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**ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL SCIENCE
SCHOOL OF INFORMATION SCIENCE**

**INFORMATION ARCHITECTURE TOWARDS
AN INTEGRATED GEOSCIENCE
INFORMATION ENVIRONMENT:
THE CASE OF GEOLOGICAL SURVEY OF ETHIOPIA.**

Asaye Addissie

June, 2015

ADDIS ABABA UNIVERSITY
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SCHOOL OF INFORMATION SCIENCE

INFORMATION ARCHITECTURE TOWARDS AN
INTEGRATED GEOSCIENCE INFORMATION
ENVIRONMENT: THE CASE OF GEOLOGICAL SURVEY OF
ETHIOPIA

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Master of Science in Information Science

By
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_____	Advisor	_____	_____
_____	Examiner	_____	_____
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Abstract

The speedy advancement of information technology and the following management of digital information have opened new road for capturing, managing and disseminating geoscience information. Geological surveys now capture data from field using digital technology; laboratory results are recorded automatically in digital form and geological maps which was formerly presented in paper form are now being represented in digital form using GIS and satellite imaging systems. Even if these advancements in the technology have brought producing better quality geoscience information in Ethiopia, the accessibility of geological and geology related information is not with the expectation of users of the information.

The main objective of this research is to investigate, design and validate information architecture towards establishing an integrated geoscience information management environment.

By taking Geological Survey of Ethiopia as an enterprise and using Zachman Framework an Integrated Geoscience Information Architecture was defined taking into consideration all the participants involved in the planning, conception, building, using and maintaining activities of geoscience information. Qualitative and Design Science Research methodologies were employed. The qualitative research was required to understand the practices around the management of geoscience information. Design Science research methodology is demanded to develop an Integrated Geoscience Information Architecture. Non probability purposive sampling technique was employed for sampling. Interview, direct observation and documents were used for data collection for this research. The analyzed collected data using interview showed that geoscience information management is not effective in Geological Survey of Ethiopia. This result was triangulated via observation. To give a solution for this problem, through extensive literature examination and interview an integrated geoscience information architecture was designed and proposed to be evaluated by the concerned experts of geoscience information and IT. They have approved that the architecture is sufficiently complete and relevant. The checklist was also used to evaluate the architecture and it was verified that the architecture was designed according to the accepted guideline of Design Science Research methodology.

Acknowledgments

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List of Abbreviations

ADM	Architecture Development Method
BPR	Business Process Reengineering
DS	Design Science
DSR	Design Science Research
EA	Enterprise Architecture
FEA	Federal Enterprise Architecture
GIS	Geographical Information System
GSE	Geological Survey of Ethiopia
GSI	Geoscience Information
GSO	Geological Survey Organization
IA	Information Architecture
ICT	Information Communication Technology
IS	Information Science
IT	Information Technology
TOGAF	The Open Group Architecture Framework
UML	Unified Modeling Language
ZF	Zachman Framework

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CHAPTER ONE

1. Introduction

1.1 Overview

Geoscience information comprises a range of earth science data and interpretations derived from geological, geophysical, geochemical, and mineral studies. This information is used by governments to manage their lands, mineral, energy and water resources, to protect the environment and human health, and to assess risks due to geological hazards such as earthquakes, landslides, volcanic eruptions and floods [1, 37, 42].

Governments use geoscience information to formulate and implement public policies in such areas as resource development, environmental protection, public health and safety, land use, and infrastructure planning. Governments have variety of institutional arrangements to satisfy their requirements for geoscience information. These include units within government ministries; agencies which operate separately but accountable to ministers; and reliance on governmental and non-governmental sources. Most governments have established geological survey organizations to meet their geoscience needs [1, 15, 42].

The acquisition, management, communication, and administration of geoscience data, information, and knowledge are fundamental mission responsibilities of the Geological Survey Organizations (GSO) in every country.

A GSO is a public organization responsible for a range of tasks that generally include

- geological surveying (mapping) of the nation, state, or province;
- conducting geological research to support economic development, public health, and environmental protection;
- distributing geoscience information; and
- advising government at various levels regarding water, mineral and energy resources, environmental issues, and earth hazards [1].

With the massive and ever-increasing amount of geoscience information, information architecture is essential to ensure that people can access what they need when they need it [2, 3].

Planning and development of geoscience information solutions using well-defined design patterns help system development projects as well as simplify the communication among stakeholders. A GSO using the optimal information architecture for its information management can enjoy advantages such as lowered costs of doing its day to day activities since experts and users spend less time creating and finding the information [5].

1.2 Statements of the Problem

The competitiveness of any economy or sector of an economy is based primarily on how effectively information can be organized, accessed and utilized. This provides the underlying drive for change for all organizations that handle information, [25].

The Geological Survey of Ethiopia (GSE), the organization that is selected for case study for this research, is Ethiopia's foremost supplier of geoscience solutions. As any GSO, the acquisition, management, communication, and administration of geoscience data, information, and knowledge are fundamental mission responsibilities of the GSE. Geoscience experts in GSE collect, maintain, and exchange raw geoscience data and interpret and analyze it to produce a wide variety of geoscience products. The Ethiopian government uses this information for decision making. Investors use the information for their business activities. Thus, information is the primary product of the GSE, and it flows to geologists, ministers, partners, and a wide base of customers, including local, Regional, and Federal agencies, private sector organizations, and individual citizens. Since its establishment, this geoscience information has been stored in large volumes in numerous dispersed databases, archives and other digital and non-digital formats in Geoscience Information Directorate and other technical departments. Currently, there are still no standard existing centralized databases for geoscience information. Most of the raw data collected and different types of geoscience information have been neither properly described nor archived, and its significant proportion has been lost.

Departments that are involved in producing geoscience information need to integrate data from one another in conducting projects. Under the current set-up, the data and information sharing mechanisms is so poor. Each department's data and information is stored unconnectedly and is

not linked up with one another. Apart from these, there is no similar sharing facility. It is necessary that sharing of data and information between the various departments of the GSE. To support a multidisciplinary geoscience information management activity and decision making, the data from the different departments need to be integrated to so that they could be easily be analyzed together.

With the recent advancements in information technology, demand has grown for easy access of organized geoscience information. Stakeholders work in isolation and collaborate with their respective systems.

Although organizing and providing the information according to the reasonable requirements of its users is costly, the cost of not doing it may well be even larger if GSE become unable to respond their expectations which have been elevated by observing developments in other countries and by the capabilities of technology. Recent survey consisting of 300 companies conducted by the Society of Information Management showed that Information Architecture is one of following top 10 management concerns about IT [35, 36].

1. IT and business alignment
2. Retaining IT professionals
3. Security and Privacy
4. IT strategic planning
5. Speed and agility
6. Government regulation
7. Complexity reduction
8. IT governance
- 9. Information architecture**
10. Business process reengineering

From this, we can conclude that there is need a more robust Information Architecture to make collecting, managing, analyzing, and sharing information more effective. To date there have been a number of articles and books published on designing an information architecture from different perspectives in different areas. In contrast, a limited number of publications can be retrieved relating to geosciences information architecture.

Experienced experts in GSE were asked what had been done previously to effectively manage geoscience information. They said that many software development projects were implemented with big budgets at different times but due to different reasons most of them failed. As mentioned by the experts, since the project products could not solve the problems of managing geoscience information, most of these projects have failed. Still today many tools and applications are being used in GSE for data processing and information management. Some of them are GIS software, Image Processing software, different relational database management software namely Microsoft SQL Server, Ms Access MySQL and Spreadsheet software and lately intranet system. However, implementing these individual technologies will not be successful unless GSE develops an integrated geoscience information architecture, which identifies what information to capture, where to store it, who needs it, when it is relevant, and how it should be maintained because none of these issues were raised while implement the softwares.

Thus, this research sought to understand the status of geoscience information management in GSE and proposed a framework that guides how geoscience information should be organized, interlinked, accessed and presented by identifying an enterprise architecture of the GSO. This was achieved by capturing of all behavior that goes on in GSE: the data that is processed, the information that is kept, who does what, when, how, why and where.

1.3 Research questions

The two research questions that will be answered in the course of this study are:

RQ1. How effective and manageable is the access to geoscience information?

RQ2. How can geoscience information management be improved through information architecture?

1.4 Objectives

1.4.1 General Objective

The general objective of this thesis is to investigate, design and validate an information architecture towards establishing an integrated geoscience information management environment.

1.4.2 Specific objectives

To attain the general objective, the following specific objectives will be achieved:

- Identifying appropriate methods, tools and techniques for designing Information Architecture.
- Identifying the structure and requirement of geoscience information management.
- Designing geoscience information architecture.
- Evaluating the geoscience information architecture and communicating the result

1.5 The Significance of the Study

This research will contribute in practice for more effective handling of geoscience information in GSOs particularly in Geological Survey of Ethiopia. Any system that will be acquired based on the designed architecture expected to boost the capacity of any stakeholders particularly geologists in capturing data, storing vast quantities of geoscience information in a database and retrieve specific items on demand.

1.6 Scope and Limitation

The study focused designing geoscience information architecture from organizational structure point of view of Geological Survey of Ethiopia. Due to resource constraint, other federal and regional organization that works in the mining sector were not included in this research. Developing a system is not part of this study. Due to time constrain, from the six Zachman's framework perspectives this research considered the top three rows, namely scope (contextual) perspective aimed at the planner (executive), the business context perspective aimed at the owner (Business Management), and the system logic perspective aimed at designer (architect).

1.7 Thesis structure

The final thesis report has been presented in six chapters. The contents of the chapters is briefly discussed below

The first chapter provides the overall view of the research. Background overview, research problems, objectives and sub-objectives is discussed. Then, significance of the study follows the objectives. Further, the chapter also discusses the status of geoscience management in Ethiopia. The second chapter, Literature Review, focuses on literatures in the issues and trends

information architecture, geoscience information management and approaches in designing information architecture. Chapter three, talks about on how the research was conducted. The chapter describes about the methodology that has been followed along with how the potential key respondents were identified and the methodology used to define the information architecture. The data collected for the research are analyzed in chapter four. The results obtained from the data analysis were further used for designing architecture. Chapter five gives the enterprise architecture of GSE from which the Information Architecture is derived, which is one of the objectives of this research. It is based on the approached described in this chapter and the results from the previous chapters. The concluding remark of the whole research along with some recommendations is discussed in the last chapter.

CHAPTER TWO

2. Literature Review

2.1 Introduction

Different literatures regarding information architecture, geoscience information management and design science research methodology are discussed in this chapter. The chapter is divided into four further sections. Section 2.2 discusses information architecture, its concept and application. In section 2.3, the concept of designing IA is discussed. Section 2.4 reviews IA towards geoscience information environment. Section 2.5 identifies the gap in the literature this research tried to fill. Finally, in section 2.6, different IA developing approaches have been discussed. This chapter gives partial answer to the second research questions.

2.2 Information Architecture (IA)

Multiple descriptions and definitions of information architecture exist in the literature. The term “information architecture” was first devised by Richard Saul Wurman in 1975 [8]. Wurman's initial definition of information architecture was “organizing the patterns in data, making the complex clear” [24].

Since then many researchers and practitioners have been trying to define Information Architecture [4, 5, 7, 8, 9, 10, 17]. There is no widely accepted definition of information architecture [9]. Dillon & Turnbull in [10] reported that no formal definition of Information Architecture has been agreed upon. That still appears true today. According to Evernden and Evernden [33], information architecture is a term that is applied to the structure and organization of information, and it is therefore a key part of managing corporate information. The authors emphasized that Information Architecture embraces rich techniques drawn from disciplines information science, artificial intelligence, linguistics, library management, management theory, knowledge management, programming, information engineering, and object-oriented methodologies. They defined Information Architecture as

“A foundation discipline describing the theory, principles, guidelines, standards, conventions and factors for managing information as a resource. It produces drawings, charts, plans,

documents, designs, blueprints and templates helping everyone make efficient, effective, productive and innovative use of all types of information.”

The authors went further in highlighting the importance of architecture based on the above definition:

- Information as a resource: – if information is not treated as an asset by applying guidelines and standards users to use it successfully, then it will become underutilized and wasted.
- Information architecture provides practical tools, improves efficiency, effectiveness and productivity and supports the organizational strategy, innovation, creativity and flexibility.
- Information architecture does not only apply to the design and navigation of websites, nor is it for the development of information technology or software. It is a universal discipline that applies to uses of information in general.

Bailey’s definition of Information Architecture is perhaps the simplest and most straightforward: “Information Architecture is the art and science of organizing information so that it is findable, manageable and useful”, [11]. It is consistent to [33]. Similarly, Resmini and Rosati defined it as “professional practice and field of studies focused on solving the basic problems of accessing, and using, the vast amounts of information available today”.

Morville and Rosenfeld [5] made Information Architecture popular but focusing more on the designing of information on the World Wide Web. They defined Information Architecture as:

- The structural design of shared information environments.
- The combination of organization, labeling, search and navigation systems within web sites and intranets.
- The art and science of shaping information products and experience to support usability and findability.

- An emerging discipline and community of practice focused on bringing principles of design and architecture to the digital landscape.

Table 1: Summarized Definition of Information Architecture

No	Defined by	Structure	Organize	Label	Art	Guideline	Find/use	Manage
1	Richard Saul Wurman , [8]		✓					
2	Evernden and Evernden, [33]	✓	✓			✓		
3	Bailey						✓	✓
4	Morville and Rosenfeld [5]	✓	✓	✓	✓		✓	✓

From the above definitions of Information Architecture, what can be agreed upon is that Information Architecture is foundational in this information rich era [13]. Moreover information architecture is the design of shared information environments to enable the creation, sharing, management and delivery of information products. This study is about how Information Architecture supports the environment that manages geoscience information; we focus on definition of Information Architecture from enterprise perspective. As described in [33], Information Architecture in an enterprise provides a means to describe and manage information consistently so it can be accessed, understood, compared, shared and composed in a coordinated, integrated manner across the enterprise at every hierarchical level.

According to [33], Information Architecture provides the framework for planning and implementing a rich digital information infrastructure with well-integrated services and activities. Such architecture, based on a shared vision and principles, can help the enterprise foster:

- Easier information sharing and exchange
- Lower costs for system support, and deployment

- Increasingly effective matrix organization structure
- Faster and more effective response to existing and new customer requirements through these

The definition of Evernden and Evernden, [33] is used for this work.

2.2.1 Information Architecture, Information Systems and Information Technology

In some literature the three areas of IA, IS and IT are used interchangeably, which show there is apparent lack of clarity. According to Marchand in [43],

- **IT** focuses on the infrastructure demanded to manage information ranging from desktop based infrastructure to servers and networks;
- **IS** is primarily concerned with focuses on the software applications which perform defined business functions ranging from design, manufacturing and production to accounting, human resource management and other associated processes within the organization.
- **IA** emphasis on designing the structure of information to support a business.

2.3 Designing/Defining Information Architecture for an Enterprise

As there are different definitions of Information Architecture, there is no all agreed approach of designing the information architecture of an enterprise.

Iain Barker, [24] advices effective information architecture comes from understanding business objectives and constraints, the content, and the requirements of the people that will use the information system.

The author described Information Architecture using the following diagram, figure 1:

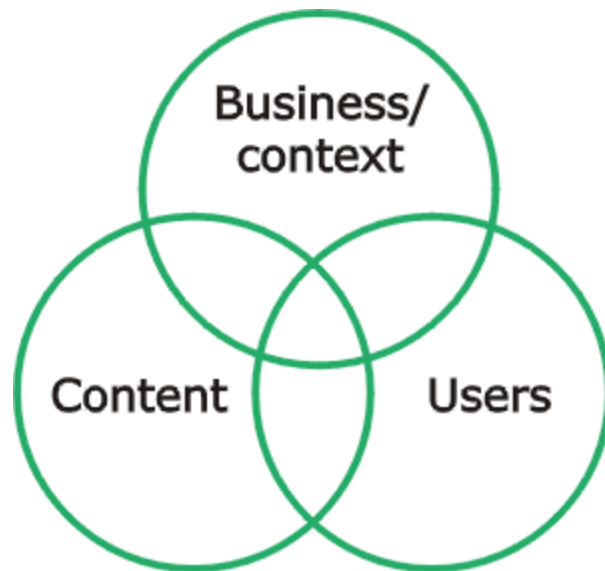


Figure 1: Information Architecture Diagram

According to the paper, the main components in designing the architecture are

- Business/Context: understanding the enterprise's business objectives, politics, culture, technology, resources and constraints.
- Content: the most effective method for understanding the quantity and quality of content (i.e. functionality and information) proposed for a system is to conduct a content inventory. Content inventories identify all of the proposed content for a system, where the content currently resides, who owns it and any existing relationships between content.
- Users: the reflection of the way people think about the subject matter.

Iain Barker did not show how to understand the enterprise's business requirements and how to adopt the above steps for non-website system development. Richard Watson, [31], designed Information Architecture by defining the vision, principle and strategic objective statements for the information of the enterprise. He identified key architectural elements and represented them as pyramid, figure 2 &3.



Figure 2 Interrelationships of IA elements for enterprise: Applications and Layers comprise two faces with IA Stewardship and Support as the base on which the pyramid rests [31].

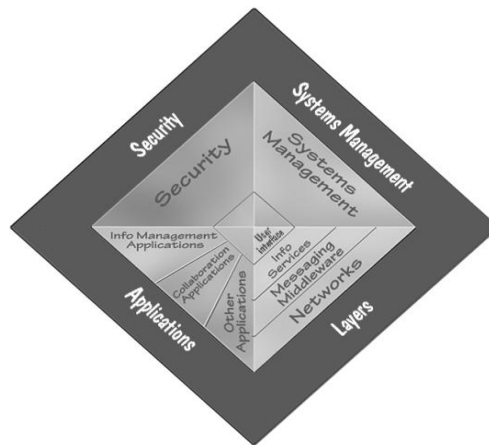


Figure 3 Top view for the Security and System Management faces [31]

The layers in the pyramid represent important elements of the enterprise’s Information Architecture that are built on each other. Each of the application and infrastructure domains represented on the other three pyramid faces requires services from each of the layers: Network, Messaging and Middleware, Information Services, and the User Interface/Desktop. All elements involve data elements, structures and models. The paper only considers an enterprise having an integrated system that can be layered into Network, Messaging and Middleware, Information Services, and the User Interface/Desktop. Walt in his dissertation paper [14] “Developing a Scaleable Information Architecture for an Enterprise Wide Consolidated Information Management Platform” tried to address the concept of “information architecture” as a way of

visualizing and describing the various information assets and interaction of these assets within the organization. The research employs the information audit and information model as key tool for the information manager in defining the information architecture. The establishment of the information architecture is illustrated through a case study within a large conglomeration of companies requiring a scalable information architecture in order to address its information requirements. The author proposed the following scalable information architecture.

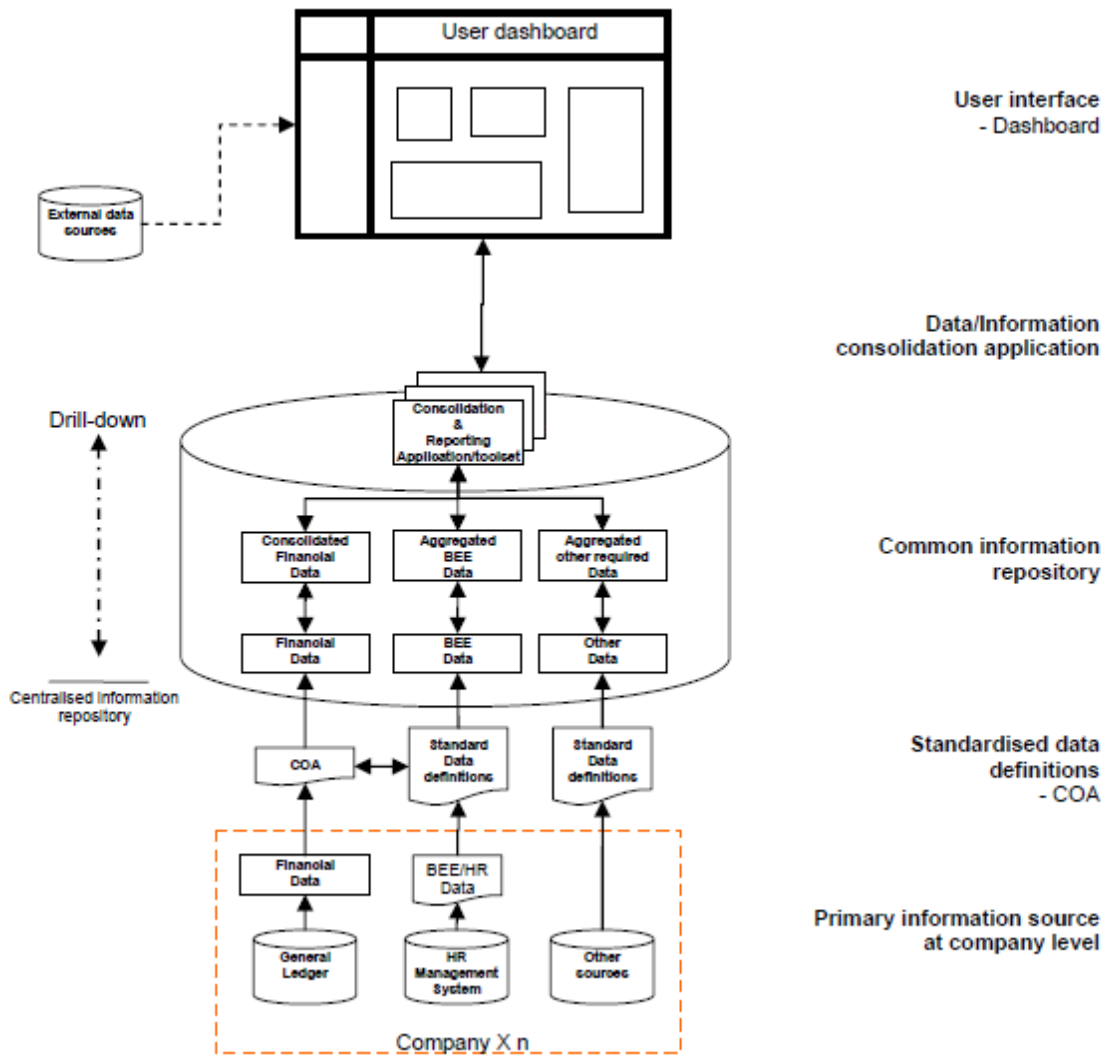


Figure 4: Scalable information architecture, [14].

The questionnaire used for data collection focused on the underlying accounting and transaction systems and the interconnectivity of the companies. The study did not take in to account the

direct integration between the systems and networks; this had to be taken into consideration for the design of the information architecture.

2.4 Geoscience Information

Geoscience information comprises a range of earth science data and interpretations derived from geological, geophysical, geochemical, and mineral studies. This information is used by governments to manage their lands, mineral, energy and water resources, to protect the environment and human health, and to assess risks due to geological hazards such as earthquakes, landslides, volcanic eruptions and floods [1, 42].

Geoscience Information Management refers to Geophysical, Geological, and Micro Seismic that is gathered in field formats (Data), processed formats (Information) and interpreted formats (Knowledge) both physical and digital.

The last two decades have seen companies in the mining sector focusing increasing interest on access to digital data and their proper management [48]. Reviewing technology, business and methodology evolution over this period reveals a number of factors that have caused a new recognition of the link between effective data management and exploration performance. In the 90's, computer technology was the focus of attention as hardware and software emerged that was capable of processing the large data utilized during integrated interpretation. During the same period, the Internet evolved from being an entertaining curiosity to a core component of routine information management and computing infrastructures [49].

GSOs and mining companies have been reassessing their data management requirements and most are concluding that upgrading and investment in data management are essential. In recognition of some failures during previous attempts to manage data corporately, a more rigorous approach is being adopted for designing data management systems to ensure that all requirements were identified and met. In some cases, formalized analysis tools and procedures have been used to provide an understanding of the requirements.

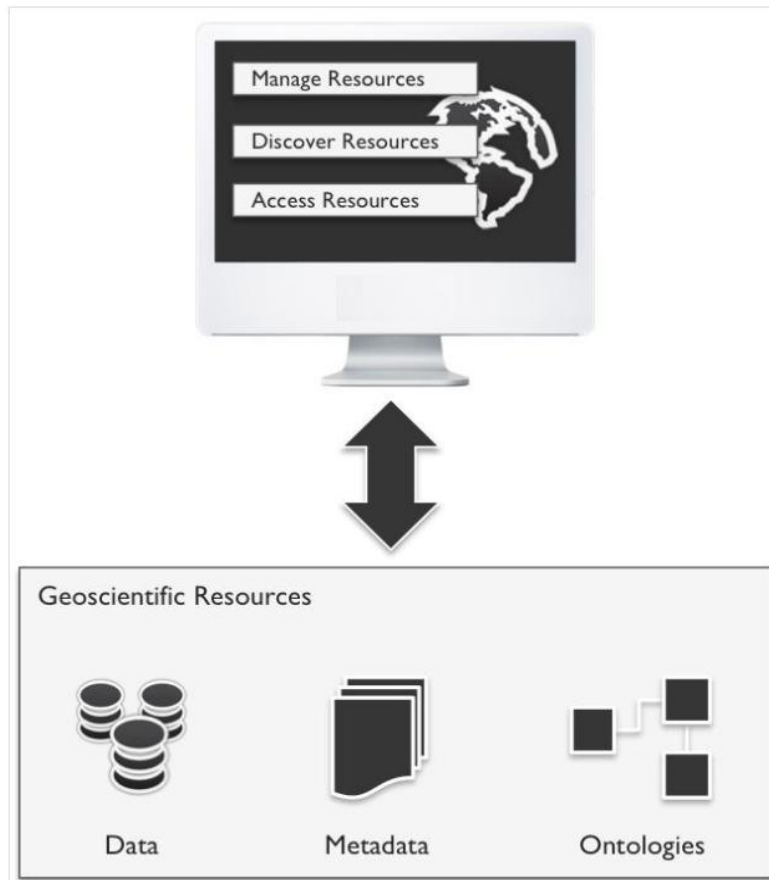


Figure 5: Integrated Geoscience Information System high level view [53]

2.5 Development Approaches of Information Architecture

Since information architecture is a component of enterprise architecture that deals with the information component when describing the structure of an enterprise, an enterprise architecture designing approaches is selected for this research. The lion share (90 percent) of the field use one of the following four approaches [18].

- The Zachman Framework for Enterprise Architectures
- The Open Group Architectural Framework (TOGAF)
- The Federal Enterprise Architecture
- The Gartner Approach

2.5.1 Zachman Framework

The Zachman "Framework" is a taxonomy for organizing architectural artifacts (in other words, design documents, specifications, and models) that takes into account both who the artifact targets (for example, business owner and builder) and what particular issue (for example, data and functionality) is being addressed [18, 19].

The Zachman Framework is a method for organizing all documents and analyses that are necessary for a major development project. The cells in the framework provide a way to organize information so that it can be analyzed and is readily available to all in an organization. One way to think about the cells is that they are storage bins holding information about what information an organization needs to do its work, how it does its work, where it does its work, who does its work, when its work is done, and why its work is done. This information ranges from general (scope perspective) to detailed (detailed representation perspective). The methodology and tools used to gather the information for a particular cell need to be documented, along with where the information is kept [18, 19].

The Zachman Framework typically is depicted as a bounded 6 x 6 matrix with the communication interrogatives as columns and the reification transformations as rows. The framework classifications are represented by the cells, that is, the intersection between the interrogatives and the transformations. This matrix would necessarily constitute the total set of descriptive representations that are relevant for describing something anything: in particular an enterprise [18, 19, 20].







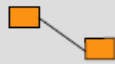
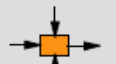




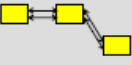
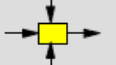
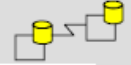







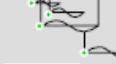







ENTERPRISE ARCHITECTURE - A FRAMEWORK TM							
	DATA <i>What</i>	FUNCTION <i>How</i>	NETWORK <i>Where</i>	PEOPLE <i>Who</i>	TIME <i>When</i>	MOTIVATION <i>Why</i>	
SCOPE (CONTEXTUAL)	List of Things Important to the Business 	List of Processes the Business Performs 	List of Locations in which the Business Operates 	List of Organizations Important to the Business 	List of Events/Cycles Significant to the Business 	List of Business Goals/Strategies 	SCOPE (CONTEXTUAL)
<i>Planner</i>	ENTITY = Class of Business Thing	Process = Class of Business Process	Node = Major Business Location	People = Major Organization Unit	Time = Major Business Event/Cycle	Ends/Mean = Major Business Goal/Strategy	<i>Planner</i>
BUSINESS MODEL (CONCEPTUAL)	e.g. Semantic Model  Ent = Business Entity Rein = Business Relationship	e.g. Business Process Model  Proc. = Business Process IO = Business Resources	e.g. Business Logistics System  Node = Business Location Link = Business Linkage	e.g. Work Flow Model  People = Organization Unit Work = Work Product	e.g. Master Schedule  Time = Business Event Cycle = Business Cycle	e.g. Business Plan  End = Business Objective Means = Business Strategy	BUSINESS MODEL (CONCEPTUAL)
<i>Owner</i>							<i>Owner</i>
SYSTEM MODEL (LOGICAL)	e.g. Logical Data Model  Ent = Data Entity Rein = Data Relationship	e.g. Application Architecture  Proc. = Application Function IO = User View	e.g. Distributed System Architecture  Node = I/O Function (Processor, Storage, etc.) Link = Line Characteristics	e.g. Human Interface Architecture  People = Role Work = Deliverable	e.g. Processing Structure  Time = System Event Cycle = Processing Cycle	e.g. Business Rule Model  End = Structural Assertion Means = Action Assertion	SYSTEM MODEL (LOGICAL)
<i>Designer</i>							<i>Designer</i>
TECHNOLOGY MODEL (PHYSICAL)	e.g. Physical Data Model  Ent = Segment/Table/etc. Rein = Pointer/Key/etc.	e.g. System Design  Proc. = Computer Function IO = Data Elements/Sets	e.g. Technology Architecture  Node = Hardware/Systems Software Link = Line Specifications	e.g. Presentation Architecture  People = User Work = Screen Format	e.g. Control Structure  Time = Execute Cycle = Component Cycle	e.g. Rule Design  End = Condition Means = Action	TECHNOLOGY MODEL (PHYSICAL)
<i>Builder</i>							<i>Builder</i>
DETAILED REPRESENTATIONS (OUT-OF-CONTEXT)	e.g. Data Definition 	e.g. Program 	e.g. Network Architecture 	e.g. Security Architecture 	e.g. Timing Definition 	e.g. Rule Specification 	DETAILED REPRESENTATIONS (OUT-OF-CONTEXT)
<i>Sub-Contractor</i>	Ent = Field Rein = Address	Proc. = Language Statement IO = Control Block	Node = Addressing Link = Protocol	People = Identity Work = Job	Time = Interrupt Cycle = Machine Cycle	Ent = Sub-condition Means = Step	<i>Sub-Contractor</i>
FUNCTIONING ENTERPRISE	e.g. DATA	e.g. FUNCTION	e.g. NETWORK	e.g. ORGANIZATION	e.g. SCHEDULE	e.g. STRATEGY	FUNCTIONING ENTERPRISE

Figure 6: Zachman Framework [19]

Advantage over other framework

- It uses well-defined perspectives,
- It uses comprehensive abstracts,
- It has been normalized
- It has been extensively used in practice,

Disadvantages

- The absence of a methodology to specify modeling approach.

2.5.2 The Open Group Architecture Framework (TOGAF)

TOGAF is a framework for enterprise architecture which provides an approach for designing, planning, implementing, and governing enterprise information technology architecture [18,].

TOGAF divides an enterprise architecture into four categories, as follows:

- I. Business architecture—describes the processes the business uses to meet its goals
- II. Application architecture—describes how specific applications are designed and how they interact with each other
- III. Data architecture—describes how the enterprise data stores are organized and accessed
- IV. Technical architecture—describes the hardware and software infrastructure that supports applications and their interaction

The TOGAF has an architecture development method (ADM) which offers a confirmed and repeatable process for developing architecture framework.

The steps that are implemented in developing an architecture framework with the open group architecture framework are shown in Figure 7.

TOGAF has guidelines for implementing ADM. The guidelines are used to maintain specific tasks within the ADM [59]. The guidelines are the following

- Applying Iteration to the ADM
- Applying the ADM at Different Enterprise Levels
- Security Architecture and the ADM
- Using TOGAF to Define & Govern service oriented architecture (SOAs)

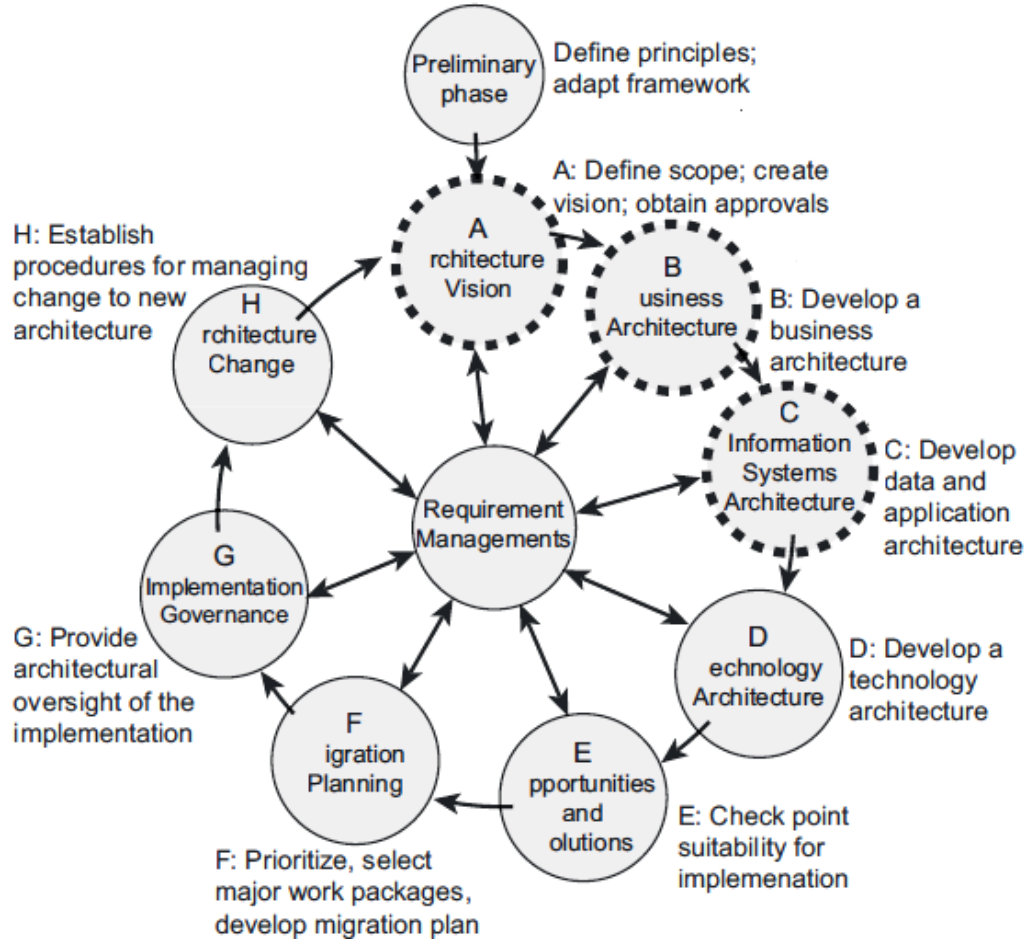


Figure 7: TOGAF Architecture Development Cycle [58]

2.5.3 Federal enterprise architecture (FEA)

FEA is the enterprise architecture of a federal government. It provides a common approach for the integration of strategic, business and technology management as part of organization design and performance improvement [20, 21].

Most writers describe FEA as simply consisting of five reference models, one each for performance: business, service, components, technical, and data. It is true that FEA has these five references models, but there is much more to FEA than just the reference models. A full treatment of FEA needs to include all of the following, [18, 21].

- A perspective on how enterprise architectures should be viewed

- A set of reference models for describing different perspectives of the enterprise architecture (the five models, mentioned earlier)
- A process for creating an enterprise architecture
- A transitional process for migrating from a pre-EA to a post-EA paradigm
- A taxonomy for cataloging assets that fall within the scope of the enterprise architecture
- An approach to measuring the success of using the enterprise architecture to drive business value

2.5.4 The Gartner Approach.

It is the enterprise-architecture practice of one of the best known IT research and consulting organizations in the world, Gartner. It is neither a taxonomy (like Zachman), a process (like TOGAF), nor a complete approach (like FEA). Instead, it is a practice [18].

Since ZF has been well accepted within IS community, who considers it the de facto standard for enterprise architecture, it was used in defining Information Architecture in this study.

2.5.5 Why Zachman Framework?

From the above discussion, we can see that there are many frameworks for enterprise architecture developed by different scholars and institution. This research has chosen to work with the Zachman Framework for enterprise architecture because of its huge popularity. According to [55], the Zachman Framework is the most widely known framework in the Enterprise Architecture context. The reason for its extensive popularity and use is that it is an extremely flexible framework and just defines the logical structure of any enterprise. Thus it does not impose a particular method or any restrictions on users to use a particular set of pre-defined methods unlike the other frameworks developed in the field. Zachman Framework differs from other architectural frameworks in its independent and holistic view of the enterprise. According to [57], Zachman Framework is neutral with respect to methodology, process, and technology, including the breadth of scope for the enterprise. Even if the external influences on the enterprise change, Zachman Framework remains the same.

2.6 Related Works

As mentioned in the section 1.2, no specific articles related to geoscience information and information architecture (having the above definition) could be found.

Hilina Dejene [60] in her thesis paper entitled “Developing an Enterprise Framework for Mental Health Information System in Addis Ababa” developed an enterprise framework for mental health information system in hospitals that provides mental health care in Addis Ababa. She used Zachman framework and TOGAF to develop the framework.

The objectives of the architecture of Mental Health Information System (MHIS) are

- To propose ICT for mental health system to improve morbidity, mortality and quality of mental health service.
- To define mental health indicators to be collected and analyzed.
- To provide knowledge based systems to improve decision making
- To increase access and utilization of mental health service through ICT.
- To implement/ develop online patient consultation system [60].

Since the result of the research was not evaluated, it is not known that the architecture is viable.

Using DSR methodology and employing Zachman framework for describing the enterprise which is involved to managing road accident related information, Tibebe et al [4] presented an Information Architecture Framework for road safety data collection and analysis systems. This paper is a good example to demonstrate that Information Architecture can guide to develop a system for managing information in an area of interest.

Loudon on his book, [15], “A scenario for systems geology” proposed a framework model aims to provide a shared, explicit structure to link geological thinking with its computer representations. Its intended purpose is to provide a map of content and terminology so that users and systems developers know where to put information, where to find it, and how to handle and process it.

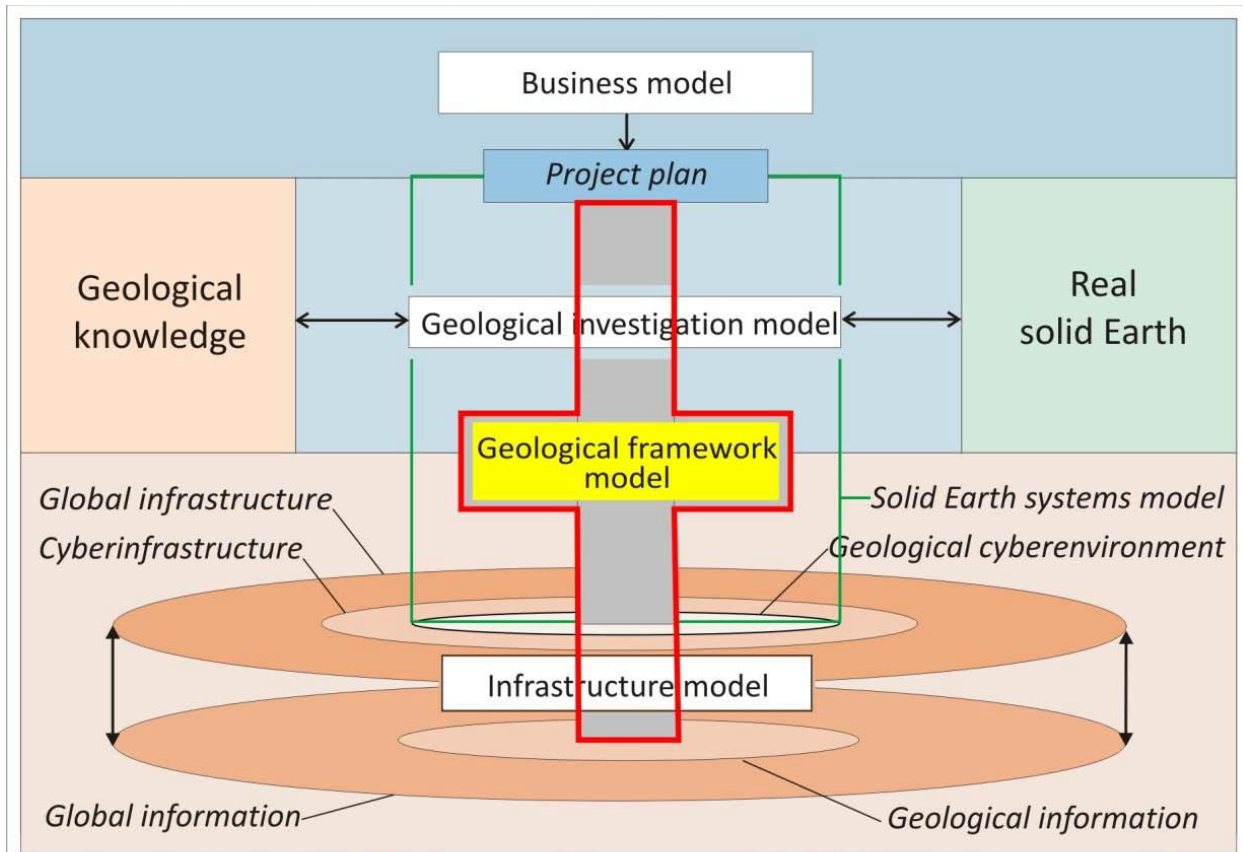


Figure 8: Framework model for System Geology (Aspects of the geological knowledge system), [15].

The framework model proposed by the author (Figure 8) is a structure that depicts and clarifies the principal relationships in the real Earth systems model in order to organize and assemble dispersed information relevant to geology. It is a multidimensional map connecting geological thinking and its computer representation. Tsehaie Woldai, [26] claims that to properly manage geoscience information in Africa metadata is the main tool. If one Africa countries demands to develop a metadata, the author advised the following points,

- political will at the highest level of Governments;
- a solid infrastructure based on policy,
- guidelines and administrative arrangements,
- technical standards,

- fundamental datasets, and
- a means by which geoscience information is made accessible to the community.

The author did not identify the means of accessing the geoscience information, which is the main problem in GSOs.

2.7 Gaps in the Literature

A number of gaps were identified in the literature, which encourages the need for a design science research in geoscience information management area. Geoscience information management research in the mining industry is primarily focused on the use of modern information technology infrastructure and information system application specially GIS applications [47]. If the management of geoscience information is intended to answer the different demands of stakeholders, there should be a framework that depicts the structure, organization and management of geoscience information. This study tries to fill this gap.

Table 2: Summary of Related works

No	Author/year	Title	Objective/Purpose	Methodology	Key finding	Gaps in the literature
1.	Hilina Dejene/ 2013	<i>Developing an Enterprise Framework for Mental Health Information System in Addis Ababa</i>	To develop an enterprise framework for mental health information system in hospitals that provides mental health care in Addis Ababa.	Iterative system development methodology was used for over all framework development. Literature review	By using the perspectives of the Zachman framework and the open group architecture template different business, data and information architecture works were done. Taking the mental health organization mission, strategy and objectives in to consideration the investigator identified the architecture mission, business and information principles, information flow between different departments and different stakeholders that have impact on mental health information systems.	The result of the research was not evaluated consequently it is difficult to prove that the framework is viable.
2.	Loudon, T.V., 2012	<i>A Scenario for Systems Geology</i>	How to improve and extend the representation of geological knowledge as a comprehensive systems model	Research review	Different systems models	The study considers the natural system of earth and models the evolution

No	Author/year	Title	Objective/Purpose	Methodology	Key finding	Gaps in the literature
3.	Tsehaie Woldai	<i>Geospatial Data Infrastructure: The Problem of Developing Metadata for Geoinformation in Africa</i>	Developing a proper metadata for geospatial data infrastructure	Research review	The implementation of a proper metadata in Africa requires a political will at the highest echelon of Governments; a solid infrastructure based on policy, guidelines and administrative arrangements, technical standards, fundamental datasets, and a means by which spatial data is made accessible to the community.	The author did not identify the means of accessing the geoscience information, which is the main problem in GSOs.
4.	Frantz Rowe Duane Truex Marc Bidan	<i>Information Systems Architectures and Systems Integration: an empirical study of French Small to medium</i>	Finding main IS architectures in SMEs of France Identifying systems integration approaches are present in SMEs	Case study	Three IS architectures were found	The study is confined to French's small and medium enterprises
5.	Berg R., Mathers M., Kessler H., and Keefer D (2011)	<i>Synopsis of current three-dimensional geological mapping and modeling in geological survey organizations</i>	To investigate the status of the three dimensional geological mapping and modeling in geological survey organizations	Case study	Three-dimensional geological mapping and modeling is becoming an established technique for portraying geological information.	The study only focused on 3D geological mapping.

No	Author/year	Title	Objective/Purpose	Methodology	Key finding	Gaps in the literature
6.	Tibebe Beshah, Dejene Ejigu, Ajith Abraham (2012)	<i>A Novel Road Safety Information Architecture (RSIA): An Enterprise View</i>	<p>To define road safety information architecture for structuring and representing road safety data collection and analysis.</p> <p>To identify the role of collision related factors to the severity of accidents in explaining road safety solutions.</p>	Combination of DSR & Case Study	A Novel Road Safety Information Architecture (RSIA) Framework and using data mining technique the paper proved that Accident type, accident cause and accident sub city are the three top determinant factors in predicting severity	<p>The study employed only four of the six dimension of ZF</p> <p>The proposed architecture works for road safety information</p>
7.	Nambiar U., Ludaescher B., Baru C. & Lin K	<i>The GEON Portal: Accelerating Knowledge Discovery in the Geosciences.</i>	The objective of the paper is to discuss how geoscience research community's challenge in managing and sharing resources is being addressed by the GEON Portal(a Web based application),	Even if it is not explicitly mentioned it is design science	A framework that contains capabilities of both a data warehouse (data providers can store their datasets within the GEON network) and a data mediation system (users can design views spanning multiple distributed databases).	The research is specific to one product, GEON Portal.
8.	Walt, P.W (2006)	<i>Developing a scaleable information architecture for an enterprise-wide consolidated information management platform</i>	To address the concept of information architecture as a way of visualizing and describing the various information assets and interaction of these assets within the organization.	Case Study	Information auditing process is the key building block for the information architect.	There are issues that cannot be applied for geoscience information

No	Author/year	Title	Objective/Purpose	Methodology	Key finding	Gaps in the literature
9.	The National Academy of Sciences	<i>Geoscience Data and Collections: National Resources in Peril</i>	to develop a comprehensive strategy for managing geoscience data in the United States.	Case study	a strategy for determining what geoscience, paleontological, petrophysical, and engineering data	It proposed a strategy for geoscience data management not a framework
10	Matt Yacopetti and Stephen Mundell 2010	<i>Improving the quality of geoscientific information</i>	To Identify issues that are main factor to improve the quality of Geoscience information	Literature Review	People, Process and Technology are basic issue in improving geoscience information	A framework that can be applied for the Ethiopian context was not proposed

CHAPTER THREE

3. Research Methodology

Research is defined as the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions [41]. This chapter lays emphasis on the methodology followed to conduct the research.

This study used mixed methodology of qualitative and design science approaches with a case study.

3.1 Design Science Research (DSR)

This is a research in information system discipline. Hevner et al. [23] categorized research in IS into two scientific paradigms including behavioral science which is to develop and verify theories that explain or predict human or organizational behavior and design science which extends the boundaries of human and organizational capabilities by creating new and innovative artifacts.

For many years humans have been undertaking design-related activities, scholars in the area claim that the origin of the approach to Herber Simon specifically coined on his Sciences of the Artificial, [44].

Simon [44] argues that, in contrast to the natural sciences of eg. physics and biology, an important source of knowledge can be found in the human-constructed world of the “artificial”. In contrast to the natural sciences which are concerned with truth and necessity, these artificial sciences are focused on usefulness and contingency. The common concept throughout these disparate fields is the notion of an artifact. However, Simon [44] argues that since the Second World War the validity of such approaches shadowed by the dominance of the natural sciences. As a consequence, the artifact has not been given attention. Simon took these artificial sciences and in particular, designs as a means for undertaking research.

Since then, design science has been examined within information systems (IS) as a research method as well as used for conducting research on IS topics, [20].

In order to tackle the geoscience information management problem, it is important to understand the truth behind in the mismanagement of the geoscience information and to propose a utility (artifact). The researcher is primarily concerned with producing a framework (artifact) that is useful to system developers.

In this case, there must be a structured approach to building and evaluating the framework to ensure it has rigor and relevance. As Hevner et al., [23] argue, IS research needs to be rigorous to provide an “addition to the knowledge base”, and relevance allows for “application in the appropriate environment”.

Design Science is evolved from the traditional and the known systems development methodology whose focus is on developing and evaluating a novel and useful information system by implementing “proof-by-construction” approach, [45]. The main differences between the broader approach of design science and information systems development are their scope and use of artifact. Design Science is applicable to a much wider range disciplines than IS development. Some of the disciplines where design science approach is applied are medicine, architecture, industrial design and law, [43] in addition to technology-based fields. Design Science takes a broader view of what constitutes an “artifact” for the purposes of research evaluation. Rather than just working instantiations, it also includes constructs, models, methods and frameworks.

In this study, the artifact is the integrated geoscience information architecture. So, while a systems development approach may be to build and test a novel system that identifies or corrects defects in geoscience information management, a design science approach allows for focus on a more abstract artifact.

Artifact can take one of four forms, as described by Hevner, et al, [23]:

1. Constructs: A conceptual objects that provide the vocabulary and symbols used to define problems and solutions.
2. Models: A conceptual object made up of constructs and links between these constructs as a way to represent or abstract a real world situation or entity.

3. Methods: A set of actions used to achieve a certain outcome or solve a problem. It may take the form of a mathematical algorithm or a general textual description for the process, or any combination of the two.
4. Instantiations: An actual system (hardware or software) that shows how constructs, models and methods can be implemented for its intended purpose.

The specific model of Design Science selected for use in this research is the one that is presented by Hevner et al. [23]. This model was selected as it is well-developed, recent and published in one of known and recognized journals in Information Systems. This suggests it is of high quality, accepted by researchers in this field and likely to be a reference source for a number of future projects. It also presents a number of criteria and guidelines for critically appraising Design Science research, which govern the research project.

This model, figure 9, makes explicit the two modes (develop/build and justify/evaluate) and links these to business needs (relevance) and applicable knowledge (rigor).

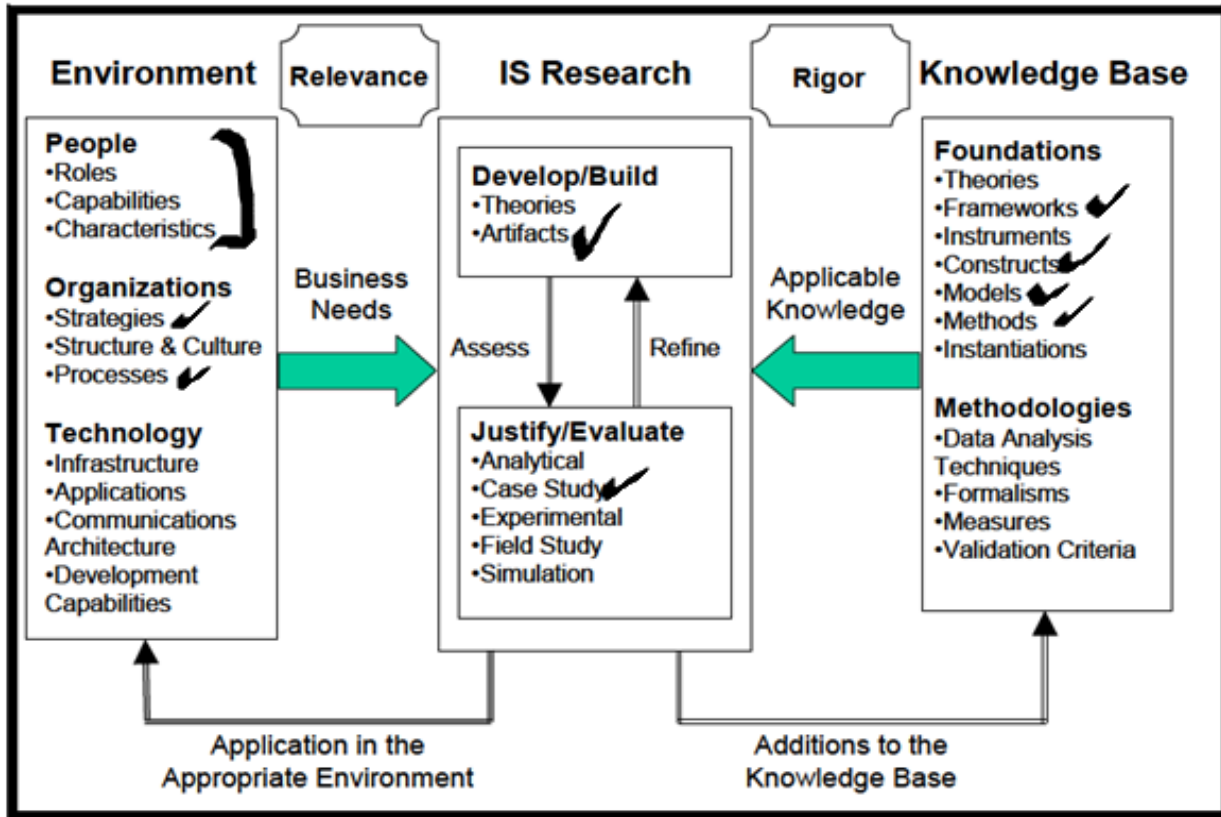


Figure 9: DSR Framework [23]

By following the DSR methodology framework model, Figure 9, innovations (artifacts) were created using Zachman framework which define the ideas, practices, technical capabilities, and products ultimately through which the analysis, design, implementation, management, and use of information systems will be effectively and efficiently accomplished, [23].

3.2 Qualitative Research Methodology

The qualitative research method involves the use of qualitative data, such as interviews, documents and observation, in order to understand and explain a social phenomenon, [30]. The purpose of qualitative, interview-based research is to clarify and describe people's experiential life “as it is lived, felt, undergone, made sense of and accomplished by human beings”, [56]. Qualitative research methodology is appropriate for this study because it is attempting to discover the level of effectiveness of geoscience information management in Geological Survey of Ethiopia.

3.2.1 Case study research

Under qualitative research methodology, this research applied case study approach. The case study approach seeks to understand the problem being investigated. It gives the chance to request thorough questions and to capture the richness of organizational behavior, but the conclusions drawn may be specific to the particular organizations studied and may not be generalizable [27]. Case studies typically combine various data collection methods such as archives, interviews, questionnaires and observations, [28]. The more sources of evidence are used in the same study, the stronger the case study evidence will be, [29].

Case study research is the most common qualitative method used for information systems scenarios, [38].

The commonly used data collection techniques in qualitative, organizational case research are observations, interviews and document analyses [30]. This research used these techniques for data collection.

Geological Survey of Ethiopia was selected as a case study. The organization is selected because it is the only organization which is authorized to administrator the country's geoscience information at the federal level.

GSE has five main technical core directorate/departments that generate geoscience information.

The Core directorates are:

- Basic Geosciences Mapping: generates basic geological, geophysical and geochemical information
- Geo-hazards Investigation: generates geohazard like land slide, flooding and earthquake information
- Mineral Exploration : is responsible to generate mineral occurrence information
- Ground Water Resource Assessment: is responsible in generating hydro geological information of the country
- Geothermal Resource Exploration and assessment: is responsible to generate information regarding the country's geothermal resources

3.3 Research design

A research design is a plan, structure and strategy of investigation considered to obtain answers to research questions or problems [40]. Table 3 gives detail overview of research design.

To answer the research question, key informant was interviewed. Data has been collected from the interview with the high level as well as operation level staff in GSE. The designed architecture has been validated by the geoscience information experts.

Table 3: Mapping Objective, Research Questions & Data source

Research Objective		Research question	Data Source	
Main	Sub		Primary	Secondary
investigate, design and validate Information architecture towards establishing an integrated geoscience information environment	Identifying appropriate IA methods, tools and techniques for designing IA	How effective and manageable is the access to geoscience information?	Interview Observation	----
	Identifying the structure and requirement of geoscience information management		Interview	Literature
	Designing an information architecture	How can geoscience information management be improved through IA?	Interview	Literature
	Evaluating the information architecture and communicating the result		Interview	Literature

The research has been conducted under three phases namely Pre-Data Collection, Data Collection and Post Data Collection phase.

Pre-Data Collection phase: By reviewing different literatures; information architecture, geoscience information and design science related issues concepts were comprehended. At this phase, questions for interview were designed, key interviewees were identified.

Data Collection Phase: This part of the research phase has been devoted in collection of primary and secondary data from the case study.

- Interviews and observations method was followed to collect primary data.

- Secondary data was collected from the relevant document on geoscience information.

Post Data Collection Phase: After data collection activities were completed, analysis was done to find the existing problem, appropriate component and input of Information Architecture. And on the basis of that, geoscience information architecture was designed and evaluated by geoscience experts.

3.4 Data collection

As stated by Stake [39] and Yin [29]; interview, direct observation, participant-observation physical artifacts, documents and archival records are the six sources of evidence that are advised for the case study. Interview, direct observation and documents were used for data collection for this research.

3.4.1 Interviews

Interview was the main source of data collection for this research. All the questions in the interview consist of open questions to cover the broader range of issues in geoscience information. The questions tried to identify the current status of administering geoscience information, the challenge it has and asked concerned respondents to list things important to geoscience information production business, processes that the business performs, locations in which the business operate, bodies important of the business, events important to the business and the goals/strategies of GSE for GSI administration. These types of questions were used as a source of information in populating the cells of Zachman Framework matrix.

Since the interview questions were not structured, different issues that arouse during understanding the concept of geoscience information administration were also made clear during the interview. Further, different sets of questions were prepared for different respondents according to their roles in GSE and positions. The respondents were chosen as such that they represent the target group.

The way data is collected using the interview is discussed in the sections below.

3.4.1.1 Research Respondents

In total number of employs at GSE are approximately 600 people of whom approximately 10% is considered to be experts and managers that are directly related in collecting, producing and

managing geoscience data and information. Due to the vastness of people that could be interviewed it was decided in the interest of time and diversity of experts for the study to limit the number of interviews. A representative sample from top managers, middle managers, experts and stakeholders as the following were interviewed:

In a study of sufficient sample sizes using non probability purposive sampling, Guest et al [50] found that a sample of twelve was sufficient to establish a stable view of parameters, particularly if the research is aimed at describing perception or behavior among participants. Romney et al [51] similarly explain that even a sample of four may be sufficient to provide an accurate explanation of phenomena so long as they were experts in their field. Fifteen interviews were carried out with top manager (1); Middle Managers (5); experts (7) and beneficiaries of geoscience information (2), all of whom were experts responsible for information management within GSE and their respective organizations (for beneficiaries). The respondents involved are described in the Table 4.

Table 4: List of Respondents

Type	Respondent	Number
Top Manager	Chief Geologist (the vice director)	1
Middle Managers (Department heads)	Heads of Technical Departments	5
Geoscience experts and librarians	Geologist, Geophysicist, Geochemist etc.	5
	Information Experts	1
	IT experts	1
Customers	External Geoscience Information beneficiaries	2

The interview focused on identifying how geoscience information is being managed and to seek information to populate the Zachman Framework matrix that can represent information management of the integrated geoscience environment.

3.4.1.2 Challenges

The time at which the interview was demanded to be conducted is also the period for GSE for field work, some of the potential respondent were absent and thus needed to wait for them until to return back to office. Some of the respondents didn't seriously take the interview. Some did

not allow recording the interview. Thus, it was a challenge to jot down all the statements that were said during the interview.

3.4.2 Observation

Observation is a technique that involves directly observing behavior with the purpose of describing it. The way geoscience information is being managed in GSE was observed by the researcher using a checklist (see the checklist on annex 2) and note was taken for analysis. The existing system in GSE was observed how it generates, organizes and integrates geoscience information.

3.4.3 Documents

To understand the business process of GSE, BPR Documents, proclamation and other papers were referenced.

By collecting data using the three approaches, key problems were identified. During the interviews, ethical issues also were considered. When recording the interviews, interviewees were asked for their consent beforehand. For those respondents that did not want to be recorded notes were taken.

3.5 Evaluation Techniques

This study is a design science research, so its process and resulting design must be evaluated against some criteria. The guidelines proposed by Hevnar et al [23] on their paper entitled “Design Science in Information Systems Research” were used as checklist. As it is justified in [45], the paper’s guideline, Table 5, was selected for the following reasons:

- The objective of the paper is “to describe the performance of design-science research in Information Systems via a concise conceptual framework and clear guidelines for understanding, executing, and evaluating the research” [23].
- it specifically addresses Design Science in an Information Systems research context
- MISQ is a recognized journal in Information Systems and this paper is widely read and cited,
- the authors have experience in conducting DS research projects

- the paper is contemporary and reflects current thinking,

Table 5: Design Science Research Guideline

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

CHAPTER FOUR

4. Research Results and proposed architecture

Details of data collection methodology, sources of information, types of data collected and respondents were discussed in previous chapter. This chapter analyses the data collected for this research and produce the result which is used for designing appropriate information architecture.

4.1 Current status of geoscience information management at GSE

Form observation and interview, it is understood that GSE currently produces a wide-ranging set of geoscience maps and technical reports for the country and to the world, mainly the results of its own surveys. Extensive archives of supporting information are held in geoscience directorate and other technical directorates for references, including some information of variable quality from external sources both in hard as well as in soft copies. The archives take many forms, such as data files, field notes, borehole records, logs, charts, photographs, satellite and aircraft imagery, references to external sources of information, including papers, and so on. There is no common metadata that describes the archives across GSE.

4.2 Research findings

Data collected for this research was processed manually since complex analysis was not necessary and also the data were easy to handle. All interviews were conducted face to face; each lasting approximately 45 minutes, then each was transcribed in Microsoft Word then analyzed. The interview was conducted in Amharic language and translated into English while transcribing.

The collected data were organized around the subtopics derived from the research questions. Furthermore, the data from the interview, observation and documents were used to triangulate and checked against each other whenever it sensed to do it so. The analysis was carried out following the thematic analysis process as outlined by Boyatzis [52]. The complete process is illustrated in Fig 10.

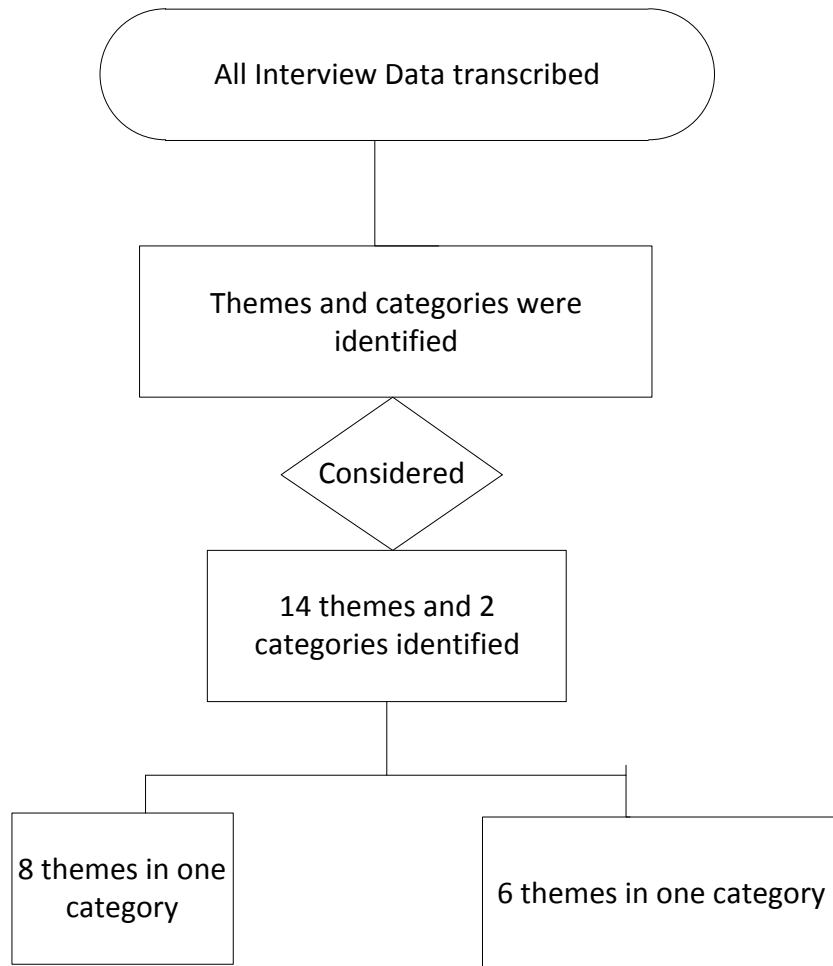


Figure 10: Thematic analysis process [52]

There are two categories namely the status of geoscience information management and inputs for Zachman framework. The results for the first category are discussed below and the results for the second category are used in designing the Information Architecture.

Table 6 Categories of Themes

Category One		
No	Themes	Main Source of Interview Question (see annex 1)
1	Inconsistencies in the use of Metadata	Interview question 9(j), 10
2	Poor performing systems	Interview question 8
3	Lack of data management policy	Interview question 9 (f)
4	Skills Shortage	Interview question 3, 9
5	Resistance to Change	Interview question 10
6	Poor sharing culture	Interview question 9 (k)
7	Status of geoscience information	Interview question 9

	management at GSE:	
8	Response on proposing geoscience information management problems' solution	Interview question 10
Category two		
No	Themes (Zachman Framework Dimensions)	Main Source of Interview Question (see annex 1)
1	What (Data)	Interview question 1
2	How (Function)	Interview question 9 (a)
3	Where (Network)	Interview question 2
4	Who (People)	Interview question 3
5	When (time)	Interview question 4
6	Why (Motivation)	Interview question 5

Metadata Inconsistencies

Even if there are standards in collecting geoscience data, there is no accepted metadata that describes the geoscience products specifically the technical reports and maps. When one expert was asked “*does GSE have its own standard for metadata?*” he explained that “*since there is no fully qualified definition of our geoscience information, there is always a duplication of producing the same information from the same area.*”

Poor performing systems

Even where the solutions have been implemented specially in those departments that use proprietary software, interviewees explained that different systems implemented to manage geoscience information often end up “*not doing exactly what they (the experts) wanted them to do*”. It is clear that this was due to the concerned bodies not being clear about their original requirements; limitations in the ability of the system analyst to design the architecture of the geoscience information.

Lack of data management policy

There is inadequate useable guidance on the process of developing and implementing a Geoscience Information Management Strategy in the mining sector. While clear standards that provide guidance on collecting information through the project lifecycle, no similar solutions have been proposed for how IM can be aligned to GSE’s strategies or how context specific metadata standards can be developed and implemented to suit GSE’s needs. As an interviewee

explained when she was requested whether there is any policy which says about providing easy access to information to users *“we don't have so far we need things like standards. There are interesting standards in other geological survey organizations”*. The responses indicate that guidance is required even if it is difficult to mimic those advanced systems implemented in other countries' geological survey organizations.

Shortage of Skills

There is a shortage of qualified experts with the requisite skill, which impede the development and implementation process of the required geoscience information architecture. Emphasizing this, one expert stated that *“it is difficult to find the right people to do this job”*.

Resistance to Change

If new solutions are developed and introduced, it is the difficulty in getting people to change their ways of working and adopt new systems. The challenge here was summed up by one respondent who explained *“accessing information on the system, capturing it and allowing people to access it in different forms isn't that difficult once you put the initial systems in place. What is not easy is getting people to use it”*. One expert stressed that resistance to change is a difficult challenge because *“you can't avoid it. You can mitigate it but you can't avoid it. Users sense they know exactly what they're doing and you can't tell them how to do it differently because they feel they know everything”*.

Poor information sharing culture

The realization of such an integrated geoscience information environment is dependent on a willingness to share information, a culture which sometimes can be lacking within organizations that are working in the mining sector. According to one respondent for the question *“what do you say of the integrity, completeness and usefulness of the GSE's geoscience information?”* he said that *“I think the problem we had was sharing useful geoscience information among us.” Even if there is a law that abides us to share what we have to GSE, the willingness is not there ”*. This was similarly echoed by others, one of whom explained the

attitude of those who resist "they think that there information is the most important that no one else can possibly understand it, especially maps".

Status of geoscience information management at GSE:

The respondents' answers for Interview Question 6 and 9

- Study has not been done in detail in managing geoscience information.
- Waste of time and resource for searching data
- Data duplication occur
- Lack of access to geoscience data/information: Interviewees repeatedly said that they could not access important data at different times because as staffs leave GSE they took data with them without leaving copies in GSE. The top manager and the middle managers all agreed that it is often difficult to find copies of raw data collected six years ago.

Response on proposing geoscience information management problems' solution

The respondents answers for Interview Question 10

- Linking and sharing data help in decreasing data redundancy
- The basic problems of accessing, and using the vast amounts of geoscience information available today should be solved.
- A structure should be designed to identify geoscience data flows and controls, logical design, and physical implementation.

The interview process revealed that the existing geoscience management approach does not support the business of GSE, thus there is a need of designing information architecture based on the existing structure of GSE.

4.3 Proposed Information Architecture

The requirements were identified from the interview of respondents and the results from the previous research done in geoscience information management. The main reason for which

interview was conducted for this study was to get the idea about requirements in Information Architecture.

As it is mentioned in Chapter 3, Zachman Framework was used to design an artifact there will be used as a base in developing geoscience information management system.

The Zachman framework is a normalized six by six classification matrix for organizing descriptive representations of GSE. The rows represent different stakeholder perspectives of GSE, while the columns depict different areas of interest within those perspectives. The Zachman framework is simply a framework – it is not a process, a method, a notation or a tool.

Table 7 : An Empty Zachman Framework, [17].

Classification names Audience Perspective	1. What (data)	2. How (function)	3. Where (network)	4. Who (people)	5. When (time)	6. Why (motivation)	Classification names Model Name
Executive Perspective (Business Context Planner)							Scope Contexts (Scope Identification list)
Business Mgmt Perspective (Business Concept Owner)							Business Concepts (Business Definition Models)
Architect Perspective (Business Logic Designers)							System Logic (System Representation Model)
Engineer Perspective (Business Physics Builders)							Technology Physics (Technology Specification Model)
Technician Perspective (Business Component Implementers)							Tool Components (Tool Configuration Model)
Enterprise perspective (users)							Operations Instances (Implementations) The Enterprise

Each cell in the matrix contains at least one artifact.

The framework is an ontology that is a theory of the existence of a structured set of elemental components of a complex objects that require description and are relevant for creating, operating, maintaining and changing the artifact. Accordingly, Zachman developed a “framework” or structure for logically defining and capturing an architecture [17]. The framework was used to define information architecture in integrated geoscience information management environment.

The Zachman Framework focused on creating artifacts for the different players in managing GSI in GSE. Each player in GSE has a different perspective on each step of the process. The framework created artifacts focusing on function, data, time, people, networking and motivation, Each of these areas focused on from the view point of the following people; owner, planner, and designer. This leads to an understanding that everyone who is under the scope of this study is heard and solutions can be developed with everyone’s voice in mind.

4.3.1 Populating ZF Cells with the Requirements of Integrated GSI Architecture

This section defines the contextual, conceptual and logical systems architecture for Integrated Geoscience Information from a top-level perspective using the findings from the literature review, interviews, observation and document analysis (Chapters 2 and 4) to populate the requirements of the Zachman Framework necessary to ascertain the design the artifact of GSI management system. Specifically, the combined views of the planner, the owner and the designer of Rows 1, 2 and 3 of the framework were discussed. Since the other three perspectives deal with construction and implementation [54], they are beyond the scope of this research.

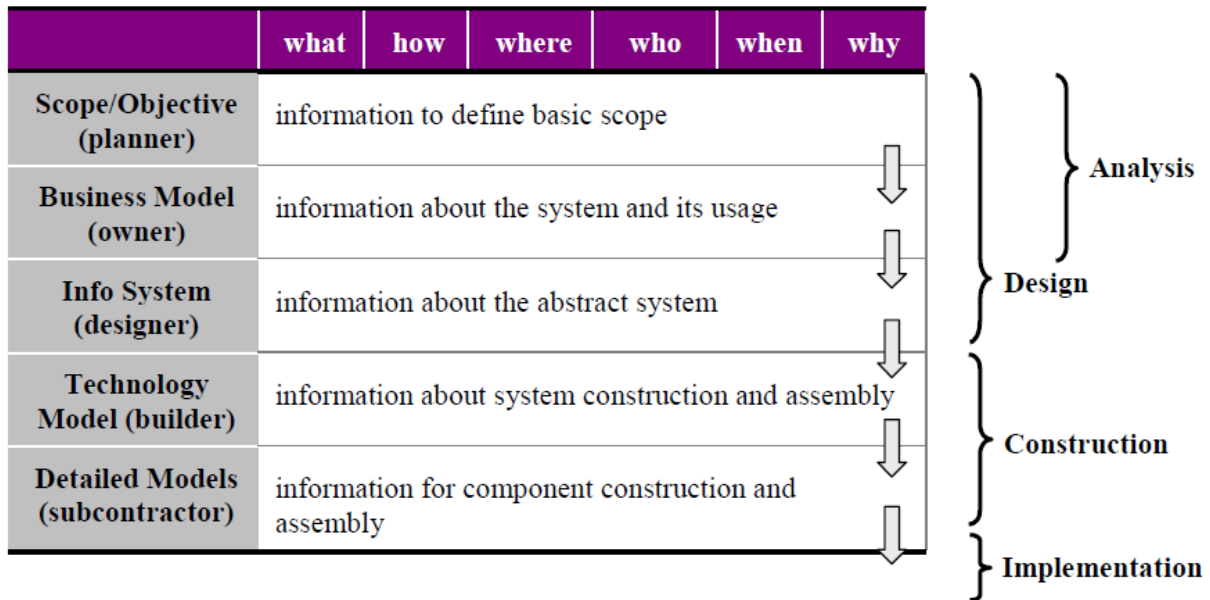


Figure 11 Sequential nature of Zachman Framework, [54]

The Rows

The rows stand for different stakeholders perspectives in GSI management, Table 8.

Table 8: Rows of ZF

Perspective	Description	Represented by
Executive Perspective (Business Context Planner)	Understands the geoscience information management scope. It describes GSE’s vision, mission, context, boundaries, architecture and constraints towards geoscience information.	Top Managers
Business Mgmt Perspective (Business Concept Owner)	Understands the business model and can provide a conceptual view of GSE. It defines goals, strategies, structure and processes that are used to support the mission of GSE.	Geoscience experts
Architect Perspective (Business Logic Designers)	Produces the technology model and can provide a physical view of the enterprise. It contains system requirements, objects, activities and functions that implement the business model.	The researcher
Engineer Perspective (Business Physics Builders)	Develops the system model and can build a logical view of the enterprise. It considers the constraints of humans, tools, technology and materials.	This row was not considered for this study
Technician Perspective (Business Component Implementers)	Understands detailed representations of specific items in the business. It presents individual, independent components that can be allocated to contractors for implementation.	This row was not considered for this study
Enterprise perspective (users)	provides a view of the functioning enterprise, from the perspective of a user	This row was not considered for this study

The columns

The columns of a Zachman framework present the following aspects of the enterprise Table 9.

Table 9: Columns of ZF

Dimensions	Description
What (data)	Describes the entities that are considered important to GSI management, as viewed from each perspective.
How (functions)	Defines the functions, or activities, GSE is concerned about relative to each perspective.
Where (network)	Shows geographical locations and interconnections between activities within the enterprise.

Who (people)	Represents the actors who are involved in geoscience information management.
When (time)	It describes when are the geoscience information are collected.
Why (motivation)	Describes the motivations of GSE in managing geoscience information.

Source of data

The data sources which were used for populating the Zachman Framework matrix are the six themes under the second category of Table 6, Literature review specially [55] and Observation.

4.3.1.1 What (data)

Data content from Executive perspective (Row1, Column1)

This table begins with resources that are needed by the enterprise for efficient functioning of GSI Management. Interview's response from the top management (please see interview question 1 from Annex 1), Literatures review & Observation are the main data sources. The identified resources are.

- Data sharing policy
- Projects
- Field Station
- Geological Sample
- Laboratory Analysis
- Raw Data
- GIS data set
- Lithology
- Maps
- Publication
- Photographs
- Metadata

Data content from Business Management perspective (Row 2, Column 1)

This cell gives the picture of the business and is represented using Entity Relationship diagrams, figure 12. Interview's responses from the middle management and experts (please see interview question 1 from Annex 1), Literatures review & Observation are the main data sources. The diagram is derived from Row 1, Column 1. The entity relationship diagram was broken into seven primary entities connected by conceptual and logical relationships that represent the way that geoscience data are collected, edited, and analyzed by different users.

The entity relationship diagram was broken into seven primary entities connected by conceptual relationships that represent the way that geoscience data are collected, edited, and analyzed by different users.

The selected primary entities are

- **Field station:** data that are collected in the field to support geologic mapping, resource investigations, and hazard evaluations.
- **Geological Sample:** is a sample collected from a field station.
- **Sample analyses:** are analyses and descriptions of geologic samples. They include summary and secondary analysis information as well as original laboratory data.
- **Publication:** is information about geoscience publications and for external publications that are cited as sources in geoscience researches. It includes information about distribution, electronic files used to make the publications, and the archive location of those publications.
- **Spatial data Classification:** is a classification of geological maps that are defined by geometry, location and classification.
- **Geospatial data set:** is a set of spatially referenced, interrelated features.
- **Metadata:** is a collection of information that bibliographically cites geoscience resources.

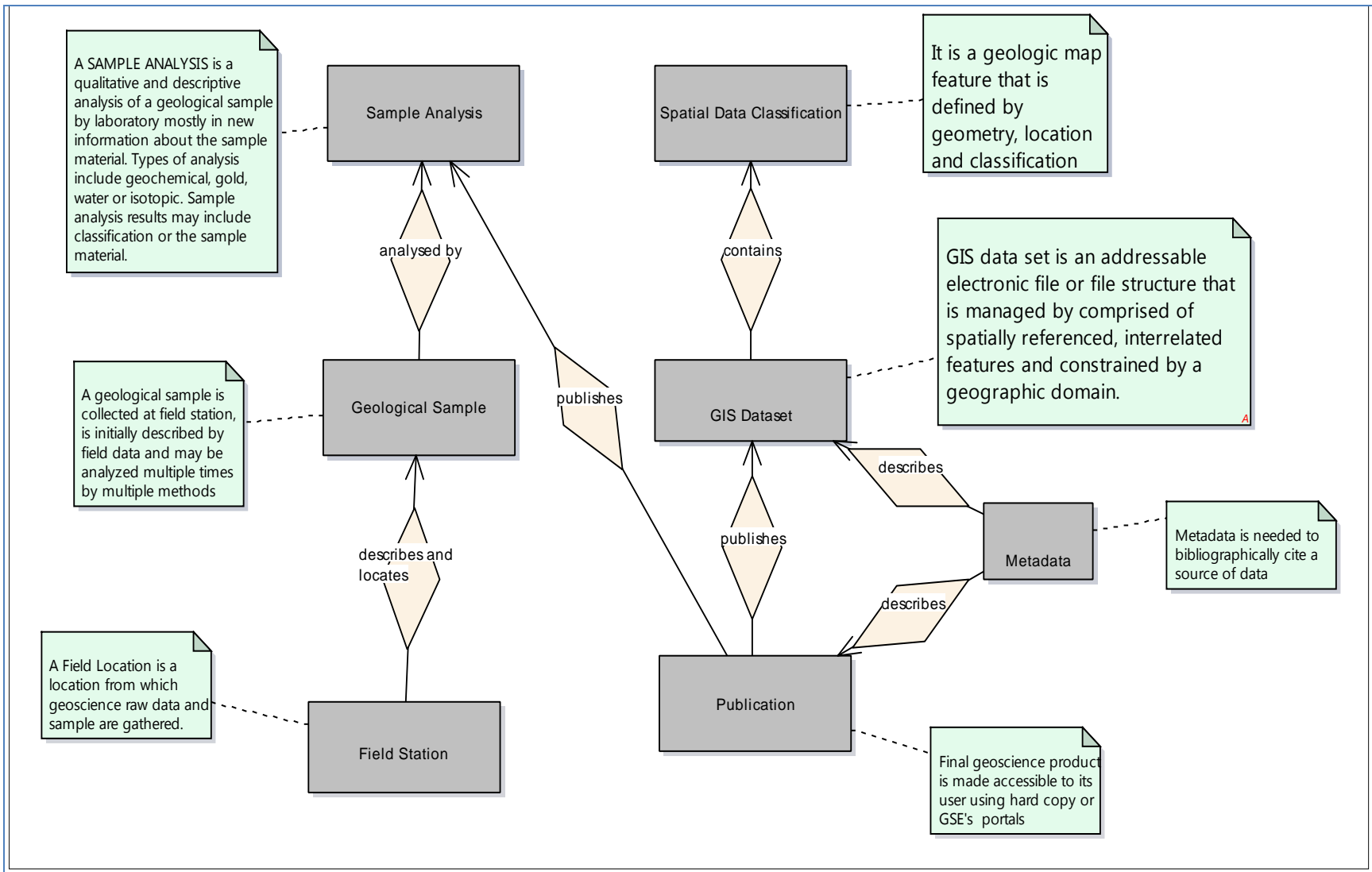


Figure 12: Conceptual Data model represented by ER diagram

Data content from Architect/designer/ perspective Row 3, Column 1

This cell consists of Logical data model that is represented using Class diagram figure 13. This is the logical representation of a system that will be developed to manage GSI. It is derived from row 2, column 1.

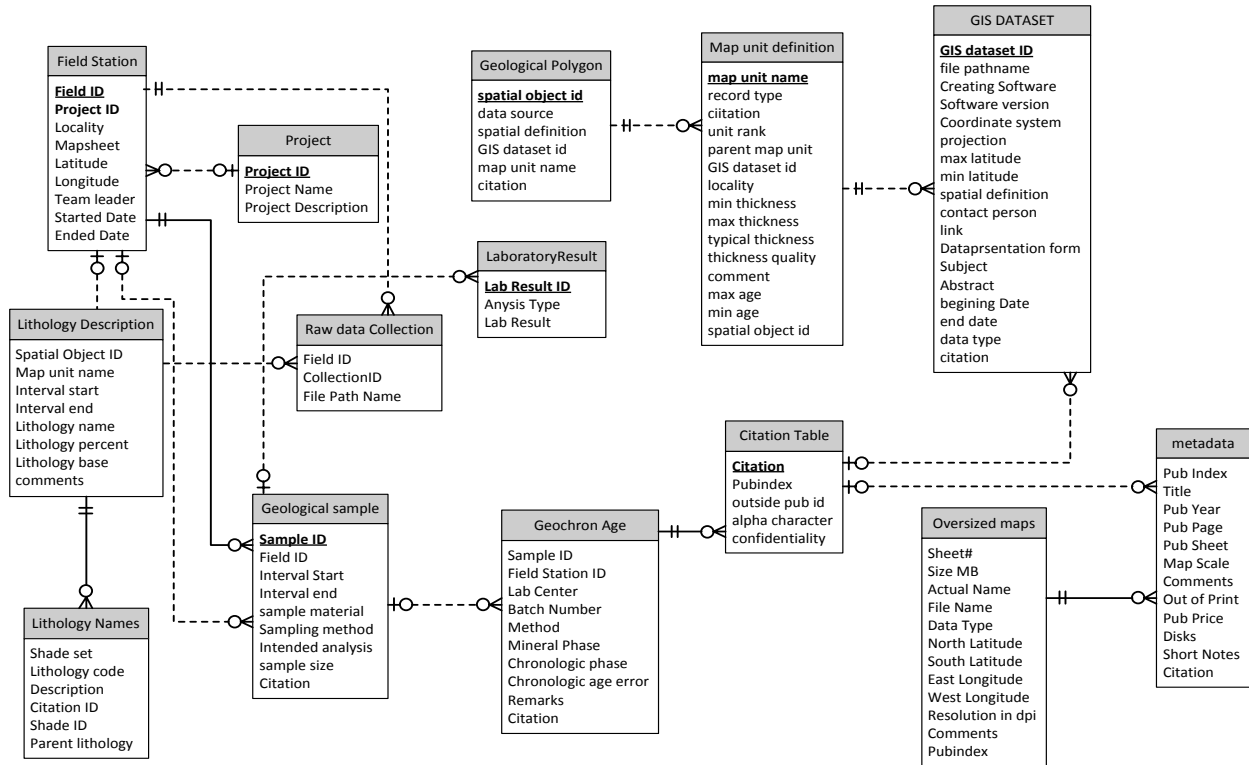


Figure 13: Logical Geoscience data Model

4.3.1.2 How (functions)

Functions from Executive perspective (Row 1, Column 2)

This cell indicates the basic project running activities. They are list of processes; GSE performs to produce geoscience information. They are

- incepting the project,
- identifying the field area,
- pre field data collection,
- data analysis (includes laboratory result),
- technical
- report and map preparation,

- dissemination of geoscience information.

Functions from Business Management perspective (Row 2, Colum 2)

This cell represents the conceptual function of producing and sharing geoscience information. It is depicted by flow chart in figure 14.

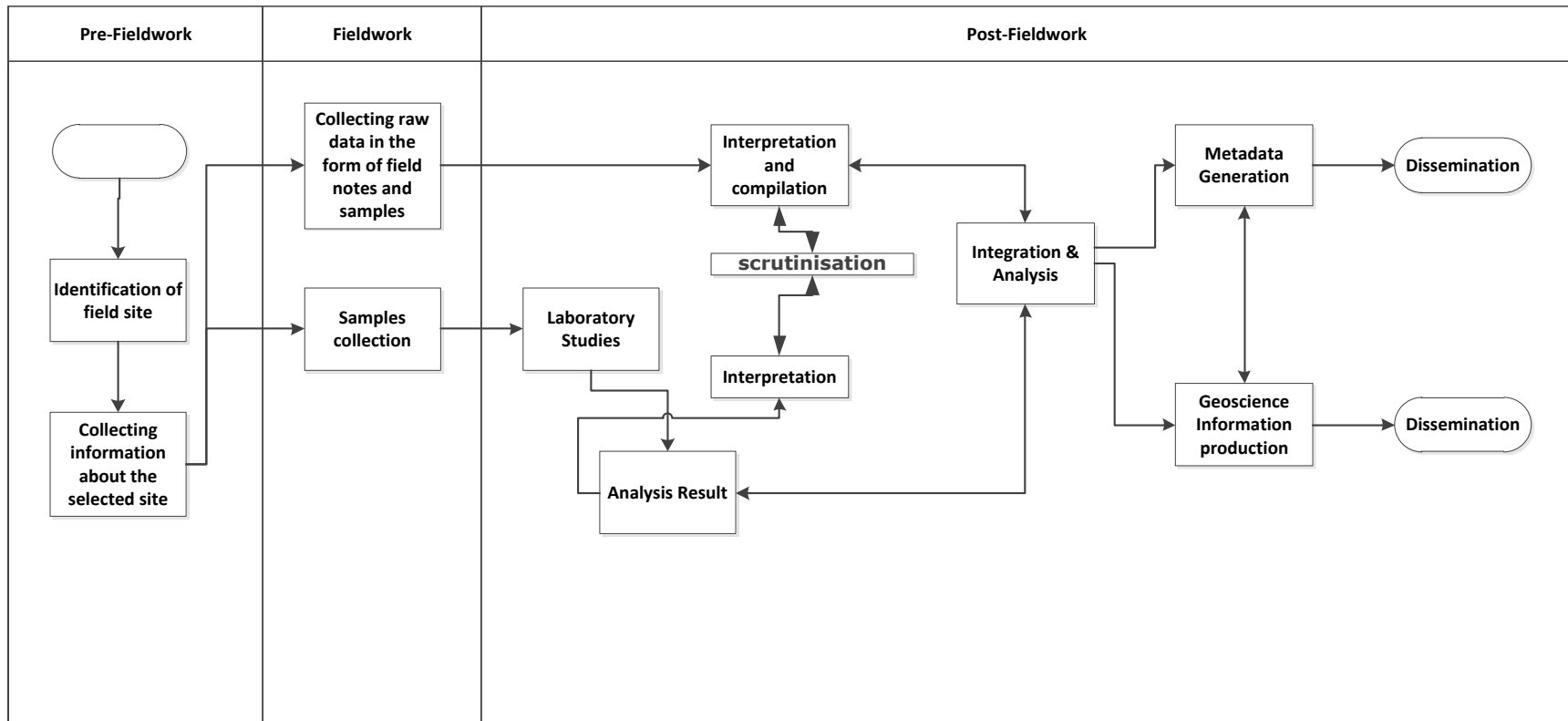


Figure 14: Business Process model

Functions from Architect perspective (Row 3, Column 2)

This cell portrays the logical data process representation the GSI management system and shown in the figure15.

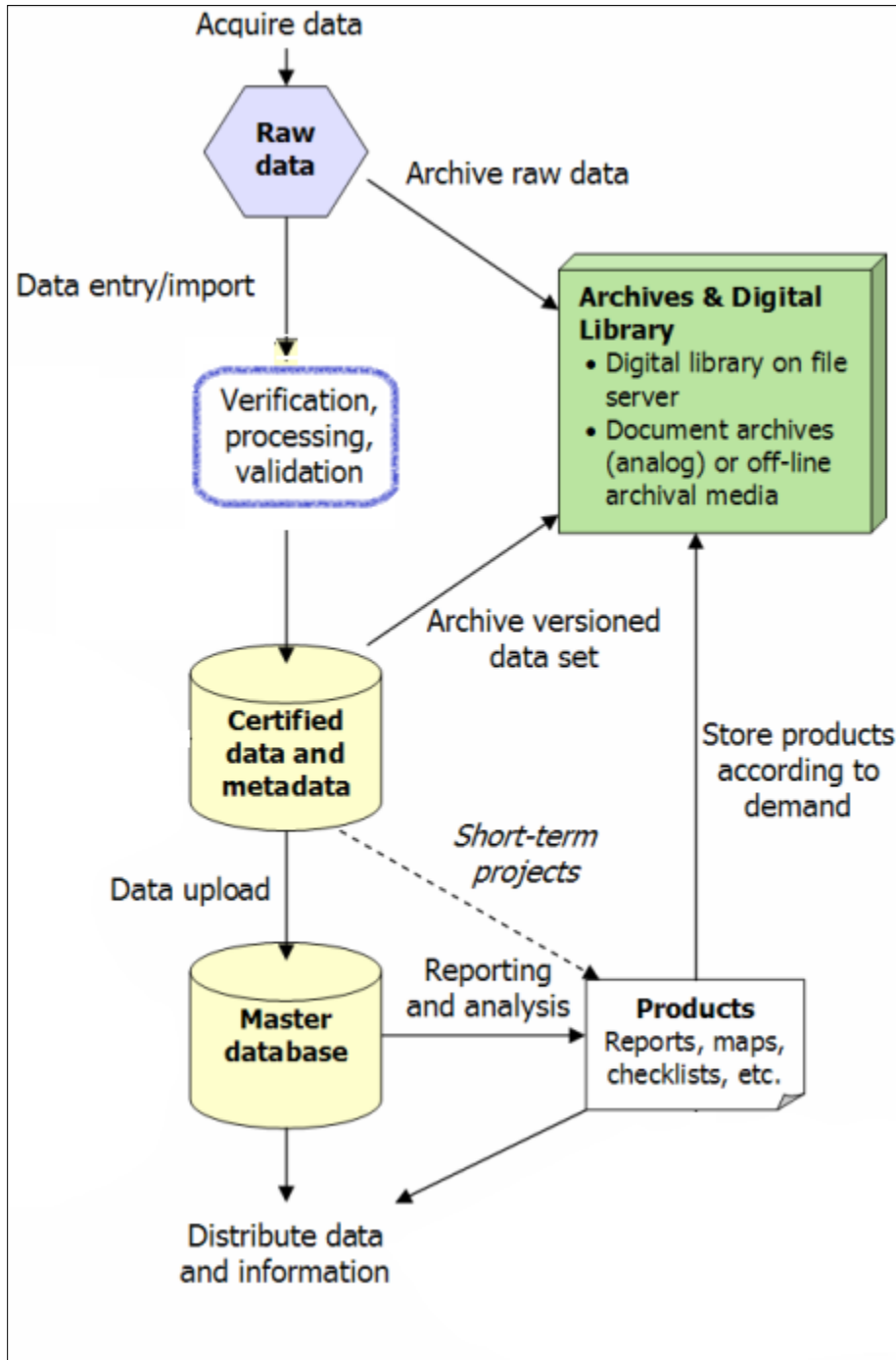


Figure 15: GSI Management System, Application architecture

4.3.1.3 Where (network)

Network from Executive perspective (Row 1, Columns 3)

This cell contains List of Locations in which the business of managing geoscience information operates. The lists of the locations are

- GSE’s head office in Addis Ababa
- Geoscience Laboratory Directorate
- Field Stations in every region.

Network from Business Management perspective (Row 2, Columns 3)

This cell represents conceptual location by which geoscience information is collected and organized. From the interview, it is understood that geoscience information is collected and organized according to index map of Ethiopia, figure 16.

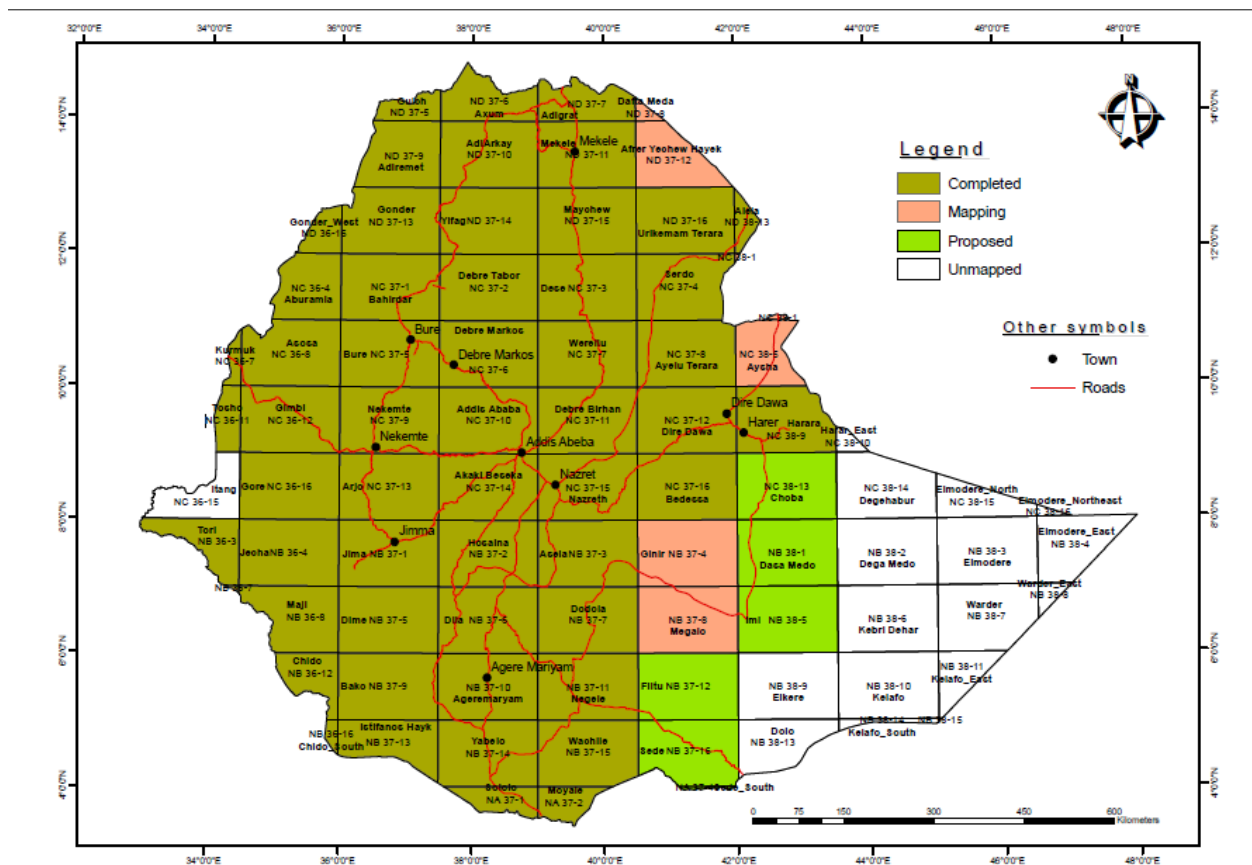


Figure 16: Basic Geoscience mapping coverage of Ethiopia organized in index map of Ethiopia. Copy Right GSE, 2015

Network from Architect perspective (Row 3, Columns 3)

This cell presents the logical model of the network component of the GSI management system environment. It is depicted by figure 17.

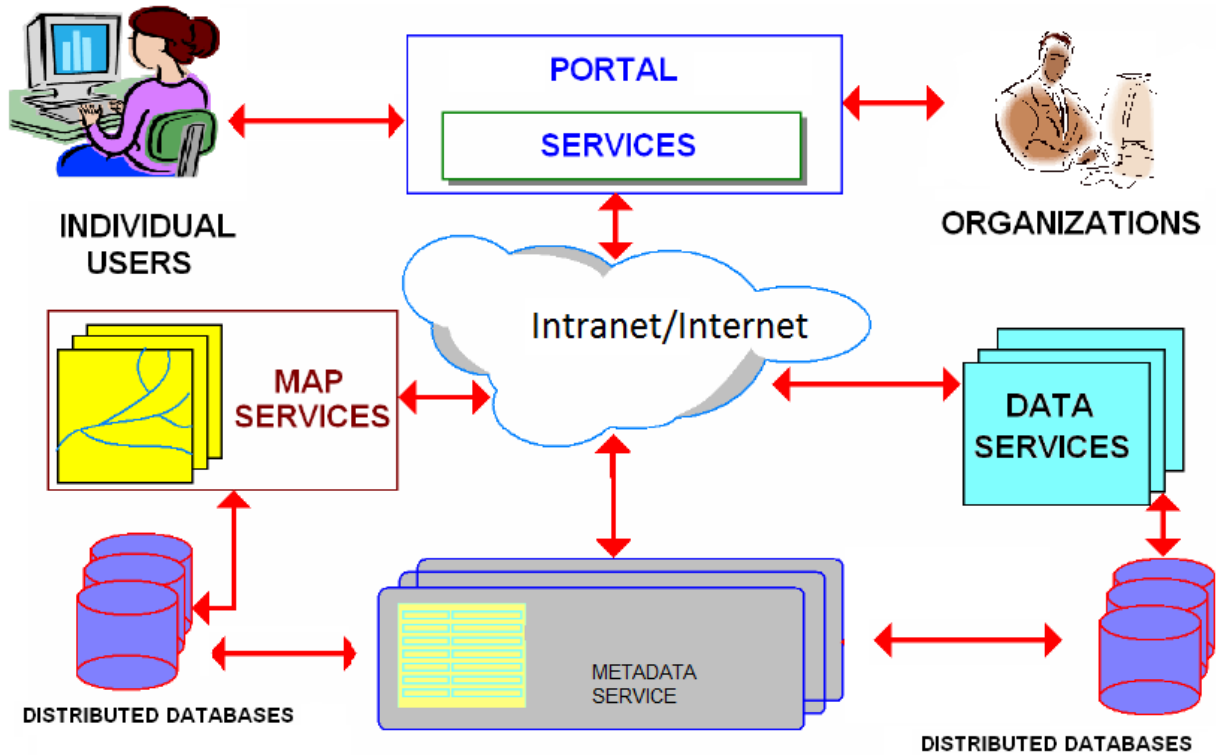


Figure 17: Distributed GSI System Architecture

4.3.1.4 Who (people)

People from Executive perspective (Row 1, Columns 4)

This cell represents list of major GSE's unites and other actors that are directly involved in collecting, analyzing, managing and disseminating geoscience information.

The lists are

- Basic Geoscience Mapping Directorate
- Mineral Exploration Directorate
- Geohazard Investigation Directorate
- Ground Water Investigation Directorate
- Geothermal Investigation Directorate
- Geoscience Information Directorate
- Geoscience Laboratory Directorate

- ICT Directorate
- Mining Companies
- Research institutions

People from Business Management perspective (Row 2, Columns 4)

This cell identifies and defines the roles of actors participating in GIS management in GSE [19]. It is represented by Actors Vs Process matrix table, Table 9.

Table 10: Actors Vs Process matrix

Actors	Processes							
	Geological Sample collection	Laboratory Analysis process	Raw Data Collection	GIS data set creation	Maps production	Publication	Photographs collection	Metadata production
Basic Geoscience Mapping Directorate	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Mineral Exploration Directorate	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Geohazard Investigation Directorate	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Ground Water Investigation Directorate	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Geothermal Investigation Directorate	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Geoscience Information Directorate	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Geoscience Laboratory Directorate	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Research institutions	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mining Companies	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

People from Architect perspective (Row 3, Columns 4)

This cell contains the interaction between actors and GSI management system and is depicted by use case diagram on figure 18.

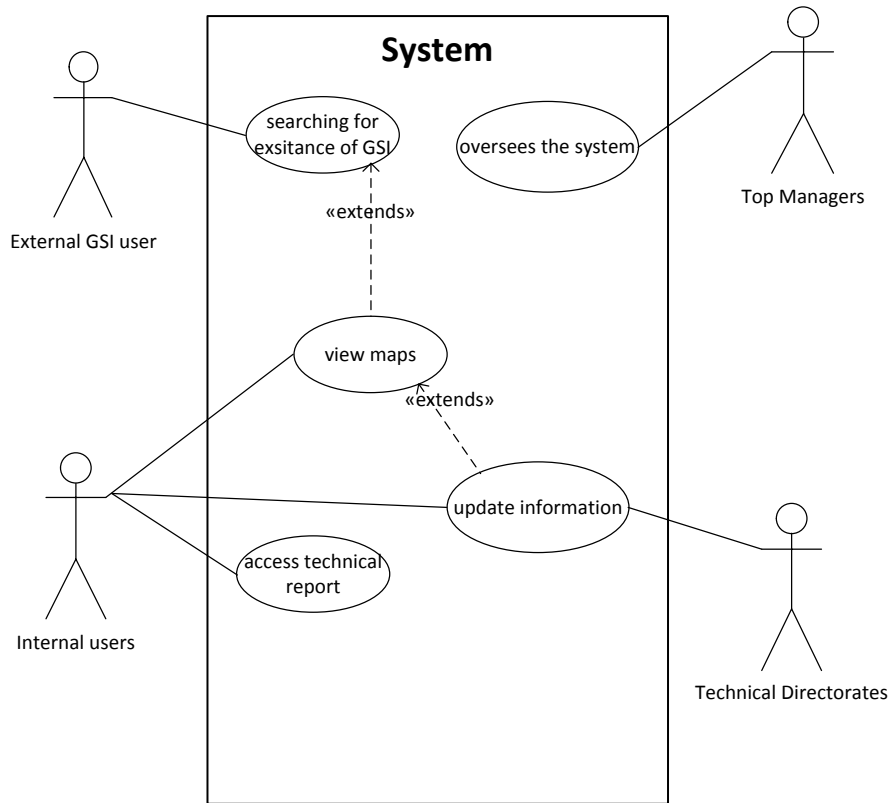


Figure 18: Human Interface Architecture for GSI system

Table 11: Actors and their responsibilities, [1, 15, 25]

No	Actors	Responsibility
1.	Top Managers	➤ Oversees every activities of managing geoscience information
2.	Basic Geoscience Mapping Directorate	<ul style="list-style-type: none"> ➤ Observing and recording of data in relation to geological feature, classification and projection to depth to figure out deeper structures ➤ Collecting and analyzing of geological materials at predefined distribution at regional scale. ➤ Making instrumental measurement of geophysical parameters from aircrafts, vehicles or hand held instruments.
3.	Mineral Exploration Directorate	<ul style="list-style-type: none"> ➤ Assessing mineral resources potential ➤ Monitoring proven resources, maintaining statistics on production and advice on regulations and legislature with regard to exploration, minerals planning and environmental impact of mining. ➤ Giving technical advice to small-scale miners. Possibly more detailed, localize mineral resources evaluations and exploration programs.

No	Actors	Responsibility
4.	Geohazard Investigation Directorate	➤ Identification, continuous monitoring and prediction of geohazards (geological, geotechnical and geochemical), to provide information and advice to the public and concerned groups on remedial action and/or appropriate protection and mitigation.
5.	Ground Water Investigation Directorate	➤ monitoring of groundwater resources to ensure a continuity of supply through sensible abstraction policies, ➤ Providing of information on the surface and sub-surface distribution and hydraulic properties of aquifers.
6.	Geothermal Investigation Directorate	➤ Exploration and assessment of energy resources and maintenance of information from these activities done by the survey or private firms.
7.	Geoscience Information Directorate	➤ Preservation and making available data acquired and collected by GSE as a national asset. ➤ Indexing and safe storage of diverse information resources including rocks, samples, , records, analytical data, field note books and maps, reports and publications and systems for locating and retrieving data in appropriate ways.
8.	Geoscience Laboratory Directorate	➤ Making chemical analysis of geological, hydrogeological and geothermal fluids, petroleum and natural gas samples using “wet classical” analysis methods (i.e., gravimetric, colorimeter, volumetric, electrogravimetry, etc.)..
9.	Research institutions	➤ Research and Development to take advantage of electronic media, Information Technology, digital cartography and Geographic Information System for integration of datasets to produce customized, thematic maps and models and dissemination.
10.	Mining Companies	➤ Participating in mining investment using the geoscience information

10.1.1.1 When (time)

Time from Executive perspective (Row 1, Column 5)

This cell contains list of events that are important to GSE in GSI management. From the interview, they are identified as

- Pre field time
- On field time
- Post field time

Time from Business Management perspective (Row 2, Column 5)

This cell consists of the master schedule for GSE. The master schedule is Growth and Transformation Program (GTP) period of Ethiopia.

Time from Architect perspective (Row3, Column 5)

This cell is represented by processes with corresponding events. It is represented on Table 12.

Table 12: Processing Structure of GSI

Process	Event
Pre field data collection	Pre field time
On field raw data collection	Field time
Data analysis	Field and post field time
Technical Report and Map preparation	Post field time
Dissemination of geoscience information	Any time

10.1.1.2 Why (motivation)

Motivation from Executive Perspective (Row1, Column 6)

This cell represents the strategic direction for the integrated geoscience information management project. From the Growth and Transformation Document, the mission and goal of GSE towards GSI management is stated as

Strategy: *“To carry out geoscientific surveys of Ethiopia so as to produce high quality geodata in a format suitable for easy utilization by end users, thus enabling rapid development of the mining sector”.*

GOAL: *“To improve the quality and coverage of the geoscience data of the country”.*

Motivation from Business Management Perspective (Row2, Column 6)

The planner identifies the vision statement needed to define the strategic direction for the integrated geoscience information. The cell value is derived from the mission and business needs of the organization.

The cell values are

- successful identification, location, and analyses of geoscience data
- improved access to geoscience data and information.
- integration of multidisciplinary data

Motivation from Architect Perspective (Row3, Column6)

Using data from interviews and document review, the cell value for the Motivation (Why) component of Row 3 are

- Quicker access to the documents,
- More efficiency in the search process,
- Simultaneous access by several people to the most current version of the document
- Enable capturing complete quality and accurate information
- Provide a platform for information sharing
- Enable periodic descriptive

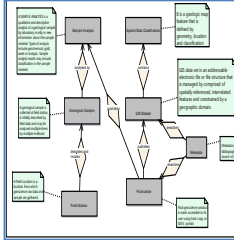
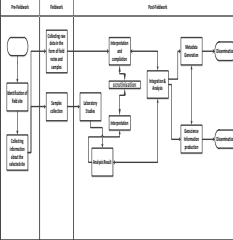
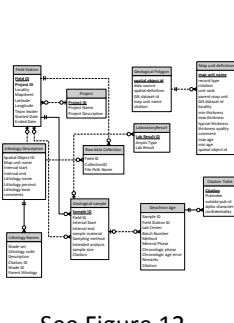
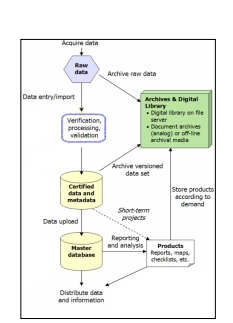
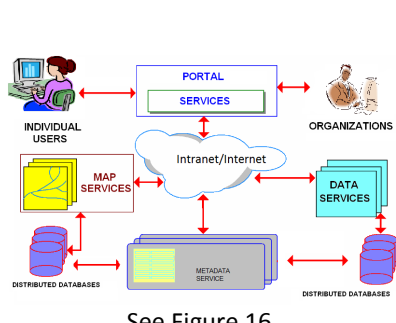
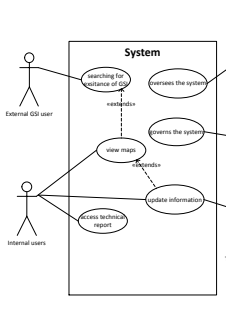
a b	1. What (data)	2. How (function)	3. Where (network)	4. Who (people)	5. When (time)	6. Why (motivation)												
Scope (Contextual) Planner	<ul style="list-style-type: none"> ➤ Data sharing policy ➤ Projects ➤ Field Station ➤ Geological Sample ➤ Laboratory Analysis ➤ Raw Data ➤ GIS data set ➤ Lithology ➤ Maps ➤ Publication ➤ Photographs ➤ Metadata 	<ul style="list-style-type: none"> ➤ incepting the project, identifying the field are, ➤ pre field data collection, ➤ data analysis ➤ technical report and map preparation; and ➤ then dissemination of geoscience information 	<ul style="list-style-type: none"> ➤ GSE's head office in Addis Ababa ➤ Geoscience Laboratory Directorate ➤ Field Stations in every region. 	<ul style="list-style-type: none"> ➤ BGM Directorate ➤ MinEx Directorate ➤ Geohazard. Directorate ➤ Groundwater Dir ➤ Geothermal Dir ➤ Geo.Info.Directorate ➤ GeoLab.Directorate ➤ ICT Directorate ➤ Research institutions ➤ Mining Companies 	<ul style="list-style-type: none"> ➤ Pre field time ➤ On field time ➤ Pose field time 	<p>Strategy: "To carry out geoscientific surveys of Ethiopia so as to produce high quality geodata in a format suitable for easy utilization by end users, thus enabling rapid development of the mining sector".</p> <p>GOAL: "To improve the quality and coverage of the geoscience data of the country".</p>												
Business Model (Conceptual) Owner	 <p>See Figure 11</p>	 <p>See Figure 13</p>	<p>Index map of Ethiopia See Figure 15</p>	<p>Table 13: Actors Vs Process matrix</p>	<p>Growth and Transformation Program (GTP)</p>	<ul style="list-style-type: none"> ➤ successful identification, location, and analyses of geoscience data ➤ improved access to geoscience data and information. ➤ integration of multidisciplinary data 												
System Model (Logical) Designer	 <p>See Figure 12</p>	 <p>See Figure 14</p>	 <p>See Figure 16</p>	 <p>See Figure 17:</p>	<table border="1" data-bbox="1472 862 1640 1182"> <thead> <tr> <th>Process</th> <th>Event</th> </tr> </thead> <tbody> <tr> <td>Pre field data collection</td> <td>Pre field time</td> </tr> <tr> <td>On field raw data collection</td> <td>Field time</td> </tr> <tr> <td>Data analysis</td> <td>Field and post field time</td> </tr> <tr> <td>Technical Report and Map preparation</td> <td>Post field time</td> </tr> <tr> <td>Dissemination of geoscience information</td> <td>Any time</td> </tr> </tbody> </table> <p>Table 11</p>	Process	Event	Pre field data collection	Pre field time	On field raw data collection	Field time	Data analysis	Field and post field time	Technical Report and Map preparation	Post field time	Dissemination of geoscience information	Any time	<ul style="list-style-type: none"> ➤ Quicker access to the documents, ➤ More efficiency in the search process, ➤ Simultaneous access by several people to the most current version of the document ➤ Enable capturing complete quality and accurate information ➤ Provide a platform for information sharing ➤ Enable periodic descriptive
Process	Event																	
Pre field data collection	Pre field time																	
On field raw data collection	Field time																	
Data analysis	Field and post field time																	
Technical Report and Map preparation	Post field time																	
Dissemination of geoscience information	Any time																	

Figure 19: Integrated Geoscience Information Architecture

a=Classification Name
b= Audience Perspective

10.2 Discussion

This study identified the necessity of proposing a solution in the field of geoscience information management to help everyone make efficient, effective, productive and innovative use of all types of geoscience information. Problems in managing geoscience information were discussed in section 1.2 and this research came up with the need of information architecture which was then designed with the help of Zachman Framework.

The major objective of the study was to investigate, design and validate information architecture towards establishing an integrated geoscience information management environment. For this, the case of Geological Survey of Ethiopia was taken to study.

Interviews were conducted with the key respondents who were identified according to selected sampling method. From the interview, 14 themes were identified and grouped into two categories.

Using the interview, observation and literature examination an integrated geoscience information architecture was defined.

This section is presented according to the research objectives and discussed in detail on the basis of specific objectives that are stated in chapter one. The major objective was to investigate, design and validate information architecture towards establishing an integrated geoscience information management environment. To support in achieving this objective, four specific objectives were defined. Thus, the results were discussed for each specific objective as follow.

I. Identifying appropriate methods, tools and techniques for designing Information Architecture.

Since this is a research in information system discipline seeking to propose an innovation (artifact), Design Research Methodology was employed as a method. The techniques that are advised by Hevner et al [23] were implemented. Innovations (artifacts) were created using Zachman framework.

Conclusion:

This objective was achieved since appropriate methods, tools and techniques for designing Information Architecture were appropriately identified.

II. Identifying the structure and requirement of geoscience information management.

While populating the Zachman Framework, the function (how) column which represents the structure of geoscience information management was identified and the data (what), network (where), people (who), time (when) and motivation (why) columns consist of information that are the requirements of geoscience information management. Thus, the requirement of geoscience information management was identified.

Conclusion:

Since the structure and requirement of geoscience information management are identified, the research achieved this specific objective.

III. Designing geoscience information architecture.

Using the grid model of Zachman framework, the integrated geoscience information environment was classified and organized with representation of six different dimensions and each this dimensions was perceived in three perspectives. The geoscience information architecture was defined across two independent aspects. The views of the planner, the owner and the designer were represented by the rows and the columns represent the data, function, network, people, time, and motivation aspects of the architecture. The points of intersection between the rows and the columns hold important information of the GSI management system. The contents in each cell are the artifacts of the study. Since it was possible to define the requirements, organization, processes and information flows of Geoscience information by applying ZF while conducting this research; the geoscience information architecture was effectively designed, Figure 20.

Conclusion:

From the above discussion we can conclude that the objective of designing geoscience information architecture is achieved.

IV. Evaluating the geoscience information architecture and communicating the result

Since this study followed a design science research methodology, the guideline proposed by Hevner et al [23] was used as checklist to evaluate the process, Table 13.

Table 14: Evaluation Checklist

Guideline	Checklist Description	Assessment Result
Guideline 1: Design as an Artifact	Was the research produced a viable artifact in the form of a construct, a model, a method, or an instantiation?	<p>Yes, in the ZF, each cell is an artifact and each column at each row point has a unique model.</p> <p>The framework produced during the development phase meets the criteria of an artifact, as it represents a construct (conceptualization of problem row 1), a model (represent a real world situation)</p>
Guideline 2: Problem Relevance	Was the study developed technology-based solutions to important and relevant business problems?	The collected data revealed that there are persistent problem in managing GSI at GSE. This study developed/defined artifacts (using technology based) to solve the problems solutions.
Guideline 3: Design Evaluation	Were the utility, quality, and efficacy of a design artifact rigorously demonstrated via well-executed evaluation methods?	The artifacts derived from the ZA were validated by three experts (two geoscience experts, one system expert) at GSE whether they are complete and acceptable. Both said that even if the design was not complete, it is acceptable.
Guideline 4: Research Contributions	Will the study provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies?	There are rare researches in IS field in geoscience sector Ethiopia, therefore this research will provide clear and verifiable contribution for both design science and geoscience disciplines.
Guideline 5: Research Rigor	Does the research rely upon the application of rigorous methods in both the construction and evaluation of the design artifact?	Yes, the research applied ZF, for artifact construction. More over in the process, it employed DSR methodology; it used interviews, observation and literature to understand the business need and existing knowledge.

Guideline	Checklist Description	Assessment Result
Guideline 6: Design as a Search Process	Did the research utilize available means to reach desired ends while satisfying laws in the problem environment.	Yes, the research utilized acceptable data collection mechanism to answer the first research question and used ZF as a tool to define the artifacts.
Guideline 7: Communication of Research	Was result of the research presented effectively both to technology-oriented as well as management-oriented audiences?	The result was communicated for the concerned experts at GSE. It is will be also communicated for technology- oriented audiences through this thesis.

Conclusion:

This research tried evaluate the geoscience information architecture and communicate the result. Therefore, the goal of this specific objective is also realized.

CHAPTER FIVE

11. Conclusions and Recommendations

11.1 Conclusions

With the massive and ever-increasing amount of geoscience information, designing the information architecture was essential to enable the creation, sharing, management and delivery of geoscience information products. This study is about how Information Architecture supports the environment that manages geoscience information.

The research questions that guided this research were defined as:

- How effective and manageable is the access to geoscience information?
- How can geoscience information management be improved through information architecture?

From the collected data the research has revealed that the access to geoscience information is not effective and manageable since

- Geoscience data and information are not readily accessible to the user community.
- Geoscience data and information is lost due to poor data management practice.
- Multiple use and reuse of field data is difficult as it is not readily available in suitable format. Each department's data is treated separately
- Unpublished reports and out of print maps and reports are not readily accessible to a wide user base.

Since it was possible to define the requirements, organization, processes and information flows of geoscience information by applying Zachman Framework; the means to improve the management of geoscience information has been found through information architecture.

This research achieved its objective since

- Appropriate methods, tools and techniques for designing Information Architecture were identified.
- Using the Zachman framework, the structure and requirement of geoscience information management identified and its information architecture was designed.
- The designed geoscience information architecture was evaluated and communicated with the concerned people.

11.2 Recommendations

Using design science research methodology as main approach, an integrated geoscience information architecture has been developed for Geological Survey of Ethiopia. Still all the issues have not been addressed in this research. Thus, the following researches in the field of Information Science, Design Science and Geoscience for the future studies are recommended.

11.2.1 Recommendation for future work

- Since most of the data that are collected by GSE are spatial data, this study can be enhanced by incorporating geospatial data concept to this research result.
- This study focused on geoscience information in general. Taking this research result as a foundation, researchers can develop specific geoscience architecture mineral exploration, ground water exploration, geo-hazard investigation, engineering geology and geothermal exploration sub disciplines

11.2.2 Recommendation for practice

- The architecture proposed by this research is a logical and conceptual architecture. So, to develop and implement an Integrated Geoscience Information System on the basis of the designed architecture, there are some issues that have to be addressed. Like for instance, what could be the detail technological specifications like capacity of database servers, network environment, the financial requirements and so on. Thus, if this issues are addressed, Geological Survey of Ethiopia has to use this opportunity to develop a geoscience information system that solves its long time geoscience administration problems.

References

- [1]. Berg R., Mathers M., Kessler H., and Keefer D (2011). *Synopsis of current three-dimensional geological mapping and modeling in geological survey organisations*. Illinois State Geological Survey, USA.
- [2]. Ministry of Mines Annual Report, July 2014.
- [3]. Geological Survey of Ethiopia Annual Report, 2006 E.C.
- [4]. Tibebe Beshah, Dejene Ejigu, Ajith Abraham (2012). *A Novel Road Safety Information Architecture (RSIA): An Enterprise View*. In Conference Proceeding of WICT 2012. IEEE Conference Publications.
- [5]. Morville, P. and Rosenfeld, L. (2006). *Information Architecture for the World Wide Web (3rd ed)*. O'Reilly Media, California, USA.
- [6]. Nambiar U., Ludaescher B., Baru C. & Lin K. *The GEON Portal: Accelerating Knowledge Discovery in the Geosciences*. University of California, San Diego, USA.
- [7]. Zachman, J.A. (1999). *A framework for information systems architecture*. IBM Systems Journal, 38(2&3), 454-470
- [8]. Wurman, R.S. & Bradford, P. Eds. (1996). *Information Architects. Zurich, Switzerland*. Graphic Press.
- [9]. Rosenfeld, L. (2002). *Information architecture: looking ahead*. Journal of the American Society for Information Science and Technology, 53(10) 874-876.
- [10]. Dillon, A. & Turnbull, D. (2005). *Information architecture*. Encyclopedia of Library and Information Science: First Update Supplement, London, UK: Taylor & Francis.
- [11]. Bailey, S. (2002). *Do you need a taxonomy strategy?* retrieved from <http://www.ikmagazine.com/>
- [12]. Stiglich, P. (2007). *Data architecture vs. information architecture*. Ask the Data Management Expert: Questions & Answers, retrieved from <http://searchdatamanagement.techtarget.com>
- [13]. Laura Downey L. & Banerjee S. *Building an Information Architecture Checklist*. Journal Of Information Architecture Volume 2 Issue 2

- [14]. Walt, P.W (2006). *Developing a scaleable information architecture for an enterprise-wide consolidated information management platform*. University of Johannesburg, South Africa.
- [15]. Loudon, T.V. (2012). *A Scenario for Systems Geology*. BGS Research Report. www.bgs.ac.uk/systemsgeology
- [16]. US National Center for Supercomputing Applications, 2008. *NCSA 2010: The future of NCSA*.
- [17]. Resmini A. and Rosati L. (2003). *A Brief History of Information Architecture*. *Journal of Information Architecture*. Volume 3 Issue 2
- [18]. Roger Sessions, (2007). *A Comparison of the Top Four Enterprise-Architecture Methodologies*. Object Watch, Inc. <http://msdn.microsoft.com/en-us/library/bb466232.aspx>
- [19]. Zachman J. (2003) *Zachman Framework for Enterprise Architecture: Primer for Enterprise Engineering and Manufacturing*. Zachman International
- [20]. Draheim D. & Weber G. (2007) *Trends in Enterprise Application Architecture: 2nd International Conference*, TEAA, Berlin, Germany.
- [21]. Whitehouse, 2012. *A Common Approach to Federal Enterprise Architecture*. http://www.whitehouse.gov/sites/default/files/omb/assets/egov_docs/common_approach_to_federal_ea.pdf (accessed, 02/06/2015)
- [22]. Laura Downey L. & Banerjee S. *Building an Information Architecture Checklist*. *Journal Of Information Architecture* Volume 2 Issue 2
- [23]. Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). *Design science in information systems research*
- [24]. Iain Barker, (2005) *What is information architecture?* Step Two Designs Pty Ltd www.steptwo.com.au/papers/kmc_whatisinforch/ (accessed, 02/06/2015)
- [25]. Currie A., Charlesworth P., Mandryk G. and Boon J . *Geoscience Information Systems In Canadian Geological Surveys*
- [26]. Tsehaie Woldai. *Geospatial Data Infrastructure: The Problem of Developing Metadata for Geoinformation in Africa*. ITC, The Netherlands

- [27]. Gable, G.G (1994). *Integrating Case Study and Survey Research Methods: An Example in Information Systems*. European Journal of Information Systems, Vol 3, No 2, 1994, pp.112-126.
- [28]. Eisenhardt, K. (1989). *Building theories from case study research*. Academy of Management Review, Vol. 14, No.4: 532-550.
- [29]. YIN, R. K. (2009). *Case study research: design and methods*. Thousand Oaks, Sage Publications
- [30]. Cassell, C.M. and Symon, G. (1994). *Essential Guide to Qualitative Methods in Organizational Research* London: Sage
- [31]. Watson.R. (2000) *An Enterprise Information Architecture: A Case Study for Decentralized Organizations* Hawaii International Conference on System Sciences
- [32]. Evernden, R. & Evernden, E. (2003). *Information first – integrating knowledge and information architecture for business advantage*. Amsterdam. Elsevier.
- [33]. Helen Nneka Eke , (2011). *Library Portals and Information Architecture: Librarians emerging Info- architects* International Research: Journal of library & Information Science | Vol. 1 No. 2, Dec.2011
- [34]. Malloy, M., Masek E., Miller R., Winkowski D. (2010). *An Information Architecture Framework for the USAF: Managing Information from an Enterprise Perspective*. The MITRE Corporation. USA
- [35]. Xu J., Quaddus M. (2013). *Managing Information Systems: Ten Essential Topics*. Springer Science & Business Media. Berlin, Germany.
- [36]. Gelinas U., Dull R. (2009). *Accounting Information Systems*. Cengage Learning, Boston, USA
- [37]. Broome, J. et. al., (1993) *The NATMAP digital geoscience data-management system*. Computers and Geosciences, Vol. 19, No 10
- [38]. Montealegre, R. (1999). *A case for more case study research in the implementation of information technology in less-developed countries*. Information technology for development.
- [39]. Stake, R. (1995). *The art of case research*. Thousand Oaks, CA: Sage Publications.
- [40]. Kumar, R. (2005). *Research Methodology: A Step - by - step Guide for Beginners* (Second edition ed.). London etc.: Sage.

- [41]. Soanes, C. & Stevenson, A. (2008). *Concise Oxford English Dictionary*. 11th ed. Oxford: Oxford University Press.
- [42]. Duke J.M. (2010). *Government geoscience to support mineral exploration: public policy rationale and impact*. PDAC Geosciences Committee, Canada.
- [43]. Marchand, D., (2000). *Competing with information - A manager's guide to creating business value with information content*. Wiley, UK.
- [44]. Simon, H. (1996). *The sciences of the artificial*. 3rd ed. Cambridge MA: MIT Press
- [45]. Hill, G. (2009). *A Framework for Valuing the Quality of Customer Information*. The University of Melbourne, Australia.
- [46]. Burstein, F., and Gregor, S. (1999). *The Systems Development or Engineering Approach to Research in Information Systems: An Action Research Perspective*. Proceedings of the 10th Australasian Conference on Information Systems.
- [47]. Cheney, W. (2003). *Implications of Information Technologies in Geo- and Bio-Sciences: A Literature Review*. Silver Spring, USA.
- [48]. Broome, J. & Cox, S. (2007) *Geoscience Information Management and Access: Evolution of a Key Enabler for Exploration Success*. Proceedings of Exploration 07: Fifth Decennial International Conference on Mineral Exploration, Canada.
- [49]. Bonham-Carter, G. F. (1997). *GIS methods for integrating exploration data sets, in Geophysics and Geochemistry at the Millennium*. Proceedings of Exploration '97, Fourth Decennial International Conference on Mineral Exploration, Prospectors and Developers Association of Canada, Toronto, 59-64.
- [50]. Guest, G., Bunce, A. and Johnson, L. (2006). *How many Interviews are Enough? An experiment with Data Saturation and Variability*.
- [51]. Romney, A., Batchelder, W. and Weller, S. (1986). *Culture as consensus: A theory of culture and informant accuracy*. *American Anthropologist*
- [52]. Boyatzis, E. R. (1998). *Transforming qualitative Information: Thematic analysis and code development*. Sage. Thousand Oaks.
- [53]. Lassoued Y. (2008). *GeoDI - Geoscientific Data Integration*. University College Cork, Ireland.
- [54]. Wolfgang Effenberg (2001). *Spatial Cadastral Information Systems The maintenance of digital cadastral maps*. PHD Dissertation, The University of Melbourne.

- [55]. Pereira C.M and Sousa P.(2004). *A Method to Define an Enterprise Architecture using the Zachman Framework*. Nicosia, Cyprus.
- [56]. Schultze U. and Avital M.(2011) . *Designing interviews to generate rich data for information systems research*. Information and Organization, Elsevier.
- [57]. O'Rourke, C., Fishman, N., Selkow, W. (2003). *Enterprise Architecture: Using the Zachman Framework*. Boston, Massachusetts: Course Technology Inc.
- [58]. Godinez M., Hechler E., Klaus Koenig, Lockwood S., Oberhofer M. & Schroeck M. (2010). *The Art of Enterprise Information Architecture: A Systems-Based Approach for Unlocking Business Insight*. IBM Press Pearson plc Upper Saddle River, NJ, USA.
- [59]. Version T. 9, The Open Group Architecture Framework (TOGAF) (2009). The Open Group.
- [60]. Hilina Dejene, 2014. *Developing an Enterprise Framework for Mental Health Information System in Addis Ababa*. Master of Science Thesis, School of Public Health, Addis Ababa University: Addis Ababa, Ethiopia

Annex 1: Interview Questions

I. Introduction

- a. Introducing myself
- b. Informing the purpose and the background of the interview

II. About the interviewee

- a. Who are you?
- b. Current position/role?

III. Questions

1. What are the assets/deliverables of GSE in managing geoscience information at your department?
2. Can you list those locations where your department operates to produce geoscience information?
3. Can you list those users/groups who are involved in producing geoscience information?
4. Can you list of times geoscience information is collected?
5. Can you list GSE's business goals/strategies in geoscience administration?
6. Size.
 - a. How much geoscience information are there in GSE/in your department/? (Whatever unit of measurement you use: perhaps number, volume, area, etc).
 - b. How do you evaluate your capacity for managing the geoscience information?
 - c. How fast is the collection of geoscience information growing?
7. Usage.
 - a. What sorts of people use the geoscience information in a year? What for?
8. Existing System
 - a. Is there a functional integrated geoscience information system?
 - b. What are its good features?
 - c. What are its drawbacks?
9. Accessibility.
 - a. How do you get geoscience information from other department?
 - b. Is the information stored digital or in paper?
 - c. Any difficulties in getting geoscience information?
 - d. How to minimize those difficulties?

- e. Are all of the geoscience information accessible at any given point in time?
- f. Is there any policy which says about providing easy access to information to users?
- g. Is there any difficulty in linking and sharing data among departments in GSE?
- h. What type of geoscience information does need any restriction in accessing it?
- i. What is the information you require from the customers to provide those services?
- j. Does GSE have its own standard for metadata?
- k. What do you say of the integrity, completeness and usefulness of the GSE's geoscience information?

10. Data Management.

- a. Information Architecture is the art and science of organizing information so that it is findable, manageable and useful. Do you think that this is the right time to design IA for GSE's geoscience information?

Annex 2: Observation Checklist

Observed checklist which was used to observe how the existing system generates, organizes and integrates geoscience information.

Observation 1 Information organization	Organized	Not Organized	Semi organized	Cannot be determined
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Observation 2 Information generation	Standardized	Non Standardized	Semi standardized	Cannot be determined
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Observation 3 Information integration	Integrated	Semi Integrated	Not Integrated	Cannot be determined
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>