

MANAGING KNOWLEDGE IN MEGA- INFRASTRUCTURE PROJECTS

By

Bekezela Maria Moloi



Thesis presented in fulfilment of the requirements for the degree of
Master of Philosophy (Information and Knowledge Management)
in the Faculty of Arts and Social Sciences
at Stellenbosch University

iyUNIVESITHI
STELLENBOSCH
UNIVERSITY

100
1918 - 2018

Supervisor: Christiaan Maasdorp
December 2018

DECLARATION:

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third-party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: December 2018

OPSOMMING

Die tesis fokus op die kennisbestuurskwessies wat tipies in groot infrastruktuurprojekte ontstaan. Mega-infrastruktuurprojekte is kompleks omdat hulle op grootskaal uitgevoer word en tipies baie duur is (gewoonlik meer as US \$ 1 miljard). Hulle het meer komplekse koppelvlakke, betrek gewoonlik 'n wye reeks openbare en private belanghebbendes met teenstrydige belange wat potensieël baie mense kan beïnvloed, is meer riskant aangesien omvangsveranderinge onvermydelik is omdat dit oor 'n langer tydshorison loop wat oor baie jare van ontwikkeling en konstruksie strek. Hulle bied ook groter personeeluitdagings aangesien hulle hulpbronintensief is en as gevolg van die lang tydhorisonte is dieselfde spanlede nie altyd oor die duur van die projek teenwoordig nie.

Hierdie kompleksiteit beteken dat kennisoordrag en integrasie uitdagings groter is as vir ander projekte. Omdat die tegnologie en ontwerpe vir megaprojekte dikwels nie standard is nie, word hierdie projekte deur die deelnemers beskou as eenmalige of unieke ondernemings. Standardisering van die industrie is moeiliker end it belemmer die leer van ander projekte. Die vraag is hoe kennis in megaprojekte effektief bestuur kan word, gegewe die bogenoemde uitdagings.

Ten einde hierdie kwessie te ondersoek, is twee groot infrastruktuurprojekte van Eskom, naamlik die ontwikkeling van die projek Medupi en projek Kusile steenkool-termiese kragstasies, as gevallestudies gekies.

Die tesis begin met 'n literatuuroorsig oor die algemene bestuursuitdagings van mega-infrastruktuurontwikkeling, gevolg deur 'n hoofstuk wat Boisot se sosiale leersiklus in die i-Space beskryf as basis vir die analise van die gevalle. Dan word 'n oorsig van die Eskom-bouprogram verskaf voordat die twee projekte en die kennisbestuursprogramme vir hierdie projekte beskryf word. Onderhoude is uitgevoer met sleuteldeelnemers oor die projekte en die bevindinge uit die onderhoude word aangebied, bespreek en geïnterpreteer in terme van Boisot se teorie.

Daar is bevind dat topbestuur nie die grondslag gelê het vir die sosiale leersiklus in projekte nie, dat die kennisbestuurbeampies nie effektiewe stelsels ondersteun het om effektiewe skandering, kodifisering en abstraksie van kennisbates in die Eskom i-Space te verseker nie, en dat die projekspanne nie effektief was in die uitvoering van kennisbestuursprosesse van diffusie, absorpsie en impak van kennisbates nie.

SUMMARY

The thesis focuses on the knowledge management issues that typically arise in large infrastructure projects. Mega-infrastructure projects are complex because they are large-scale and very costly (typically over US\$ 1 billion); have more complex interfaces; usually involve a broad range of public and private stakeholders with conflicting interests often impacting many people; are more risky as scope changes are inevitable as they run over a longer time horizon spanning many years of development and construction. They also attract greater staffing challenges as they are resource intensive and the same participants are less likely to be present due to the long time-horizons.

This complexity means that knowledge transfer and integration challenges are greater. Moreover, because the technology and designs are often non-standard for mega projects, these projects are considered to be once-off or unique undertakings in the minds of most of the participants and standard industry benchmarking is more difficult impeding learning from other projects. The question is how one can effectively manage knowledge in mega projects given the above challenges.

In order to investigate this issue, two large infrastructure projects undertaken by Eskom, namely the development of the project Medupi and project Kusile coal-thermal power stations, were selected as case studies.

The thesis starts out with a literature review on the general management challenges of mega-infrastructure development, followed by a chapter describing Boisot's social learning cycle in the i-Space to be used as the basis for analysis of the cases. Then an overview of the Eskom build program is provided before describing the two projects and the knowledge management programs for these projects. Interviews were conducted with key participants on the projects and the findings from the interviews are presented, discussed and interpreted in terms of Boisot's theory.

The findings include that management failed to lay the foundation for embedding the social learning cycle in projects; that the knowledge management custodians did not provide effective systems support to ensure effective scanning, codifying and abstracting of knowledge assets in the Eskom i-Space; and that the project teams were not effective in carrying out knowledge management process diffusion, absorption and impacting of knowledge assets.

ACKNOWLEDGEMENTS

With the completion of this study, I am indebted to the following without whom this would not have been possible:

- My husband Mohale Moloi thank you for your continued support and encouragement to set a good example to our boys by completing this work.
- To my sons Kopano and Morena your curiosity and interest on my academic work motivated me. Kopano your question is finally answered yes this book will be published.
- To my family thank you for their continued support and encouragement.
- My study leader, Christiaan Massdorp whose leadership, insight and professional approach guided me through the study. His guidance, support and advice were unmistakably the cornerstone for the successful completion of this study.
- My employer Eskom, for allowing me the opportunity to broaden my perspectives through this research study. I also extend my thanks to all the respondents who took time from their very busy schedules to allow me the personal interviews that I needed to finalise the empirical portion of this degree

TABLE OF CONTENTS

CHAPTER 1.....	1
RESEARCH QUESTION AND BACKGROUND.....	1
1.1. INTRODUCTION	1
1.2. STATEMENT OF THE RESEARCH FOCUS	6
1.3. OBJECTIVE OF THE RESEARCH AND RESEARCH QUESTIONS.....	7
1.4. RESEARCH METHODOLOGY	8
1.4.1. RESEARCH PARADIGM	9
1.4.2. SAMPLING AND POPULATION.....	10
1.4.3. SAMPLE CRITERIA AND SELECTION	12
1.4.4. INTERVIEW DESIGN AND PROCEDURE	13
1.4.5. ETHICAL CONSIDERATIONS	15
1.4.6. DATA COLLECTION.....	16
1.4.7. CODING.....	17
1.5. SCOPE OF THE STUDY	21
1.6. LIMITATIONS OF THE STUDY	22
1.7. STRUCTURE OF THE DISSERTATION.....	23
CHAPTER 2.....	25
MANAGING KNOWLEDGE IN MEGA INFRASTRUCTURE PROJECTS	25
2.1. INTRODUCTION	25
2.2. KNOWLEDGE	25
2.2.1. Explicit Knowledge.....	27
2.2.2. Tacit Knowledge.....	27
2.2.3. Embedded Knowledge	28
2.3. DEFINING A PROJECT	28
2.3.1. Project Scope Management	29
2.3.2. Project Time Management.....	29
2.3.3. Project Cost Management	29
2.3.4. Project Quality Management.....	29
2.3.5. Human Resource Management.....	30
2.3.6. Project Communications Management	30
2.3.7. Project Risk Management.....	30
2.3.8. Project Procurement Management	30
2.3.9. Project Integration Management.....	31
2.3.10. Initiation Process.....	32
2.3.11. Planning Process.....	33
2.3.12. Execution Process.....	33
2.3.13. Controlling Process.....	33
2.3.14. Closing Phase.....	33
2.4. DEFINING A MEGAPROJECT	34
2.5. KNOWLEDGE TRANSFER IN PROJECTS.....	37
2.6. THE RELATIONSHIP BETWEEN PROJECT RISK AND KNOWLEDGE MANAGEMENT	40
2.7. CONCLUSION	41
CHAPTER 3.....	43
LITERATURE REVIEW.....	43
INFORMATION SPACE METHODOLOGY (I-SPACE).....	43
3.1. INTRODUCTION	43
3.2. THE I-SPACE FRAMEWORK	44
3.3. FOUNDATIONAL CONCEPTS OF THE I-SPACE	48
3.3.1. The social learning cycle (SLC).....	48

3.3.2.	<i>The social learning approach</i>	49
3.3.3.	<i>Knowledge</i>	51
3.3.4.	<i>Data</i>	52
3.3.5.	<i>Information</i>	52
3.3.6.	<i>Scanning</i>	54
3.3.7.	<i>Codification</i>	55
3.3.8.	<i>Abstraction</i>	56
3.3.9.	<i>Diffusion</i>	56
3.3.10.	<i>Absorption</i>	57
3.3.11.	<i>Impacting</i>	57
3.4.	CONCLUSION	58
CHAPTER 4		59
CASE STUDY		59
MEDUPI AND KUSILE POWER STATION		59
4.1.	INTRODUCTION	59
4.2.	MEDUPI POWER STATION	60
4.3.	KUSILE POWER STATION	61
4.4.	GOVERNANCE PROCESS OVERVIEW FOR MEDUPI AND KUSILE PROJECTS	61
4.5.	TECHNOLOGY OVERVIEW	63
4.6.	ENVIRONMENTAL FACTS	64
4.7.	COMMON RISKS IN BOTH POWER PROJECTS	64
4.8.	FINANCING FOR MEDUPI AND KUSILE POWER STATIONS	66
4.9.	SOCIOECONOMIC IMPACTS OF MEDUPI AND KUSILE PROJECT	67
4.10.	CHALLENGES FOR MEDUPI AND KUSILE PROJECT	69
4.10.1.	<i>Ambitious Implementation timelines</i>	69
4.10.2.	<i>Construction market grid lock</i>	70
4.10.3.	<i>Environmental Impact Assessment authorization</i>	70
4.10.4.	<i>Contract management</i>	71
4.10.5.	<i>Resource Constraints</i>	71
4.10.6.	<i>Project Sites Infrastructure logistics</i>	72
4.10.7.	<i>Time line Schedules</i>	72
4.11.	COMMON CHARACTERISTICS AT MEDUPI AND KUSILE POWER STATIONS	73
4.12.	THE ESKOM KNOWLEDGE MANAGEMENT PROCESS	74
4.13.	KNOWLEDGE CAPABILITY REQUIREMENTS	79
4.14.	SUMMARY	80
CHAPTER 5		82
DISCUSSION		82
5.1.	INTRODUCTION	82
5.2.	DATA ANALYSIS	83
5.4.1.	DATA ANALYSIS PROCEDURE	83
5.4.2.	RESULTS ANALYSIS	87
5.3.	SOCIAL LEARNING IN MEDUPI AND KUSILE PROJECT	89
5.3.1.	FRONT-END ENGINEERING AND SITE DEVELOPMENT	89
5.3.2.	EXECUTION PHASE	93
5.4.	PROPOSITIONS FOR MANAGING KNOWLEDGE IN DEVELOPMENT OF MEGAPROJECTS	95
5.5.	SUMMARY	104
CHAPTER 6		106
CONCLUSION		106
6.1	INTRODUCTION	106
6.2.	IMPORTANCE OF EFFECTIVE MANAGEMENT OF KNOWLEDGE FOR THE LONG-TERM SUSTAINABILITY OF ESKOM	108

6.3.	EFFECTIVENESS OF CURRENT KNOWLEDGE MANAGEMENT PROCESS AT Eskom.....	109
6.4.	PROCESSES REQUIRED TO OVERCOME THE MAJOR ISSUES WITH THE CURRENT PROCESS AT Eskom	110
6.5.	<i>METHODOLOGY TO ABSTRACT AND DIFFUSE KNOWLEDGE AT Eskom</i>	110
6.6.	CONTRIBUTIONS OF THE STUDY	111
6.7.	FURTHER RESEARCH.....	111
<i>BIBLIOGRAPHY</i>		<i>113</i>
<i>APPENDIX 1 - SEMI-STRUCTURED INTERVIEW GUIDE</i>		<i>121</i>

LIST OF ABBREVIATIONS

AFDB	African Development Bank
DME	Department of Minerals and Energy
EA	Environmental Assessments
GDP	Gross Domestic Product
IPPs	Independent Power Producers
KM	Knowledge Management
PLCM	Project Life Cycle Model
SLC	Social Learning Cycle
WULA	Water Use License Authorisation
RFP	REQUEST FOR PROPOSALS
RFQ	REQUEST FOR QUALIFICATION

LIST OF FIGURES

FIGURE 1: PROJECT LIFE CYCLE MODEL	32
FIGURE 2: THE MOVEMENT OF KNOWLEDGE IN THE I-SPACE	47
FIGURE 3: THE SOCIAL LEARNING CYCLE	51
FIGURE 4: DIFFUSION CURVE IN THE I-SPACE	53
FIGURE 5: ANNUAL RAND EXCHANGE RATE, 2011 - 2014	67
FIGURE 7: MANAGING THE TRANSITION FROM A STEP-CHANGE TO KNOWLEDGE MANAGEMENT	75
FIGURE 8: CONTINUOUS IMPROVEMENT IN KNOWLEDGE MANAGEMENT AT ESKOM	77
FIGURE 9: ESKOM PROJECT DEVELOPMENT KNOWLEDGE AREAS	79

LIST OF TABLES

TABLE 1: INTERVIEW RESPONDENT	15
TABLE 1: VARIOUS DEFINITIONS OF KEY CHARACTERISTICS OF MEGAPROJECTS	35
TABLE 4: ESKOM PROJECT LIFE CYCLE MODEL.....	62
TABLE 2: MEDUPI POWER STATION PROJECT	73
TABLE 3: KUSILE POWER STATION PROJECT	73
TABLE 7: KNOWLEDGE MANAGEMENT THEMES	85
TABLE 8: TEMPLATE ANALYSIS	86
TABLE 9: DEMOGRAPHIC PROFILE	87
TABLE 10: VALUE OF KNOWLEDGE MANAGEMENT IN ESKOM	87
TABLE 12: GAPS IN KNOWLEDGE MANAGEMENT PROCESS PRACTICES	88
TABLE 12: IMPLICATIONS OF KNOWLEDGE MANAGEMENT CYCLE GAPS.....	88
TABLE 13: ACCOUNTABILITY FOR KNOWLEDGE MANAGEMENT IMPLEMENTATION	89
TABLE 14: PROPOSITION 1: TOP MANAGEMENT SHOULD LAY THE FOUNDATION FOR EMBEDDING THE SOCIAL LEARNING CYCLE IN THE ESKOM I-SPACE	96
TABLE 17: PROPOSITION 2: KNOWLEDGE MANAGEMENT REQUIRES EFFECTIVE SYSTEMS SUPPORT IN ORDER TO ENSURE EFFECTIVE SCANNING, CODIFYING AND ABSTRACTING OF KNOWLEDGE ASSETS IN THE ESKOM I-SPACE	101
TABLE 18: PROPOSITION 3: A ROBUST KNOWLEDGE MANAGEMENT PROCESS REQUIRES EFFECTIVE SYSTEMS SUPPORT IN ORDER TO ENSURE EFFECTIVE SCANNING, CODIFYING AND ABSTRACTING OF KNOWLEDGE ASSETS IN THE ESKOM I-SPACE	103
TABLE 19: PROCESS REQUIRED OVERCOMING MAJOR ISSUES WITH ESKOM'S KNOWLEDGE MANAGEMENT PROCESS	110
TABLE 20: METHODOLOGY TO ABSTRACT AND DIFFUSE KNOWLEDGE AT ESKOM.....	110

LIST OF EQUATIONS

EQUATION 1: KAPPA STATISTIC	17
--	----

Chapter 1

Research Question and Background

1.1. Introduction

This chapter provides the reader with an introductory discussion about the area of research chosen for this study. The nature of managing knowledge in megaprojects and its challenges are discussed followed by the statement focus of the research, which provide context to the research objective. This is then followed by a discussion on the chosen research method and reasons followed by a discussion on key limitations of the study. The chapter concludes with an outline of the thesis.

Organizations need to become better learning organisations in order to better manage knowledge and becoming a learning organization is as imperative as meeting business objectives. Senge describes a learning organization as an organisation with an ideal learning environment, perfectly in tune with the organization's goals. Such an organization is a place where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the reality together.¹

Management of knowledge is so essential for effective management of all organisations given the fast paced infrastructure development environment of the 21st century where (amongst other key trends) technology diversity is broadening, increasing instability of global financial markets is ever prevalent, global competitiveness is increasingly becoming more significant as a competitive advantage, and the ever changing working class profile continues to be a challenge for managing knowledge where every undetected

¹ Senge 1992. *The Fifth Discipline The art and practice of the learning organisation*. London: Century Business; 1992 371

learning opportunity lost is disguised as a possible irreparable challenge. South Africa is not immune from these global trends.

Organisational learning capability (is a key aspect impacting how well knowledge is managed) and has been conceptualised as the ability to make sense of the environment, and develop new understandings which ultimately manifest itself through internal and external organisational actions. Organisational learning can be viewed as the goal of managing knowledge. Organisation learning fosters innovation and knowledge management and in turn has a complementary effect on the competitive advantage of an organization.

Typically developed economies like Europe and America are more likely to experience comparably slower economic growth for a number of reasons including the fact that they are operating close to their technological frontier, while developing economies (like most in Africa) stand out as the land of untapped opportunities with potentially higher growth prospects because they are in a position to pursue “catch-up growth” which is almost always faster than frontier growth. Despite this, the African continent is being held back by a number of factors such as lack of adequate infrastructure and high transport costs (estimated to be anywhere from 50 to 175% higher than global average according to The African Development Bank (ADB)). ADB estimates that the African continent will require US\$93 billion in basic infrastructure investment every year in order to meet demand.² Managing knowledge is critical for a country to succeed in the delivery of cutting-edge infrastructure associated with many public services such as access to water, energy, water, transport, and communication which are viewed as essential to economic progression. The criticality of managing knowledge equally applies at an organizational level in the delivery of strategic objectives that are usually complex and are of a long term nature.

According to a KPMG report if infrastructure development is planned appropriately over an extended period this can yield long lasting economic results and efficiencies. Investments in modern infrastructure remains key in laying the foundations for economic development and growth.

² KPMG –*Insight*, Global Information Magazine 4, 7-45

Assessing the extent of contribution made by infrastructure development to economic improvement is an important question to many policy decision makers. These infrastructure developments in the form of mega projects, that are the preferred delivery methods for goods and services across a range of businesses and sectors (such as transport, water and energy, information technology, mining, supply chains, banking, defense) create many job opportunities. During construction and operation, these projects help a society increase its wealth and its citizen's standard of living to a greater extent.

Countries like China have overtime established a capability to acquire skills speedily and application at a massive proportion, this can be seen in the engineering and construction fields. This is not only evident in the modern construction, to this day the Great Wall is evidence of the China's capability to testimony to the strength of China's ability to utilise technology, financial resources and its massive population to achieve intimidating projects. China is ahead globally on implementation of mega infrastructure developments with some of the world's largest dams, the longest bridge, the biggest road network and largest port.³ China invests about 9% of its GDP in infrastructure projects.

The African Development Bank (AFDB) argues that Infrastructure investments can similarly accelerate economic development in less developed nations and emerging markets. Nations that invest in infrastructure are better positioned to attract direct foreign investment, stimulate commerce and support local businesses. Their citizens are more likely to enjoy better health care, sanitation and other markings of well-being. China, South Korea and Taiwan owe their economic successes in part to infrastructure investments. India plans \$1 trillion investments over the next five years to modernize its economy.

As large infrastructure projects can strain the finances of a single country, experts say sub-Saharan nations should jointly finance projects to lessen this burden but at the same time this can spur regional development. Energy infrastructure projects are some of the more

³ Greater Pacific Capital LLP. 2010. *The Role of Mega Scale in Building Industrial Power Some of China's Top Engineering and Construction Feats*

common projects driven by demand in electricity. Though the International Energy Agency report a global electricity demand in 2013 of 20,144 Terawatt hours (TWh) compared to a supply of 23,318 TWh (i.e. a surplus of 15.7%.⁴), the picture is different in Africa with demand exceeding the current supply. The global surplus is driven by developed nations for a number of reasons including the fact that some are currently facing economic downturn and some have over time moved to service driven economies that are not as electricity intense as highly industrialised economies. As such, South Africa and countries such as China, USA and Germany are currently embarking on the building of power stations while the construction industry is portentous globally, which inevitably negatively influences the pricing market for human resources and building materials.

Understanding developmental learning and training during the construction of power station Megaprojects is an opportunity to be exploited that can assist how to achieve the delivery of infrastructure projects within the time, scope and budget in other industries as well. One of the objectives for many utilities embarking on the construction of Megaprojects will be to establish a learning organization, suited to a fast-paced major capital project environment in which access to skills and the retention of knowledge are significant and a priority. Initial proof-of-concept interventions have shown that tremendous learning is taking place within project teams.

The challenge is to create an openly collaborative environment in which colleagues and peers accept knowledge from different sources and actively apply it to continuously improve productivity and the delivery of mega infrastructure projects. The business imperative to achieve this objective of efficient management of knowledge has been hindered mainly by the limitation of financial resources brought about by factors such as the historic financial crises and ever rising costs for resources. The electricity industry involves delivery of many mega infrastructure projects that make the business naturally very capital intensive and long term in nature. As such these mega infrastructure projects are subject to long lead times during project planning, development and implementation making managing knowledge even more challenging. Another aspect that poses a challenge for managing knowledge is how to use learnings across different technologies.

⁴International Energy Association 2015. *World Energy Outlook*. energy outlook

Utilities normally deploy a technology mix to minimise risk associated with one type of technology. In the case of generation mega projects such as project Medupi and Kusile, production capacity can be met by harnessing different energy sources and applying different technologies. These technologies differ in their generation costs, performance and utilisation characteristics, suitability for the South African environment and state of commercial development.

The choice of generation technology is multifaceted and complicated and has to be conducted within the context of the South African policy legal and regulatory framework. In 1998, the Department of Minerals and Energy (DME) issued an Energy White Paper, which highlighted the need for independent electricity power production in South Africa to introduce competition in the industry with the objective driving down costs. Introducing Independent Power Producers (IPPs) was intended for new capacity to be developed cost effectively and competitively and during that time Eskom was not mandated or allocated to add new generation capacity to its existing supply. It was during this time that a lot of skills and people that were knowledgeable about building generation power stations were lost by Eskom. How does an organisation manage knowledge during policy swings of this nature?

By 2004, the concept of IPPs adding new capacity had not materialised for a number of reasons including policy and regulatory uncertainty, and Eskom was then requested to build the capacity that would have been added by IPPs. This meant that six years of planning and development of new projects had been lost (1998 to 2004), and Eskom then had to act swiftly to initiate the planning and development of new projects. The downside was that more than 15 years was lost since the last power station (Majuba) was built by Eskom. Eskom had also lost a significant number of skills to others out there that were building.

According to the World Bank South Africa has been in the middle of an electricity crisis since 2008 when demand started to exceed supply. Major investments in new power generation had not been made since the 1980s. Eskom is currently executing its second mega build programme since the growth period from 1969 to 1990. As such, the company

has developed world - class capital projects execution capabilities and has had to rebuild its capability to execute large capital spend since the decline in capital investments from 1991- 2004 and subsequent loss of skills.

The current build programme (which mainly includes two super-critical coal-fired power stations and a pumped storage scheme) commenced in 2007. This programme had a steep ramp-up schedule, and needed to meet South African development goals. Eskom had to rapidly re-build its capital execution capabilities, and in order to meet this aggressive investment programme, Eskom partnered with reputable international project management companies to transfer skills and knowledge to Eskom staff. Mega infrastructure projects can fail for many reasons. Lack of managing knowledge adequately might be a major cause. Managing knowledge was critical for this programme to be a success and is the key focus for this research paper. The question is how did Eskom do this? Are there some general good and bad lessons that others can use to apply on other mega infrastructure projects for greater performance from a scope, schedule, cost and quality performance perspective.

1.2. Statement of the Research Focus

The inadequate standard of managing complex knowledge in Megaprojects is one of the major challenges being experienced worldwide and indeed in the current South African build programme. The current build programme provides a unique opportunity for learnings and to rectify mistakes of the past to ensure that a in future Mega infrastructure projects are set up with process suitable for complex projects in place to manage the knowledge required to enhance the effectiveness of long-term infrastructure development program.

The electricity industry plays a key role in South Africa's economic growth by ensuring an adequate supply of electricity, providing electricity efficiently, reliably and at internationally competitive and affordable levels. Eskom is currently undertaking one of the most progressive infrastructure development programs in its entire history, estimating to invest more than R330bn in new electricity infrastructure over a five year period.

The current generation new build programme started 15 years after Eskom constructed its last power station. At that time, there was no proper process in place to manage knowledge that could be used to guide future infrastructure projects in Eskom. The organization, therefore, had no useful body of knowledge upon which it could draw to guide the current infrastructure programme. What are some of the aspects of managing knowledge that could have been applied to make this transition more successful and what are some of the learnings that can be applied to future mega infrastructure projects and more specifically to future Eskom mega infrastructure projects.

1.3. Objective of the Research and Research Questions

The primary objective of this study is the following:

- (i) To investigate how managing knowledge can influence the successful development of mega infrastructure projects.

Mega infrastructure projects can fail for many reasons. Lack of managing knowledge adequately might be a major cause.

Secondary objectives were set to ensure that the study results culminate into the achievement of the primary objective. These are:

- (ii) to assess factors that influence effective management of knowledge.
- (iii) to assess the current knowledge management process and practices in the development of Megaprojects Medupi and Kusile in Eskom;
- (iv) to assess the strengths and shortcomings that exist between the current knowledge management process in Eskom and the process required in order to enhance the effectiveness of future long-term infrastructure development program;
- (v) to make specific recommendations for an enhanced project development knowledge management process at Eskom.

In other words the objective of this thesis is to explore the complexity of managing knowledge in Mega Infrastructure projects. Inadequate management of knowledge may

result in failed mega infrastructure projects. This study investigates the following research question:

- **What are the main challenges to managing knowledge in mega infrastructure projects?**
- **How effectively can knowledge be managed to bring greater success in mega infrastructure projects?**

In order to address the academic research questions, Eskom current new build program (In particular the Medupi and Kusile projects) will be used as case studies to investigate challenges of managing knowledge in mega projects. The following secondary research questions will also be investigated:

- (i) What does success mean in project management?
- (ii) What are the key aspects to consider in setting up effective knowledge management processes and systems?
- (iii) What current knowledge management process exist within the build program?
- (iv) What strengths and gaps exist between the current process and the required knowledge management process?
- (v) Can there be lessons good and bad to be learned that can be transferred to other initiatives?

1.4. Research Methodology

The study was based on qualitative research methods, utilizing grounded theory as the primary research method. Grounded theory (aimed better at determining what actually happens of diverse phenomena) was chosen as a preferred method because of personal preference by the thesis author and because the researcher did not want to make any assumptions but opted to adopt a more neutral view on managing knowledge and its impact on mega infrastructure projects. This project studies the impact of the effective management of knowledge when developing Megaprojects. It's the social organizational phenomena that guide decision making in the application of knowledge management in Megaprojects that becomes important in this study. The research

design of the thesis did not only utilize pure grounded theory but it included the additional four following elements:

- Reviewing challenges in Megaprojects,
- Analysis of how management of knowledge was handled in Medupi and Kusile projects,
- The Social Learning Cycle (SLC) within the I-Space to analyses these challenges,
- Interviews with subject matter experts and results were interpreted in terms of the I-Space.

1.4.1. Research paradigm

Firstly, the thesis explored grounded theory and its benefit for a study of social nature. Grounded theory is the descriptive or explanatory theory that has its basis and foundation in the empirical data that gave rise to it. It can and has been used to discover theories that explain, describe or predict situations in which contextual factors play a significant role, mainly in the social sciences, used more recently in the fields of management. Martin & Turner describe grounded theory as an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of general features of topic while simultaneously grounding the account in empirical observation of data. Grounded theory is a suitable method when a study is of a social nature while managing knowledge in mega project presents its self as socio technical nature.⁵

For this reason, the study was based on qualitative research methods, utilizing grounded theory as the primary research methodology.⁶ The disadvantage of grounded theory methods is that they tend to produce large amounts of data, often difficult to manage.

Grounded theory refers to the attempt to use the interview data inductively, so that production of abstracted analytical categories comes from the respondent's accounts. In inductive studies data analysis is often hard to distinguish from data collection since

⁵ Martin, P, Y & Turner B, A, 1986. *Grounded Theory and Organization Research*. organization research. 141-157

⁶ Amit, R. and Zott, C. 2001. *Value Creation in E-Business*. 494-520

building theory that is grounded in the data is an iterative process in which the emergent frame is compared systematically with evidence from each interview.⁷

Grounded theory is the name given to a descriptive or explanatory theory that has its basis and foundation in the empirical data that gave rise to it. It can and has been used to discover theories that explain, describe or predict situations in which contextual factors play a significant role, mainly in the social sciences, although more recently in the fields of management.⁸

Grounded theory is not generated a priori and then subsequently tested. Rather, it is “inductively derived from the study of the phenomenon it represents. That is, discovered, developed, and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon. Therefore, data collection, analysis, and theory should stand in reciprocal relationship with each other. One does not begin with a theory, and then prove it. Rather, one begins with an area of study and what is relevant to that area is allowed to emerge”.⁹

Within this general framework, data analysis involved generating concepts through the process of coding. According to Strauss and Corbin coding represents the activities of firstly dissembling the data, and later assembling the data again in new ways. This is a central process by means of which theories are built from data.¹⁰

1.4.2. Sampling and population

Two basic sampling methodologies are possible. These are either probability sampling or non-probability sampling. In probability sampling, the elements in the population have an equal chance of being selected as sample subjects, while in non-probability sampling the elements do not have an equal chance of being selected as subjects.¹¹

⁷ Eisenhardt, K.M. 1989. *Building Theories from Case Study Research*. 532-550).

⁸ Amit, R. and Zott, C. 2001. *Value Creation in E-Business*. 494-520

⁹ Strauss, A. and Corbin, J. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. 23

¹⁰ Strauss, A. and Corbin, J. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. 57

¹¹ Welman, J.C. and Kruger, S.J. 1999. *Research Methodology for the Business and Administrative Sciences*. 47-48

According to Deming non-probability sampling is best used when information is needed that is relevant to and available only within certain groups, and when responses are needed from specific minority groups.¹² Purposive sampling and convenience sampling are two specific sampling methods that apply to non-probability sampling.¹³

Convenience sampling is the collection of information from members of the population who are conveniently available to provide the information. Purposive sampling refers to the collection of information from specific targets of people who will be able to provide the needed information either because they are the only ones who can give the information or they are the only ones who conform to some criteria that have been established by the researcher.

Purposive, non-probability sampling consists of either judgment sampling, where the sample includes subjects who are in the best position to provide the information required based on their experience or position within the firm (these are used when a limited category of people have the information that is sought), or quota sampling which is a form of proportionate stratified sampling in which a predetermined proportion of people are sampled from different groups, but on a convenience basis.

Deming further explains the concept of judgment sampling as "one in which an expert in the subject matter makes a selection of "representative" areas or business establishments." In evaluating the reliability of such a sample one must rely on the expert's judgment and that the theory of probability sampling cannot be used in such cases. If a sample "is confined to only 1, 6, or 10 units, a judgment sample would be preferable to a probability sample".¹⁴

In such small samples the errors of judgment are usually fewer than the random errors of a probability sample. Bryman argues that qualitative research follows a purposive

¹² Deming, W.E. 1990. *Sample Design in Business Research*. 31

¹³ Welman, J.C. and Kruger, S.J. 1999. *Research Methodology for the Business and Administrative Sciences*.

¹⁴ Deming, W.E. 1990. *Sample Design in Business Research*. 31

rather than a statistical logic.¹⁵ This is described as the link between sampling and theory when he explains that “(purposive) sampling means selecting groups or categories to study on the basis of their relevance to your research questions, your theoretical position...and most importantly the explanation or account which you are developing...(it) is concerned with constructing a sample...which is meaningful theoretically, because it builds in certain characteristics or criteria which helps to develop and test your theory and explanation” (words in parenthesis added by the author of this document).

In summary, purposive, non-probability sampling was used for this project, utilising the concept of judgment sampling. This is done as the particular elements within the organisation (Eskom in this instance) included into the sampling framework consist of experts who deal specifically with the development of Megaprojects.

1.4.3. Sample criteria and selection

In selecting the sample for this study, it was important to ensure relevance to the theoretical basis of this study. This study focuses on the application of knowledge and the management thereof as an element of the development of Megaprojects. The most important area where prior knowledge will play a major role is in the planning phase of the development of large mega capital projects, specifically new power stations.

In order to select a sample of individuals for the personal interviews it was important to develop sample selection criteria. The criteria for selecting a sample of individuals on judgmental sampling bases, as discussed above, was as follows:

- (i) Current involvement in the management and codification / application and disbursement of prior project knowledge and lessons learnt in the planning and development of new large capital projects in Eskom (especially involvement at the “Concept” and “Definition” stages of the lifecycle)

¹⁵ Bryman, A. 1988. *Quantity and Quality in Social Research*. 90

- (ii) Extensive experience in excess of 5 years in project planning and development in the electricity industry
- (iii) Academic levels of at least first degree level in engineering / project management / finance / knowledge management or business management
- (iv) Ability to influence the development of new projects through their responsibilities (measured by the content of their job descriptions)

For the purpose of selection of the sampling unit, information about individuals within Eskom that fit these criteria were obtained from the Eskom Human Resources Database.

The sample identified through this approach indicated six individuals that comply with the sampling criteria.

1.4.4. Interview design and procedure

As DeMarrais points out, an interview is the conversation between respondent and researcher, in order to get answers to the research questions.¹⁶ This research is required to ask a large number of complex questions with some probing and follow-up questions to receive in-depth understanding and explanation of the phenomena by cross-case comparability, which is in-line with the inductive approach. Therefore, the semi-structured interviewing is applied for the research purposes.^{17, 18}

The key process of semi-structured interview is asking right and relevant questions. Patton in his study recognizes six types of questions that can be asked in the interview: experience and behaviour, values and opinion, feeling, knowledge, sensory and background questions.¹⁹ It is decided to ask most of the above-mentioned types of questions to receive descriptive and full answers about the phenomena. These questions

¹⁶ De Marrais, K. 2004. *Qualitative interview studies: Learning through experience*. 55

¹⁷ Saunders, M., Lewis, P., & Thornhill, A. 2012. *Research methods for business students*. 375

¹⁸ Bryman, A. and Bell, E. 2011. *Business Research Methods*. 467

¹⁹ Patton, M.Q. 2002. *Qualitative research and evaluation methods*. 365

are inquired in open, closed and probing manner in the current study.²⁰ We also tried to avoid multiple, leading or yes and no questions to minimize poor answers.²¹ The level of experience of respondent is depicted in the table below:

²⁰ Saunders, M., Lewis, P., & Thornhill, A. 2012. *Research methods for business students*. 391

²¹ Merriam, S.B. 2009. *Qualitative research: a guide to design and implementation*. 100

Table 1: Interview Respondent

RESPONDENTS	LEVEL OF EXPERIENCE
Project Member 1	Specialist with experience from developing different development projects
Project Member 2	Developed precious two energy projects
Project Member 3	Recruited experiences large infrastructure projects
Project Member 4	Project manager for different refurbishment and green field projects
Project Member 5	Experience from working as a project manager of various development projects
Project Member 6	Experience from working as a project manager of various development projects and providing benchmarks

Prior to data collection, the interviewers started with the self-introduction; brief explanation of the research; ensuring the respondents that all the information and material from the interview will be respectfully used for the research process only. Moreover, interviews were recorded only after getting permission from the respondents, and their anonymity was applied. This introductory step helped to build confidence from respondents and establish credibility, minimize uncertainties from the respondent's viewpoint and hence, to increase the reliability of the results.^{22, 23}

1.4.5. Ethical Considerations

Ethics is one of the main concerns of any research because it indicates the credibility of the researcher and contains very important qualities of the study, such as validity and reliability in itself.^{24,25} Therefore, it was ensured in the current study that the ethical considerations are taken into account.

²² Bryman, A. and Bell, E. 2011. *Business Research Methods*. 477

²³ Merriam, S.B. 2009. *Qualitative research: a guide to design and implementation*. 103

²⁴ Merriam, S.B. 2009. Patton, M.Q. 2002. *Qualitative research: a guide to design and implementation*. 234 evaluation methods. 552

²⁵ Patton, M.Q. 2002. *Qualitative research and evaluation methods*. 552

The respondents were involved in the research according to their mutual consent and they were informed about the safety and confidentiality of the information provided by them. The interview guides were sent to the interviewees prior to the meeting (both via email and hard copies where made available prior to the face-to-face interviews) to save their time and give them a chance to get familiarized with the contents of the questions. Moreover, respondents were aware of the fact that the results of the research will be published and made publicly available. All the participants were addressed with messages thanking them for their time and contribution to the current research study after the interview sessions.

1.4.6. Data collection

Data collection took place via personal interviews with the selected sample. For this purpose, a semi structured interview guide (questionnaire) were used (see annexure 1). However, the grounded approach advocates the use of multiple data sources to help converging on the same phenomenon. This multiple data sources are sometimes referred to as “slices of data”. In theoretical sampling, no one kind of data on a category or technique for data collection is necessarily appropriate. Different kinds of data give the analyst different views or vantage points from which to understand a category and to develop its properties; these different views are called slices of data.²⁶

While the [researcher] may use one technique of data collection, theoretical sampling for saturation of a category allows a multifaceted investigation, in which there are no limits to the techniques of data collection, the way they are used, or the types of data acquired."

Utilisation of various data sources enables comparisons of data quality, this includes several sources such as interview responses, reports and direct observation. The use of multiple data sources enhances construct validity and reliability.²⁷ Turner concluded in a research project that was based on grounded theory, that documentary sources were treated like sets of field notes.²⁸

²⁶ Glaser, B. and Strauss, A. 1967. *The Discovery of Grounded Theory*. 65

²⁷ Yin, R. K. 1989. *Case Study Research: Design and Methods*. 98-99

²⁸ Turner, B. A. 1983. *The Use of Grounded Theory for the Qualitative Analysis of Organisational Behaviour*. 342

The reason for this phase of the research is to ensure that data is collected and analysed simultaneously and flexibility is maintained. This overlap allowed adjustments to be made to the data collection process in light of the emerging findings.

1.4.7. Coding

A computer program (Atlas.ti –ver. 07) was used to complement the analysis of data. The data was indexed using both open and axial indexing as prescribed for the grounded theory process by Strauss and Corbin.²⁹ In order to eliminate bias from the data analysis process, two independent coders were used. Consequently, it was important to ensure coder reliability and that any level of agreement between the coders that may be a result of chance, are eliminated. This was achieved by using Cohen's kappa statistic.³⁰

Equation 1: Kappa statistic

$$k = \frac{pr(a) - pr(e)}{1 - pr(e)}$$

where:

pr(a) = the relative observed agreement among raters, and

Pr(e) = the hypothetical probability of chance agreement.

If the raters are in complete agreement then $\kappa = 1$. If there is no agreement among the raters (other than what would be expected by chance) then $\kappa \leq 0$.

One of the most important features of the kappa statistic is that it is a measure of agreement between coders, which naturally controls for chance.³¹ In order to interpret the kappa statistic results it was important to obtain a general benchmark of acceptable levels of the kappa statistic. According to Hartmann, kappa levels of agreement should exceed 0.6.³² Landis and Koch however provided a more detailed benchmark for

²⁹ Strauss, A. and Corbin, J. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. 57

³⁰ Cohen, J. A. 1960. *Coefficient of Agreement for Nominal Scales*. *Educational and Psychological Measurement*. 37-46

³¹ Fleiss, J. 1971. *Measuring Nominal Scale Agreement Among Many Raters*. 378-382

³² Hartmann, D. 1977. *Considerations in the Choice of Inter-Observer/Interobserver Reliability Estimates*. 103-116

interpreting kappa values as follows; <0.00, poor agreement; 0.00 to 0.20, slight agreement; 0.21 to 0.4, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.8, substantial agreement and 0.81 to 1.00, almost perfect agreement.³³

In the same manner, Fleiss provides a benchmark for interpreting kappa values as follows; 0.4, poor agreement; 0.4 to 0.75, intermediate to good agreement and >0.75, excellent agreement.³⁴ Since both Hartmann, Landis & Koch and Fleiss all indicate that kappa levels of 0.6 and above are above average, this level of inter-rater agreement was used as an acceptable level of agreement between coders.^{35, 36} Once these levels of coder agreement are achieved it can be accepted that the resultant concepts and categories identified in the data are reliable and can be used in the development of the theoretical framework.

This thesis investigated the phenomenon of managing knowledge in mega infrastructure projects and some of the challenges faced by practitioners in a practical setting. Megaprojects are complex and multifaceted in nature and require a full conceptual understanding in order for one to deal with complexities of managing knowledge associated with the broad interfaces and broad stakeholder groups with conflicting interests. Due to the complexity nature of these project and time availability very few people in the industry are willing to share their experience and information on managing knowledge that can be perceived as a competitive advantage or ‘secrets of the trade’ more so in private companies. Furthermore, to explore the underlying issues surrounding managing knowledge in Megaprojects, this study selected two South African Mega Energy projects the Medupi and Kusile coal-thermal power station projects which are currently under construction by Eskom, the South African state-owned power utility company that is the major provider of electricity in the country.

Managing knowledge is one of the common shared challenges which characterize mega large infrastructure projects in which limited body of knowledge exists pertaining to

³³ Landis, J. and Koch, G. 1977. *The Measurement of Observer Agreement for Categorical Data. Biometrics.* 159-174

³⁴ Fleiss, J. 1981. *Statistical Methods for Rates and Proportions.*

³⁵ Hartmann, D. 1977. *Considerations in the Choice of Inter-Observer/Interobserver Reliability Estimates.* 10

³⁶ Landis, J. and Koch, G. 1977. *The Measurement of Observer Agreement for Categorical Data. Biometrics.* 33

the application of knowledge management. Due to limitations in the access of mega infrastructure projects, the thesis author chose the South African context. The two megaprojects in energy were profiled (due to ease of access provided by the sponsoring organisation, Eskom). These were the Medupi and Kusile coal-thermal power station projects. Both these projects are known for their challenges which include schedule delays, cost escalations and political pressure which was imposed at their inception. The thesis author chose these projects in order to investigate managing of knowledge challenges.

Bresnena et al emphasizes that problems of cross-project learning have wider implications for processes of organisational learning, and resolving these problems could provide organisations with a competitive advantage. Different studies pinpoint both obstacles and enablers for project based learning however, there is little indication of improvement in learning from other mega infrastructure projects. Most common reasons cited include the many interruptions to schedules experienced due to the fact that they are typically long term based and multifaceted.

The discontinuities (or interruptions in schedules) of projects restricts management of knowledge and the efficient assimilation of the created knowledge. This also impacts whether managing knowledge can help to improve delivery of ensuing projects. Understanding both the enablers and restrictions of how to improve managing knowledge and information flow within Megaprojects offers important lessons to other Megaprojects. The thesis author used the I-space knowledge management model (developed by Max Boisot) that proposes a four-step learning process (or social learning cycle) that is important to understand when considering management of knowledge and information flow. Boisot proposed that new knowledge is created through problem-solving activities, shared through a diffusion process with a wider population, and internalised through an absorption process.

The I-Space model is intended to help understand the flows of information within and assist in understanding the creation and diffusion of information within groups of people. The model differs from other knowledge management models because it maps the organisational knowledge assets to social learning cycle which other knowledge management models do not directly address. Boisot proposes, in the I-Space

model, that knowledge that is better articulated (that is better structured and converted into information) will diffuse more speedily and extensively within a given population than knowledge that is not properly articulated.

Boisot proposes that information flows in a six-step (that is scanning, codification, abstraction, diffusion, absorption, and impacting) process consisting of what he terms the social learning cycle (SLC). In the SLC following a scanning process, new knowledge is created through problem-solving activities, shared through a diffusion process with a wider population, and internalized by that population through an absorption process. Codification, abstraction, and diffusion, make up only one part of a social learning process. Knowledge that is diffused within a target population must also get absorbed by that population and then get applied in specific situations.

Social learning in projects is dependent on considering knowledge as it is generally created and apparent over how it is used practically. Learning in projects happen in an informal setting and its results is seen through the manner in which certain groups communicate and do things amongst themselves. Through social learning knowledge is used as a tool and is controlled by people and groups to determine the manner they interact. Knowledge befits a dynamic process in a project environment than an item that is moved within the organisation, it also links how individuals interact and their interrelated practices. Project-based practices emerge through the context they are producing.

That implies that learning from projects takes place within projects through practices that include organisational procedures and tools, symbolic artefacts, organisational rules and norms, experience and competence of individuals and that are connected to other projects. Learning in between projects is driven by the complexity and agile nature of project context.

The thesis author selected potential respondent using the selection criteria listed above. A total of eleven people were approached and only six respondents accepted to participate in interviews. The thesis author attempted to introduce diversity by selecting individuals with different responsibilities and experiences on mega infrastructure projects for the interviews. The individuals selected were mostly senior experienced

professionals who are considered subject matter experts in the project management field. The minimum experience of respondents that were interviewed is summarised below:

- Managed and coordinated the successful development (initiation, planning, execution, monitoring, controlling and closing) of more than one project.
- Has successfully developed no less than two previous energy mega projects and technology types.
- Recruited staff and participated on mega infrastructure projects.
- Led as Project Manager both Brownfields and Greenfields mega projects of different technology types.
- Participated on a strategic level and participated on project steering committees, workgroups and forums.
- Participated in business case motivations and preparing submissions to investment committees for approval.

Open ended questions were used for interviews and questions were set to harness much of the input from the experts. Questionnaires were designed to start with general non-leading questions informed by objectives and research questions. During the interview the participants were encouraged to open up and talk freely. The nature of questions asked in grounded theory were of a conversational nature and participant led. The thesis author made notes and documented all responses.

Finally, the interview responses were interpreted in terms of Boisot's I-Space model. Computer assisted qualitative data analysis software (Atlas.ti) was utilized for coding.

1.5. Scope of the study

This study evaluated the impact of managing knowledge on the success of mega infrastructure projects. The context is set in South Africa with a focus on case studies from the major electricity utility company being Eskom. Understanding how managing knowledge can influence success of mega infrastructure projects could assist in identifying and recommending potential solutions to this problem in general. The intention is to assist other practitioners to understand and address similar problems

experienced regarding managing knowledge in mega infrastructure projects in different settings, even though other factors will differ like organisation type. It is envisaged that the outcome of this study will contribute towards better decision making and ensuring sustainable and successful project development on mega infrastructure projects in work settings.

However, this study does not cover the broad context of knowledge management but focuses only on its application to the managing complex knowledge in mega infrastructure projects using the current Eskom build program as a case study.

1.6. Limitations of the study

The Swedish Research Council emphasizes that a discussion should be carried out concerning the limitations of a study in order to increase the quality and trustworthiness of a study. This study deals with managing knowledge in Megaprojects and limited literature is available on such a topic for many reasons including that most organisations treat such information with confidentiality as it is a competitive advantage more so in private sector because of the commercial driven mandate. The complex nature of Megaprojects and associated long lead times to delivery often implies a greater risk related to staff attrition over time. The key limitations of this thesis are summarised below.

Generalisability. The sample size is limited to the South African context and the Eskom environment. Therefore the applicability of research findings to other settings could be arguable. The knowledge and experiences are also unique and limited to those interviewed whose experience was mostly from a particular phase of the project life cycle that is the development phase. A larger sample of firms, as well as respondents, would have further confirmed findings. Future researchers could conduct studies in other settings to compare alignment of findings. Nonetheless different projects might benefit and use the practices differently depending on for example the repetitiveness of the project and its process.

Reliability. The measuring instrument was interview questions meaning that reliability could have also been improved by triangulating findings from other data sources such as internal reports, memos and independent reports where available. The literature review on the subject of managing knowledge on mega infrastructure projects helped to improve reliability despite this limitation.

Researchers own bias. The experience, education and background of the thesis author may have had some impact on the respondent's feedback as well as on the interpretation of the findings to some extent whether noticeable or not. The author tried to be conscious of this during interview sessions and avoided to lead respondents during data collection.

Access to information. Information relating to projects in general which forms part of company strategy is often considered as trade secrets more so in private sector companies that are highly competitive. It is anticipated that information on managing knowledge from other organisations will be restricted and hence the thesis author will only be limited to information from the sponsoring organisation.

1.7. Structure of the thesis

The primary objective of this study is to investigate how managing knowledge can influence the successful development of mega infrastructure projects. The general guideline for structuring a thesis was adopted as summarised below:

- (i) Chapter one introduces the study through the formulation of the issue at hand, it outlines and describes the research problem. Furthermore the chapter provides the objectives, limitations of the study, overview of the research methodology that was applied and the explanation of the chosen methodology.
- (ii) Chapter two presents literatures review on Mega infrastructure projects and managing knowledge in these complex projects.

- (iii) Chapter three provides a literature overview of managing knowledge in the context of Boisot's I-Space model that describes the social learning cycle (SLC).
- (iv) Chapter discusses Eskom's build program to date and investigates how managing knowledge was applied to two coal thermal plant mega infrastructure projects namely project Medupi and Kusile.
- (v) Chapter five discusses an analysis of the results and interpretation of the findings based on findings from the literature review and fieldwork findings from the interviews.
- (vi) Chapter six discusses the conclusion and makes some recommendations for both further studies and improvements that could be considered for the thesis project.

CHAPTER 2

Managing Knowledge in Mega Infrastructure projects

2.1. Introduction

Early research on the context of knowledge and information in organisations focused substantially on information processing as a basis for generating knowledge. Knowledge was generated by matching information available with information requirements.^{37 38} However according to Tushman this approach presents significant barriers to effectiveness in project-based organisations as a project consists of a large number of project members. Tushman further argued that some of these project members have inappropriate knowledge within the project group and are, therefore, forced to solicit knowledge from outside of the group.³⁹

The delivery of a mega-project requires the combination of knowledge from a wide range of specialists who cognitively understand how their different roles in the project combines to deliver a successful project. This cognitive dimension, according to Tushman cannot be overcome by information processing alone but needs the integration of various independent bodies of knowledge across the organisation.⁴⁰

2.2. Knowledge

According to Empson, knowledge can be categorised into two perspectives that is as an asset which can be managed and controlled or as a process. Knowledge as a process

³⁷ Simon, 1957. *Administrative Behaviour: A Study of Decision-Making Processes in Administrative Organisation.*, 3rd.

³⁸ Galbraith, J.R. 1974. *Organisation Design: An Information Processing View.* 28–36

³⁹ Tushman, M.L. 1978. *Technical Communication in Red Laboratories: The Impact of Project Work Characteristics.* 624–45

⁴⁰ Daft, R.L. and Lengal, R.H. 1986. *Organisation Information Requirements.*, 554–71

is viewed as a social construct which is developed and transmitted in a social context.⁴¹ Baker and Badamshina define knowledge by focusing on what distinguishes knowledge from information.

Snowden argues that knowledge can be seen paradoxically, as both a ‘thing’ and a ‘flow’ requiring diverse management approaches.⁴² Hansen et al. propose that these approaches culminate in either codification or personalised strategies. According to Hansen “When knowledge is seen as a ‘thing’, codification strategies, which especially disseminate explicit knowledge through person-to-document approaches, are considered. When knowledge is seen as a ‘flow’, personalised strategies, which especially disseminate tacit knowledge through person-to-person approaches, are considered”.⁴³

Davenport and Prusak define knowledge as “a mixture of experience, values, information and expert insights that provide a framework for evaluating and incorporating new experiences and information”.⁴⁴ According to Civi knowledge is the intellectual property of the organisation. It therefore becomes an asset that needs to be managed in order to ensure that it optimizes the returns of the organisation.⁴⁵

Knowledge defines the boundaries between organizational units and divisions as it sets out specific behaviours, procedures, routines and past experiences of individuals in the context of what it is being used to achieve.⁴⁶ However, from an organizational perspective knowledge presents itself in various forms, most notably either as explicit knowledge, tacit knowledge or embedded knowledge. Embedded knowledge refers to the knowledge that is locked in processes, products, culture, routines, artefacts, or structures.⁴⁷

⁴¹ Empson, L. 2001. Knowledge Management in Professional Service Firms 814

⁴² Snowden, D. 2002. *Complex Acts of Knowing: Paradox and Descriptive Self-awareness*. 100–110

⁴³ Hansen, M.T., Nohria, N. and Tierney, T. 1999. *What’s Your Strategy for Managing Knowledge*. 106 Knowledge 106

⁴⁴ Davenport, T. H. and Prusak, L. 1998. *Working Knowledge. How Organisations Manage What They Know*.

⁴⁵ Civi, E. 2000. *Knowledge Management as a Competitive asset. Marketing Intelligence and Planning*.

⁴⁶ Yang, J. 2004. *Job-related Knowledge Sharing: Comparative Case Studies*. 118-126

⁴⁷ Horvath, J.A. 2000. *Working with Tacit Knowledge*. IBM Institute for Knowledge Management

2.2.1. *Explicit Knowledge*

According to Brown and Duguid explicit knowledge is formalized and codified, and is sometimes referred to as know-what. It is easily identifiable and easy to store and retrieve. It is therefore also easy to facilitate its storage, retrieval and modification through information systems.⁴⁸

The greatest challenge associated with explicit knowledge is ensuring that people have access to what they need, that the knowledge that is stored is in fact exactly what is required (i.e. the reliability of the knowledge) and that it is reviewed and updated frequently. Explicit knowledge alone is sometimes regarded as of lesser importance as it does not contain the rich experience and know-how of individuals that is required for the sustainability of organisations.⁴⁹ Explicit knowledge refers to codified knowledge such as that found in documents.

2.2.2. *Tacit Knowledge*

Originally defined by Polanyi, tacit knowledge refers to intuitive, hard to define knowledge that is largely experience based. Tacit knowledge is therefore often personal in nature.⁵⁰ It is hard to communicate and is deeply rooted in action, commitment, and involvement (Nonaka, 1994).⁵¹

Tacit knowledge is regarded as the most valuable source of knowledge, but it is the most difficult to deal with from a systems perspective. Tacit knowledge is normally found in the minds of people and normally includes cultural beliefs, values, attitudes, mental models, etc. as well as skills, capabilities and expertise.⁵² Tacit knowledge resides in people, it is subconsciously used and it's difficult to convey and stems from experiences and sharing that happens best via interactive activities. Tacit knowledge refers to non-codified and often personal/experience-based or idiosyncratic knowledge.

⁴⁸ Brown, J.S. and Duguid, P. 1991. *Organizational Learning and Communities of Practice: Towards a Unified View of Working, Learning, and Innovation*. 40-57

⁴⁹ Brown & Duguid 1991: *Organizational Learning and Communities of Practice: Towards a Unified View of Working, Learning, and Innovation*. 40-57

⁵⁰ Polanyi, M. 1966. *The Tacit Dimension*. London, Routledge & Kegan Paul, 1966

⁵¹ Nonaka, I. 1994. *Theory of Organizational Knowledge Creation*. *Organizational Science*, vol 5, no.1

⁵² Botha, A., Kourie, D., and Snyman, R. 2008. *Coping with Continuous Change in the Business Environment, Knowledge Management and Knowledge Management Technology*.

2.2.3. *Embedded Knowledge*

Embedded knowledge can either be contextualized formally (such as through a management initiative to formalise a certain beneficial routine), or informally as the organisation uses and applies the other two knowledge types. Embedded knowledge refers to the knowledge that is locked in processes, products, culture, routines, artefacts, or structures.⁵³

There are many challenges in managing embedded knowledge. Culture and routines can be both difficult to understand and hard to change. Formalized routines on the other hand may be easier to implement and management can actively try to embed the fruits of lessons learned directly into procedures, routines, and products.

The methodology of the diffusion of such embedded knowledge is described through the Information Space (I-Space) methodology. According to Boisot, the I-Space model is based on the principle that proposes that organised knowledge will flow much easier within the framework than unorganised knowledge.

2.3. **Defining a Project**

The Project Management Institute's (PMI), a well renowned and credible reference for project management according to practitioners, defines a project as "a temporary endeavour undertaken to create a unique product, service, or result". The temporary nature of projects indicates a definite beginning and an end. The end is reached when the project's objectives have been achieved or when the project is terminated because its objectives will not or cannot be met, or when the need for the project no longer exists." It is defined as temporary because every project should have a defined beginning date and end date thus running for a defined time frame. Operations are on the other hand defined as ongoing activities.

Projects are termed unique because the product delivered is different in some distinguishing way from all similar products.⁵⁴ Projects need to be managed to ensure

⁵³ Horvath, J.A. 2000. *Working with Tacit Knowledge*. IBM Institute for Knowledge Management

⁵⁴ Burke, R. 2007 *Introduction to project management*. London: Burke Publishing Company.

successful completion, which in turn entails meeting the set objectives for the project. Some projects are more complex than others and require thorough management throughout the project life cycle.⁵⁵ Projects are unique and non-repetitive, coordination of limited resources and they have a single point of responsibility in the form of a project manager or leader responsible for the execution of the whole project by the project team involved.

The Project Management Book of Knowledge (PMBOK) defines project management in nine knowledge areas within project management, namely the management of: scope, quality, risk, time, human resource management, procurement, cost, communication and integration. These nine knowledge areas have been elaborated by Burke as following;

2.3.1. Project Scope Management

This involves the identification of all work required to complete the project successfully. This area is primarily concerned with defining and controlling what is or what is not included in the project to meet the client's expectations. It consists of scope planning, definition, scope verification, creating the work breakdown structure, scope control and scope change management.

2.3.2. Project Time Management

This component of project management is to ensure that the project is completed within the defined time. It includes activity definition, activity sequencing, and the time allocation to each activity.

2.3.3. Project Cost Management

This is to ensure that the project will be completed within the approved budget. To achieve this, resource planning is to be done, cost planning and budgeting. During the project cost controls are established to ensure that cash flow allocated to the project is spent according to budget.

2.3.4. Project Quality Management

⁵⁵ Project Management Institute, 2013. *A guide to A Guide to the Project Management Body of Knowledge*.

During the project quality management is established to ensure that the end product meets the quality expectation of the client. This is done by ensuring that standard controls are in place to warrant highest quality output.

2.3.5. Human Resource Management

Each project needs to establish procedures that will ascertain that people employed in a project for a specific time are utilised productively and efficiently. This can be achieved by developing projects structure, recruitment required and development of the project team.

2.3.6. Project Communications Management

Communication is also one of the knowledge area in project management, the purpose of establishing this is to develop a process that will determine how project information will be collected and distributed within and external to the project. To achieve the above a communication plan should be established, outlining how often reporting on the progress should be done, how many project meetings will be held and when and how project closure will be communicated.

2.3.7. Project Risk Management

This knowledge area is aimed at ensuring that all possible risks are identified, analysed and mitigation strategies are put in place. It is critical to the success of the project to thoroughly identify and quantify and ensure mitigation controls are established. Risk management is a standard good project practice which if done properly can assist in eliminating costly project risk.

2.3.8. Project Procurement Management

Goods and services from external service providers are often sought in many projects. Establishing procurement management processes will enable the project to plan, select suppliers, and source and handle the administration of this process in an efficient manner. Furthermore this knowledge area ensures that all contracts are handled according to prescribed standard and the project contract close activities are properly carried out.

2.3.9. *Project Integration Management*

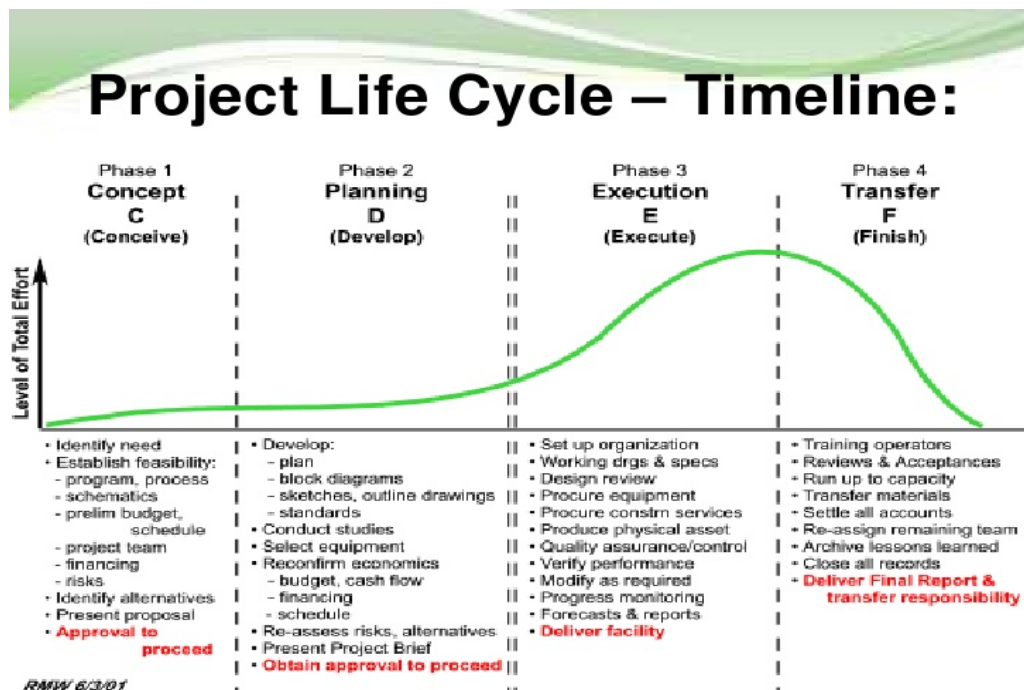
This knowledge area includes integrating all project related processes and activities in a coordinated manner. The Project Management Institute prescribes that in order to achieve efficiency in the project a project manager is required to develop a project charter. The role of the project charter is to normally specify the project requirements for each knowledge area, the roles and responsibilities and to define the processes that will be integrated to ensure proper planning and execution.⁵⁶

PMBOK further explains that a project life cycle is a collection of generally chronological and sometimes overlapping project phases whose name and number are determined by the management and control needs of the organization or organisations involved in the project, the nature of the project itself, and its area of application. A life cycle can be documented with a methodology.

The project life cycle is flexible, can be determined or shaped by the unique aspects of the organisation, industry or technology employed. While every project has a definite start and a definite end, the specific deliverables and activities that take place in between will differ with each project. The life cycle provides the basic framework for managing the project, regardless of the specific work involved.

The figure below shows the intensity of cost and staff during the generic phases of a project and as shown, costs and staff are used mostly during the carrying out of the work (project launch or execution).

⁵⁶ Project Management Institute, 2013. *A guide to A Guide to the Project Management Body of Knowledge*.

Figure 1: Project Life Cycle Model ⁵⁷

The value of project controls can be seen in the performance of a project when unexpected technical problems arise or when quality and reliability problems occur. Market changes will most likely result in the need for project controlling to occur, along with owner or client changes to the technical specifications of the project.

PMI also describe the five process stages that each project generally undergoes that are briefly described below. Each of the nine knowledge areas described above will have some work to be managed in each of these processes steps in some way or another.

2.3.10. Initiation Process

The purpose of the first phase, the initiation phase is to establish a need or opportunity for a product, facility or service. This is where the project starts, it is the stage where the project is identified, the charter is drawn up to give the project identity and a feasibility study is put together to ensure that the product can be made and the best use of company resources. ⁵⁸ At this stage, the project manager has to perform activities that will establish

⁵⁷ Project Management Body of Knowledge., *A guide to Project Management Body of Knowledge*. Fourth Edition,

⁵⁸ Burke, R. (2007) *Introduction to project management*. London

and assess the size of the project, scope, budget and complexity of the project (Healy, 1997).

2.3.11. Planning Process

Having designed the project and the drawings and specifications are available, this phase of the project cycle involves clear definition of the activities and the work needed to complete each activity. This part of the phase involves selecting and developing the best course of action to attain the objectives established at the initiation stage.⁵⁹ Hoffer *et.al* further states that the planning stage often requires a lot of assumptions made on the requirement and availability of resources. A budget is allocated at this phase as well as procurement for long lead times [where applicable].⁶⁰

2.3.12. Execution Process

On acceptance of the baseline plan the actual physical construction takes place; The execution process involves putting the plans into action through an integration of processes, instructing and coordinating people and other resources to implement and carry out the project management plan.

2.3.13. Controlling Process

According to Burke (2007) the monitoring and controlling process ensures that the project objectives are not deviated from during the implementation of the project by monitoring and measuring progress regularly to identify variances from the management plan.

2.3.14. Closing Phase

This process involves a formal acceptance of the projects and bringing it to an orderly end. This involves commissioning the product and handing over to the clients. The project is considered to be concluded when all the requirements have been met.⁶¹

⁵⁹ Burke, R. (2007) *Introduction to project management*. London

⁶⁰ Hoffer, J., Jeffrey, A., George, J. F., Valacich, F.S. 2002. *Modern Systems Analysis and Design*. Pearson Education

⁶¹ Hoffer, J., Jeffrey, A., George, J. F., Valacich, F.S. 2002. *Modern Systems Analysis and Design*.

2.4. Defining a Megaproject

Currently there is no formal definition for megaproject- there are collections of projects that are universally realized and referred to as “Megaprojects,” there is no specific way to determine whether a project is or is not mega. According to Flyvbjerg ⁶² a mega project has the following four criteria, must cost more than US\$1 billion, must take more than 5 years to move from design through to operations, must affect more than a million people and must have transformational impact on the area in which it’s located.

Flyvbjerg cautions that these criteria must be somewhat flexible and based on the local context for example a US\$100 million project will probably not be considered a mega project in the context of New York or Singapore but if US\$100 million would be invested into a single project in Congo or Myanmar that project will be considered to be a megaproject. The United States Federal Highway Administration defines Megaprojects as major infrastructure projects that cost more than US\$1 billion, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and budgets.⁶³

Over the years it has become evident that characteristics that elevate a project to mega-status are much more complex than simply project cost. Flyvbjerg describes "Mega" as implying that the magnitude size of the task involved in developing, planning, and managing projects of this magnitude. He further explains the risks in Megaprojects are substantial, with cost overruns of 50% being common and overruns of 100% not uncommon. He elaborates that the substantial benefit shortfalls trouble many Megaprojects. Finally, regional development effects and environmental impacts often turn out very differently from what proponents promised.

⁶² Flyvbjerg, B., Bruzelius, N. & Rothengat TER, W. 2003. *Megaprojects and Risks: An Anatomy of Ambition*,

⁶³ Zhai, Li, Yanfei Xin, and Chaosheng Cheng. 2009. "Understanding the value of project management from a stakeholder's perspective: Case study of mega-project management.." 99-109.

Cost overruns combined with benefit shortfalls spell trouble. But an interesting paradox exists for Megaprojects: More and bigger Megaprojects are being planned and built despite their poor performance record in terms of costs and benefits.⁶⁴

Table 2 depicts different characteristics of Megaprojects by different authors.

Table 2: Various definitions of key characteristics of Megaprojects⁶⁵

Characteristics of Megaproject	Author
<ul style="list-style-type: none"> ▪ Above US\$1 billion investment spending ▪ 50years or more life span ▪ Substantial improbability to the projections and cost approximations ▪ Derives multiple benefits not only for project users but for other third parties as well. 	(Bruzelius et al, 2000)
<ul style="list-style-type: none"> ▪ Produces physical infrastructure assets that can be measured over a long period of time. ▪ Government or State owned entities are usually client to such projects ▪ Executed by private owned contractors 	(Sanderson, 2012)
<ul style="list-style-type: none"> ▪ These projects are have massive scope and gigantic in size ▪ At inception they are under scoped and under cost ▪ Controversial, Complex and Have control issues 	(Sturup, 2009)
<ul style="list-style-type: none"> ▪ Multiple organisations seeking success with different objectives ▪ Changing priorities by project objectives ▪ The project being subject to the impact of a wider socio-political environment 	(Ruuska et al.,2009)
<ul style="list-style-type: none"> ▪ Investment value of over £150million ▪ Complex management structure ▪ Politics playing an important role in how senior management appointments and activities are defined. 	(Stoddart-stones, 1998)
<ul style="list-style-type: none"> ▪ Massive in size and can have different owners ▪ Public can be in disagreement with the intent of the project and the impact on society and environment ▪ Can take long period of time to develop and to finance. ▪ Situated in remote and or inhabitable location ▪ Disrupt the market by its demand of workers and suppliers ▪ Complicated in sourcing funding ▪ Lack of adequate experience in managing complexity of such projects 	(Hayens, 2002)

⁶⁴ Flyvbjerg, B., Bruzelius, N. & Rothengat TER, W. 2003. *Megaprojects and Risks: An Anatomy of Ambition*

⁶⁵ Flyvbjerg, B., Bruzelius, N. & Rothengat TER, W. 2003. *Megaprojects and Risks: An Anatomy of Ambition*

Examples of megaprojects of this nature include the following:

- Boston's Big Dig
- Channel tunnel between France
- Eskom Medupi Power Station
- Eskom Kusile Power Station
- Gautrain Project
- Airbus A380
- London Crossrail

The impact of Megaprojects is not just on a huge economical scale but on a broad social and political impact as well. Megaprojects are commonly developed to transform lives and to improve the economic situation of most countries, most of these projects have resulted in “strategic learning value” embedded in these projects. Over and above the economic and social impact of Megaprojects some of the multiple benefits of such projects include the following:

- 1) **Multiplication of Economic Benefits.** Majority of Megaprojects are intended to have longer life span economic benefits to societies. In the long-term well-designed infrastructure such as, electricity, railway, sea ports etc. enable the creation of financial worth that exceed the cost of construction and operating.
- 2) **Break Productive Norms.** Countries like China have mastered the art of using Megaprojects to get its massive population to deliver critical infrastructure that has benefited the country. These mega projects have enabled China to reach new levels of productivity, quality and economic performance as evident from the infrastructure and assets developed by this country in relatively short time lines.⁶⁶
- 3) **Accruing of Critical Skills.** Megaprojects can be used as a tool of identifying and creating new skills. In most of these projects workers need to be trained in order to execute and deliver on the project. Once the project is completed new advance skills will emerge and be utilised in another similar project, in the long term this enables creation of new knowledge.

⁶⁶ Greater Pacific Capital LLP 2010 *The Role of Mega Scale in Building Industrial Power Some of China's Top Engineering and Construction Feats*

- 4) **Launching of Multiple New Industries.** The complexity nature of Megaprojects can yield positive results of new industries that didn't exist before. Prior to construction of the Three Gorges Dam project in China, manufacturing capabilities for turbines were focused on small and domestic turbines. This project propelled the industry to innovate and invest in developing bigger turbines which resulted in a new market created for both domestic and international opportunities. Because of such mega projects, China has been able to grow and become a significant international player in supplying energy related products some bigger than what they started with.⁶⁷

Megaprojects are not only seen through the benefits they yield but are criticised for various reasons discussed below:

1. At the inception of a Megaproject it is not always clear what would be the economic need and benefit of certain mega infrastructure. Some Megaprojects have ended up being white elephants or abundant engineering which resulted in wasteful expenditure rather than being economic multipliers.
2. Megaprojects attract major overrun, are usually highly politicised and most run over the stipulated delivery time lines eroding economic value.
3. Megaprojects are often leave a legacy of displacement of people and have massive impact on the environment. As an example, the Three Gorges Dam, required the relocation of 1.4 million people. These people had to vacate land that they were farming on for decades to a place that would potentially be flooded in future caused by the dam. Alteration of the dam from its natural tributaries of the Yangze River is assumed by many to have caused the worst drought in 50 years in 2011.

2.5. Knowledge transfer in projects

Limited body of knowledge exists pertaining to the application of management knowledge in the Mega infrastructure projects. The most prominent research on the subject can be divided into two broad categories. Firstly, learning within individual projects, and secondly learning between projects.

⁶⁷ Greater Pacific Capital LLP 2010 *The Role of Mega Scale in Building Industrial Power Some of China's Top Engineering and Construction Feats*

According to Cacciatori many firms have invested in organisational processes and information technology to support the transfer of learning across projects in an attempt to deal with the problems caused by the transfer of knowledge in projects.⁶⁸ Bresnena, Edelmanb, Newell, Scarbroug, and Swan emphasize that problems of cross-project learning have wider implications for processes of organisational learning, and hence the development of competitive advantages.⁶⁹

The context of the fundamental problem of how project learning can be transferred across projects is attracting considerable attention in current research. Many studies are attempting to clarify reasons why knowledge transfer between projects is a difficult challenge. Keegan and Turner found that the most prominent methods applied by project organisations to transfer knowledge includes:

- Lessons learned databases
- Project end reviews
- After Action Reviews
- Corporate level Training Programs
- Competence models with descriptions of competence exemplars at various level
- Learning Resource Centers
- Intranet
- Quality Procedures and Process Documentation
- Client Procedures and standards
- Centers of Excellence.⁷⁰

Recent studies of knowledge management and organisational learning in project environments have emphasized the difficulties of learning within and across projects. Crucially, problems of cross-project learning have wider implications for processes of

⁶⁸ Cacciatori, E., Tamoschus, D. and Grabner, G. 2012. *Knowledge Transfer Across Projects: Codification in Creative, High-tech and Engineering Industries*. 43. 309

⁶⁹ Bresnena, M., Edelmanb, L., Newell, S., Scarbroug, H., Swan, J. 2003. *Social Practices and the Management of Knowledge in Project Environments*. 157-166

⁷⁰ Keegan, A. and Turner, J. R. 2001. *Quantity Versus Quality in Project-based Learning Practices*. 77–98.

organisational learning and, not surprisingly therefore, developing the capability to manage knowledge across projects is seen as an important source of competitive advantage for organisations.⁷¹

Söderlund states that projects bear possibilities to develop new competencies but also the ability to re-use that gained knowledge. Learning in projects can contribute to knowledge transfer. He further points that projects are such arenas and areas where different knowledge elements can be integrated and in addition to that, the knowledge and experience gained in certain projects can be saved for later projects. These factors can ensure that the organization will not make the same mistakes project by project.⁷² Reich substantiated that a higher level of applying knowledge management shows a positive correlation with the depths and size of project based knowledge.⁷³

According to Senaratne & Sexton in the information age; organisation theories have addressed problem-solving as an information-processing activity. However, in this era, with the realisation of knowledge-based views of the organization, shared problem-solving is increasingly recognized as a knowledge creation trigger. During shared problem-solving, stakeholders bring different types of knowledge into the problem situation and it is captured, created and shared by the team members.⁷⁴

In construction projects, shared problem-solving often takes place through pragmatic problem-solving on site, in particular, through managing project changes. Tah and Carr argue that different forms of knowledge are created during the project change process within development projects. However, this knowledge remains largely tacit and does not disseminate to the wider organization due to imbalanced codification and personalization strategies existing in such settings. Furthermore Tah and Carr elaborate

⁷¹ Bresnena, M, et Al. 2003. *Social Practices and the Management of Knowledge in Project Environments*. 157-166

⁷² Söderlund, J. – Vaagaasar, A.L. – Andersen, E.S. 2008 *Relating, reflecting and routinizing: Developing project competence in cooperation with others*. 517-526

⁷³ Reich, B.H. – Gemino, A. – Sauer, C. 2014. *How knowledge management impacts performance in projects: An empirical study*. 590-602.

⁷⁴ Senaratne, S. and Sexton, M. 2008. *Managing Construction Project Change: a Knowledge Management Perspective*. Construction Management and Economics 1303–1311.

that increasing complexity and dynamism of major construction projects can influence a project manager's ability to effectively manage project risks.⁷⁵

Bassi argues that projects and their management create conceptual, networking, corporate and experiential knowledge. Subsequently the people implementing these projects typically either return to their original scope of activities or start a new project after closing a project, this knowledge is not efficiently reused and or built in to the corporate memory. Accumulated knowledge is not efficiently formed and archived nor effectively used and exploited for delivery of new projects.⁷⁶

Because of the possibility of great negative consequences, project managers cannot afford to repeat past mistakes for any reason including being unaware of successful risk management strategies that were applied elsewhere. Bassi proposes the use of information technologies to capture prior learning's regarding project risks as a method to overcome the problem of repeating past mistakes on projects. Bassi proposes the establishment of a central repository project managers can tap into and share learnings relating to project risks.

2.6. The relationship between project risk and knowledge management

Governance of projects is a critical part of overall corporate governance because projects are inherently risky. According to Neef the concept of "knowledge management" is witnessing a renaissance as a critical tool for managing corporate risk and that the key to a proactive risk management processes lies in the organisation's ability to mobilise the knowledge and expertise of its employees.⁷⁷

O'Dell emphasizes the importance of creating a visible connection between knowledge sharing and business strategy as being an imperative in organizations. He argues that

⁷⁵ Tah, J. H. M. and Carr, V. 2001. *Towards a Framework for Project Risk Knowledge Management in the Construction Supply Chain*. Advances in Engineering software 32.

⁷⁶ Bassi, A. 2014. *Project management: human and organizational learning. Human Capital without Borders: Knowledge and Learning for Quality of Life*. 460; 462.

⁷⁷ Neef, D. 2005. *Managing Corporate Risk Through Knowledge Management*. The Learning Organization.

this should be the main focus in improving project management and that the appropriate knowledge management activities should include best practices and their transfer between projects as lessons-learned.

According to the O'Dell key issues to be resolved regarding managing knowledge efficiently include the understanding of responsibilities, identification of internal sources and flows of knowledge, and choosing appropriate governance frameworks. O'Dell adds that knowledge management needs to be one area of management's responsibility, and appropriate measures need to be put in place to proactively ensure that it happens to the benefit of successful project delivery. These measures can be both "hard measures" such as reduction in project development costs or "soft measures" such as enhanced innovation, better morale, and employee satisfaction.⁷⁸

O'Dell further adds that these measures evolve with the maturity of the knowledge management initiatives within a specific organisation. Lelic argues that an organization cannot manage its risk without managing its knowledge. This author proposes that an integrated Knowledge / Risk Management process be employed in organisations by "creating a dedicated knowledge management process that leverages best practice risk and knowledge management procedures and systems that span from the shop floor to the board and senior company officers".⁷⁹

2.7. Conclusion

Mega infrastructure projects are typically dynamic and very complex in nature. Removal of barriers to managing knowledge through greater sharing, and making learning a priority go a long way towards successful project delivery. Different role players participating on mega-projects require the combination of knowledge from a wide range of specialists who cognitively understand how their different roles in the project combine to deliver a successful project. Understanding the different knowledge types (that is embedded, tacit and explicit knowledge), their characteristics and how to unlock learnings together with an understanding of project knowledge areas and how

⁷⁸ O'Dell, C. 2004. *The Executive's Role in Knowledge Management*.

⁷⁹ Lelic, S. 2002. *Managing Knowledge to Manage Risk*

their processes interact with one another is key to successful project delivery by practitioners. Cognitive dimension cannot be overcome by information processing alone but needs the integration of various independent bodies of knowledge across the organization.

CHAPTER 3

Literature review

Information Space Methodology (I-Space)

3.1. Introduction

Following up on the previous chapter that covers the “what” or typical project knowledge areas considered and the project management processes, this chapters discussion focuses on the “how” of managing knowledge. There are many models on this subject and Boisot’s I-Space model was found to be most extensive by the thesis author. An overview of the Information Space (I-Space) and how it enables the knowledge and information flow within an organizational setting is discussed. This model is recommended by the thesis author as a good tool to help practitioners form an understanding of the process of managing knowledge in Megaprojects in order to help with probability of success for mega infrastructure projects that can ensure sustainable project development over the long-term. Part of the success of Megaprojects is dependent on the quality of information feed to decision making during the project. The I-Space model was found particularly interesting and relevant for understanding the phenomenon of managing knowledge and what happens with knowledge as it flows within a project set up.

The I-Space social learning cycle model was used to assist in investigating effectiveness of knowledge flow for the purpose of this thesis regarding the megaprojects under study. Social learning in project is dependent on considering knowledge as it is generally created and apparent over how it is used practically. Learning in projects happen in both formal an informal settings and learning results are

seen through the manner in which certain groups communicate and do things amongst themselves. Interview results will be interpreted using Atlas.ti coding, the analysis of the results will use some elements of I-Space.

Different studies have recognized that the root cause of almost all project failure can be traced back to human error or misjudgement and poor judgment can often be traced back to the way the decisions were made or the ability to make right decisions on projects for which managing knowledge has a direct impact. Making the right decisions on projects should be a principal indicator of project management professionalism.⁸⁰

3.2. The I-Space framework

This study will utilize the Information Space (I-Space) framework developed by Max Boisot as a theoretical base.⁸¹ Boisot developed the I-Space framework, for exploring the way knowledge flows within and between organizations or groups of people. The framework is intended to enable managers to understand how knowledge and information assets differ from physical assets, and how to deal with them at a strategic level within their organizations.⁸² He further explains that knowledge assets are stocks of knowledge which service users of the information and which over time are anticipated to flow from one group to another or amongst individuals. Knowledge assets are different from physical assets in that they are expected to last indefinitely.

Boisot explains that knowledge assets residing in different levels of the organization do not come together in the same way. Knowledge assets at the lower levels of the organization moving upwards will differ with the ones at the top management level moving downwards and that the former movement within the organisation creates more complexity. The I-Space model or framework helps one to understand the different flows of different kinds of information, it helps to understand the creation and diffusion of information within groups of people. Boisot in his debates with economist argues

⁸⁰ Eweje, J., Turner, R., & Müller, R. 2012. *Maximizing strategic value from Megaprojects: The influence of information-feed on decision-making by the project manager*. 639-651

⁸¹ Boisot, M.H. 2010. *Knowledge Assets: Securing Competitive Advantage in the Information Economy*

⁸² Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I. 2004. *Simulating I-Space (SIS): An agent-based approach to modelling modeling knowledge flows*. Working papers of the Sol C.

that they (economist) should not treat information as an asset comparable to other products and goods because knowledge:

- is tangible and a human construct as well as
- develops and goes through certain cycles

Boisot's model is different from other knowledge management models because it maps the organisational knowledge assets to social learning cycle which other knowledge management models do not directly address. Boisot's model is not widely used by practitioners because of its complexity in implementation and is less accessible. The I-Space model exploits the idea that knowledge that is well articulated will diffuse more speedily and extensively within a given population than knowledge that is not well articulated.

The I-Space framework stresses that knowledge can be general and comprehensive to diverse circumstances. Boisot suggests the two important points:

- The simpler organised data can be adapted into information, the easier it can be diffused.
- The least organised data necessitates a common setting for its diffusion.

According to Boisot knowledge assets that are on the opposite ends (least abstract, least codified and undiffused) have the smallest chance of adding value. Boisot argues that to achieve greater competitiveness organizations will require to move their knowledge assets to a region that will increase its value add that is more concrete, more codified and most diffused. This implies that data is sifted to yield value adding information and this information is then abstracted and codified to yield valuable knowledge. Knowledge is applied in different situations, hence results in new experiences which then produces data and a cycle of creating new knowledge starts.⁸³

Boisot's framework recognises companies as living organisms, with ever changing processes of expanding and creating knowledge assets. This implies that companies

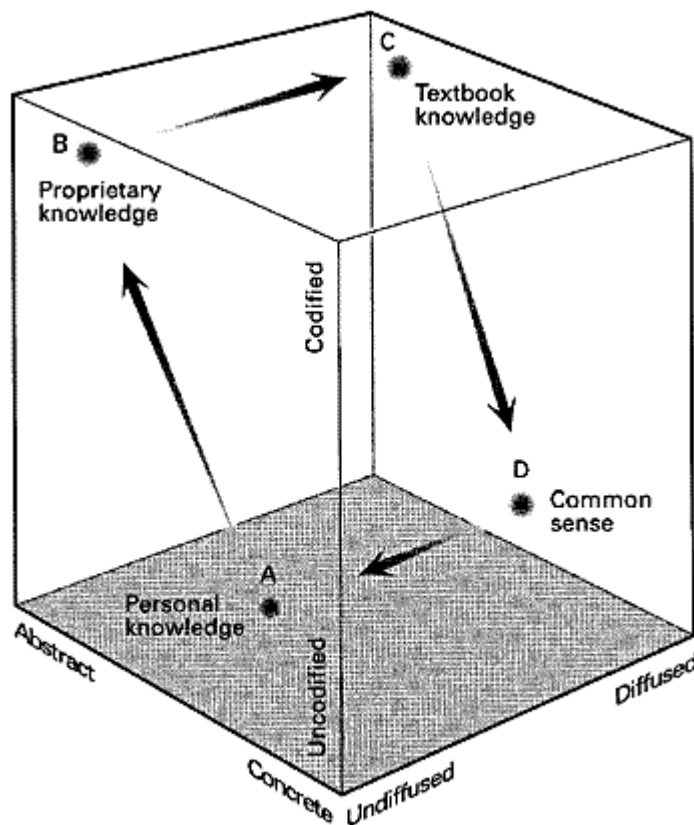
⁸³ Boisot, M.H. 2010. *Knowledge Assets: Securing Competitive Advantage in the Information Economy*.

will require to embrace dynamic knowledge management which will improve strategy and which will help to accommodate the active learning cycle of that company.

Figure 2 below depicts the movement of knowledge in the I-Space which starts off as highly personalized knowledge, such as biographical knowledge, which is neither codified nor diffused tacit knowledge. Once this knowledge becomes sharable and usable by others under control of its creator it becomes proprietary knowledge, such as patents and official secrets, which is codified but not diffused. Overtime this exclusive knowledge moves into common sphere which results in it being diffusible, it then enters the spaces of public knowledge, such as textbooks and newspapers which is codified and diffused explicit knowledge.

The extent that this knowledge gets consumed and applied in different situations it is dependent on the three aspects of degree of codification, concreteness and how diffusible knowledge is. This impacts how well knowledge gets internalized and how much of it becomes common sense that is widely shared and known by everybody..

Figure 2: The movement of Knowledge in the I-Space ⁸⁴



The dynamics of this model produces a flow of knowledge from abstract to concrete to diffused knowledge. It helps describe that knowledge flows from highly personal idiosyncratic knowledge of particular events to knowledge that is shareable and usable by others as it is diffused within the organisation.⁸⁵ However, the definition of knowledge has been a debate amongst scholars from the earliest of times. Its debate can be traced as far back as 369 BC to the work of the Philosopher, Plato. In this work of Plato, a number of dialogues are referenced to the definition of knowledge, ranging from “Knowledge is perception: Knowledge is true judgment, or Knowledge is true judgment with an account (meaning that one cannot have knowledge as true belief without first having a false belief”).⁸⁶

The objective of this research project is to define knowledge from a modernist, organizational perspective. Although it becomes important to understand the early

⁸⁴ Boisot M. 1998. *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. 59

⁸⁵ Boisot, M.H. 2010 *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. 58

⁸⁶ Chappell, T. 2012. Plato on Knowledge in the *Theaetetus*. *The Stanford Encyclopedia of Philosophy*.

philosophical debates about what knowledge is, the more important context is to understand how modern organisations define knowledge and how they manage such to their advantage in the application to the development of large projects. In this context, the organizational components of knowledge become important to understand from the view of the management of such knowledge in projects.

3.3. Foundational concepts of the I-Space

3.3.1. *The social learning cycle (SLC)*

According to Boisot's information flows give rise to a four-step learning process within an agent population in the I-Space called the SLC which is the process that forms a cycle in the I-Space. Within the SLC following a scanning process, new knowledge is created through problem-solving activities, shared through a diffusion process with a wider population, and internalized by that population through an absorption process as illustrated in Figure 2 above. A different SLC configurations in the I-Space helps reveal the learning strengths and weaknesses of different agent groups. To determine as an example whether some are given to hoarding their knowledge or to sharing it.⁸⁷ (Boisot et al. 2003:9).

Codification, abstraction, and diffusion, make up only one part of a social learning process. Knowledge that is diffused within a target population must also get absorbed by that population and then get applied in specific situations. When applied, such knowledge may not fit in well with existing schema and may trigger a search for adjustments and adaptations. This is referred to by Boisot et al. (2003:9) as scanning.⁸⁸

⁸⁷ Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I. 2004. *Simulating I-Space (SIS): An agent-based approach to modeling knowledge flows*. Working papers of the Sol C.

⁸⁸ Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I. 2004. *Simulating I-Space (SIS): An agent-based approach to modelling modeling knowledge flows*. Working papers of the Sol C.

3.3.2. *The social learning approach*

Bandura acknowledges that social learning identifies the nature of the social context in which the learning is taking place within a given community of practice.⁸⁹ In a project community social learning is dependent on considering how knowledge is socially organised and will be evident through practice. Social learning also materializes as a form of social interaction through which standardised rules and prescribed conducts in communities of practice are publicly communicated with new members.⁹⁰

The relationship between knowledge and practice are perceived as different entities intricately tied. Tacit knowledge is often used as a tool in knowing the definite in practice. In a project knowledge is dynamic process of knowing rather than an object which is transferred within the organisation. Knowledge is also linked to how people interact amongst themselves and interlinked practice is then established.⁹¹

Learning is viewed as part of training which cannot be disconnected from any of its actions, it is also subject to circumstance and it does not rely on a person's previous experience and authority in a particular context.⁹²

Cook and Brown agree with Bandura that learning happens as part of social interaction of people in which standardise rules of operation are set and communicated with new members.⁹³ The social learning approach has the potential for enhancing our understanding of learning and thus managing knowledge in projects. This is further emphasized by the imperative role of social interaction and processes for learning within projects.⁹⁴ The social interaction in projects is the main traditional method of the sender or receiver of information which accommodates the flow of knowledge created in a particular location and is absorbed at another location.⁹⁵

⁸⁹ Bandura, A 1977. *Social Learning Theory.*, Englewood Cliffs,

⁹⁰ Easterby-Smith, M. Crossan, M. Nicolini, D. 2000. *Organizational learning: debates past, present and future.* 783-796

⁹¹ Plaskoff, 2003. *Intersubjectivity and community building: learning to learn organizationally*

⁹² Elkjaer, B. 2003 *Social learning theory: learning as participation in social processes.* 43

⁹³ Cook, J., & Brown, J. S. 1999. Bridging Epistemologies: The Generative Dance between Organizational Knowledge and Organizational Knowing. 381-400

⁹⁴ Bakker, R, M, . Cambré, L. Korlaar, J. Raab, 2011. *Managing the project learning paradox: a set-theoretic approach toward project knowledge transfer.* 494-503

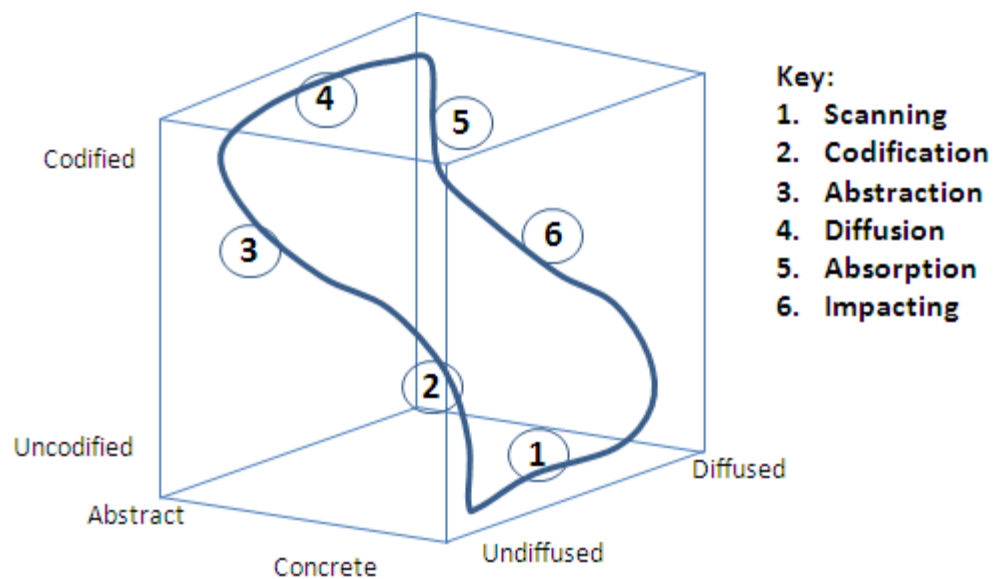
⁹⁵ Noorderhaven, N., Harzing, A.W., 2009., *Knowledge-sharing and social interaction within MNEs.* 719-741

Engwall emphasis that in a project environment practices are closely linked to a person's social and organizational context. This later forms part of the project, while being dynamic, project-based practices emerge through the context they are produced in, therefore projects cannot be viewed as islands. Meaning that learning from projects takes place within projects through practices that include organisational procedures and tools, symbolic artefacts, organisational rules and norms, experience and competence of individuals and that are connected to other projects.⁹⁶

Contextual setting is essential for learning across projects and the complex and dynamic nature of the project will regulate how learning will transpire between projects.⁹⁷

⁹⁶ Engwall, M. 2003. *No project is an island: linking projects to history and context.*, Research policy, 789-808

⁹⁷ Bresnena, M., Edelmanb, L., Newell, S., Scarbroug, H., Swan, J. 2003. *Social Practices and the Management of Knowledge in Project Environments.* 157-166

Figure 3: The Social Learning Cycle⁹⁸

The six elements of the social learning cycle as depicted in the figure above shows the stages of information flows as follows: scanning, codification, abstraction, diffusion, absorption and impacting. Before discussing each of these six stages a discussion on knowledge, data and information and their distinctions is presented below.

3.3.3. Knowledge

The the I-Space model helps to explain how knowledge flows, how this knowledge is formed, its value and the manner in which it is distributed. Boisot defines knowledge as set of expectations which is adhered to and held by agents as well as how it is altered. Boisot admits that the value chain which he prescribes to data which becomes information and later its knowledge is not the only way in which knowledge is created. Boisot ⁹⁹ further states that “knowledge builds on information that is extracted from data, whereas data can be categorised as a property of *things*, knowledge is a property of agents predisposing them to act in particular circumstances”. Boisot further describes that creation of knowledge occurs when new insights are created through a process of extraction of information from data. Figure 4 below depicts a series of downward

⁹⁸ Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I. 2004. *Simulating I-Space (SIS): An agent-based approach to modelling modeling knowledge flows*. Working papers of the Sol C

⁹⁹ Boisot M.H. 1998. *Knowledge Assets: Securing Competitive Advantage in the Information Economy*.12

movement across transformation curve, while related knowledge is examining the insight produced in different situations that permit for build-up of data depicted by upward movement towards the left along the transformation curve.

3.3.4. Data

According to Boisot data is a discrimination between physical state and might convey any information to the receiver with no link between data processor and discernible difference from physical form. Data has a physical basis, but restricted by the observer's ability to discern differences in physical states. Data can be described as property of things.

3.3.5. Information

Information has been defined in many ways by a number of researchers. Lundu defines information as data, signals, facts, views, opinions, events that influences actions, decisions and/or behaviour.¹⁰⁰ Stone defines information as data that has been converted into a form that is meaningful for the accomplishment of an objective.¹⁰¹ This view is supported by Turan et al. who defines information as discreet, definite and complete enough to be treated as an attribute.¹⁰²

Boisot distinguishes information from data by emphasizing that information is what an observer will extract from data as a function of his or her expectations or prior knowledge. Boisot and Canal 2004 argue that information derived from data acts as knowledge that can be adapted or tallied to the stock of knowledge acquired.

The transfiguration of information into knowledge is the main goal of information management. According to Choo "the basic goal of information management is to harness the organisation's information resources and information capabilities to enable it to learn and adapt to its changing environment."¹⁰³

¹⁰⁰ Lundu C.M. 1998. *The Library in the Service of Society*

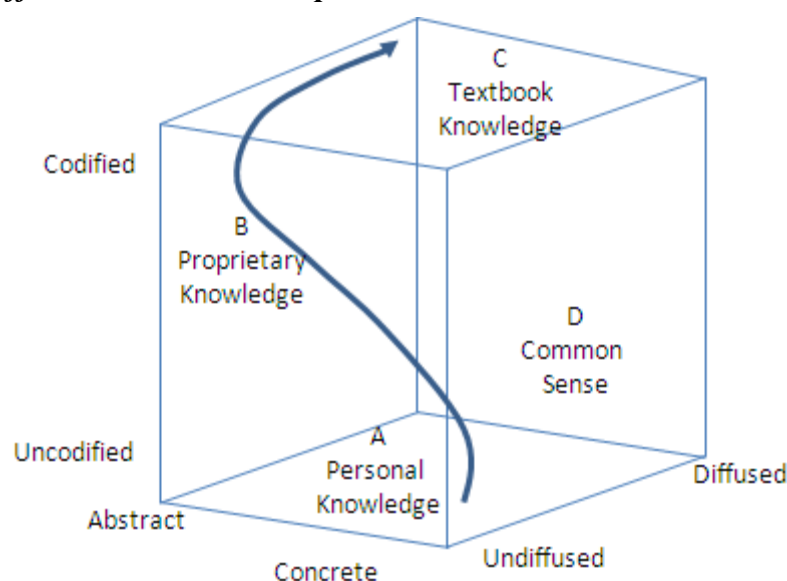
¹⁰¹ Stone, G. 2002. *Customer Relationship Management*.

¹⁰² Turan, E. McClean, E. and Wetherbe, J. 2003. *Information Technology for Management: Making Connections for Strategic*

¹⁰³ Choo, W. C. 2002. *Information Management for the Intelligent Organisation: The Art of Scanning the Environment*. 3rd edition.

Thelen and Smith describe that knowledge that people possess as a result of built up of information through a two way procedure of discrimination and association.¹⁰⁴ Framing this as an information processes, the I-Space model implies that information structuring is achieved through two cognitive activities: codification and abstraction. The relationship between codification, abstraction and diffusion is illustrated in the following figure.¹⁰⁵

Figure 4: Diffusion curve in the I-Space



The figure illustrates that if the message given is additionally codified and abstract the bigger will be the population of data process at a particular time which can be diffused. Agents in the I-Space framework can be people within the organisation, company departments, the entire organisations or even participants on a mega infrastructure projects. What is happening in the I-Space is a cycle in which data is filtered to produce meaningful information and this information is then abstracted and codified to produce useful knowledge. As the knowledge is applied in diverse situations it produces new experiences in an uncoded form that produces the data for a new cycle of knowledge creation.¹⁰⁶

¹⁰⁴ Thelen, E. and Smith, L.B. 1994. *A Dynamic Systems Approach to the Development of Cognition and Action*

¹⁰⁵ Boisot, M.H. 2010 *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. 58

¹⁰⁶ Boisot, M.H. 2010 *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. 58

According to Boisot et al. what is required to establish this is firstly an ability to receive, process and transmit data between various agents within the organisation (or project) and secondly, a capacity for a unified approach across the entire project development life cycle.¹⁰⁷

According to Boisot as illustrated in figure 4, personal knowledge generated at point A can move to point B over time as it becomes proprietary knowledge. Over a period of time proprietary knowledge can move to public domain which then is diffused easy and this knowledge will then be transferred to textbook knowledge once diffused at point C.¹⁰⁸ Once the textbook knowledge is applied and internalised it then becomes common sense at point C. The example of the traffic light explains well the concept of common sense. At the beginning they struggle to understand the concept of the colours and meaning when they are first taught how to use the traffic light to guide them in crossing the road. As they grow and understand and read about the purpose and use of the traffic lights and the meaning of the colours it become common to all and later its common sense, they will associate a colour with the meaning in relation to crossing the road.

3.3.6. *Scanning*

According to Boisot scanning is how we collect raw data but our individual knowledge and experience allows us to interpret it in our own way. Scanning involves the identification of threats and opportunities in general.¹⁰⁹ Scanning patterns of such data into unique or idiosyncratic insights then becomes the possession of individuals or small groups. Scanning may be very rapid when the data is well codified and abstract and very slow and random when the data is uncoded and context-specific.

During the development of a Megaprojects in the project conception and initiation phase, the applicability of scanning will be relevant since it is this phase in which an

¹⁰⁷ Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I.2004. *Simulating I-Space (SIS): An agent-based approach to modeling knowledge flows*. Working papers of the Sol C.8

¹⁰⁸ Boisot (2010:58) Boisot, M.H. 2010. *Knowledge Assets: Securing Competitive Advantage in the Information Economy*

¹⁰⁹ Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I.2004. *Simulating I-Space (SIS): An agent-based approach to modeling knowledge flows*. Working papers of the Sol C.

idea for a project will be carefully examined to determine whether or not it benefits the organization. During concept phase, a decision-making team will identify if the project can realistically be completed.

3.3.7. *Codification*

Organisations have become crucial generators of new knowledge. Organisations that have invested in creation of such new knowledge through research and development tend to do better than organisations that rely on knowledge created by others. Codification follows scanning in the I-Space model as illustrated in Figure 4 above. The codification process occurs as an individual's response to data that has been scanned, an initial pattern of raw information can be fuzzy but once the individual has gone through a process of classifying, interpreting and eliminating ambiguity the knowledge can be codified. Codification is important, because once knowledge is codified standards often create a lock effect that overtime become irreversible.¹¹⁰

The extent to which a particular event is codified is dependent on the amount of data processing needed to categorise it. The more complex the event the larger the effort required in processing that data. Boisot has found that codification establishes a selection from competing perceptual and conceptual alternatives which can be seen as a way reducing excess data.

Knowledge codification, understood as the inscription of knowledge into text, drawings, templates, models and similar media, often plays a central role in the strategies devised by firms to preserve and transfer learning.

Boisot distinguishes between uncoded and coded knowledge, uncoded knowledge is knowledge that cannot be documented losing the importance of the experience it relates to for example a smile or riding a bicycle. While coded knowledge is knowledge that can be documented without inducing loss of that information for example your home address, exchange rate or the constitution of your country.¹¹¹

¹¹⁰ Braitiana C, 2015. *Organizational Knowledge Dynamics: Managing Knowledge Creation, Acquisition.*, 103

¹¹¹ Naidoo S, 2008, The I-space as an evolutionary framework for an economics of knowledge.

3.3.8. *Abstraction*

Abstraction is the generalization of the application of newly codified insights to a wider range of situations. This involves reducing them to their most essential features. Both codification and abstraction have a highly hypothetical structure given an individual's expertise and realities.

In abstraction to reduce the categories which have to be drawn in order to achieve single context knowledge can be done by handling different things as if they are the same. According to this author, when a number of categories is highly correlated they can stand in lieu of the other. The fewer the categories that are drawn upon to make sense of a phenomena, the more abstract our experience of them becomes. Through abstraction data processing loads associated with the abstraction are reduced.

Codification and abstraction work as a duo. Codification enables the relations required to achieve abstraction, they both create a joint strategy for economising on data processing. This will result in well organised data, in turn better organised data lessens encoding, transmission, and decoding efforts which enables faster diffusion of knowledge saving on communicative resources. Abstraction can be achieved by exploiting the way that different attributes are correlated with each other as it is another way of reduction that works by allowing few information to represent many.

3.3.9. *Diffusion*

Diffusion refers to the sharing of the newly created insights with a target population. Boisot describes diffusion as a way of simulation whereby communication is a critical component at play. The diffusion of well codified and abstract data to a large population is bound to have the least technical challenges than that of uncoded data and context-specific. Splitting up of context by sender and receiver can facilitate faster diffusion of uncoded data.¹¹² Shannon and Weaver have described the following question to be asked in a communication process:¹¹³

¹¹² Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I. 2004. *Simulating I-Space (SIS): An agent-based approach to modeling knowledge flows*. Working papers of the Sol C. 10

¹¹³ Shannon, C., Weaver, W., *The Mathematical Theory of Communication* (Urbana: University of Illinois Press 1949)

- The message sent is it the same as message received? This question deals with issues of channel capacity, noise level and information redundancy.
- Is the message received understood? This question deals with the meaning.
- Has the message been received and executed upon as it was meant? This question is at pragmatic level – the message might be meaningful however it turns out to be ineffective in motivating action.

Shannon stresses that for the message to lead to the desired effect, both the sender and receiver should share compatible orientations like values, attitudes and motivation.

3.3.10. Absorption

Absorption refers to implementing the new codified insights to diverse situations, it is also “learning by doing” and “learning by using”. Codified insights assist to guide the application of knowledge in particular circumstances. The movement down the codification dimension of the I-Space model through which eventually codified data is applied to a variety of situations producing new learning experiences. Learned behaviour becomes uncoded or tacit.¹¹⁴

While codification assists in the associations needed to realise abstraction, sequential abstraction, reduces the amount of categories down in order for data processing. The outcome is better organised data that minimises encoding, transmission, and decoding attempts. This fast-tracks diffusion of knowledge to a particular population.

3.3.11. Impacting

Impacting is the embedding of abstract knowledge in concrete practices. The embedding can take place in artefacts, technical or organisational rules, or in behavioural practices. Impacting is movement away from the abstract and towards the concrete end of the abstraction dimension of the I-Space.¹¹⁵ Absorption and impact often work in tandem.

¹¹⁴ Max Boisot, Markus Nordberg, Saïd Yami, Bertrand Nicquevert. 2011. *Collisions and Collaboration: The Organization of Learning in the ATLAS Experiment at the LHC*. 39

¹¹⁵ Max Boisot, Markus Nordberg, Saïd Yami, Bertrand Nicquevert. 2011. *Collisions and Collaboration: The Organization of Learning in the ATLAS Experiment at the LHC*. 39

3.4. Conclusion

The I-Space social learning cycle model developed by Boisot was found most useful in establishing how managing knowledge should be efficiently managed. The social learning cycle combines all the elements required for the effective management of knowledge in organisations found to also apply to the mega infrastructure projects context. This I-Space model or framework will help to investigate and analyse whether managing knowledge is done efficiently and to help determine challenges in managing knowledge on mega projects.

After understanding the importance of social learning and that learning is in its self a social action ingrained in most organisations the thesis author was ready to go into the field research to collect data. In a project setting the understanding is that learning is an integral part of the project community, having been firmly established historically and that the organisational and cultural context plays a huge role.

CHAPTER 4

Case Study

Medupi and Kusile Power Station

4.1. Introduction

Eskom is executing its second major build program since the growth period from 1969 to 1990. As such the company has developed a capital projects execution capabilities and has had to rebuild its capability to execute large capital spends since the decline in capital investments from 1991- 2004 and subsequent loss of skills.

During the early periods of Eskom's current capital delivery journey (2006/7), the focus was to rapidly get projects up and running (whilst controlling costs during a period of funding challenges). As the capital funding gap was closed and Megaprojects delivery stabilised, Eskom diverted attention to standardise and institutionalise its project delivery capabilities

This chapter will provide an overview of Medupi and Kusile project, the context of the projects, technology chosen, environmental facts, common risks, financial and project schedules. Furthermore it will provide the governance framework utilised and knowledge management process.

The current build program (which mainly includes two super-critical coal-fired power stations - Medupi ~4,800MW and Kusile ~4,800MW and a pumped storage scheme – Ingula ~1,332MW) commenced in 2005. This program had a very steep ramp-up schedule, and still needed to meet South African development goals. Eskom had to rapidly re-build its capital execution capabilities, and in order to meet this aggressive

investment program, Eskom partnered with reputable international project management companies to transfer skills and knowledge to Eskom staff.

4.2. Medupi Power Station

Medupi is a greenfields mega coal-fired power plant project that was conceived in 2004 after it became clear that the Independent Power Producers (IPPs) would not be able to supply the power needed as envisaged by the Government. A mega power project (UMPP) is a power plant with 4 000 megawatts or more.¹¹⁶ Medupi originally started as mega project (Project Alpha) which was a 3 x 800 megawatt unit power station. A megaproject can be described as an extremely large-scale investment project typically costing more than US\$4 billion.^{117,118} Medupi power station now comprise of six units with a gross nominal capacity of 800MW each, resulting in a total capacity of 4 800 MW and is located at Lephalale, in the Limpopo Province. To save water, Medupi power plant will use dry cooling technology. Upon completion Medupi will be amongst the biggest dry-cooled power stations in the world. The power station has a design lifespan of 50 years and the project will utilize a range of technologies pertaining to cooling, combustion and pollution abatement.

Once complete, the coal-fired power plant will represent around 12% of South Africa's power generation. The objective of the Project is to increase the country's generation capacity and improve reserve margins in order to adequately, efficiently and reliably serve electricity demand in the country and in the Southern Africa Region.¹¹⁹

¹¹⁶ Vikas P., Prabhakar T., Sharma, N.K., Tiwari, A.N., & Singh, M.K. 2013. *Ultra- Mega Power Projects: additional restructural capacity to existing Indian grid system*. Available from: <http://www.ijrte.org/attachments/File/v2i1/A0506032113.pdf>. (Accessed 10 November 2015)

¹¹⁷ Knowledge Today 2015. *Ultra- Megaprojects*. Available from: <http://www.gktoday.in/blog/ultra-mega-power-projects/>. (Accessed 12 November 2015)

¹¹⁸ Locatellia, G., Littaub, P., Brookesc, N.J., & M. Mancinid, M. 2014. *Project characteristics enabling the success of Megaprojects: an empirical investigation in the energy sector*. Available from: http://ac.els-cdn.com/S1877042814021612/1-s2.0-S1877042814021612-main.pdf?_tid=f2d5d6b4-87a1-11e5-99c8-00000aab0f6b&acdnat=1447156713_307679ee9d091367514ac6e405234189. (Accessed 10 November 2015)

¹¹⁹ AfDB 2009. *Medupi power project appraisal report*. Available from: http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/South_Africa_-_Medupi_Power_Project_-_Appraisal_Report.pdf. (Accessed 10 November 2015)

The Project came at a time when Eskom had lost its niche in world class performance in construction and contract management due to many years of being inactive in that space. Lack of front end planning led to a “virtual design” being adopted based on Majuba power plant. In 2005 the total cost of Medupi power station project (then Project Alpha) was estimated at R26.1 billion. In December 2006 the cost was revised to R66 billion for six units, effectively doubling the expected capacity of the new power station.

4.3. Kusile Power Station

Kusile power station is a 4800 MW (6 x 800 MW) coal-fired power station located on the Hartbeesfontein and Klipfontein farms in the Nkangala District of the Mpumalanga Province. It is classified as a mega power plant. The Kusile site is about 1 355 hectares in size.¹²⁰ The project’s justification is to address security of power supply in the country. Upon full commercial operation, 4 800MW of electricity will be added to the grid, boosting the energy security of the country which is under threat. The cost to completion of the project is estimated at R118.5 billion.¹²¹ To save water, Kusile power plant will also use dry cooling technology. The power station has a design lifespan of 50 years and the project will utilize a range of technologies pertaining to cooling, combustion and pollution abatement.

4.4. Governance Process overview for Medupi and Kusile projects

Eskom has developed a Project Life Cycle Model (PLCM) tailored to meet internal requirements. The Eskom PLCM is designed to guide project teams in delivering project activities. It defines the governance gates, activities and work packages, associated roles and responsibilities of the different departments and parties involved amongst other key project related guiding information. The PLCM is a hierarchically structured process grouping logically related elements of project work together in Stages. This process facilitates the planned implementation of project work to create specific outputs in the

¹²⁰ Eskom, 2011. *Medupi and Kusile power station under construction*, (accessed 12 November 2015) http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/Kusile_and_Medupi.pdf

¹²¹ Eskom 2015. *Kusile power station project*. Available from: http://www.eskom.co.za/Whatweredoing/NewBuild/Pages/Kusile_Power_Station.aspx. (Accessed 12 November 2015)

correct sequence, without incurring excessive cost or risk. It facilitates project management decision making to maximise the allocation of limited resources. The Eskom PLCM is intended and structured to facilitate development and construction of projects including mega and large capital projects which are complex in nature

The PLCM defines functions which are Accountable or Responsible for each of the PLCM Stages and the deliverables of each Stage. It also defines the Work Packages applicable to each stage. At its simplest form the Eskom adapted PLCM consist of four phases and ten stages, this is shown in table 2 below

Table 3: Eskom Project Life Cycle Model

Eskom Project Lifecycle Model										
Phase	Concept		Definition			Execution			Finalisation	
Stage	Opportunity Screening	Pre-Feasibility	Feasibility	Business Plan	Project Execution Planning	Contract Concluding	Implementation	Transfer	Close-Out	Evaluate

Each of the ten stage of the PLCM are grouped in relation to the four phases as shown. Governance approval is required after completion of every phase before proceeding to the next phase. Stages are completed once sufficient data supporting a particular work package is completed and delivered before the project is taken for approval and it moves to the next stage. The PLCM prescribes that a project may not skip any stage or phase so that risks are adequately managed in an efficient way without over committing scarce resources earlier than required.

Numerous resources will have to be co-opted onto the project during the course of each Stage. These resources will be assigned by cross-functional teams, each with specific work Activities and Outputs. Each Stream of work have an individual assigned as Project Manager and it is the responsibility of the Project Manager to lead the work of the Stream. This helps ensure focus and continuity, as these Streams of Work will probably survive the duration of the project functioning as sub-projects, co-opting people as and when required.

The benefits of the project life cycle model can be summarised as:

- Defines clear boundaries of where the project starts and ends.
- Facilitates a standard and repeatable framework for implementing projects.
- Creates a standard model for all stakeholders to refer to.
- Breaks the overall work of the project down into more manageable inter-related chunks.
- Organises the work and deliverables into logical groupings in phases and stages.
- Assigns clear accountability and responsibility for each Stage of the project.
- Improves planning and contracting to reduce scope-creep, and over or under delivery

The Eskom PLCM has been developed and elaborated over time and represents the project fraternity's codified knowledge of the activities, interrelated processes and internal stakeholders required greater probability of successful delivery of projects in the Eskom context. The Eskom PLCM can also be considered a product of absorption as the implementation of the codified insights are applied to diverse project situations, as an example of what Boisot refers to as "learning by doing" and "learning by using". The Eskom PLCM codified insights assist to guide the application of knowledge in project circumstances including in the successful delivery of mega infrastructure projects.

4.5. Technology overview

The specific technology employed in the Medupi and Kusile power plant project is super critical boilers and turbines technology designed to operate at higher temperatures and pressures than previous generation units for greater efficiency. Supercritical refers to the critical transition point of water to steam at pressures over 220 bar. Supercritical units typically refer to main steam conditions of 240-300 bar and 538 -600°C with a single reheat stage at 566-600°C.¹²²

The supercritical boiler is a once-through design which (with sliding pressure) means heating, evaporating, and superheating of the incoming feed water are completed within a

¹²² Eskom, 2009. *Medupi power station*, http://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Pages/Medupi_Power_Station_Project.aspx

single pass through the evaporator tubes and therefore does not require the use of a steam drum to separate and recirculate water.

The benefits of supercritical technology are:

- The move to supercritical steam conditions would result in gross efficiencies of 40% measured on a high heating value basis.
- The increase in efficiency would result in a reduction in coal consumption of approximately 5%
- Reduction in emissions would be of the order of 6%

4.6. Environmental facts

Eskom applied for Environmental Impact Assessment (EIA) and was issued with Record of Decision (ROD) by the Department of Environmental Affairs. A thorough nature conservation exercise was conducted to preserve endangered species resulting in the relocation of trees including baobab trees, snakes, trees, animals and birds. This was done in compliance of the Environmental authorization ROD.

4.7. Common risks in both power projects

A discussion on key common risks experienced on the two projects used as case studies are provided below.

Design risks: those related with the planning phase of the megaproject, such as delivery method, contract formation, and scope control.

Both Medupi and Kusile projects came at a time when Eskom had lost its niche in world class performance in construction and contract management due to many years of being inactive in that space. Lack of front end planning led to a “virtual design” being adopted based on Majuba power plant.

Labour risks: those related with the workers linked to training, language, accident cost, and culture.

By September 2013, eight months into construction time, continued labour unrests had already significantly put project Medupi behind schedule.¹²³ Around April and May 2011 disgruntled employees embarked on strike at Medupi and Kusile over Thai welders, riggers and pipe fitters, claiming that these foreign workers had been employed although there were already sufficiently skilled welders of South African origin available.¹²⁴

Contractual risks: include those associated with delays due to the renegotiation of contracts, due to midstream change of project scope, and issues caused by change in assumptions and materialised risks impacting cost and schedule.

Eskom looks set to pay at least R3bn in penalties to Exxaro over the next three years, owing to the new delays of Medupi. Exxaro spent R10,2bn developing the Grootegeluk Medupi expansion project to supply 14,6Mt/year to the power station, but has been unable to supply the coal since 2012 because Medupi was not ready to burn it. Exxaro has exacted penalty payments to recoup its investment costs.¹²⁵

Construction risks: Were the most significant in the whole life of the megaprojects thus far. Cost overruns (or cost escalation), project schedule, coordination problems, and inappropriate design and accidents during the construction phase were examples cited by respondents.

In 2005 the total cost of Medupi power station project (then Project Alpha) was estimated at R26.1 billion. In December 2006 the cost was revised to R66 billion for six units, effectively doubling the expected capacity of the new power station. Each year the costs were increasing for various reasons including scope creep due to design changes, contractor claims, cost of cover, owner's development costs, etc. and now the

¹²³ Cokayne, R. 2013. *Eight months lost in construction of Medupi*. Available from: <http://www.iol.co.za/business/news/eight-months-lost-on-construction-of-medupi-1.1577876#.VkJxzbcrlIU>. (Accessed 11 November 2015)

¹²⁴ Parliamentary Monitoring Group 2011. *Labour issues at Medupi and Kusile power stations: Eskom briefing*. Available from: <https://pmg.org.za/committee-meeting/13108/>. (Accessed 11 November 2015)

¹²⁵ Financial Mail 2015. *Exxaro/Eskom: paying for nothing*. Available from: <http://www.financialmail.co.za/fmfox/2015/05/07/exxaroeskom-paying-for-nothing>. (Accessed 11 November 2015)

cost to completion is estimated at R147.5 billion in the latest project forecast based on the P50 risk scenario. Completion date of Medupi power project was 2015 and now it is only expected in 2020/21.¹²⁶

In some cases mega power projects have an element of human rights violation in the name of development. Communities will be uprooted to give way to the project while ignoring and/or disregarding environmental and social impact reports. Or worse still, erroneous and misleading Social, Environmental and Economic Impact Assessment reports will be produced which overlook the real impact of the projects on the communities.

4.8. Financing for Medupi and Kusile Power Stations

Financial and/or economic risks were impacted by a number of factors and changes in assumptions. Some of the key events related to finance and funding that had an impact on these mega infrastructure projects included the following:

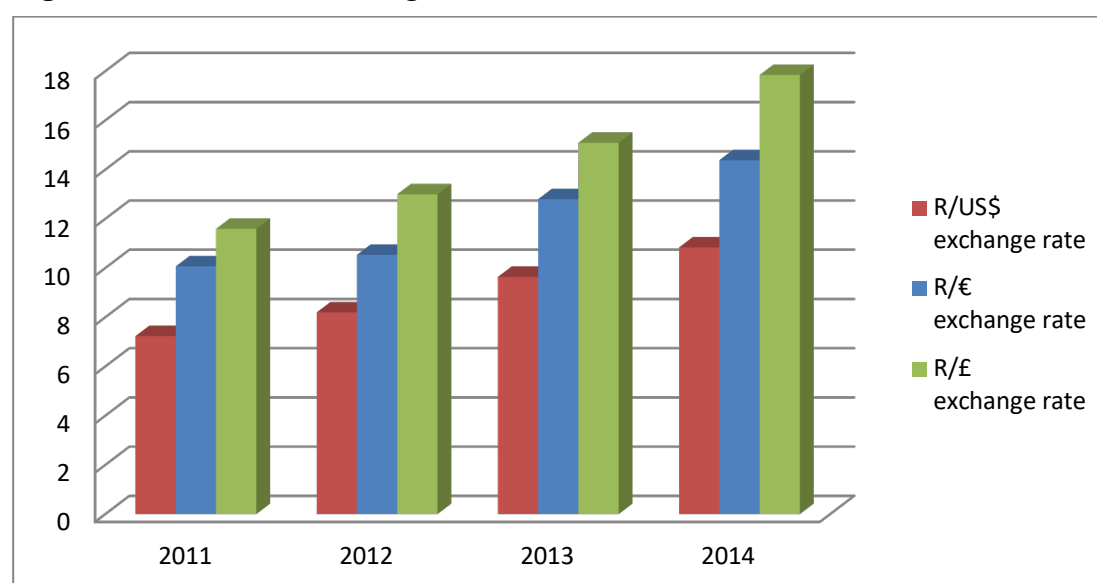
- Economic risks related with the investment or economic structure of the megaproject, such as lower-than-expected profitability, and inappropriate metrics about the project;
- Financial risks due to the high level of leverage which exerted an impact on the megaproject solvency;
- Liquidity risks, such as financial restrictions, availability of funds, and historic downgrading of Eskom's credit rating that affected interest during construction negatively; and
- Foreign-exchange and interest-rate risk derived basically from long-term interest rates and foreign exchange rate deterioration.

South Africa and Eskom have experienced several credit downgrades from the major credit rating agencies and this has impacted on the accessibility of credit for Medupi and Kusile power projects due to deterioration of some key financial credit ratios. In November 2014 Moody's downgraded Eskom's credit rating to Ba1, also known as

¹²⁶ ENCA 2015. *Kusile and Medupi dogged by further delays*. Available from: <https://www.enca.com/south-africa/kusile-and-medupi-power-stations-dogged-further-delays>. (Accessed 11 November 2015)

“junk” status, making borrowing more expensive. The Government was downgraded to Baa2, just two notches above “junk” status. The rand exchange rate against other major currencies has also been unstable and unfavourable. To illustrate this point the table below depicts the rand exchange rate over the four years between 2011 and 2014. This negative trend has continued and the rand has been depreciating against major currencies beyond the four year period mentioned impacting negatively on the mega projects’ cost performance.

Figure 5: Annual rand exchange rate, 2011 - 2014¹²⁷



Due to the huge capital cost of UMPP, the sources of finance include more than one, including a consortium of banks, multilateral agencies such as African Development Bank, World Bank and International Monetary Fund (IMF), Exim banks, and External Commercial Borrowing (ECB). Funds were also sourced from national financial institutions (NFIs).

4.9. Socioeconomic impacts of Medupi and Kusile project

- Direct and indirect employment opportunities

¹²⁷ OANDA 2015. Historical exchange rates. Available from: <http://www.oanda.com/currency/historical-rates/>. (Accessed 11 November 2015)

The socio-economic impact assessment reports cited employment benefits of the projects, during and after construction. According to the Eskom factor more than 22 000 people were to be employed at Medupi and Kusile power plants.^{i 128}

- Social benefits

The social benefits of the project include 117 education projects having been undertaken at Kusile where 90 students were awarded bursaries for tertiary studies to the value of R30 million by the Eskom-Alstom bursaries in 2014.

In Wilge, a new school is under construction and will provide education to \pm 480 learners. The total cost of the school project is estimated at \pm R28 million. An amount of R5.5 million has been spent on renovating Sibukosethu Primary School in Witbank where an estimated 530 students receive their education. The total amount spent by Kusile on socio-economic development around the surrounding communities is approximately R118 million.

Since the beginning of the Medupi Project in August 2007, the project has invested a total of R2.3 billion in infrastructure in Lephalale. To date, Eskom has built 995 houses and bought 321 in the Lephalale area. Eskom invested R11.5 million in the upgrading of the initial 2.2 km of the D1675 road leading to the project site. Eskom and Exxaro invested R180 million in the construction of the Kuipersbult road and the expansion of Nelson Mandela road.¹²⁹

- Business opportunities

UMPP are said to be stimulating small, medium, and micro enterprises (SMMEs). 368 SMMEs were linked to business opportunities created through the construction of the Kusile Power Station. This has resulted in approximately 4000 people benefiting from job opportunities created. The 368 SMMEs benefitted from bids awarded ranging from construction, catering and material supplies to the project.

¹²⁸ Eskom 2011. *Eskom factor*. Available from:

<http://www.eskom.co.za/OurCompany/SustainableDevelopment/Documents/EskomFactor.pdf>. (Accessed 12 November 2015)

¹²⁹ Eskom 2014. *Fact sheet: Eskom power station project*. Available from:

http://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Documents/NB_0002MedupiFactSheetSept2013.pdf. (Accessed 10 November 2015)

4.10. Challenges for Medupi and Kusile project

According to Association of Researchers in Construction Management the exceptional South African political history and context should be taken into consideration when planning to implement Megaprojects. These significant considerations should include the following:¹³⁰

- Prolonged industrial actions which are common in south African which can result in costly delays of Megaprojects.
- Inadequate time allocated to front end planning as a result of political pressure to quickly implement such projects for political mileage.
- Perceived corruption associated with mega projects as a result of top down decision instead of inclusive decision making.
- Institutional weakness with no room to pushback on decision made by the shareholder being the state.

There were number of aspects within and outside Eskom control, which resulted in cost increases and schedule delays for both Medupi and Kusile projects.

4.10.1. Ambitious Implementation timelines

Due to the time constraints, insufficient upfront work was done on the projects leading to incomplete scoping before contract awards. When the decision was made for construction commencement pressure to bring new capacity online placed time constraints on project teams. Additional work that was not part of the plan as well as additional engineering information led to delays and cost movements.

Impact of not having done proper Front End Engineering Design (FEED) led to construction starting without complete designs further leading to design changes and risks being managed during construction. Globally projects are not built the way Eskom approached Medupi and Kusile, however, due to power shortage constraints and pressure from powerful Stakeholders to mitigate the power shortage contributed significantly to the

¹³⁰ Khatleli, N 2016 The Impediments to efficient megaproject implementation in South Africa. In: PW Chan and CJ Neilson (Eds) Proceeding of the 32rd Annual Arcom Conference 5-7 September 2016 803-812 <http://www.arcom.ac.uk/-docs/proceedings/1bd9d0e800faf4e2f0b894f947857286.pdf> Accessed 2-04-2017

situation. The results of poor pre-planning due to late start decisions are detrimental to project execution.

4.10.2. Construction market grid lock

Global market demand for mega project resources (skills, materials and funding) and uncertainty on availability and timing of order placement played a major role in driving up costs. The material price fluctuations, specifically commodities, steel, copper and aluminum, fluctuate depending on the market demand. An important point here is that during construction of both plants specifically, China was also expanding rapidly and rigorously, driving up the prices of commodities and coupled with the local infrastructure development in South Africa for hosting the 2010 World Cup. This resulted in significant cost increases and premiums being paid for construction related services and materials.

The cost estimates used were based on the costs at the time of developing the technical design packages and due to a high demand in the market in the time there was a huge mismatch in the estimated prices versus the actual prices when the orders were placed for equipment. Eskom anticipated the demand but not the scale the demand was experienced in the market and hence incurred further costs.

4.10.3. Environmental Impact Assessment authorization¹³¹

The rise of social media has provided a mechanism to increase stakeholder power for community groups and environmental groups who are often opposed to the projects in their communities. Sometimes this opposition is based on an “interpretation” of the truth, rather than reality. This definitely added complexity to the process of executing these Megaprojects. Some of the delays in the projects were due to prolonged Environmental Impact Assessment (EIA) activities and appeals lodged by affected communities with regard to culturally sensitive issues like relocation of old graves, vegetation and wild life species.

¹³¹ Eskom website: <http://www.eskom.co.za>

4.10.4. Contract management¹³²

Eskom had to make an impact on the local economy content through its contracting approach. Notwithstanding the markets' lack of appetite for the turnkey approach, the multi-package approach fulfilled this local development requirement. The implementation of multi-package approach meant a slight deviation from market practice whereby implementation risks are normally undertaken by turnkey contractors.

The multi-package approach works well if the contracts are developed with input from project controls specialists, the requirements are captured clearly to manage the contractor performance. However, the accommodation of local content resulted in additional functionality from Eskom and coupled with shortage of skilled resources resulted in greater challenge to balance the project delivery performance, mitigation of risks and supporting local content and benefit from the project and accommodation of Stakeholder needs in the projects.

4.10.5. Resource Constraints

During the implementation of Medupi and Kusile projects, Eskom was also in parallel executing other, Return to Service Power Stations (Camden, Grootvlei and Komati) and Gas Power Station projects (Ankerlig and Gourikwa) and Transmission lines.

Eskom recognised from the beginning of the new build programme that there were insufficient competent engineering practitioners to execute all the Megaprojects at the same time. This competition and demand for construction management resources was also occurring at a global level with countries like China and India also executing large mega infrastructure power projects.

A strategy was formulated to contract-in large and multinational Engineering Companies to assist Eskom. However, the roles and responsibilities were not ideally defined. As a result, the decision making and processes to be followed sometimes took too long, and in some cases resulted in the duplication of effort. The design assurance accountability and requirements for compliance with the South African Engineering Profession Act was not dealt with early enough. The Panel members had limitations in this regard and Eskom had to close the gap. In the end, the context in which Eskom operated in proved to be something

¹³²Eskom website: <http://www.eskom.co.za>

that the contractors were unable to cope with; these included some of the commercial / procurement processes and requirements, the public finance management act requirements of a state owned company.

Eskom supplemented its skills shortage, knowledge and experience with that of the Execution Partners who were also only partially successful and the gap contributed to duplication and unavoidable delays which resulted in cost and time overruns.

4.10.6. Project Sites Infrastructure logistics

The infrastructure logistics around the sites where the projects were being constructed had major challenges and this contributed to serious delays in the construction schedules

- The roads to both Medupi and Ingula power stations projects sites were in a bad condition and much pressure was put on government to resolve the issue. This posed a challenge in that it was very difficult to move equipment and resources in and out of the area
- The areas around Medupi and Ingula project sites were very under-developed, not being able to meet the electricity, water and sanitation demands needed for contractors and the construction village. Eskom had to work with the communities and local authorities to develop this infrastructure (not originally envisaged to be part of the project scope), and this also required a lot of time.

4.10.7. Time line Schedules

Due to the challenges described in section 4.9.above, this impacted the project schedules negatively and the Tables below respectively highlight the key project milestones delays.¹³³

¹³³ Eskom website: <http://www.eskom.co.za>

Table 4: Medupi power station project

Milestone description	Revised Completion date	Comment
Unit 1	May 2020	In progress
Unit 2	December 2019	In progress
Unit 3	June 2019	In progress
Unit 4	July 2018	In progress
Unit 5	March 2018	In progress
Unit 6	August 2015	Completed

Table 5: Kusile power station project

Milestone description	Revised Completion date	Comment
Unit 1	July 2018	In progress
Unit 2	July 2019	In progress
Unit 3	August 2020	In progress
Unit 4	March 2021	In progress
Unit 5	November 2021	In progress
Unit 6	September 2022	In progress

4.11. Common characteristics at Medupi and Kusile Power Stations

Both Medupi and Kusile are super-critical coal-fired power stations, which mean they are more efficient than Eskom's current fleet of coal fired power stations resulting in the likelihood of them being able to produce more electricity with less coal, also consuming less water and therefore producing less emissions per unit of electricity generated.¹³⁴

¹³⁴ Eskom 2011. Cop 17 fact sheet. Available from: http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/Kusile_and_Medupi.pdf. (Accessed 11 November 2015) Vikas P., Prabhakar T., Sharma, N.K., Tiwari, A.N., & Singh, M.K. 2013. Ultra Mega

For Medupi and Kusile the bulk of the coal were to be sourced from what is termed mine mouth operations (meaning a coal burning electricity generating plant that is built close to a coal mine.)¹³⁵ Site selection was based on availability of fuel, land, water and environmental considerations. Lephalale was chosen as the preferred site for the construction of the Medupi project because of the following reasons:

- Availability of land which was close to the source of supply (Exxaro's Grooteegeluk Coal Mine with the world's largest beneficiation complex)
- Close proximity to Eskom's Matimba Power Station leveraging its experience with and knowledge of the properties of the coal acquired

4.12. The Eskom knowledge management process

Eskom's philosophy of knowledge management is influenced by its project management maturity which in general refers to the degree to which an organisation is capable of capturing and aggregating lessons learned, turning them into broadly applicable best practices and ensuring adherence. Lessons are learned through the business activities of delivering projects, as well as proactive initiatives to seek out global practices applicable to Eskom.

Deming's PDCA (plan-do-check-act) model is utilised for Eskom's knowledge management processes. This involves identification of issues and their root causes and driving the implementation of remedial actions to ensure sustainability and improved performance.¹³⁶

Historical step change improvements in project delivery at Eskom have rapidly boosted performance on a number of dimensions. These step changes have a higher risk of not being sustainable and repeatedly applied. Thus project delivery performance is still at

Power Projects: additional restructural capacity to existing Indian grid system. Available from: <http://www.ijrte.org/attachments/File/v2i1/A0506032113.pdf>. (Accessed 10 November 2015)

¹³⁵ Eskom 2011. Cop 17 fact sheet. Available from: http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/Kusile_and_Medupi.pdf. (Accessed 11 November 2015)

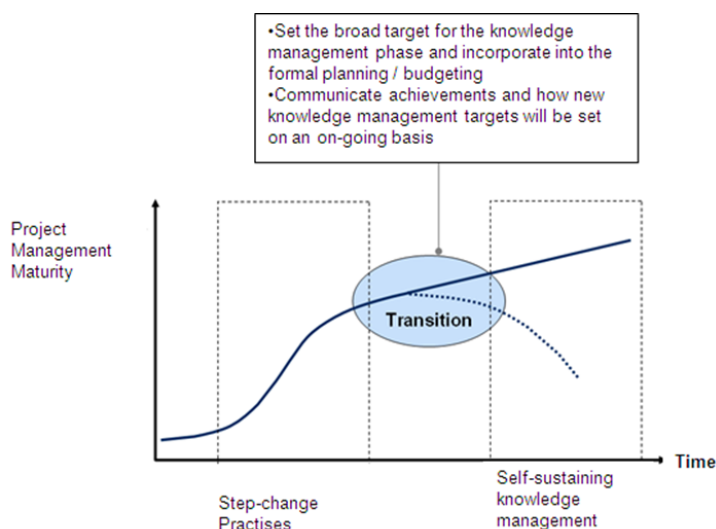
¹³⁶ Deming, W.E. 1990. *Sample Design in Business Research*.

risk of sliding back down to lower levels. The knowledge management system must create a tight reinforcing environment, with incremental changes maintaining and building upon the new performance level. Step-changes in project delivery practices are more likely to be induced externally through, among others, peer visits, peer benchmarking, external capability assessments or project management conferences.

Operational, incremental improvements are usually based on internal reviews such as the megaprojects audits, departmental operational meetings or implementation reviews. The lessons learned need to be codified retrospective to the project being completed.

Alternatively, lessons should be drawn after an incident occurs or even when a particular challenge occurs on the project. What is required is a step change from the current process to a formal and effective knowledge management process. The proposed Eskom approach to this is depicted in the following figure.

Figure 6: Managing the transition from a step-change to Knowledge Management



Eskom is currently in the “transition” phase of this model and therefore needs to start to implement more effective knowledge management processes.

The current Eskom knowledge management context is embedded in three elements:

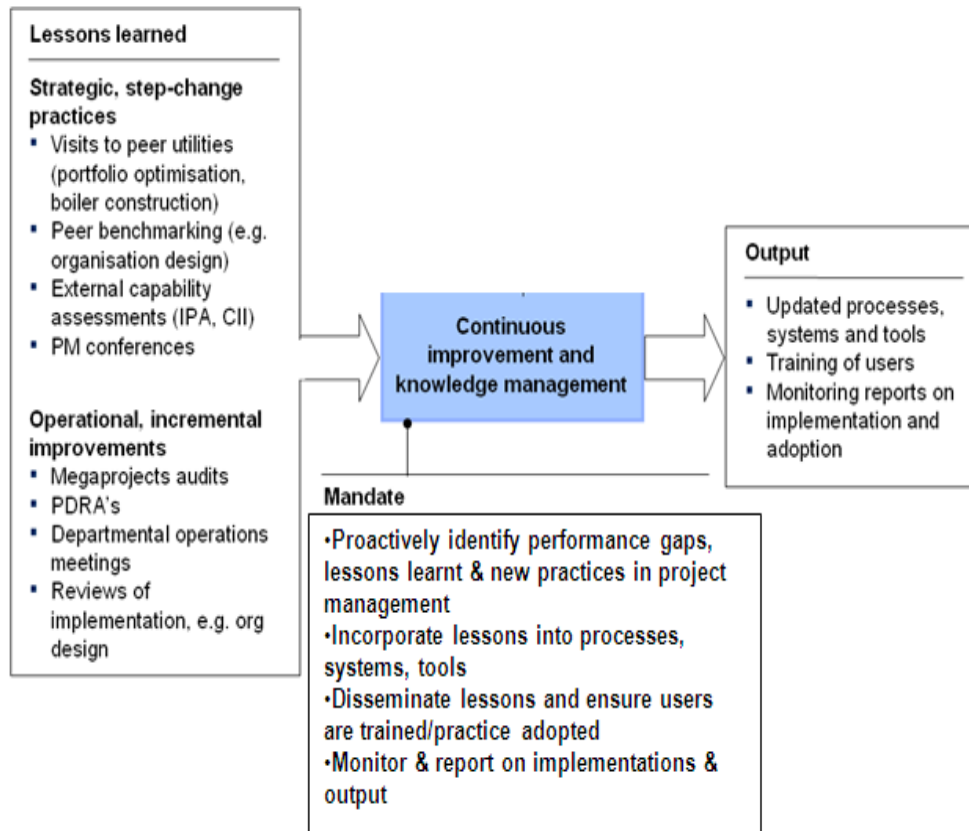
- (i) Principles and a complete, codified knowledge base of how projects are delivered (e.g., a project development guidebook and process control modules)
- (ii) A standardised method of problem solving and driving improvement/change (e.g., identification and prioritisation of opportunities; tools such as “Plan, Do, Check, Act” (PDCA) to analyse and delivery on opportunities
- (iii) A process for translating ideas into the new, standard, sustainable way of delivering projects (e.g., updates to procedures/tools; training; monitoring of adherence)

Within Eskom’s project development context, it is imperative to ensure continuous improvement and implementation of a knowledge management process that will result in continuous improvements in project development. This context should include the following tasks:

- Proactively identifying performance gaps, lessons learned and new practices in managing projects in Eskom and across divisions
- Incorporating lessons into processes, systems, and tools
- Disseminating lessons, ensuring users are trained and best practices are adopted
- Monitoring and reporting on implementation and output
- Identifying new project management best practices, industry standards, tools and methodologies

The process required to achieve this is depicted in the following figure.

Figure 7: Continuous improvement in knowledge management at Eskom



In particular, this ensures learning before, during, and after project delivery. The Knowledge Management aspect pertaining to this framework has several objectives:

- Bridge the knowledge and skills divide
- Develop knowledge assets that will enable business to generate profit (human, organisational and relational capital)
- Align Knowledge Management with business drivers
- Prevent knowledge loss
- Provide business sustainability
- Provide early warning of risks or opportunities for the business
- Mitigate risks by means of a business-informed knowledge process
- Improve collaboration through knowledge creation and sharing, e.g., Communities of Practice (CoP) and Communities of Interest (CoI)

This approach will help to ensure processes, systems and tools are updated, users are trained, and reports are monitored to track implementation and adoption. The very important monitoring role is required to:

- Set up a Performance Management system with top-down target setting and bottom up problem escalation, tracking performance
- Measure overall activity levels of improvement work and the overall impact of these efforts

Eskom has a dedicated career path for project managers, starting as project trainees, and progressing to coordinators/supervisors, managers, senior managers, programme and portfolio managers. Each project management role may encompass various disciplines such as project, risk, contract, quality and documentation managers, project planners, schedulers, cost engineers or quantity surveyors. The career path should be supported by various interventions and programs offering support to build the required capabilities.

Knowledge sharing and learning over the entire project lifecycle should be delivered through the following recommended framework:

- Peer Assist (learning before)
- After Action Review (learning during)
- Retrospect (learning after)
- Knowledge Exchange (learning with the organisation and its partners)
- Knowledge Visits (learning externally)
- Communities of Practice/Practice Networks

These frameworks should be supported by various knowledge management systems that allow Eskom to document, share and retrieve codified knowledge, and maintain version control (in a continually evolving organisation) of the current, official body of knowledge.

4.13. Knowledge capability requirements

In successfully achieving the project objectives there are a number of knowledge area capabilities that need to be coordinated and integrated to achieve a bankable project and appropriate investment decision. A “bankable” project is ideally one in which all the key development activities have been developed to such an extent so as to provide certainty with regard to scope, price and schedule. It is at this point that an investment decision should, in theory, be made. These knowledge areas are illustrated in the following figure.

Figure 8: Eskom Project Development knowledge areas



The integration of these knowledge areas is such that if any one factor changes, at least one other factor is likely to be affected. The specific project will influence the constraints on which the project developer needs to focus. Project stakeholders may have differing ideas as to which factors are the most important, creating an even greater challenge.

4.14. Summary

Eskom commenced the current new build programme in 2004, after 6 years had lapsed since the inception of the government independent power producer (IPP) programme, which did not succeed. Having not started a build program for over 20 years, Eskom had to quickly establish a department for execution of the New Build Programme. Due to the urgency of the projects, Eskom was not able to complete the required front end planning and development that should have taken about 5 years.

Eskom moved onto site prematurely, as it needed to show tangible progress towards providing the country with power and also due to pressure from government. The project in hindsight was built to meet a supply requirement, rather than focus on what was a realistic project delivery schedule. Previous build programs in SA were not without issues for example there was a chimney collapse at Matla Power Station that caused problems with the cost and delivery of that plant; crucially though the majority of the resources that managed these projects, with the wealth of experience, were not available. The context in which this build program occurs is uniquely different politically, economically and also from a social (labour) perspective. This means that there was little precedent available to manage projects of this magnitude in this context.

The research was aimed at investigating how managing knowledge can improve performance of mega infrastructure projects. The thesis author did not intend to re-invent the wheel and found Boisot's I-Space model as a useful tool for determining how well managing knowledge occurs by looking at the six stages and how well these are occurring in a practical setting. Mega project teams could use this model to analyse in their own settings how well managing knowledge occurs. In relation to projects Medupi and Kusile, there are some areas of improvement regarding managing of knowledge as highlighted below borrowing from Boisot's model:

Scanning: There is evidence that this was not done very well. Insights were not effectively gained from the previous build programme. There was no available diffused data from the previous era. This resulted in poor and inadequate time spent on front end planning that resulted in a lot of downstream changes to the projects during construction.

Codification: This has occurred to a limited extent in Eskom. One example is the Eskom PLCM framework developed to help guide project managers in the best way to develop mega infrastructure projects. The improvements for this stage are on more specific aspects mentioned above like contract management, risk management and financing lessons on mega projects that still need to be codified for benefit of future practitioners. In other words problem solving was given structure and coherence based on past and current insights and codification needs greater attention.

Abstraction: Newly codified insights from the mega infrastructure projects can be generalized to a wide range of situations and as current knowledge on projects has become more abstract.

Diffusion: These new insights are currently shared with the project management community in a number of forums including investment committees, project core teams, procurement committees, finance and engineering fraternities to mention a few. There could be more areas of improvement for greater diffusion of knowledge.

Absorption: The newly codified insights on mega infrastructure projects are being applied to a variety of current projects and this is producing new learning experiences. Absorption is also occurring to some limited extent but is negatively impacted by a lot of senior executives involved during the inception of the current mega projects leaving Eskom for a number of reasons including retirement and seeking better job prospects. Some of this knowledge has become tacit or uncoded.

Impacting: Eskom's project management maturity has increased and a lot of the abstract knowledge has been embedded in concrete day-to-day practices. As an example a lot of artefacts, guides, procedures, process control manuals and policies to name a few have been developed to help future practitioners.

The above findings demonstrate that managing knowledge and learning on projects takes place in a social nature which is not something that exclusively takes place in the human mind but occurs through the interaction of people during their daily activities.

CHAPTER 5

Discussion

5.1. Introduction

The objective of the study was to investigate how managing knowledge can influence successful development of mega infrastructure projects. Mega projects fail for many reasons. It was discovered that lack of managing knowledge adequately played a huge role. The thesis author did not intend to re-invent the wheel and the literature review also helped to uncover Boisot's I-Space model which helped with an example of a process for managing knowledge and to determine how well this was done in Eskom's context. The case studies on Eskom's mega projects Medupi and Kusile also helped to uncover factors that influence management of knowledge, some common practices in project management, strengths and shortcomings and to identify possible improvement areas. From the results of the empirical study, a number of conclusions emerged regarding management knowledge and Eskom's experiences on mega infrastructure projects. These conclusions, to a greater extent, support the initial ambitious objectives of this study and provide support for the propositions recognising that there could be some areas of improvement to this study.

The following chapter will discuss data analysis and findings with the support of the theoretical framework that was adopted. Combining the results of the content and grounded theory analyses a number of theoretical categories and concepts emerged which eventually grounded into the formulation of three specific propositions. These propositions formed the cornerstones for the development of the recommendations of this study. The results of the research led to the formulation of the following propositions as discussed in in this chapter:

- (i) Lack of adequately managing knowledge on mega infrastructure projects is one of the major causes of their failures.

- (ii) Boisot's I-Space social learning cycle model can be used as a way to assess effectiveness of managing knowledge.
- (iii) Managing knowledge can be achieved by specifically analysing how effectively knowledge/information is handled within, and flows across, the six stages, mainly: scanning, codification, abstraction, diffusion, absorption and impacting of knowledge.

This chapter starts with a discussion on data analysis approaches and options selected and the subsection which includes a discussion on coding and analysis results. This is followed by a discussion on the social learning experiences on the chosen case study mega projects during development and execution based on the theoretical framework stages as adopted from Boisot's model. A discussion on proposals for managing knowledge is also provided.

5.2. Data Analysis

5.4.1. Data analysis Procedure

The analysis of the research data was done through merging two methods, the literature review that helped to uncover a theoretical concept being Boisot's I-Space social learning cycle as well as fieldwork interview to uncover learnings on the Eskom Medupi, Kusile case studies. The grounded theory approach was adopted by the thesis author. Unstructured interviews were utilised comprising of open ended questions, this provided a combination of quantitative and qualitative data. The methodical analysis of the contents was to document frequencies of themes.¹³⁷

According to Welman and Kruger "the statistical analysis of the data obtained consists of the determination of the frequencies or percentages of occurrence of the chosen content". Results of the content analysis will then be utilised to outline the theoretical model and form part of the basis of the final recommendations while using grounded theory.

¹³⁷ Welman, J.C. and Kruger, S.J. 1999. *Research Methodology for the Business and Administrative Sciences*. 201

Grounded theory refers to the attempt to use the interview data inductively, so that production of abstracted analytical categories comes from the respondent's accounts. In inductive studies data analysis is often hard to distinguish from data collection since building theory that is grounded in the data is an iterative process in which the emergent frame is compared systematically with evidence from each interview.¹³⁸

Data analysis is central to grounded theory research. The process of building grounded theory requires integration of the various phases of a research study. These phases (research design, data collection, data ordering, data analysis and literature comparison) form the foundation for the main findings of the research, but need to be further enhanced by evaluating each against specific research criteria: construct validity, internal validity, external validity and reliability.

Saunders distinguish two types of approaches, depending on whether a research process starts with the theory or is built at the end of the qualitative study: deductive methods, such as the pattern matching, explanation building; or inductive methods, such as grounded theory, template analysis, analytic induction, narrative and discourse analysis. While paying attention to inductive strategies, it can be recognized that such approaches as grounded theory, analytic induction, narrative analysis and discourse analysis may involve some deductive aspects during the analysis of the data.¹³⁹

In contrast, template analysis incorporates deductive elements at the beginning, and then concentrates on inductive aspects, as it is done in the present paper. In terms of the interviewing process, Bryman & Bell emphasize that during the empirical data collection process, there is always a possibility to observe new topics, which have not been covered in the literature review. The process of reviewing existing literature (deductive element), including academic papers and books, can also affect the choice of data collection methods in inductive study.¹⁴⁰

¹³⁸ Eisenhardt, 1989. *Building Theories from Case Study Research*. 532-550

¹³⁹ Saunders, M., Lewis, P., & Thornhill, A. 2012. *Research methods for business students*. 6th edition. Harlow: Pearson Education. 548

¹⁴⁰ Bryman, A. and Bell, E. 2011. *Business Research Methods*. 581

Due to the reason that the current study uses a “mixed” approach, where a theoretical framework is generated using a deductive approach to identify research gaps in the literature and establish a frame by which research questions are analysed; and inductive approach is employed to understand and explain the interaction of social actors that create the social phenomena. Template analysis is additionally associated with the following advantages: flexibility of the approach which can be regulated as per requirements of the particular study; operation with prior identified codes aligned with theoretical framework of the work; presence of defined structure.¹⁴¹

The thesis has a deductive approach even though some inductive elements were also adopted. The themes for the interview guide are a particular illustration of the deductive element, because they were developed by considering the theoretical approaches generated from the literature. Table 6 below provides the four themes and interview questions asked in relation to the theme.

Table 6: knowledge management themes

Knowledge Management theme	Interview Questions numbers
Value of knowledge management in Eskom	Q1,Q2 & Q3
Gaps in knowledge management practices	Q4 & Q6
Implications of knowledge management gaps	Q5 & Q10
Accountability for implementing knowledge management	Q9 & Q11

Prior to the analysis, a predefined, generally descriptive template with the list of the concept-driven codes or categories is created, which are obtained from the theoretical framework to facilitate analysis of the qualitative data.¹⁴² According to the template analysis method, each area of the template consists of categories and each category includes the abbreviations or codes, which help to interpret the large texts of interview transcripts as it is displayed in the fragment. Data analysis started with interview transcripts and the coding of the results as per Table 7 below:

¹⁴¹ Smith, V., J. 2011. *It's the relationship that matters: a qualitative analysis of the role of the student/tutor relationship in counselling training*. Counselling Psychology Quarterly, 24 (3). pp. 233-246.

¹⁴² Saunders, M., Lewis, P., & Thornhill, A. 2012. *Research methods for business students*. 558

Table 7: Template analysis

No	Data Aggregation	Code
1	Value of knowledge management in Eskom	VKME
1.1	There is no knowledge management measuring system in the company	VKME1.1
1.2	Knowledge management is necessary but tools and systems is lacking	VKME1.2
1.3	Knowledge management is an element of the general strategy	VKME1.3
2	Gaps in knowledge management process practices	GKMP
2.1	Knowledge maintenance	GKMP 2.1
2.2	Knowledge creation	GKMP 2.2
2.3	Knowledge sharing	GKMP 2.3
2.4	Knowledge localisation	GKMP 2.4
2.5	Knowledge acquisition	GKMP 2.5
2.6	Use of knowledge	GKMP 2.6
3	Implications of knowledge management cycle gaps	IKMG
3.1	Financial loss (cost overruns)	IKMG 3.1
3.2	Operational benefits (quality, costs, cycle time, lead time, product to market)	IKMG 3.2
3.3	Business process inefficiencies (reworks, insufficient support infrastructure)	IKMG 3.3
3.4	Dysfunctional culture (poor productivity, non-accountability culture)	IKMG 3.4
4	Accountability for knowledge management implementation	AKMI
4.1	All employees	AKMI 4.1
4.2	Project Implementation Manager (Project Managers, Construction Managers, Construction Managers)	AKMI 4.2
4.3	Human Resources Managers	AKMI 4.3
4.4	Executive Managers	AKMI 4.4

5.4.2. Results analysis

The demographic profile of the participant is summarised in Table 5.3, however, for confidentiality purposes the names of Eskom personnel that participated in the interviews were coded accordingly.

Table 8: Demographic profile

Respondent Level	Respondent Gender	Respondent Role	Respondent Code
Executive Manager	Male	Project Development Manager	R1
Executive Manager	Male	Project Manager	R2
Executive Manager	Male	Contracts Manager	R3
Middle Manager	Female	Project Development Intelligence Manager	R4
Middle Manager	Male	Project Development Intelligence Manager	R5
Middle Manager	Male	Project manager	R6

Table 9: Value of knowledge management in Eskom

Codes	Respondents					
	R1	R2	R3	R4	R5	R6
VKME1.1	X		X	X	X	
VKME1.2	X	X		X	X	X
VKME1.3		X	X			X

The above tables reflect that the general view among respondents is that they acknowledge the importance of managing knowledge and its role in mega infrastructure projects. There seems to be some consensus among respondents that effective system and tools for managing knowledge are lacking and knowledge management is not being explicitly driven in the organisation.

Table 10: Gaps in knowledge management process practices

Codes	Respondents					
	R1	R2	R3	R4	R5	R6
GKMP 2.1				X	X	X
GKMP 2.2				X		
GKMP 2.3	X	X	X	X	X	
GKMP 2.4	X	X	X			X
GKMP 2.5	X					
GKMP 2.6		X				

Analysis of the knowledge management practices highlights that existing knowledge is not being collected, captured and shared in a structured manner therefore resulting in a mixed view of the extent of the current value of knowledge within Eskom. Majority of respondents acknowledged that Eskom has lot of processes, however, there are no basic tools available to ensure that the information is shared in the company.

Table 11: Implications of knowledge management cycle gaps

Codes	Respondents					
	R1	R2	R3	R4	R5	R6
IKMG 3.1	X	X	X	X		X
IKMG 3.2						
IKMG 3.3					X	
IKMG 3.4		X	X	X	X	X

The primary impact of the mentioned gaps in knowledge management practices is financial loss which emanates from project cost and schedule overruns, poor project front end processes and dysfunctional culture. The culture has a direct influence on the ability of the organisation to be successful.

Table 12: Accountability for knowledge management implementation

Codes	Respondents					
	R1	R2	R3	R4	R5	R6
AKMI 4.1				X		
AKMI 4.2	X	X	X			X
AKMI 4.3	X	X				X
AKMI 4.4	X	X			X	X

The unanimous view among all respondents is that Project Managers, Construction Managers, Human Resources and Executive Managers are responsible for implementation of knowledge management.

5.3. Social Learning in Medupi and Kusile Project

5.3.1. Front-end engineering and site development

Mega projects are developed according to Eskom's established PLCM, typically such projects requires 5-7 years development work prior to execution, this ensures that adequate project development work (such as site permits, fuel source agreements, engineering design and purchase of land) is done and completed before construction work begins. When the decision was made for Eskom to bring additional capacity online after the IPPs did not deliver on the required capacity, it was clear to the Eskom that time will be a constraint for these projects.

Medupi and Kusile projects utilised the Eskom PLCM governance framework which is a hierarchical structured process grouping of logically related elements of project work required during a typical project. The Eskom PLCM has four phases two of which are under the front end engineering design phase which are concept and definition phase. The execution phase has the construction of what was developed in the front end engineering design and the last phase is the finalization phase which consist of the close out and evaluation of the projects

The development of both Medupi and Kusile projects had to happen under enormous time and commitment pressures. In both projects flow of information differed at each stage

gate, at the concept phase which consist of opportunity screening and prefeasibility stage, information was not clear to the projects team which consist of different subject matter expects. The project teams were made up of subject matter expects from various areas including project management, project development, finance, procurement, environmental, engineering, transmission, construction management, to name a few. At opportunity screening stage the project team had to deal with raw data such as understanding the justification of technology selected, site/s, fuel source, identifying stakeholders etc. During this stage of fuzziness the teams are relying on their own individual knowledge and experience to interpret data therefore knowledge at that stage was at personal level. The limited development time provided on both projects by key stakeholders placed a lot of risk on adequate development of these projects prior to construction commencement.

Project teams had no previous information to work with as knowledge from the previous build era was uncoded. Eskom had lost a lot of project development and construction experience and skills gained from the previous build programme. Furthermore the current mega projects were utilizing different technology. Usually opportunity screening affords an opportunity for scanning patterns of data that emerge, providing insights that become knowledge in the possession of project teams going forward. The project development team at this stage had limited insights to work with while still trying to understand the opportunity identified. This resulted in scanning being very slow because of the lack of uncoded data.

The project had to progress to prefeasibility stage with data which was uncoded, some of the prefeasibility work like geo technical studies were not completed which later stalled the project. For the rest of the team this stage arrived prematurely. Knowledge was not fully classified, interpreted nor was ambiguity removed so that knowledge could be appropriately coded. If adequate time was available for developing these projects, codification could have also been adequately effected and this would have assisted with inscription of knowledge into text, drawings, templates, models and other media. This would have played a central role in preserving and transfer knowledge and learnings. Applying coded insight, which is the abstraction stage in the I-Space framework, would have served as a huge benefit to successful development of these projects. Instead development of these projects was prolonged with personal level knowledge being used

instead. The project teams had to rely on the current expertise of each team member – rather than the insight brought by codified data from the past which was absent. This posed a huge risk later in the project since these new insights that emerge were not also documented.

The abstraction of the project knowledge happened mostly during the feasibility of the projects. Knowledge and data associated with the abstraction were reduced to distinguish categories that were drawn upon to make sense of the world and context at the time. Typically during the feasibility stage the project team would have defined the feasibility scope, the project key milestone associated with schedule timelines with substantial assumptions, this would have been as a result of comprehensive opportunity screening and prefeasibility studies. At this stage knowledge was not completely uncoded, a lot was unknown to the team and some approvals which were supposed to be in place in terms of the PLCM couldn't be sourced in time.

After completing the feasibility stage, the business case was swiftly put together with data which was not substantial. The governance framework specifies that at business case stage, the project development manager should have prepared a bankable project which includes having the following in place;

- Funding sources for the projects.
- Stakeholder engagement agreement(s).
- Project designs completed and frozen.
- All license approvals sourced.
- Solid project plan base-lined with milestone and schedule timelines.

Knowledge at this stage should have been diffused meaning codified and abstract data would have been less technically challenging for use by the project teams. For both these projects it was the opposite, the business case which was presented to Eskom board was based on a virtual design of the previous station, resulting in high-level cost estimates for the projects, the funding sources were at high level not comprehensively defined or confirmed, stakeholder agreement were not outlined and most of the Environmental Assessments (EA) and Water Use License Authorisation (WULA) were not yet completed.

During the project set up and development, time constraints, insufficient upfront work was done on the projects leading to incomplete scoping before contract awards. Additional work that was not part of the plan as well as additional engineering information led to delays and cost movements. Changes in environmental standards and requirements, the geotechnical and environmental conditions at the location of the projects and the lack of updated and current engineering standards during the early days of the projects further resulted in cost escalations and time delays later in the projects.

5.3.2. Execution Phase

The Eskom PLCM prescribes that a project cannot skip a work package or stage which can further compromise project readiness and delivery performance. However due to time pressures skipping of some work packages were allowed to happen by the project teams in order to meet the tight deadlines. In May 2007 Medupi construction started and the execution had to meet a fast tracked schedule and a year later Kusile started construction. The lack of an upfront integrated schedule covering all project development, engineering, procurement and construction management activities and timelines meant that all activities were out of phase and this resulted in rework later that resulted in further delays and culminated in funding risk materializing as well.

During the execution of the projects, teams should be applying the new codified insights to different situations evident by ‘learning by doing’ or ‘learning by using’ which is characteristic of knowledge absorption. The learning from previous insights should have helped to guide the application of the knowledge in these mega projects. Instead the project execution teams received a mixed bag of data or information and knowledge from the development team. The information flow across the stages of the I-Space social learning cycle did not happen as effectively (with only some information or knowledge codified) at the dis-benefit of the execution team and project performance.

The execution phase presented the organisation with an opportunity to reflect and take stock of the challenges that these projects encountered that affected project performance in terms of cost, scope, quality and schedule. At that time the projects were experiencing cost overruns and schedule delays. Respondents reported the following lessons from the Medupi and Kusile mega projects:

Knowledge Management,

- Knowledge to be documented at the inception of projects. Increased engagement with the international asset creation community must happen to share experiences and lessons.

- Projects leads must create knowledge empowered teams of professionals capable of solving problems on projects.

Front-end engineering and site development:

- Typically this requires 5-7 years, depending on a project, to develop a project according to Eskom's established project lifecycle model and relatively recently introduced project definition readiness index.
- Ensure that an adequate project pipeline is maintained to prevent the loss of skills and capabilities and to build on the existing capabilities through continuous improvement.
- The attraction and retention of key skills such as project management, engineering, procurement and construction management skills are considered to be a key enabler.

Execution:

- Development of an integrated project construction schedule which integrates all the contractors' schedules and consolidates the master schedule with consistent assumptions should always be a priority. The schedule must also be expanded to incorporate provision of risk events.
- A thorough review of the project's cost to completion must be always undertaken and reviewed by independent external experts before construction commencement.
- Contract management expertise need to be up skilled to improve management of claims with support from external expertise and resources.
- Business cases must be reviewed and supported by independent external expertise and resources.

During the execution phase, Eskom had to introduce a discipline of Knowledge management in mega projects. This assisted in clawing back time that had been lost due to scope changes as the two mega projects started sharing learning as the units were subsequently placed into commercial operation and across the two projects.

5.4. Propositions for managing knowledge in development of Megaprojects

The following are the three propositions that emerged from the results of this study.

5.4.1. Proposition 1: *Lack of adequately managing knowledge on mega infrastructure projects is one of the major causes of their failures.*

Analysis of the concepts and categories resulted in the formulation of the first proposition. Management should lay the foundation for the organisation to commit to manage knowledge and embed the social learning cycle within the development of Megaprojects in the Eskom I-Space. As explained by Boisot that the organisation's orientation to its knowledge assets is a function of where it believes its critical knowledge resides, either as tacit or explicit. Therefore, the willingness of the organization to embed its critical knowledge plays a critical role in developing Megaprojects. Regarding the management of knowledge, the below were most reported recommendations from respondents:

- (i) commitment from top management is an important element of a strong foundation for knowledge management;
- (ii) building the knowledge management capabilities of the organisation; and
- (iii) Inculcating knowledge management autonomy is a prerequisite for the effective management of knowledge.

The following table shows the results of the axial indexing for this proposition.

Table 13: Proposition 1: (i) Lack of adequately managing knowledge on mega infrastructure projects is one of the major causes of their failures.

Concept	Categories	Kappa
<p>Voluntary involvement of senior management in knowledge management</p> <p>Management's efforts are visible</p> <p>Strategic direction for knowledge management is set by senior management</p> <p>Frequent strategic knowledge reviews at senior management level.</p> <p>Focusing resources on strategic aspects of knowledge management</p> <p>Strengthening knowledge management support capability.</p> <p>Involving many levels of the organisation in knowledge management</p> <p>Establishing processes that will enhance organisation-wide knowledge dialogue.</p>	<p>Commitment from senior management</p> <p>Build the knowledge management capabilities of the organisation</p>	<p>Number of observed agreements: 87.50% of the observations</p> <p>Number of agreements expected by chance: 68.75% of the observations</p> <p>Kappa= 0.600</p> <p>95% confidence interval: From -0.133 to 1.333</p> <p>The strength of agreement is considered to be 'good'.</p>
<p>Allowing changes at business unit level.</p> <p>Multi-level organisational involvement.</p>	<p>Implant strategic knowledge management autonomy</p>	

5.4.1.1. Commitment from senior management

Continuous improvement of project performance has to be a cornerstone of the Eskom Social Learning Cycle in its I-Space to ensure a sustained, high-performance project environment. This accelerates the rate at which innovative solutions are developed, applied and embedded to deliver the project portfolio faster, at lower cost, and higher quality.

Management's involvement in knowledge management contributes to its effectiveness. While the electricity industry consists of monopolistic, vertically integrated entities, top management is involved in managing the organisation on a quantitative manner, focusing on financial indicators. While this is very important, top management should also in addition focus their efforts on qualitative aspects of the organisation, including the manner in which learning from past experiences is affecting its long-term future.

Top management is responsible for the development of the strategic direction of the organisation, thus becoming an important link in the process of setting the strategic direction within which knowledge management can be implemented.

In laying the foundation for effective knowledge management, top management should view their task as that of aligning the organisation strategically. An important element that has emerged from the analysis was that top management not only develops the strategic direction of the organisation, but their commitment to managing knowledge should become much more visible to the organisation. In 100% of the responses, communication by business unit managers was identified as an initiative to ensure effective implementation of knowledge management. Such visibility indicates the commitment of senior management to the knowledge management strategy that is to be implemented at lower levels.

In building a strong foundation for managing knowledge, top management should set the strategic direction of the organisation in such a manner that it emphasizes the commitment for overall strategic success of the organisation. This will include mapping the knowledge assets within the development of mega project, link to subject matter experts personal knowledge at different phases of the project. To lessen the complexity

of mega project once personal knowledge is identified it should be noted which of it is proprietary knowledge and how does this information flow up to common sense level, this will enable quick learning and non-repeat on similar mistake which can be sometimes costly

Management frequently should include knowledge management principles in their strategic reviews to monitor performance of the organisation. Respondents indicated that both quarterly, monthly and in a few instances, even daily control of information and knowledge should be taking place to ensure continuous improvement. At these review meetings, both lagging and leading indicators should be reviewed. Lagging indicators refer to the performance of the organisation in line with the predetermined strategic direction, while leading indicators are used to determine whether the current performance is still appropriate in the light of any new knowledge and information that may have emerged during the review period.

Through voluntary involvement, visible efforts, clear direction and continuous strategic reviews, knowledge management becomes a continuous process and not one that is triggered by episodic events. However, the commitment from top management alone does not ensure a strong strategic foundation for knowledge management if it is not enhanced by their commitment to building the knowledge management and continuous improvement capabilities of the organisation.

5.4.1.2. Building the knowledge management capabilities of the organisation

Building the knowledge management capabilities of the organisation includes the focusing of resources on the management of knowledge, the strengthening of the knowledge management support capability of the organisation, the involvement of many levels in the organisation in the management of knowledge, and enhancing organisation-wide knowledge management dialogue.

Focusing of resources on the strategic aspects of the organisation's knowledge management I-Space is required to enhance the foundation for continuous improvement. This is obtained through integrating the knowledge management activities of the entire organisation with effective integrated information systems

(indicated by 100% of respondents) and involving many levels of the organisation in knowledge management (indicated by 100% of respondents) (and not leaving the management of knowledge to a single department).

The involvement of the entire organisation in knowledge sharing is achieved through effective communication, linking continuous improvement through the effective management of knowledge to the incentive schemes that will result in an organisation-wide focus on the importance of knowledge management, consistent monitoring of activities to ensure alignment, and effective information sharing.

Management should invest in the knowledge management capabilities of the organisation through investment in information systems, knowledge codification and dissemination analysis processes and knowledge management analysis instruments. The use of knowledge management instruments such as documentation management processes and systems is found to be critical in the effectiveness of the development of projects. This is integrated to formulate the overall establishment of the knowledge support capability of the organisation. The entire organisation should be involved in continuous improvement through knowledge sharing and management through continuous two-way strategic communication.

Proper and effective communication is an element for effective knowledge sharing, and the inputs of all levels in the organisation should be used. Respondents indicated that regular feedback should be provided on all aspects pertaining to the development of projects through frequent review sessions. This will not only support project development, but will also build the longer-term strategic capabilities of the organisation. Frequent review sessions across all levels of the organisation enhance organisation-wide dialogue. Management should create the opportunities to discuss these lessons learnt and strategic issues on a frequent basis with employees.

5.4.1.3. Implant strategic knowledge management autonomy throughout the organisation

Management's commitment to knowledge management is also grounded in the level in which they implant a culture of sharing of knowledge within the organisation. This

involves the implementation of a robust knowledge management strategy that allows strategic changes to be made over the short-term, and also allows business unit managers autonomy in implementation of concepts of prior learning and knowledge throughout the organisation at business unit level. Robust knowledge management strategies operate on a short cycle time basis that encourages implementation to take place exactly as and when required. Allowing for a wider organisational input forms the cornerstone of the foundation for effective knowledge management.

The commitment to allow certain autonomous decisions to be made based on the outcomes of previous knowledge must be visible from top management in order to create and sustain such a foundation. Support for this proposition was found from both the empirical research and the literature. In addition to the areas already mentioned, this proposition is supported by Fuller, who indicates that communication from top management does not only build understanding, but also trust, which in turn, leads to the commitment needed to implement knowledge management strategy.¹⁴³

Lower levels within the organisation should be able to influence the organisation's operations and strategies. In this manner, the long-term success of the organisation becomes the responsibility of the entire organisation, and not only a few top managers, or a specific knowledge management department.¹⁴⁴ In addition, Bower finds that the relationship between organisational performance and autonomy in decision-making leads to higher performance in dynamic and complex environments. Some researchers have found that autonomous decision-making and forced choices build capabilities which subsequently will determine the long-term success of the organization.¹⁴⁵

5.4.2. Proposition 2: *Boisot's I-Space social learning cycle model can be used as a way to assess effectiveness of managing knowledge in order to identify improvement areas.*

The best knowledge management support system does not simply enable the effective management of knowledge; it increases both the efficiency and quality of the

¹⁴³ Fuller (1985:5),

¹⁴⁴ Andersen, T.J. 2000. *Strategic Planning, Autonomous Actions and Corporate Performance. Long Range Planning*. 185-197

¹⁴⁵ Bower, J.L. 1982. *Managing the Resource Allocation Process*. Boston, MA: Harvard Business School Press

development of projects, ensures current situations are addressed timeously, and links common solutions and risk reduction measures across projects and business units. The support systems should utilise information systems optimally.

Table 14: Proposition 2: (ii) Boisot's I-Space social learning cycle model can be used as a way to assess effectiveness of managing knowledge in order to identify improvement areas.

Concept	Categories	Kappa
Responsive systems. Address the current situation in systems. Data availability Develop scanning, codification and abstraction instruments	Information support.	Number of observed agreements: 85.71% of the observations Number of agreements expected by chance: 48.98% of the observations Kappa= 0.720 95% confidence interval: From 0.212 to 1.228 The strength of agreement is considered to be 'good'.
Data transparency Information sharing Link common solutions across projects	Integration support.	

5.4.2.1. Information support

Information support refers to responsive information systems that address the current situation and ensure data availability, as well as effectively using knowledge management instruments such as mentorships and training, peer review meetings, capturing processes and systems, knowledge analysis and lessons learnt, benchmarking, and scenario and risk management analysis. Information systems should provide for a wider organisational integration of knowledge that is responsive to the needs of the entire organisation.

The use of integrated information systems and continuous information gathering is a requirement for a robust knowledge management process. The lack of continuity as a

result of poor organisation-wide commitment to knowledge management is one of the main reasons for the requirements to changing the current knowledge management process. This can be resolved by maintaining effective information support that will resolve uncertainty that relates to the development of new mega infrastructure projects. However, knowledge management support systems should not be used as extrapolative planning systems, as this leads to the petrification of the system into simplistic, linear checklists and lock step approaches.

Both the quantity and quality of external information and the assessment of its potential and risks are important to sustain the effectiveness of the development of projects. To implant a robust knowledge management process within the organisation, this integration of external and internal data becomes an ongoing process. Continuous information gathering and analysis was indicated by 100% of respondents as elements of effective knowledge management, while 87% of respondents indicated that the ad hoc nature of the current knowledge management process at Eskom results in loss of continuity. Integration of external and internal information is achieved through effective information systems that link external data with internal data.

5.4.2.2.Integration support

Integration support refers to the process of integrating knowledge management strategically throughout the entire organisation, and specifically to information transparency, information sharing and linking project development solutions that are common to multiple projects and business units across the organisation. Continuous communication of lessons learnt and knowledge gained in projects developed in the past is an important element required for the effectiveness in the development of future infrastructure projects and organisation-wide commitment to the knowledge management process. Information transparency and information sharing ensure that the entire organisation has the opportunity to access information that could guide the development of future infrastructure projects.

5.4.3. Proposition 3: Managing knowledge can be achieved by specifically analysing how effectively knowledge/information is handled within, and how it flows across the six stages, mainly: scanning, codification, abstraction, diffusion, absorption and impacting of knowledge.

Beyond building a solid foundation for strategic planning, a robust knowledge management process is required. This includes an intensive and ongoing analysis of the situation that faces the organisation as well as the development of robust knowledge management approaches.

Table 15: Proposition 3: (iii) Managing knowledge can be achieved by specifically analysing how effectively knowledge/information is handled within, and how it flows across the six stages, mainly: scanning, codification, abstraction, diffusion, absorption and impacting of knowledge.

Concept	Categories	Kappa
Implement initiatives to resolve knowledge diffusion issues.	Develop robust diffusion, absorption and impacting of knowledge assets approaches	Number of observed agreements: 82.54% of the observations
Organisation-wide knowledge dialogue.		Number of agreements expected by chance: 48.00% of the observations
Continuous process, not episodic		<p>Kappa= 0.615</p> <p>95% confidence interval: From - 0.059 to 1.290</p> <p>The strength of agreement is considered to be 'good'</p>

The primary goal is to be able to identify and address particular issues that carry major implications for the development of projects and initiate options and initiatives to resolve them. This should ensure that the knowledge management process maintains an emphasis of integrating internal and external information, quantifying such information, ongoing strategic communication within the organisation and continuous risk assessment associated with continuous improvements in the project development context of the organisation.

5.4.3.1. Develop robust diffusion, absorption and impacting of knowledge assets approaches

A robust knowledge management process requires that the organisation implement initiatives to disseminate information required in the project development process on a continuous basis. Lack of continuity is an important reason for changing the knowledge management process. In order to effectively implement this, the process should cater for innovative and autonomous choices to be made by involving many levels within the organisation in the knowledge management process and in continuous information gathering and analysis.

Some of the knowledge within the Megaprojects can be valuable and sometimes not depending on how comprehensive codified and abstraction captures relevant knowledge. Through the results of mapping knowledge assets, the organisation can locate the diffusion level of the knowledge within the project for example taking a project through the project life cycle can be codified for a new engineer who has just joined the project team, over a period of time they should be a measure to see how much of the knowledge has become common sense over time. Boisot argues that once knowledge has been transferred from tacit to explicit knowledge it acquires a life of its own and can be diffused rapidly and extensively.

This proposition conforms to the works of Vriend who describes organisations as complex adaptive systems, who propose that a firm should achieve a balance between adaptation (promoting creativity) and integration (emphasising control and co-ordination of internal resources).¹⁴⁶

5.5. Summary

The combination of the two methods of data analysis used (content analysis and grounded theory) resulted in the formulation of a number of theoretical frameworks for knowledge management in the development of mega infrastructure projects at Eskom.

In summary, the development of infrastructure projects has increased in complexity and Eskom needs to be able to align itself effectively with the complex environment in which it operates. Effective management of knowledge becomes critical in order to

¹⁴⁶ Kochugovidian, S., and Vriend. N. J., 1998., *The Study of complex adaptive systems.*, 58

respond strategically to any environmental changes that may have an effect on the organisation. In achieving the proposed capacity expansion programme Eskom will need to develop and construct a number of mega infrastructure projects in South Africa. The concept of learning from prior projects and the diffusion of this knowledge between projects becomes an integral part of the success that the organisation will have to achieve with this massive expansion program

The integration of the concepts and categories analysed within the three propositions may provide the needed impetus for effective knowledge management.

CHAPTER 6

Conclusion

6.1 Introduction

The primary objective of this study to investigate how managing knowledge can influence the successful development of mega infrastructure projects has been largely met. Secondary objectives discussed in section 1.3 above have also been largely met. The critical literature review supports the argument that lack of effective managing knowledge is one of the main factors that can negatively affect performance of groups or organisations. Like so, lack of effective management of knowledge is one of the main reasons mega projects can fail or underperform from a scope, cost, quality and schedule perspective. The literature review also helped to uncover typical key knowledge areas considered in project management as well as a theoretical framework (Boisot's I-Space model) that can be used as an example to determine effectiveness of management of knowledge and how information flows through the six stages (i.e. scanning, codification, abstraction, diffusion, absorption and impacting) of his proposed I-Space model for social learning cycle. The literature review helped to frame some questions to ask respondents in the field research. Further, evidence from the field research further confirmed that managing knowledge effectively can largely affect delivery of mega infrastructure projects. Respondents were asked to share their experiences regarding managing knowledge on two Eskom mega infrastructure project case studies.

The results of the research led to the formulation of the following propositions as discussed earlier:

- (i) Lack of adequately managing knowledge on mega infrastructure projects is one of the major causes of their failures.
- (ii) Boisot's I-Space social learning cycle model can be used as a way to assess effectiveness of managing knowledge in order to identify improvement areas.

- (iii) Managing knowledge can be achieved by specifically analysing how effectively knowledge/information is handled within, and how it flows across the six stages, mainly: scanning, codification, abstraction, diffusion, absorption and impacting of knowledge.

Mega project teams could use Boisot's social learning cycle model to analyse in their own settings how well managing knowledge occurs. In relation to projects Medupi and Kusile, there are some areas of improvement regarding managing of knowledge as highlighted below and reported from respondents:

Scanning: Insights were not effectively gained from the previous build programme. There was no available diffused data from the previous era. This resulted in poor and inadequate time spent on front end planning that resulted in a lot of downstream changes to the projects during construction.

Codification: This has occurred to a limited extent in Eskom. One example is the Eskom PLCM framework developed to help guide project managers in the best way to develop mega infrastructure projects. Lessons on mega projects still need to be codified for benefit of future practitioners. In other words problem solving was given structure and coherence based on past and current insights and codification needs greater attention.

Abstraction: Newly codified insights from the mega infrastructure projects can be generalized to a wide range of situations and as current knowledge on projects has become more abstract.

Diffusion: These new insights are currently shared with the project management community in a number of forums including investment committees, project core teams, procurement committees, finance and engineering fraternities to mention a few. There could be more areas of improvement for greater diffusion of knowledge.

Absorption: The newly codified insights on mega infrastructure projects are being applied to a variety of current projects and this is producing new learning experiences.

Absorption is also occurring to some limited extent but is negatively impacted by a lot of senior executives involved during the inception of the current mega projects leaving Eskom for a number of reasons including retirement and seeking better job prospects. Some of this knowledge has become tacit or uncoded.

Impacting: Eskom's project management maturity has increased and a lot of the abstract knowledge has been embedded in concrete day-to-day practices. As an example a lot of artefacts, guides, procedures, process control manuals and policies to name a few have been developed to help future practitioners.

Other key considerations and improvements recommended in relation to the Eskom emanating from the case studies are discussed below.

6.2. Importance of effective management of knowledge for the long-term sustainability of Eskom

Managing knowledge is critical for any organisation since sustainability of any organisation in the current knowledge economy is dependent on building, maintaining and leveraging its knowledge. The ability of an organisation to harness and maximise knowledge management goes a long way in ensuring its survival especially in a globalised environment with increased talent and skills mobility.

Managing knowledge is therefore very important, because effective management of knowledge assist in the process of developing unique strategic capabilities by ensuring that proper skills are consolidated, leveraged and retained. It also empowers its employees with the context of their core responsibilities.

Eskom has had a history of cost overruns and project delays that could have been mitigated if management of knowledge was handled effectively. There was clear indication in the data that the respondents view knowledge management as of critical importance to the long-term success of the organisation.

The results indicate that there is a substantial agreement between respondents and the literature that the effective management of knowledge will ensure that organisations and groups will perform effectively. The consolidation and retention of skills was identified as an important element of knowledge management in Eskom. Knowledge Management principles and models are important aspects to be introduced in this build programme in order to ensure that an appropriate knowledge management environment is in place (aligned to Eskom standards) and that relevant knowledge is captured for future use.

6.3. Effectiveness of current knowledge management process at Eskom

The analysis from respondents accounts and the content analysis of related literature indicated clearly that the current Knowledge Management process in Eskom is ineffective.

Historically Eskom has not focused as much of its attention to the management of knowledge in project development as would be expected of a multi-billion Rand project development entity.

Eskom should take a proactive approach in the management of knowledge in project development to progressively improve its project body of knowledge rather than place the company in a risky and unsustainable position.

Eskom has lost an opportunity to apply lessons learnt from previous experiences to improve on current new build projects. This should be a lesson not to be repeated for the next mega projects. There is also a history of project managers not documenting their experiences or not loading relevant information in Eskom's central repository system or similar tools at their disposal. These shortcomings should be addressed. There is also a need to better share knowledge gained from departments, project managers.

6.4. Processes required to overcome the major issues with the current process at Eskom

The following table provides the results of the process required to overcome major issues with knowledge management at Eskom.

Table 16: Process required to overcome major issues with Eskom's knowledge management process

Concept
Increase surveillance and control to ensure compliance
Include as a performance measure
Involvement of all users and effective stakeholder management process
Proper access to information and knowledge to form part of induction process and information sharing sessions
Relevant training and in house support.
Develop a capturing process and tool/system which is user friendly to use and easily accessible

6.5. Methodology to abstract and diffuse knowledge at Eskom

The analysis of responses and the content analysis of the selected literature (as per the application of grounded theory) indicated that Eskom need to apply the following in order to ensure that knowledge is effectively abstracted and diffused.

Table 17: Methodology to abstract and diffuse knowledge at Eskom

Concept
Staged approach over each phase of the life cycle of the project
Peer meetings and workshops
Mentorship and training

Eskom currently applies project post-mortem and project conclusion sessions but the disadvantage is that by then, most of the people involved in the project have been

demobilised and the knowledge management exercises through project post-mortem sessions becomes academic. This can be overcome if project sessions are held with the view of sharing knowledge, throughout the life cycle stages of the project.

Project managers have a crucial role to play. They need to be empowered, through sufficient and adequate resources, but they also need to be trained to use the proper tools and processes and no digression from this should be allowed.

Knowledge management systems should be specific in terms of lessons learnt, not just a matter of loading and storing documents. Meetings with peers before starting critical stages of the project are an important element. This would allow the project manager to put flags at specific stages and to research the actual details in the central repository system or any other relevant system.

6.6. Contributions of the study

The electricity industry in South Africa is currently in transition. Substantial contextual changes are expected to occur that will see the local industry propelling towards the levels of their global counterparts. Throughout this study, it has been emphasized that Eskom cannot rely on traditional knowledge management processes to guide them through the complexity and volatility inherent in the development of new mega infrastructure projects.

This study has contributed by offering an integrated view to knowledge management processes as applied to the development of Megaprojects.

The critical contribution made by this study is entrenching the concept of managing knowledge as an organisational wide accountability with a need to be driven by top management.

6.7. Further research

This study has attempted to isolate the many issues of managing knowledge that are evident in the development of mega infrastructure projects. Against the background of the objectives of this study, attention has been given to managing knowledge as a

process. Two areas that may need further attention are the development of strategic planning models for knowledge management to occur in real-time and skills and resource optimisation models for the implementation of effective knowledge management processes.

In this regard, it is recommended that research is conducted:

- (i) to develop analytical models that can be used for the implementation of knowledge management processes in real-time.
- (ii) to determine the specific changes required in the skill base of organisations moving towards an integrated knowledge management situation and to develop a model for the enhancement of skills transfers to enable a sustainable approach to project development over time.

Bibliography

- AfDB (2009). *Medupi power project appraisal report*. Available from: http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/South_Africa_-_Medupi_Power_Project_-_Appraisal_Report.pdf. (Accessed 10 November 2015)
- Amit, R. and Zott, C. (2001) (December). *Value Creation in E-Business*. Strategic Management Journal. 22, (12), New York: Wiley
- Andersen, T.J. (2000). Strategic Planning, Autonomous Actions and Corporate Performance. *Long Range Planning*. 33
- Bandura, A., 1977. *Social Learning Theory*. Englewood Cliffs, Prentice-Hall, New York
- Bakker, R., Cambré, M., Korlaar L., Raab J., 2011. *Managing the project learning paradox: a set-theoretic approach toward project knowledge transfer*. International journal of project management, 29 (2011), pp. 494-503
- Biro, F, et al 2015 *World Energy Outlook 2015*. International Energy Agency, chapter 8 Power Sector Outlook. 307
- Boisot M.H. (1998). *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. Oxford University Press, May 1998 ISBN: 0198290861
- Boisot, M.H. (2010). *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. Oxford.
- Boisot, M. H., Canals, A. G. U. S. T. Í., & MacMillan, I. (2004). *Simulating I-Space (SIS): An agent-based approach to modelling knowledge flows*. Working papers of the Sol C. Snider Entrepreneurial Research Center, Wharton School, University of Pennsylvania.
- Max Boisot, Markus Nordberg, Saïd Yami, Bertrand Nicquevert. 2011. *Collisions and Collaboration: The Organization of Learning in the ATLAS Experiment at the LHC*. Oxford University Press, ISBN: 9780199567928. pp 39
- Bassi, A. 2014: *Project management: human and organizational learning. Human Capital without Borders: Knowledge and Learning for Quality of Life*. Management, Knowledge and Learning International Conference, Portoroz, Szlovénia, 2014. június 25-27. pp. 460; 462.
- Botha, A., Kourie, D., and Snyman, R. (2008). *Coping with Continuous Change in the Business Environment, Knowledge Management and Knowledge Management Technology*. Chandice Publishing Ltd
- Bower, J.L. (1982). *Managing the Resource Allocation Process*. Boston, MA: Harvard Business School Press

- Bresnen M., Edelmanb, L., Newell, S., Scarbroug, H., Swan, J. (2003). *Social Practices and the Management of Knowledge in Project Environments*. International Journal of Project Management. 21. 157-166
- Braitiana C, 2015, *Organizational Knowledge Dynamics: Managing Knowledge Creation, Acquisition*, IGI Global. pp103
- Brown, J.S. and Duguid, P. (1991). *Organizational Learning and Communities of Practice: Towards a Unified View of Working, Learning, and Innovation*. The Institute of Management Sciences. Organization Science. 1991. 2(1): pp40-57
- Bruzeliuss, N., Flyvbjerg, B. & Rothengat TER, W. 2002. *Big decisions, big risks. Improving accountability in Megaprojects*. Transport Policy, 9, pp143-154.
- Bryman, A. (1988). *Quantity and Quality in Social Research*. London: Unwin Hyman
- Bukowitz, W., and Williams, R. (1999). *The Knowledge Management Fieldbook*. Financial Times/Prentice Hall
- Burgelman, R.A. (1983). *A Model of the Interaction of Strategic Behaviour, Corporate Context, and the Concept of Strategy*. Academy of Management Review. 8
- Burke, R. (2007) *Introduction to project management*. London: Burke Publishing Company.
- Bryman, A. and Bell, E. (2011). *Business Research Methods*. Third Edition. Oxford: Oxford University Press.
- Cacciatori, E., Tamoschus, D. and Grabner, G. (2012). *Knowledge Transfer Across Projects: Codification in Creative, High-tech and Engineering Industries*. Management Learning. 43, pp 309
- Chakravarthy, B.S. and Lorange, P. (1984). *Managing Strategic Adaptation*. Options in Administrative Systems Interfaces. The Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania, Vol 14, (1)
- Chappell, T. (2012). *Plato on Knowledge in the Theaetetus*. The Stanford Encyclopedia of Philosophy. (Winter 2012 Edition)
- Choo, C.W. (1995). *Information Management for the Intelligent Organization: Roles and Implications for the Information Professions*. 1995 Digital Libraries Conference (March 27-30, 1995; Proceedings pp. 81-99). Singapore: National Computer Board of Singapore.
- Choo, W. C. (2002). *Information Management for the Intelligent Organisation: The Art of Scanning the Environment*. 3rd edition. ASSIST Monograph series. American Society for Information Science and Technology. Medford, NJ
- Civi, E. (2000). *Knowledge Management as a Competitive asset*. Marketing Intelligence and Planning. Marketing Intelligence & Planning, Vol. 18 (4) pp166-174
- Cohen, J. A. (1960). *Coefficient of Agreement for Nominal Scales*. Educational and Psychological Measurement. New York University, Vol XX , (1).

- Cokayne, R. (2013). *Eight months lost in construction of Medupi*. Available from: <http://www.iol.co.za/business/news/eight-months-lost-on-construction-of-medupi-1.1577876#.VkLxzbcrlIU>. (Accessed 11 November 2015)
- Cook, J., & Brown, J. S. (1999). *Bridging Epistemologies: The Generative Dance between Organizational Knowledge and Organizational Knowing*. *Organization Science*, 10 (4), pp 381-400.
- Daft, R.L. and Lengal, R.H. (1986). *Organisation Information Requirements, Media Richness and Structural Design*. *Management Science*, 32(5), 554–71
- Davenport, T. H. and Prusak, L. (1998). *Working Knowledge. How Organisations Manage What They Know*. Cambridge MA. Harvard Business School Press
- Davenport T.H. & Prusak, L. (2000). *Working Knowledge. How Organisations Manage What They Know*. Cambridge MA. Harvard Business Review Press; 2nd edition (May 2000) pp 43-57
- De Marrais, K. (2004). *Qualitative interview studies: Learning through experience*. In K.deMarrais & S.D.Lapan (Eds.), *Foundations for research*, pp. 51-68. Mahwah, NJ: Erlbaum
- DeFillippi, R.J. (2001). *Project-based Learning, Reflective Practices and Learning Outcomes*. *Management Learning*. SAGE Publication 2001; 32(1): pp 5–10
- Deming, W.E. (1990). *Sample Design in Business Research*. New York: Wiley-Interscience Publication
- Easterby-Smith, M. Crossan, M. Nicolini, D. (2000) *Organizational learning: debates past, present and future*. *Journal of management studies*, Vol 37, pp. 783-796
- Eisenhardt, K.M. (1989). *Building Theories from Case Study Research*. *Academy of Management Review*. 14
- Elkjaer, B. 2003. *Social learning theory: learning as participation in social processes*. In Easterby-Smith, M. and Lyles, M. (Eds.). *The Blackwell handbook of organisational learning and knowledge management*. Malden/Oxford, UK: Blackwell publishers, The Blackwell, pp 43
- Empson, L. (2001). *Knowledge Management in Professional Service Firms* pp 814
- ENCA (2015). *Kusile and Medupi dogged by further delays*. Available from: <https://www.enca.com/south-africa/kusile-and-medupi-power-stations-dogged-further-delays>. (Accessed 11 November 2015)
- Engwall, M. *No project is an island: linking projects to history and context*. *Research policy*, 32, (5) pp. 789-808
- Eskom (2015). *Kusile power station project*. Available from: http://www.eskom.co.za/Whatweredoing/NewBuild/Pages/Kusile_Power_Station.aspx. (Accessed 12 November 2015)

- Eskom (2011). *Cop 17 fact sheet*. Available from:
http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/Kusile_and_Medupi.pdf. (Accessed 11 November 2015)
- Eskom (2011). *Eskom factor*. Available from:
<http://www.eskom.co.za/OurCompany/SustainableDevelopment/Documents/EskomFactor.pdf>. (Accessed 12 November 2015)
- Eskom (2014). *Fact sheet: Eskom power station project*. Available from:
http://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Documents/NB_0002MedupiFactSheetSept2013.pdf. (Accessed 10 November 2015)
- Eweje, J., Turner, R., & Müller, R. (2012). *Maximizing strategic value from Megaprojects: The influence of information-feed on decision-making by the project manager*. International Journal of Project Management, 30(6), pp. 639-651.
- Financial Mail (2015). *Exxaro/Eskom: paying for nothing*. Available from:
<http://www.financialmail.co.za/fmfox/2015/05/07/exxaroeskom-paying-for-nothing>. (Accessed 11 November 2015)
- Fleiss, J. (1971). *Measuring Nominal Scale Agreement among Many Raters*. Psychological Bulletin. 76, (5)
- Fleiss, J. (1981). *Statistical Methods for Rates and Proportions*, New York: Wiley.
- Flyvbjerg, B., Bruzelius, N. & Rothengat TER, W. 2003. *Megaprojects and Risks: An Anatomy of Ambition*. Cambridge.
- Galbraith, J.R. (1974). *Organisation Design: An Information Processing View*. Interfaces, 4(3), pp. 28–36
- Gamble, P.R. and Blackwell, J. (2002). *Knowledge Management: A State of the Art Guide*. Kogan Page Business Books
- Glaser, B. and Strauss, A. (1967). *The Discovery of Grounded Theory*. New York: Aldine de Gruyter
- Greater Pacific Capital LLP, 2010. *The Role of Mega-Scale in Building Industrial Power: Some of China's Top Engineering and Construction Feats*
<http://greaterpacificcapital.com/the-role-of-mega-scale-in-building-industrial-power-some-of-chinas-top-engineering-and-construction-feats/> Accessed December 2012
- Kochugovidian S and Vriend. N J 1998, *The Study of complex adaptive systems*. Independent review. VIII, n1 Summer, pp. 58
- Hansen, M.T., Nohria, N. and Tierney, T. (1999). *What's Your Strategy for Managing Knowledge*. Harvard Business Review, 77, 106
- Hartmann, D. (1977). *Considerations in the Choice of Inter-Observer Reliability Estimates*. Journal of Applied Behaviour Analysis. 10, (1)
- Haynes, W. 2002. *Transportation at the millennium: In Search of a Megaproject Lens*. Review of Policy Research, 19, pp.62-64.

- Horvath, J.A. (2000). *Working with Tacit Knowledge*. IBM Institute for Knowledge Management
- Hoffer, J., Jeffrey, A., George, J. F., Valacich, F.S. (2002) *Modern Systems Analysis and Design*. Pearson Education, Inc. Prentice Hall.
- International Energy Association (2015). *World energy outlook*, www.iea.org accessed February 2016
- Keegan, A. and Turner, J. R. (2001). *Quantity Versus Quality in Project-based Learning Practices*. *Management Learning* 32(1): pp.77–98.
- Khatleli, N (2016) *The Impediments to efficient megaproject implementation in South Africa*. In: PW Chan and CJ Neilson (Eds) *Proceeding of the 32rd Annual Arcom Conference 5-7 September 2016 Manchester UK*, Association of Reserchers in Construction Management Vol 2, 803-812 <http://www.arcom.ac.uk/-docs/proceedings/1bd9d0e800faf4e2f0b894f947857286.pdf> (Accessed 2 April 2017)
- Knowledge Today (2015). *Ultra Megaprojects*. Available from: <http://www.gktoday.in/blog/ultra-mega-power-projects/>. (Accessed 12 November 2015)
- KPMG, 2013, *Insights*, Global Information Magazine / issue number 4, pp.7-45
- Landis, J. and Koch, G. (1977). *The Measurement of Observer Agreement for Categorical Data*. *International Biometrics Society*. Vol 33 pp 159-174
- Lelic, S. (2002). *Managing Knowledge to Manage Risk*. *Knowledge Management*, Vol. 6 No. 1 available at: www.kmmagazine.com
- Locatellia, G., Littaub, P., Brookesc, N.J., & M. Mancinid, M. (2014). *Project characteristics enabling the success of Megaprojects: an empirical investigation in the energy sector*. Available from: http://ac.els-cdn.com/S1877042814021612/1-s2.0-S1877042814021612-main.pdf?_tid=f2d5d6b4-87a1-11e5-99c8-00000aab0f6b&acdnat=1447156713_307679ee9d091367514ac6e405234189. (Accessed 10 November 2015)
- Lundu C.M. (1998). *The Library in the Service of Society: Philosophical Foundations*. Ndola. Mission Press
- Mintzberg, H. (1987). *Crafting Strategy*. *Harvard Business Review*. 65, (4)
- Merriam, S.B. (2009). *Qualitative research: a guide to design and implementation*: Jossey –Bass, A Wiley Brand, pp 137
- Martin, P, Y & Turner B, A, 1986 *Grounded Theory and organization research*. *The Journal of Applied Behavioral Science*, 22 (2) pp.141-157
- Naidoo S., 2008, *The I-Space as an evolutionary framework for an economics of knowledge. A comparison with generalized Darwinism*. Thesis submitted to the Faculty of Art and Social Sciences at Stellenbosch University

- Neuman, F., Bruinsma, W. and Flor, G. A. (2003). *The Role of Information Management in Development*. Available at [www./interSard.org/home/materials/paper//m.pdf](http://www.interSard.org/home/materials/paper//m.pdf). Accessed 29 December 2012
- Neef, D. (2005). *Managing Corporate Risk Through Knowledge Management*. The Learning Organization. Vol. 12 No. 2, 2005. Emerald Group Publishing Limited. Chester, New Jersey, USA
- Noda, T, and Bower, J. L. (1996). *Strategy-making as Iterated Processes of Resource Allocation*. Strategic Management Journal. 17
- Nonaka, I. (1994). *Theory of Organizational Knowledge Creation*. Organizational Science, vol 5, no.1
- Noorderhaven, N, Harzing, A.W, 2009, *Knowledge-sharing and social interaction within MNEs*. Journal of International Business Studies, 40 (2009), pp. 719-741
- Normann, R., in Pennings, J.M., (ed.) (1985). *Organisational Strategy and Change: New Views on Formulating and Implementing Strategic Decisions*. San Francisco: Jossey-Bass
- OANDA (2015). *Historical exchange rates*. Available from: <http://www.oanda.com/currency/historical-rates/>. (Accessed 11 November 2015)
- O'Dell, C. (2004). *The Executive's Role in Knowledge Management*. APQC Publications. Houston 54-74
- Parliamentary Monitoring Group (2011). *Labour issues at Medupi and Kusile power stations: Eskom briefing*. Available from: <https://pmg.org.za/committee-meeting/13108/>. (Accessed 11 November 2015)
- Patton, M.Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Polity Press
- M. Easterby-Smith, M. Lyles (Eds.), *Plaskoff Intersubjectivity and community building: learning to learn organizationally*. Handbook of Organizational Learning and Knowledge Management, Blackwell Publishing, Malden, MA (2003), pp. 161-184
- Polanyi, M. (1966). *The Tacit Dimension*. London, Routledge & Kegan Paul, 1966
- Prencipe, A. and Tell, F. (2001). *Inter-project Learning: Processes and Outcomes of Knowledge Codification in Project-based Firms*. Research Policy. 30: pp.1373 –1394
- Project Management Institute (2000). *A guide to the Project Management Body of Knowledge* (PMI). (<http://www.pmi.org>) last viewed 26th May 2014.
- Project Management Institute (1996). *A Guide to the Project Management Body Knowledge*. 2nd Edition, PMI website (<http://www.pmi.org>) last viewed 26th May 2014.

- Project Management Body of Knowledge, *A guide to Project Management Body of Knowledge*. Fourth Edition, http://www.euroi.ktu.lt/CBDCB21E-E3D4-4747-99CC-3133C8085000/FinalDownload/DownloadId-321810EEA1073DF6EBC4A4C62305EDFF/CBDCB21E-E3D4-4747-99CC-3133C8085000/lt/images/stories/Paskaitos/pmbok_2008_print.pdf, viewed 1 April 2015
- Reich, B.H., Gemino, A., Sauer, C. (2014): *How knowledge management impacts performance in projects: An empirical study*. International Journal of Project Management, 32/4. pp. 590-602.
- Ruuska, I., Art To, K., A Altonen, K. & Lehtonen, P. 2009. *Dimensions of distance in a project network: Exploring Olkiluoto 3 nuclear power plant project*. International Journal of Project Management, 27, pp142-153.
- Senaratne, S. and Sexton, M. (2008). *Managing Construction Project Change: a Knowledge Management Perspective*. Construction Management and Economics (October–December 2008) 26, pp.1303–1311. Taylor & Francis
- Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students*. 6th edition. Harlow: Pearson Education. Pp 77
- Sanderson, J. 2012. *Risk, uncertainty and governance in Megaprojects: A critical discussion of alternative explanations*. International Journal of Project Management, 30, pp.432-443.
- Senge, P.M., 1992. *The Fifth Discipline The art and practice of the learning organisation*. London: Century Business; pp 371
- Simon, H.A. (1957). *Administrative Behaviour: A Study of Decision-Making Processes in Administrative Organisation*. 3rd edition, Collier Macmillan Publishers, New York. pp 499-500
- Shannon, C, Weaver, W, *The Mathematical Theory of Communication* (Urbana: University of Illinois Press 1949)
- Smith, V., J. (2011). *It's the relationship that matters: a qualitative analysis of the role of the student/tutor relationship in counselling training*. Counselling Psychology Quarterly, 24 (3). pp. 233-246.
- Snowden, D. (2002). *Complex Acts of Knowing: Paradox and Descriptive Self-awareness*. Journal of Knowledge Management, 6(2), 100–110
- Söderlund, J. – Vaagaasar, A.L. – Andersen, E.S. (2008): *Relating, reflecting and routinizing: Developing project competence in cooperation with others*. International Journal of Project Management, 26/5. pp. 517-526
- Stone, G. (2002). *Customer Relationship Management*. Atlanta. Paperback, Student Edition of Textbook) LOMA
- Strauss, A. and Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. London: Sage

- Stoddart-Stones, R. 1988. *Development of project management systems for major projects*. International Journal of Project Management, 6, pp. 34-38.
- Sturup, S. 2009. *Megaprojects and Governability*. World Academy of Science, Engineering and Technology, pp. 54.
- Tah,J. H. M. and Carr, V. (2001). *Towards a Framework for Project Risk Knowledge Management in the Construction Supply Chain*. Advances in Engineering software 32. Elsevier
- Thelen, E. and Smith, L.B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*. Cambridge, MA.: The MIT Press
- Turan, E. McClean, E. and Wetherbe, J. (2003). *Information Technology for Management: Making Connections for Strategic Advantage*. John Wiley New York
- Turner, B. A. (1983). *The Use of Grounded Theory for the Qualitative Analysis of Organisational Behaviour*. Journal of Management Studies. pp. 20
- Tushman, M.L. (1978). *Technical Communication in Red Laboratories: The Impact of Project Work Characteristics*. Academy of Management Journal, 21(4), pp. 624-45
- Vikas P., Prabhakar T., Sharma, N.K., Tiwari, A.N., & Singh, M.K. (2013). *Ultra Mega Power Projects: additional restructural capacity to existing Indian grid system*. Available from: <http://www.ijrte.org/attachments/File/v2i1/A0506032113.pdf>. (Accessed 10 November 2015)
- Welman, J.C. and Kruger, S.J. (1999). *Research Methodology for the Business and Administrative Sciences*. Oxford: University Press
- Yang, J. (2004). *Job-related Knowledge Sharing: Comparative Case Studies*. Journal of Knowledge management. 8 (3) pp. 118-126
- Yin, R. K. (1989). *Case Study Research: Design and Methods*. London: Sage. pp 8-15
- Yin, R. K. (2009). *Case Study Research: Design and Methods*. 4th edition. London: SAGE Publications.
- Zhai, Li, Yanfei Xin, and Chaosheng Cheng. *Understanding the value of project management from a stakeholder's perspective: Case study of mega-project management*. Project Management Journal 40.1 (2009): pp. 99-109

APPENDIX 1 - SEMI-STRUCTURED INTERVIEW GUIDE

B.M. Moloi
UNIVERSITY OF STELLENBOSCH
MANAGING KNOWLEDGE IN MEGA INFRASTRUCTURE PROJECTS
QUESTIONNAIRE FOR MINI DISSERTATION

Telephone : +27-11-800 3975
Cell Phone: +27-73-023 6465

E-Mail: moloibm@eskom.co.za

P.O.Box 1091
Johannesburg
2000

Questionnaire designed by B.M.Moloi

Date: 10 November 2012

GENERAL NOTES TO RESPONDENT:

ALL INFORMATION WILL BE HANDLED STRICTLY AS
CONFIDENTIAL AND

THE INFORMATION WILL ONLY BE DEALT WITH AS INTENDED
FOR THE PURPOSES OF THE EMPIRICAL RESEARCH
COMPONENT FOR A THESIS TOWARDS A MASTERS DEGREE AT
THE UNIVERSITY OF STELLENBOSCH.

THANK YOU FOR YOUR TIME.

A. DEMOGRAPHIC INFORMATION
--

Name of respondent : _____

Department: _____

Position: _____

Telephone Number: _____

Date of interview: _____ / _____ / _____

QUESTION 1

In your view, how important is effective management of knowledge for the long-term sustainability of Eskom?

QUESTION 2

How effective do you evaluate the CURRENT knowledge management process pertaining to the development of Megaprojects in Eskom? (1=poor, 5=excellent)

QUESTION 3

Main reasons for evaluation in question 2.

QUESTION 4

How should knowledge be transferred between various Megaprojects that are being developed in Eskom?

QUESTION 5

What are the major issues relating to the current knowledge management process as applied to Megaprojects at Eskom?

QUESTION 6

In your view what is the impact of these issues on the effectiveness of the development of future Megaprojects at Eskom?

QUESTION 7

What is required in order to overcome these gaps identified in question 5?

QUESTION 8

Should knowledge management be one of the strategic initiatives of Eskom? Why? Why not?

YES	NO
------------	-----------

QUESTION 9

What is the impact of ignoring knowledge management on the long-term success of Megaprojects as being developed by Eskom?

QUESTION 10

What are the elements of an effective knowledge management process in your view?

QUESTION 11

Who in your view need to be accountable for effective knowledge management in regard to Megaprojects at Eskom?
