belongs to the Data contract authorizer.
14	Only the non-restrictive data items can be used for Data contracts.
15	The system enables the linking privacy laws using Hippocratic principles and regulations relating to a data contract and its data items based on the logins.
16	The system runs on all popular internet browsers including Internet Explorer, Chrome, Firefox, and Opera.

4.4 System Evaluators

This study used 16 system evaluators as hosting the system in the 'cloud' and the time of the professional testers had a cost implication. The 16 evaluators used the DIG system on different browsers with preloaded data bundles. Table 4.2 reveals the distribution of the system evaluators, who were all professional testers from a software development company in Durban, South Africa. The system evaluators were trained to acquaint themselves with the basic functions of the DIG system. It was easy to communicate the functionalities of the DIF application to the evaluators because of their experience working with web applications. The system evaluators were specifically instructed to perform the following basic tasks using the DIG application:

a) Manage database types of connection strings.

b) Publish a data contract.
c) View a data contract.
d) Manage users.
e) Define departments.
f) Approve or disapprove published data contracts.
g) View audit log.

Table 4.2: Distribution of system evaluators

Title	Years of Experience	No. of Testers
Test Analyst	8-10	4
Senior Testers	6-8	6
Testers level 1 and 2	4-6	6

4.5 Evaluation Procedure

The evaluation of a software system is the set of activities used to determine if the system under examination meets the design requirements and to verify if the performance of the system satisfies the usability needs of the end users. While it is important in the application of DSR methodology to prove the usefulness of a system, a rigorous DSR evaluation procedure requires justifying the evaluation settings and validating the system design before it is put to practical use (Sonnenberg and vom Brocke 2012). Karmokar *et al.* (2013) proposed a user-centred procedure in design science research based on the Pries-Heje *et al.* (2008) conceptual framework and applied the procedure for the evaluation of a website. The evaluation procedure begins by asking some pertinent self-report measures that afford the evaluators the opportunity for deeper cogitation. Moreover, self-report measures are the valid and cost effective ways to collect information from the people (Glasgow *et al.* 2005). The self-report measures for the evaluation of the DIG application as suggested by Karmokar *et al.* (2013) and Pries-Heje *et al.* (2008) are the following:

a) What is being evaluated? In the case of this study, it is the data integration gateway design product.
b) How is it being evaluated? In the case of this study, it is through laboratory experiments.
c) When is it being evaluated? In the case of this study, it is ex-post naturalist using software professionals to voice their opinions about the system.
d) Who is evaluating it? In the case of this study, the evaluators are professional software testers and analysts.

The most critical response to these four evaluation measures or questions is the how question (Karmokar *et al.* (2013). The DIG system was evaluated using two methods, which are user task analysis and unit testing as shown in Table 4.3. This follows the recommendation in the literature to use multiple methods to evaluate a system (Karmokar *et al.* 2013). The user task analysis was used to evaluate interactivity and usability of the DIG system. The interaction evaluation was aimed at exploring the extent to which the DIG system provided the required feedbacks to users to successfully complete the intended data integration transactions without much rigour. The system usability is aimed at creating a system such as the DIG to ensure that it is usable with low learning overhead. The system evaluators were asked to express their opinion on the interactivity and usability of the DIG system using the data collection instrument in Table 4.1.

Table 4.3: Evaluation Methods Used in this Study

Evaluation Method	**Goal of Evaluation**
User Task Analysis	To test the human interaction, usability and functionality of the DIG system.
Unit Testing	To test the functionality, quality and code coverage at a component level. This is crucial as not all the code within the system can be evaluated with the usability test. The code related bugs can be easily identified by unit testing.

The DIG system was evaluated for quality and fulfilment of the system requirements using the software automated testing procedure. Sang *et al.* (2009) state that to test if the implemented software and its functionalities fit into the specification requirements as drafted by the analyst or the system innovator (the researcher in this case), a validation process is a mandatory task. The process of validation is an important step that must be a part of the unit test case design. For systems based on object oriented design, the process of validation is particularly germane. Khan *et al.* (2010) and Benli *et al.* (2012) argue that to test software requires a lot of resources including manpower and equipment, therefore this study implemented a unit testing procedure with the aid of NUnit tool in Microsoft Visual Studio to speed up the testing process. Tillmann *et al.* (2010) states that unit testing is an important and valuable means of improving software reliability and in recent years, it's been widely recognized in the industry, as it exposes bugs early in the software development life cycle. It is necessary to test all the individual software components separately instead of a whole system to make testing more robust and scalable. Wahid and Almalaise (2011) state that when it comes to testing procedures, unit testing plays a major role to test the source code to find out if it is fit for use and to confirm that the code fulfills its design and behaves as anticipated. Hwang *et al.* (2004) posit that unit testing has become so obvious and essential in

today's software development that there exist a number of software development frameworks to aid unit test writing, maintaining and running computer codes.

4.6 Evaluation Results

The empirical results of the prototype DIG system evaluation, using descriptive statistics were based on the findings of user task analysis (interaction testing and usability testing) and unit testing. The user task analysis questionnaire was formulated for the DIG application based on the key evaluation criteria shown in Table 4.1. is the results are presented in Figure 4.14, showing the mean of response measures against the 16 evaluation measures for the extent of interactivity and usability provided by the DIG system. In Figure 4.14 the usability testing results are plotted on the positive vertical axis, while the interaction testing results are plotted on the negative vertical axis for easy interpretation. A similar reporting approach for usability testing experiments was used in the usability analysis of a mobile recommender system (Olugbara *et al.* 2010). The user interaction analysis results show a consistent increase in all responses with a minimum mean value of 3.200 (standard deviation of 0.696) and maximum mean value of 3.930 (standard deviation of 0.463).

This result generally means that evaluators responded above the mean score of 2.5 on the measurement scale. The minimum mean value for user interaction occurred for measure M02, which is the user interaction for logging into the DIG system. The maximum mean value of 3.93 occurred for the statement M04 for the DIG system to fetch and return the data based on the user's request for viewing the data contract. This result means that evaluators found the process of data request contract and viewing as implemented by DIG more interactive and that of "log in" to be less interactive. This result was expected as users are more familiar with the "log in" system for most web applications. The result of the DIG system usability also shows a consistent increase above the mean score of 2.50 on the measurement scale. The minimum value of 3.270 (standard deviation of 0.600) for measure M11, which is the measure for the DIG system allowing only the information that the administrator allowed for publishing. The maximum value of 3.880 (standard deviation of 0.517) was recorded for the M09 measure, which means that the DIG system users understand the required information to access the system, hence it is usable.

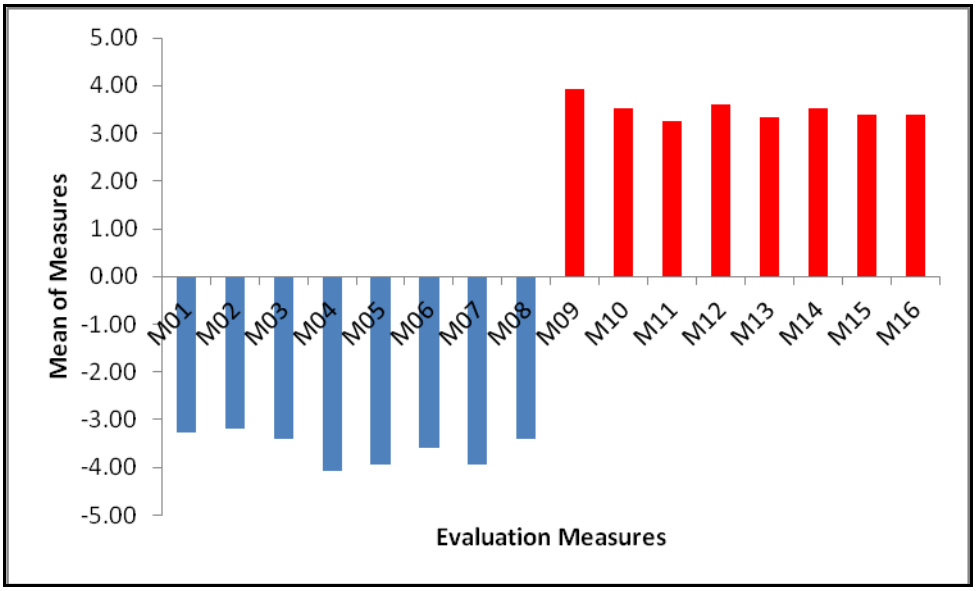

Figure 4.14: Mean of user interaction and system usability measurements

The unit testing evaluation of the DIG system was carried out using the unit testing mechanism implemented in the Microsoft NUnit. Tillmann *et al.* (2010) state that unit testing has been widely recognized as a valuable means of improving software reliability, as it exposes bugs early in the software development life cycle. Moreover, it is desirable to test individual software components in isolation to make the overall system more robust and scalable. Benli *et al.* (2012) points out that software testing is generally an expensive, *ad hoc* and unpredictable process, which requires a better process. Performing unit testing can help minimize the expensiveness of a testing procedure as it becomes simpler to manage short codes than to manage bulky ones. Wahid and Almalaise (2011) state that unit testing plays significant role in testing procedure to determine if the source code is fit for use to ensure that code meets its design and behaves as intended. Hwang *et al.* (2004) mention that unit testing has become so evident and crucial in today's software development that there are a number of unit testing frameworks to assistance unit test creation, maintaining and for execution.

The researcher chose to apply the NUnit unit testing framework which is well recognized in the developer community and software industry. There are other competing unit testing frameworks in existence such as MS Test and JUnit, but NUnit was used since it is recommended for Microsoft c# language ".Net" framework and the researcher is conversant with it. Figure 4.15 shows the results of the unit testing experiment with the DIG system. The results show that all the test cases related to the components within the DIG system passed the litmus test successfully. The unit testing was conducted for both success and failure criteria such as invalid passwords. The unit test ran through all the codes in the

DIG system and discovered any bugs buried in the code. The execution time of the components in the DIG system is also shown in Figure 4.15. The average timing for execution of the code was 588 milli seconds, which reveals that the DIG system is robust and error free.

Figure 4.15: DIG application evaluation using unit tests with passed test case

CHAPTER 5: DISCUSSION AND CONCLUSIONS

This chapter discusses the summary of findings of this study with respect to the development of a data integration gateway that can help facilitate data sharing. The discussion of the study findings also covers reflections on the lessons learnt through the research process. In addition, the chapter summarizes the study benefits and suggests recommendations for future work. The suggested recommendations are based on the outcomes of the experience of implementing the DIG system and the design science based evaluation of the implemented system. The chapter concludes by highlighting the reflections and lessons learnt by the researcher throughout the diverse stages of the study.

5.1 Summary of the Study

This study explored data sharing as an e-service within the e-government domain in the context of the South Africa system. Previous authors have seen e-service as a core component of the e-government system delivered through the internet because it bridges the intrinsic gap between the government administrators and citizens (Kaaya 2004; Misuraca *et. al*. 2011). The overarching goal of this study was to develop a web application that is based on Hippocratic database principles to support seamless sharing of data in e-government space. The research objectives have been met in order to achieve the goal of this study:

a) To enable seamless data sharing across diverse government departments without any changes to the existing system infrastructure.

   This objective was met through the development and evaluation of a data integration gateway (DIG) that could facilitate seamless data sharing without additional costs to the existing infrastructure. The DIG is able to integrate data from diverse sources and deliver the result to the requester that have been permitted by contract agreement to access parts of the data.

b) To control the volume of data sharing more securely across government departments using a coherent contract management technique implemented according to Hippocratic database principles.

   This objective was realized through the contract management policy implemented in the DIG system that was developed in this study. The gateway is able to restrict data

sharing to parts that are specified by the contract agreement policy. This implies that it is not essential to transport the entire database or data file across the network for the specific sub-data requested.

c) To reduce the time delay often experienced during cross verification of data involved in government services.

   This objective was met because data requested from one government department can be automatically shared using the DIG system for the departments that are involved in the data contract agreement. If data are automatically accessed from the sources without intermediary, it is possible to improve the processing time that will eventually improve service delivery efficiency.

d) To maintain a high level of consistency when data are shared across government departments.

   This objective was met because using the DIG system, multiple data entries at different sources can be avoided. The department that hosts a particular database can share it with other departments participating in the data sharing contract agreement.

e) To eliminate the storage of duplicate data across government departments by sharing the data from the source of truth.

   This objective was intrinsically met because DIG system eliminates the need to keep multiple sources of truth. If a database resides in a particular department, its contents can be effectively and efficiently shared across all other departments that agree to participate in the data sharing collaboration.

The DIG could be touted as a data sharing tool that could contribute to effective means of achieving data interoperability within the e-government space. Previous authors have mentioned that data sharing in government space will contribute to eliminating errors inherent from manual procedures, and eliminate duplication of data thereby decreasing the time needed for transactions (Ndou (2004). Efficiency is also achieved by streamlining the internal process by enabling more informed and faster decision making and by speeding up transaction procession. Gianluca *et al*. (2011) argue that there are still challenges with the interoperability dimension of governance openness within e-government space and propose that interoperability contributes a lot to the delivery of e-government services to local and national organizations within the European Union. Solving data interoperability problems adequately will allow any two or more organisations or departments to exchange and understand information where there are hardware and software issues (Guijarro 2007). This will also allow two or more organisations or departments to exchange data where the

structure and content of the exchanged data are different, but the information is correctly traded (Gugliotta *et al.* 2005). In codicil, it will allow two or more organisations or departments to engage in an effective exchange of information, data and services through the adoption of best practices supported by an appropriate framework (Scholl and Klischewski 2007).

5.2 Benefits of Data Integration Gateway

The data integration gateway (DIG) is a web based system that enables seamless data sharing across government departments by providing data contracts in place and by enforcing security standards for defining and sharing data. The DIG system can work with any type of the existing relational databases and is compatible across any web browser. The DIG system works on user based and role based authentication mechanisms. The communication across government departments are through secure protocols. The web application and the database that hold the data contracts and connection information reside at the secure government data centre. The DIG system administrator can track the activities that are taking place in the DIG system. The published data contracts are transparent and once published, all the authorised users can access the data contracts. The DIG system connects the vertically integrated system horizontally.

This in turn breaks the existing barriers where communication between vertically integrated systems is not possible. As a result, intra- and inter-department communications are made easy using the DIG system. There is efficient delivery of services where there is inter-dependency between the departments. The DIG system can integrate existing applications and databases in government departments and enables communication between them making the practicality of seamless data sharing a reality. This implies that no changes to the existing infrastructure in government departments are needed. A very low investment is needed to host the DIG system at the data centre. Making the service delivery faster by enabling data sharing between government departments encourages citizens to trust the government. The DIG system eliminates the duplication and inconsistency of data across government departments which also creates trust between government and citizens. The top officials in the government are already under pressure for slow delivery of government services. With a system such as the DIG that is efficient, robust and cost effective, the support from the top management should be easily obtained.

The DIG system addresses the service delivery issues faced by the South African government to reach their vision of e-government 2020. To fulfil the vision of South African government's e-government 2020, which is to bring the existing manual services online through web and internet, data sharing across government departments must be in place first. Secondly, a massive change in existing hardware infrastructure and software systems in the government space needs to occur to provide the latest internet technologies to support the online web services that can support the South African government's vision of e-government 2020. The DIG system is cross-platform, cross-browser and can support most of the different types of databases used in the government sector, thereby promoting technological interoperability. The DIG system can support most of the different types of databases used in the government sector. When the data contract is properly defined and transformed, information can be correctly exchanged between diverse government departments. The process and procedure to exchange data or information between government departments are clearly supported by the functions implemented in the DIG system. The interoperability provided by the DIG system allows any number of government departments to participate in the data or information sharing to enable more effective intra- and inter-departmental communication.

The development of the DIG system was based on the design science research hypothesis, which seek out to increase the limits of organizational and human competencies by generating new, innovative and purposeful systems. The contributions of design science research are in the collective innovation and usefulness of the developed systems that enable the understanding and creation of useful information systems in the organizations (Hevner *et al.* 2004). The contributions of the systems are valued with respect to their capability to increase performance in the growth and use of information systems (March and Storey, 2008). The DIG system developed and reported in this dissertation contributes to design science research as well as the ICT knowledge domain and satisfies the following requirements:

a) Convenient – the language based on contract management policy was borrowed from Hippocratic database principles for specifying data of interest is intuitive, simple and user friendly.
b) Preservation – enforcing data privacy policies through a set of contract agreement policies do not require any changes to the existing database systems managing the source databases.

c) Persistency – data privacy policies are created, managed and stored as contracts in an external database that is private to the gateway.
d) Protection – contents of source databases are not altered, no data write access given to the gateway and data read by the gateway from the source databases are not stored in the database maintained by the gateway, but such data are delivered to the requesters as portable files.

The potency of the Hippocratic data sharing approach being proposed in this study is built on two technical properties. Primarily it supports field and record level data privacy enforcement policies. Next, it permits full use of the standard structured query language (SQL) query proficiencies to express policies for seamless data sharing. In more detail, the contributions of the research reported in this dissertation are:

a) The investigation of an approach for a seamless Hippocratic sharing of data maintained by different heterogeneous information systems with specific reference to the e-government space.
b) The examination of several implementation issues of a seamless Hippocratic data sharing technique, including secure metadata storage, efficient query formulation policies and data structure for the storage of contract information.
c) The experimental evaluation of the proposed application shows that the data sharing approach has low overhead and speeds up data sharing and information verification time.

The DIG system therefore presents a potential framework to solve some of the existing challenges of disconnected government systems which exist in most developing countries. The DIG system provides the envisaged benefits for the government which are enunciated as follows:

a) Enables seamless data sharing across diverse government departments without any changes to the existing infrastructure and software applications.
b) Controls the volume of information sharing more securely using data contracts with Hippocratic principles among diverse government departments.
c) Reduces the time delay and the dependencies across government departments during cross verification of data involved in government services.
d) Maintains a high level of consistency when data are shared across government departments.
e) Eliminates the storage of duplicate data across government departments by sharing the data from the source of truth.

f) Delivers services at acceptable speeds.
g) Aligns government's political and delivery mandates using technology.
h) Develops and implements immediate and interim measures to support and secure the IT environment of the government.

5.3 Future Work

Implementation of the DIG system would provide a methodology and foundation upon which to apply design science research to improve data sharing in innovative ways and thereby improve the efficiency of service delivery in government departments. The evaluation of the DIG system by means of this study anchors the validity and reliability of the criteria applied. The DIG system could effectively contribute to millions of citizens and businesses in developing countries by speeding up service delivery. This system is cost-effective to implement and can support the existing infrastructure and databases in government departments. The research results provide relevant insights to extend the concept of data sharing in the government sector for future research and can be extended to apply data contracts and Hippocratic principles for mobile cloud services. Ndou (2004) states that with the rapid technological changes in ICT and availability of new technologies, government sectors can create extensive opportunities to rethink the way that services are delivered in the public and government sectors. Cost effective, robust, secure and freely available ICT solutions can be developed to bring communication and collaboration between the government, citizens and the businesses together. The pervasiveness of mobile devices means that citizens demand new ways of conducting businesses and interacting with government directly by using government services online.

Future work can look at mobile data sharing within the e-government space to support the emerging open government initiative. The emergence of mobile phones, wireless technologies and hand held devices with sophisticated features and powerful computing is creating the demand for all governments to provide mobile, open and smart government. Reffat (2003) raises an important point about the latest improvements in mobile and wireless communications and states that it is becoming easier for the governments to provide and manage services to its citizens efficiently and cost effectively using advanced solutions through the mobile. The usage of internet using the mobile phones is increasing faster than desktop usage and is likely to continue in this direction in the future. The next generation of e-government services will mainly be consumed on mobile devices, so the government are

now forced to provide the e-government service via mobile which is referred to m-government (Almarabeh and AbuAli 2010). To fulfil the mobile government requirements and to support other hand held devices governments around the world must publicize and make available government services using web/cloud services that are efficient, compatible, secure, and interoperable so that the web services can be consumed by various third party applications. The application of Hippocratic principles and the concept of the data contract can also be applied to government web/cloud service architecture, requiring user authentication for access to the web service. Future work can research issues regarding data integration, sharing and interoperability for the smart government initiative.

5.4 Concluding Remarks

To conclude, this dissertation developed a data integration gateway based on Hippocratic database design principles to facilitate seamless sharing of data across government departments that wish to participate in collaborative data sharing. In this dissertation, the necessity of data sharing is well documented and how this mechanism can help to improve government service delivery process is detailed. Firstly, considering the importance of data sharing as a way of improving service delivery in the government departments, this study can conclude that in the case of the South African e-government implementation framework, the need to have a system such as a data integration gateway in place to help facilitate service delivery process is absolutely vital. Secondly, and most importantly, the need to control how data should be shared within the e-government space to enforce security policy is critical to the successful application of a data integration gateway. The interplay between accessibility to crucial government information is associated with levels of data integration and sharing that occur at government departments. This helps to explain how government departments in South Africa could adopt ICT in their future data sharing collaboration. Thirdly, this study presents evidence in line with previous studies that data sharing can be challenged through a design science system construction.

This study emphasises that ICT development should be based on a clear understanding of the existing problem, the real system requirements and the usefulness of the solution being suggested. Innovative ideas must be developed into an ICT based artefact that must then be adapted to solve the identified problem. The ICT artefact must be useful from the viewpoint of the users for whom the solution was developed. This research study presents the work and findings from user based evaluation of the DIG system for the government

sector. The relevant parties, literature and other sources that contributed toward the content of this research, to the dissertation and personally to the researcher were acknowledged accordingly throughout the dissertation document. Overall, embarking on this study brought a challenging, but yet exciting experience for the researcher. The interaction with the various stakeholders that contributed to the success of this research cannot be described in words. The experience of interacting with real people, addressing real problems through design science research was a very rewarding and a fulfilling experience. Although the research study was conducted through a formal academic process, it provided an opportunity to learn outside the conventional ICT systems development environment and management environment through applying innovative research to solve a real world problem. The insights gathered from this study can support informed arguments related to some of the theories in the ICT domain. The proposed data integration gateway solution developed in this study can benefit governments and private businesses and organizations that want to share data across departments or organizations. The DIG framework therefore is a unique concept that can be adopted by any sector, but for the government sector the framework can make a massive difference in service delivery which will benefit citizens and businesses.

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