A NEW BLUEPRINT FOR NEW DIGITAL TECHNOLOGY ADOPTION IN THE MINING INDUSTRY USING A SYSTEMS THINKING APPROACH

Xiang Fan

A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Masters of Science in Engineering.

Johannesburg, 2019

DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted for the Degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

.... Day of...............................

(Signature)

Contents

ABSTRACT

Successful adoption of new technologies is critical for the improvement of efficiency and the enhancement of health and safety in South African mining industry operations. However, the process of new digital technology adoption in the South African mining industry has been slow and difficult. This research is aimed at addressing some of the problems associated with the process. As part of this research, a new blueprint has been developed to guide the commissioning entity through the entire process of new digital technology adoption and installation. The new blueprint will provide capability to monitor the quality of the work during adoption, as well as assessment of the outcome of the adoption by measuring the level of compliance for every activity performed by the commissioning entity during the adoption. The reliability of the new blueprint was verified by assessing the performance of the Wits Mining Institute (WMI) in its installation project of the Schauenburg system. The outcome of the new blueprint verification reveals poor planning and inadequate preparation during the installation of this project. The outcome also indicates that application of the new blueprint will reduce the problems associated with the adoption and speed up new digital technology adoption and its installation for better functionality.

ACKNOWLEDGMENTS

I would like to express my appreciation to my supervisor, Professor Fred Cawood, who has put a tremendous amount of efforts to assist me through useful comments, remarks and learning process of this dissertation. I would also like to thank Michal Dabrowski for generous assitance in putting pieces together. Furthermore, I would like to thank Sibanye-Stillwater for their generous sponsorship and all the participants for sharing their knowledge and time in my survey. Finally, I would like to thank my loved one – Dr. Lizhi Huang who has supported me through the entire process bountifully. I would not have been able to complete this dissertation without her contributions and sacrifice.

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

$	US dollar
%	Percent

LIST OF ACRONYMS

MIMACS II	Mine Wide Integrated Monitoring and Control System II
WMI	Wits Mining Institute
OEM	Original Equipment Manufacturer
WITS	University of the Witwatersrand
Wits DigiMine	Sibanye-Stillwater Digital Mining Laboratory
CMMS	Centre for Mechanised Mining Systems
CSMI	Centre for Sustainability in Mining and Industry
ICT	Information and Communication Technology
PGM	Platinum Group Metals
GDI	Gas Detective Instrument
JSE	Johannesburg Stock Exchange
MPI	Mine lens Productivity Index
NUM	National Union of Mineworkers
TRA	Theory of Reasoned Action
TAM	Technology Acceptance Model
UTA	Unified Theory of Acceptance
SOI	Systems of Interest
INCOSE	International Council on Systems Engineering
PwC	PricewaterhouseCoopers

SIPA	Swaziland Investment Promotion Authority
CIMA	Chartered Institute of Management Accountants
RFID	Radio Frequency Identification
UTAUT	Unified Theory of Acceptance and Use of Technology
SDLC	Systems Development Life Cycle
SOP	Standard Operating Procedure
UPS	Utility Power Supply

1 Introduction to the research

South Africa is a country with abundant mineral resources. Hence, such abundance greatly aided development of the nation's economy. However, as depth of mining operations increased, operational costs rose and operational efficiency decreased. The South African mining industry needs to embrace new technologies [1] to address the problem. Such technology includes digitalization, which is being progressively implemented at a global level. Although the South African mining industry is following suite, it can do more, which is especially diffcult with its harsh underground conditions. Mining firms are aware of the benefits and availability of new technologies to their business. However, they are still struggling to adopt[2] new technologies into the overall mining value chain in order to gain full potential of such technologies. The problem is that traditional technology-adoption practices often lack broader perspectives such as multiple objectives and stakeholders. *Systems thinking*[3] is a technique that enables analysis of such broader perspectives. This dissertation has developed a new blueprint for new-technology adoption in the mining industry by using a *systems thinking* approach to guide the commissioning entity[4]. This was done as follows:

Case studies on the Schauenburg MIMACS II system reveal important lessons learned by WMI. The outcome of the case study was used as input for the development of the new blueprint. The validity of the new blueprint was tested through a review on the installation project of the Schauenburg MIMACS II system. The entire new blueprint was used as a checklist to review the performance of the WMI during the installation project. Data that was generated during the verification was analysed and interpreted. The outcome of the data

[1] New digital technology refers to digital technologies or digital technology systems that are designed recently

[2] Adoption and installation of technology system into the vale chain means the same in this dissertation

[3] **Systems thinking** is an analysis method that enables broader understanding of a system by examining linkages and interactions between systems and system's components

[4] Commissioning entity refers to an organization or entity who is willing to adopt and install the technology system

interpretation shows the installation project was not well planned and inadequate preparation was carried out for the installation project. Major defects include a low level of compliance with the new blueprint and omission of effective measurements to monitor the progress and quality of the installation project. The outcome of the data interpretation also assisted analysis of the new blueprint, enabling the new blueprint to be improved accordingly.

In summary, this research found that an optional and accelerated installation-process could be experienced by developing and implementing a new blueprint for the installation of complex new digital technologies. The new blueprint also allows the commissioning entity to reach full functionality and gain potential benefits of new technologies earlier.

1.1 Problem statement

The mining sector can increase its contribution to the economy by improving efficiency of mining operations. Indeed, low operational efficiency is one of the critical challenges faced by the mining industry. Fortunately, mining firms have identified and are aware of the potential benefits and availability of new technologies for mining operations. However, as introduced earlier, the process of adoption of new technologies is still slow and stressful. Lack of investment is only one of the causes of the dilemma faced by the mining industry; another is achieving the expected benefits following adoption. Past experience in new digital technology adoption has indicated that two main stakeholders are involved in the adoption process, namely: the supplier of the technology system; and the commissioning entity who purchases and installs the technology system. Problems associated with each stakeholder are discussed separately in this section.

Problems associated with new digital technology suppliers

Generally, Vendors and OEMs are the main sources for supplying new digital technology systems. On occasion, marketing of such systems could overstate capability by not clearly defining limitations. Such may emphasize designed capacity and potential performance without taking into consideration for the actual needs and complications of commissioning entities. For example, new digital technology is often designed and tested in well-controlled environments, whereas environments where the technology will be installed and operated may be complex and harsh. Furthermore, different suppliers may use different ICT platforms to develop their products. Hence, compatibility may become a problem between different products purchased from different suppliers. The following are some factors that may contribute to sub-optimal performance or adoption failure of new technologies.

- Misunderstanding the needs and expectations of the commissioning entity;
- Poor knowledge of the commissioning entity's actual capacity to prepare for the installation;
- Poor understanding of needs for training causing inadequate training, further reducing the commissioning entity's capability in maintaining the system; and
- Poor knowledge of the commissioning entity's budget for procurement and continuous functionality of the system.

Problems associated with the commissioning entity

Generally, an adoption project of a new digital technology consists of three steps. Each step corresponds to a critical phase of the adoption. Potential problems that are associated with each phase in the adoption process are listed below.

- Pre-installation[5] phase

  The main objective of this phase is to identify an appropriate technology based on the commissioning entity's capacity and needs. On occasion, the commissioning entity could

[5] In the new blueprint, adoption process is divided into three phases to complete according to the progress of installation. There are pre-installation, installation and post-installation phases.

fall victim to inadequate supplier-presentation of actual capacity of products and services. The entity may also be misdirected by attractive prices offered by suppliers for their products and services. Such may cause an inappropriate new digital technology to be chosen by the commissioning entity. The entity may also incorrectly estimate its needs for a new digital technology by incorrectly estimating its own requirements. Lack of proper legal agreements and contracts between the commissioning entities and suppliers may also lead to the misunderstanding of the commissioning entity's needs and new digital technology supplier's actual capacity.

- Installation phase

  Poor planning and poor resource management may result in resources required by the supplier not being ready for the day of installation. Poorly guided and monitored installation processes may also cause project delay. Delay of the installation project leads to project overrun in schedule and cost. Generally, the main system consists of multiple sub-systems, all with different installation requirements. Thus, a holistic approach which considers all interfaced, related and dependent systems is required when completing the installation process. Lack of a holistic approach for the adoption process may result in the entity being unable to detect the potential interactive, interference and compatibility problems between newly adopted technologies and existing systems in the commissioning entity. Lack of a holistic approach from the managerial perspective may result in only part of the commissioning entity being considered when dealing with the impact on the entire entity after the adoption of a new digital technology.

- Post-installation phase

  After the adoption is completed, the commissioning entity needs to assess the outcome of the adoption by comparing the actual performance of the new digital technology against the needs and expectations defined in the pre-installation phase. The following are problems that may occur in the post-installation phase.

- Lack of or inadequate of a user-manual or guidance-documentation covering system calibration and testing further cause system malfunctions;
- Inadequate after-sales support affecting continuous functionality and long-term operation of the new digital technology;
- Inadequate training resulting in incompetent system-operators and inefficient working crews; and
- Inadequate training programme, reducing capability of user-maintenance of the new digital technology. Such may also cause sub-optimal use of the system in emergency situations.

1.2 Research objective

The research objective is to develop a new blueprint with the application of a systems thinking (holistic) approach and information extracted from the case study on WMI's Schauenburg MIMACS II system installation project. Two fundamental requirements are set for the new blueprint.

- The new blueprint needs to be able to guide the commissioning entity through a new digital technology adoption process smoothly and effectively; and
- The new blueprint needs to be able to monitor the adoption process. In addition, the new blueprint also needs to measure the outcome of the adoption.

1.3 Research questions

The utilization of new technologies in the mining industry has been a major driving force to boost the productivity of mining operations. Technology has the capability to break through production bottlenecks when human physical strength has reached its limits. The mining industry has never stopped seeking panaceas to improve productivity; from introduction of pneumatic drilling equipment in the early 20th century to the latest automated technology systems. Yet it has proven difficult for mining firms to adopt digital technology systems into existing mining value chains and the long-term strategic plans. In this context, the South African mining industry is considered more resistant to new digital technology system utilization than any other leading mining countries. This is due to the South African mining industry still practising an operational model that requires low technology involvement and labour intensive operations. Such operational models are unsustainable in the long term because of related low productivity and high operating costs. Thus the South African mining industry needs to reverse the situation by becoming more competitive in the global mining market through the utilization of several technologies, including digital mining. This will require effort by mining firms to deal with problems in the adoption process, such a traditional adoption method shortcomings which hinder new digital technology adoption. These shortcomings include the fact that traditional methods lack capability in dealing with adoption that involves multiple objectives and multiple stakeholders. In contrast, systems thinking is a holistic approach that focuses on the interactive relationship between all elements in a system and all systems in an entity. By applying a systems thinking approach, a big picture of the commissioning entity is created to help the relevant stakeholders to monitor the progress of adoption, as well as to understand the interaction between different systems in one commissioning entity. Thus the following research questions have been raised:

- How will a systems thinking approach facilitate the adoption process of new technologies?
- Is a systems thinking approach an appropriate method to facilitate new digital technology adoption and if so, how should it be applied in the design of the new blueprint?

This research’s study also answers the following questions;

- How should the new blueprint be developed to guide the adoption process of new technologies?
- How can the process and outcome of the new digital technology adoption be monitored and measured at the same time?
- How should the new blueprint should be designed to enable both guiding and measuring the adoption process of new technologies?

1.4 Research Background

A case study is conducted on the Schauenburg MIMACS II system to investigate the criticality of the systems thinking approach to the new digital technology adoption. WMI (also known as WITS Digimine), is one of six 21st century institutes at the University of the Witwatersrand that were established in 2012, which also hosts DigiMine, CMMS and CSMI. WMI’s aim is to promote innovation in the extractive sectors through skills, technology development and policy overhaul. In the past few years, WMI DigiMine has linked several partners with the objective of enhancing existing surface mining technologies so that they can also operate in underground mining operations. The major driving force behind the enhancement is to improve safety and productivity of underground mining operations in South Africa.

The WMI Digimine consists of two major components:

- WMI mock-up mine

  The WMI mock mine is part of the WMI digital mine project that was constructed in 2015. It is located in the basement of the Chamber of Mines building on the main campus of Wits University. The mock-up mine features the following components (see figure 1-1 and

1-2): Seventy-metre tunnel; cross-cut; lamp room; vertical shaft; stope; ventilation system; digital sensors placed inside and outside the tunnel.

Figure 1-1 WMI Mock-up mine (WMI, 2017)

Figure 1-2 Lamp room at WMI mock-up mine

- WMI partner systems

WMI recognises that digitalization in the mining industry requires collaborative actions. WMI has worked closely with its official partners and has acquired ten leading-edge digital technology systems. The functionality of these systems includes mine access control, asset surveillance, lamp room management, and mine stability and ambient environment monitoring. WMI mock-up mine has simulated an underground mining environment for several digital technology systems to be installed. Data generated in the mock-up mine is gathered and processed by individual technology systems. Processed data is then stored on the WMI servers for further utilization (see figure 1-3). Chapter 4 of this dissertation will discuss the existing WMI infrastructure in detail.

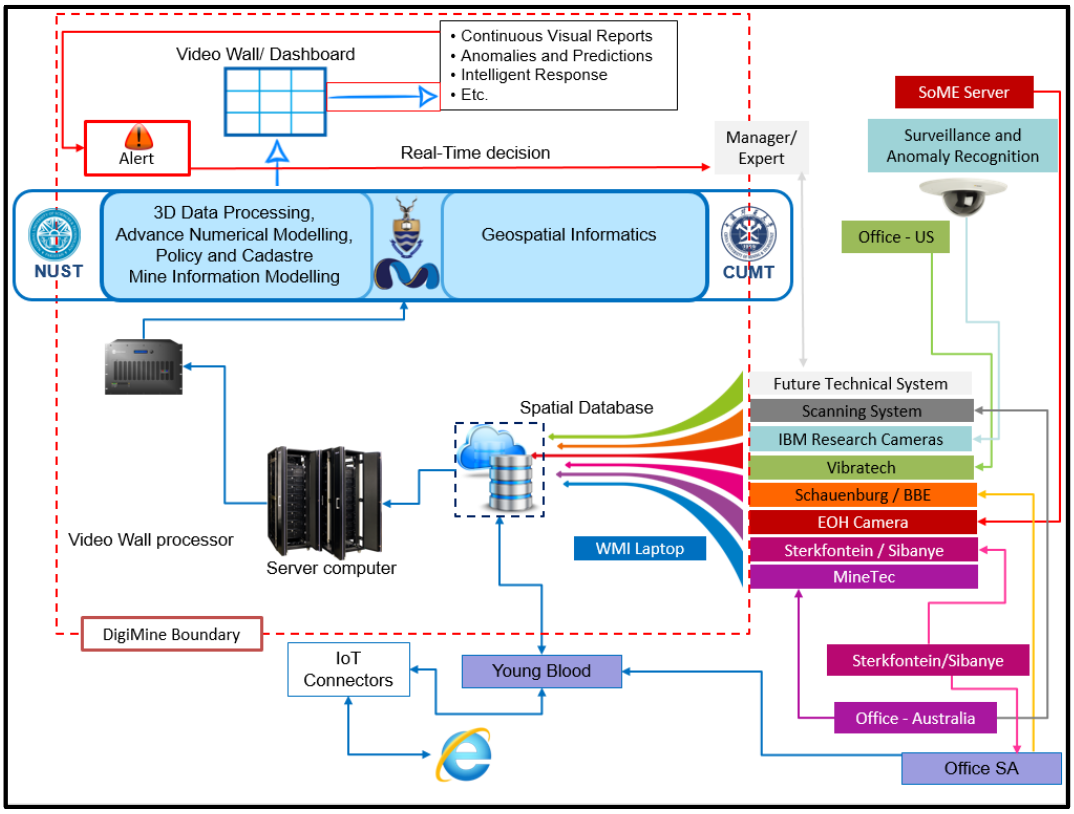


Figure 1-3 Overview of WMI Digimine new architecture

Schauenburg MIMACS II system is a communication management system that was installed at WMI in 2016. The following are the four major functions of the Schauenburg MIMACS II system:

- Lamp room management;
- Asset management;
- People and machinery tracking; and
- Gas and ambient environment testing and monitoring.

Three sub-systems are contained in the MIMACS II system to achieve the above functions:

- Intelligent lamp room management system;
- Asset Management Systems; and
- Gas detection system.

In addition, several devices and sensors are included in the Schauenburg MIMACS II system to support the system by collecting critical data regarding the ambient environment and user status. The Schauenburg system processes the collected data and displays it on a video-wall as readable information in a comprehensive manner (see figure 1-4).

Figure 1-4 Overview of the Schauenburg MIMACS II system (Schauenburg, 2018)

Schauenburg MIMACS II is indeed a complex system which merges complicated and dynamic systems behaviour. The latter characteristics are enabled via multiple supporting applications with multiple inputs. The following list includes all applications, sentinels and equipment that have been installed in the mock-up mine (see table 1-1 and 1-2) as part of the whole installation of Schauenburg MIMACS II system *(Breytenbach, 2014)*;

Table 1-1 Supporting components for Schauenburg MIMACS system

Supporting applications	
1	Apache Tomcat- Web server
2	Apache Active MQ-Message broker
3	PostgreSQL-SQL database
4	Java development kit
5	Polling Software
6	Enviro data file processor
7	Test point software
8	Sentinel agent1

Table 1-2 Fixed and handheld elements installed at the WMI mock-up mine:

Fixed and handheld equipment	
1	Cap lamps
2	Intellisens CH_4 sensor
3	Intellisens CO sensor
4	GDI Intellisens
5	Gas cylinder (to test GDI, contains CO, CH_4, O_2)
6	Self-Rescue packs

As a high end technology product, the Schauenburg system requires people, machines and software to work collaboratively to achieve the full functionality of the system. After two years of collaborative work through identification, installation, calibration, testing and maintenance, the entire installation project for the WMI Schauenburg MIMACS II system was finalised. The project has provided important learnings for both Schauenburg Systems and WMI. Thus, as will be presented in this dissertation, a worthwhile case-study has been conducted to analyse lessons-learnt from the project. The case study will also cover missing parts of the adoption process that could improve the quality of the process. The outcome of the case study will be summarised and included in a hypothesis of what could have happened if a systems thinking (holistic) approach was adopted from the outset, and what difference it would have made.

A new blueprint will then be developed using lessons learnt during the adoption project of the Schauenburg MIMACS II system. The new blueprint can then be used to enhance the experience of new digital technology adoption by other commissioning entities in the mining industry.

1.5 Research focus

As introduced in previous sections, the focus of this research is developing a new blueprint that applies a systems thinking approach in the adoption process of new technologies. In order to comprehensively achieve this objective, the study of this research will focus on essential components that have to be included in the adoption process. Furthermore, studies will also be conducted in the following areas.

- Analyse the influence of systems thinking (holistic) approach on new digital technology adoption processes; and

- Use systems thinking in the development of a new blueprint that includes all the measurements, not only those that monitor the progress and quality of the adoption process of new technologies, but also those that measure the outcome of the adoption process.

1.6 Research rationale and potential benefit

Rationale statement: previous sections identified that newly emerging digital technology is expected to reshape the operational model of the global mining industry. Utilization of such technology would therefore be key to creating competitive and sustainable mining industries, as well as improving mine safety. This potential has been recognised by the South African mining firms. Yet the progress of the digitalization in the South African mining industry has been slow and painful. One reason is lack of proper tools to guide and monitor the adoption process of new technologies. It is also unlikely any technology system will achieve its full functionality without being properly adopted into the commissioning entity. This research is aimed at addressing such problems by developing a new blueprint for the entire adoption process, which will include the systems thinking approach.

Potential research benefit

A core key to improving productivity and safety performance via digital technologies is a dependable adoption process. Without such, the complexity associated with the adoption phase could reduce the possibility of successful adoption. A well-guided process will therefore fundamentally assist successful adoption and ensure that the full functionality of the new digital technology is implemented. The following are some of the benefits a commissioning entity may receive by implementing the new blueprint for new digital technology adoption:

- Commissioning entity's needs and expectations properly understood from the outset;
- Technology system's capability also properly understood from the outset;
- Appropriate technology is pre-reviewed and chosen;
- Budget is well calculated to avoid project cost overruns;
- Adoption process is well scheduled to avoid project delays;
- Pre-installation preparation ensures all the resources are ready for the adoption, hence less time and efforts are wasted;
- Less pressure on the finance, labour and management of the commissioning entity, as such resources will be managed in advance;
- A proper adoption process ensures that full functionality of the new digital technology is achievable;
- System thinking approach with a managerial perspective ensures the technology system fulfils both the short and long-term strategic plan of the commissioning entity;
- A pre-study of the potential interaction between the newly introduced technology and the existing systems allows smooth transition and integration with other systems; and
- Better documentation of all the data and files for future use.

1.7 Importance of the research problem

In context of the importance of this research, it bears repeating that the future competitiveness of the South African mining industry depends on the extent of new digital technology utilization. The first step of new digital technology utilization is to adopt such into existing mining operations. A successful adoption will provide mining firms with a greater chance to reach their goal of productivity and safety. However, it also bears repeating that since mining operation complexity has rapidly increased in the last decade, traditional technology adoption methods are incapable in coping with the level of complexity. In contrast, the systems thinking (holistic) approach can overcome the shortcomings of traditional methods. By applying a systems thinking (holistic) approach, a big picture of the whole commissioning entity can be obtained. The latter, combined with its provision of an improved managerial perspective, will enable smoother transformation for the commissioning entity. Interactive relationship between different components in the commissioning entity will thus also be studied for the purpose of overall systems integration. The development of the new blueprint will include lessons and experience gained from adoption and installation of the Schauenburg MIMACS II system at WMI. This combined arrangement is intended to obtain realistic information for the input of the development of the new blueprint. Another consideration for using realistic information is to enable the new blueprint to be used by other commissioning entities in new digital technology adoption and installation. This will not only provide commissioning entities with clear insight into adoption and installation of currently-available new digital technology, but also into what may be required for future, as-yet undeveloped technologies, thus enabling such to be anticipated and timeously implemented (with associated future production and profit benefits).

1.8 Limitations and assumptions of the research

Limitations and assumptions cover *both* development of a new blueprint that can be used to guide the new digital technology system adoption and installation process, *and* data that is required for building the new blueprint (i.e. the outcome of the case study on the installation project of the Schauenburg MIMACS II system at WMI – note that a qualitative method was selected for the data analysis and interpretation process).

The first concern about the research limitation is the representativeness of the data that will be used for the case study of this research. The data was generated in a well-controlled environment. Therefore such data may not fully represent actual mining environments. An actual mining environment may contain more variables than the simulated mining environment in the WMI mock-up mine.

The second concern is the representativeness of the new blueprint. The foundation of this new blueprint is limited to the outcomes of the case study on the installation project of the Schauenburg MIMACS II system, as well as a comprehensive study on WMI's strategy for technology adoption and existing technologies at WMI. The objective of the case study is to create a concept for the new blueprint via lessons and experience that WMI gained during the installation project. However, certain lessons and experience may only apply to the WMI. Furthermore, some of the problems experienced by WMI may not occur when other commissioning entities use the new blueprint to guide new digital technology adoption and the installation process. Thus in some stages, it may be necessary to collect feedback from other users of the new blueprint, and use this to further modify and improve the new blueprint.

1.9 Research roadmap

This research consists of two stages, which will be presented as follows.

Stage one- Establish research concept and define problems

The first stage is initiated by a workshop involving relevant experts from WMI and industry and outlining the research direction and methodology.

A literature review on the status of new digital technology in the mining industry is then carried out after the research direction and methodology is set in the workshop. The literature review will include the following aspects: technology adoption and installation lessons; application examples in the industry of systems thinking (holistic) approach.

The literature review will build the body of knowledge for this research, aiding better understanding of status and problem. Once the literature review is completed, the research will then move to the case study of the installation project of the Schauenburg MIMACS II system.

Stage two- Research concept and methodology

Stage two study focuses on the development of the new blueprint that is capable of enhancing the experience of the new digital technology adoption and installation process.

The development of the new blueprint will be based on the outcome of the case study, and lessons and experiences gained from all adoption and installation projects at WMI. The new blueprint will be developed as a potential guideline with its core objective being smoothing the process of new digital technology adoption and installation.

Following are arrangements for sourcing data for the development of the new blueprint.

- The main source is data that was generated and documented during the installation project of the Schauenburg MIMACS II system, as well as relevant information regarding installation of other digital technology systems at WMI; and
- The existing data will be classified and sorted to fulfil requirements for building the new blueprint.

Validation of the new blueprint is critical in this research. The following are procedures that will be followed for the validation of data and new blueprint.

- After the new blueprint is developed, the entire new blueprint will be used as a checklist to measure the level of compliance of the installation project.
- Level of compliance will be considered as direct reflection of the quality of the work performed by the commissioning entity in different phases of the installation project.

Ethical issues and budget

No clearance is required as no animals will be involved in the study and the research.

The candidate, and the installation of the Schauenburg system were fully sponsored by Sibanye –Stillwater.

The research report is arranged as follows:

Chapter 1. Introduction

The purpose of this chapter is to set the direction and theme for this research. Nine chapters are included and important aspects of this research are discussed, such as: research focus, questions, objective, rationale, research limitations and research roadmap, as well as the research background and problem statement.

Chapter 2. Literature review

This chapter's purpose is to conduct a literature review of relevant publications with similar topics to this research. The objective is to set the foundation for the research by creating a platform for the body of knowledge. Such knowledge includes: current status of the global and South African mining industries, the status and impact of digitalization in the mining industry; traditional technology system adoption methods; systems thinking theories and application; methods and concepts for developing a new blueprint; data collection and validation.

Chapter 3. General research concepts

This chapter's purpose is to develop the concept of how to build the new blueprint. The first step is to determine the type of new blueprint. The second step is to investigate how many components should be included in the new blueprint. Those components need to be considered as the enabling elements for the system and are classified according to their characteristics and functionality. The systems thinking approach is applied in both the components-classification and new blueprint development.

Chapter 4. An overview of the ICT system at WMI

The main objective of this chapter is to provide a study of WMI. Focus-areas of the study include the following.

- The infrastructure of WMI, mock-up mine and control-room;
- Digital technology systems installed at WMI;
- Capacity, functionality and set-up of the ICT at WMI; and
- Data flow, network new architecture and sensor network at WMI.

The aim of the above studies is to provide understanding of WMI aspects when installing new digital technology systems.

Chapter 5. A case study on the WMI Schauenburg MIMACS II system installation project

The major task of this chapter is to conduct a case study on the Schauenburg MIMACS II system that was installed at WMI since 2016. The objective of this case study is to summarise lessons and experiences in the installation. Such lessons include the identification, negotiation, installation, testing and maintenance of the MIMACS II system. A list of all the problems that WMI encountered with system and supplier will be listed at the end of the chapter.

Chapter 6. WMI learnings on new digital technology adoption

Chapter 6 focuses on the mitigation processes that are conducted by WMI on the problems found in chapter 5. WMI recognize these mitigation processes as important lessons for WMI to learn for new digital technology adoption. Such WMI lessons include system malfunction, poor after-sale support and system integration, as well as the approach used by WMI to mitigate problems found in chapter 5, such as WMI vendor management system.

Chapter 7. New blueprint development for the adoption of new technologies

A new blueprint is developed in this chapter based on work performed in chapters 2, 3, 4 and 5. Knowledge built in chapter 2 is used to set the foundation of the new blueprint. The concept developed in chapter 3 provides the structure of the new blueprint. Outcomes obtained in chapters 4 and 5 are used to develop the logical flow and critical components of the new blueprint.

Chapter 8. New blueprint verification and discussions

The new blueprint developed in chapter 7 is verified in chapter 8: Ten Digimine personnel participated in the verification process. A comprehensive survey was prepared based on the new blueprint developed in chapter 7. The new blueprint was used to measure the level of compliance of WMI's performance during the installation project of the Schauenburg MIMACS II system. Data analysis and interpretation was conducted on the data collected from ten Digimine personnel.

Chapter 9. Conclusion and recommendation

The conclusion is based on the findings of this research, especially the outcome of the development of the new blueprint and the data analysis. Recommendations that may improve the quality of the new blueprint and this research are also made based on the discoveries and observations of the defects during the course of this research.

Reference and appendix

Relevant literature, data, records, files and documents used in this research are attached in this section.

2 Literature review

2.1 Introduction

A literature review is conducted in this chapter to explore the relevant research topics and build the body of knowledge for this research. Five relevant areas are identified to describe the literature for this research;

- The mining value chain and the current trends of new digital technology adoption in the mining industry;
- The impact caused by the introduction of new technologies on a traditional mining value chain;
- The resistance posed by people, mining industries and trade unions towards the adoption of new digital technology in the mining industry;
- The use of traditional approaches for new digital technology adoption and the lessons learned from applying such approaches; and
- Systems thinking and its application in the adoption process of new technologies.

The purpose of reviewing the five areas of literature is to build the body of knowledge for this research, thus set a foundation for this research and seek answers to research questions raised in chapter one:

A study of the traditional mining value chain of the mining industry demonstrates evidence to counter negative comments such as the South African mining industry being a 'sunset industry';

A study on the current trends of new digital technology in the mining industry offers an insight into the status quo of new digital technology development and the potential benefits of a successful adoption;

Studying the influence of, and resistance towards digitalization of the mining industry not only provides key information about the obstacles facing new digital technology adoption but also expose important stakeholders involved in the adoption process;

A study of the traditional technology adoption approach reveals the shortcomings of existing tools, and also assists in answering the question why systems thinking is better than traditional tools to facilitate new digital technology adoption;

Systems thinking provides an insight into this research, sets the main theme of this research, and is crucial to the development of the final new blueprint of new digital technology adoption, which is the main outcome that this research aims to accomplish.

2.2 Mining Value Chain - future of the mining industry

South Africa is a country with a rich endowment of mineral resources, and ranks as the fifth largest mining country in the world. Chamber of Mines statistics indicate that South Africa is the largest host of PGMs, gold, chromium and manganese deposits in the word. Figure 2-1 shows the global ranking of some key mineral reserves of South Africa. Citigroup estimates that the total worth of South African mineral is over $2.5 trillion (Dijk, 2016);

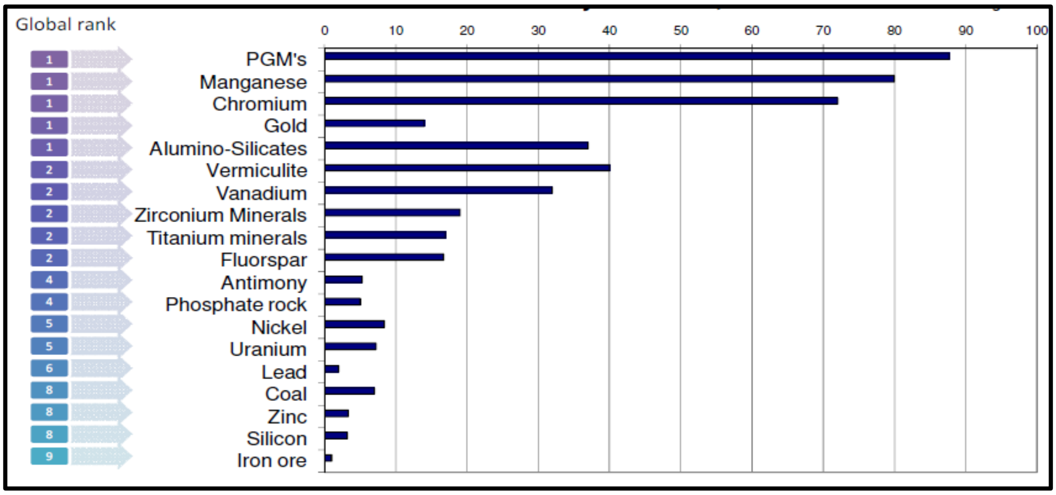


Figure 2-1 *Key mineral reserves of South Africa (Rossouw & Baxter, 2011)*

Such mineral resource abundance plays a strong contribution to the country's economy. According to PwC (2016), the benefits gained from the mining sector can be classified into two categories, namely direct and indirect benefits.

- Direct Benefits

  In the past ten years, the South African mining industry has made an average yearly contribution of 7% to the nation's GDP, earned over 50% of South Africa's total foreign exchange, made up 25% of South Africa's total exports, and created employment for half a million people (Chamber of Mines, 2017). Other significant contributions included the reception of a critical amount of corporate tax and royalties, the attraction of 8% of direct foreign investment and over 30% of foreign savings, and the formation of 1/3 of the total capital of the JSE.

- Indirect Benefits

  Based on released statistics, indirect benefits provided by the mining industry are larger than the direct contribution. Indirect benefits include 10% of the total GDP, 1 million employees in providing goods and services to mines, over 50% of total Transnet logistics, and enormous amounts of revenue generated in upstream equipment manufacture and downstream mineral beneficiary businesses. Other indirect contributions include infrastructure development and socio-economic welfare (Baxter, 2013). The following figure, produced by Antin (2013), summarises several major benefits that South Africa gained from its mining sector (see figure 2-2).

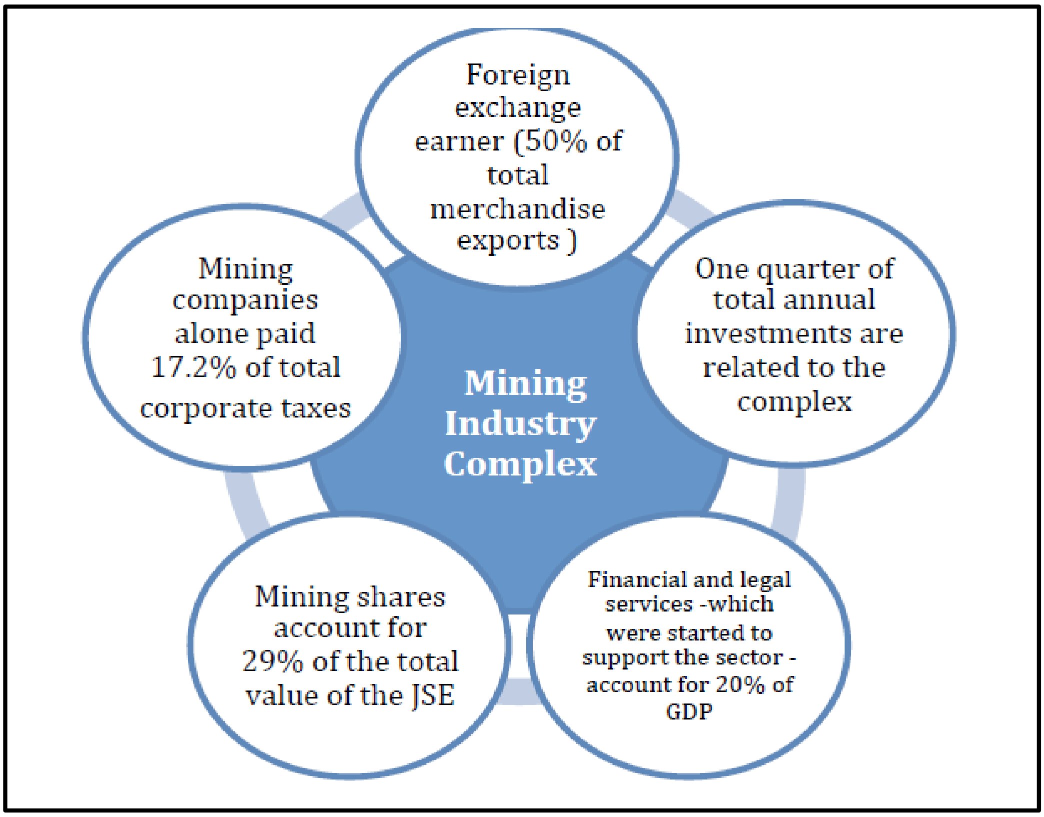


Figure 2-2 Elements of benefits mining industry provides *(Antin, 2013)*

However, the global financial crisis and slump in commodity prices have brought the global mining industry into a recession. As one of the major suppliers in the global mineral market, the South African mining industry has also been directly affected by this recession. This has greatly increased the pressure (challenges and risks) that the South African mining industry is experiencing. Such pressure is a combined result of metal price volatility, labour unrest, infrastructure incapability, and instability of regulatory and political environments. Among them, the most concerning factors are the downward trend in operational efficiency and the rapid inflation of cost (Temkin, 2016).

McKinsey & Company's 2015 report provides a perspective on the trends in the operational efficiency of the global mining industry. It concluded that "there has been an approximately 28% drop in operational efficiency in the last decade in the global mining industry and the downtrend continues." (Hugn, et al., 2015). The above finding is also supported by the MPI report, as well as the World Bank Metal and Minerals Index. MPI is an analytic tool developed by McKinsey to evaluate sectoral performances of the mining operation. The 2015 MPI report revealed an alarming trend; the overall productivity in the global mining industry had an average annual decline of 3.5% during the period from 2004 to 2013 (see figure 2-3).

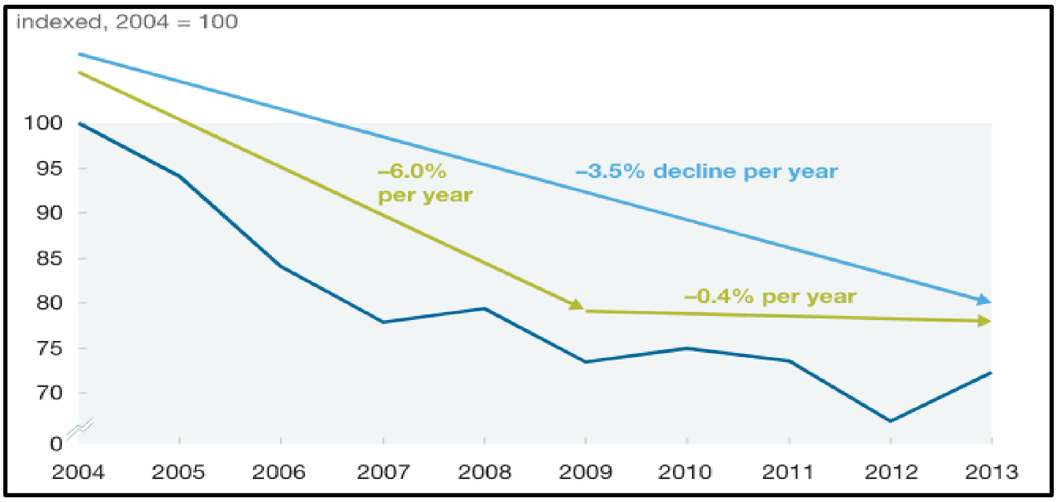


Figure 2-3 Global mining productivity measured by MPI from 2004 to 2013 *(Lala, et al., 2015)*

Figure 2-3 indicates that the downward trend in the global mining industry can be split into two periods; the first period is from 2004 to 2009, the productivity dropped rapidly-6% per year during this period; from 2009 to 2013, the trend slowed down, only as little as 0.4% of the overall productivity was lost during this time.

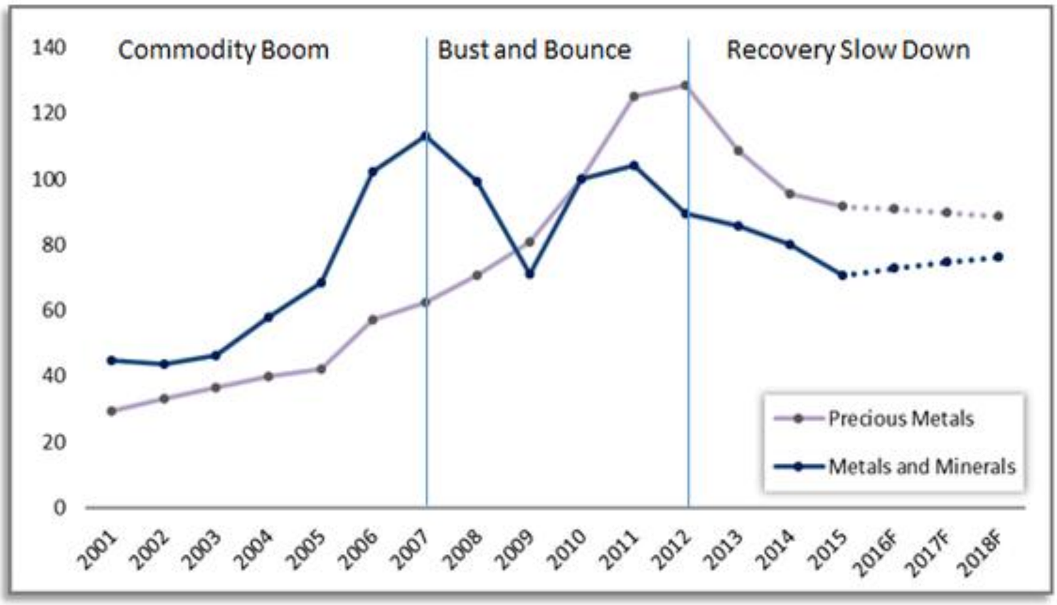


Figure 2-4 World Bank Metal and Minerals index during 2001-2018 (Schwikkard, 2016)

The World Bank Metal and Mineral index (see figure 2-4) indicates that a significant decline in commodity prices started in 2011. Since then, precious metals have lost 27% of their prices. Such a slump in commodity prices hit the South African mining industry hard, and exposed those mines that produce at any cost when commodity prices are high.

An analytic report published by the McKinsey & Company (2015) commented on the recession as follows:

> *"The industry has paid a high price regarding lower productivity for volume gains during the demand boom—but that there are signs the industry may be starting to turn its productivity performance around."*

Currently, the South African mining industry is still operating under pressure. For mining companies to survive in this recession, such challenges and risks need to be addressed promptly.

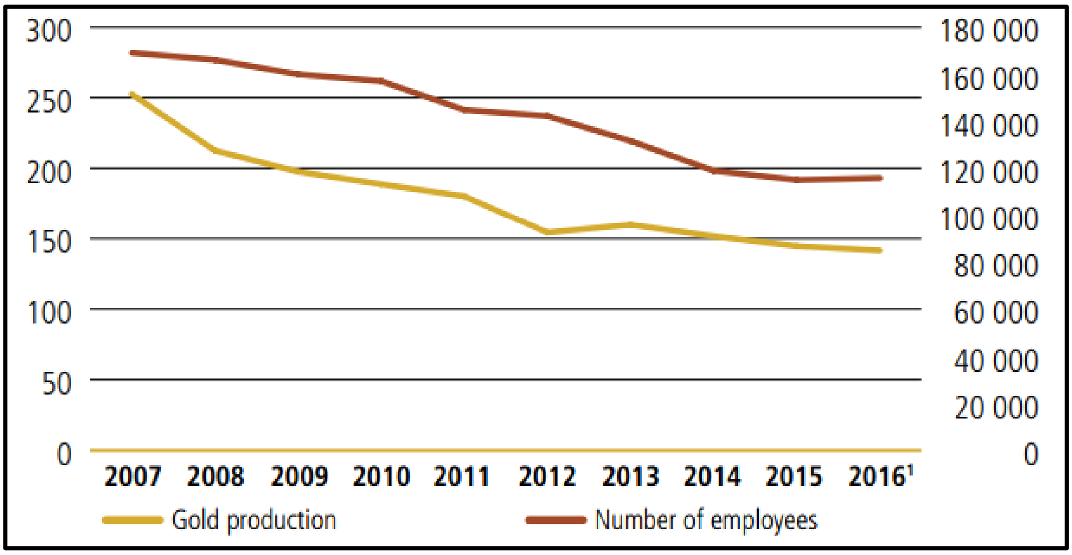


Figure 2-5 Gold production and employment in last decade (Chamber of Mines, 2016)

After several years of focusing on the practice of cost reduction, mining companies are left with limited options. In addition, the continuously increasing distance of ore haulage and the decrease of ore grade result in the decline of operational efficiency. This has occurred particularly in gold mining operations (see figure 2-5). Conversely, as result of the fortunate constant climb of the international coal price, between 2003 to 2017 production and number of employees in the South African coal mining industry rose by 7.5% and 46% respectively (Omarjee, 2016).

The traditional mining value chain and operational model is facing increasing challenges. In order to survive, mining companies are forced to seek new routes to maintain low costs by enhancing operational efficiency. Available and affordable new technologies have offered a potential opportunity to mining companies to break through the harsh environment by improving operational efficiency, facilitating agile planning and enhancing communications between stakeholders across the entire mining value chain (Glau, et al., 2016)

Both PwC Africa Mining and SIPA recognise the impact of new technologies on the productivity of mining operations. PwC Africa Mining points out the urgency of utilising innovative technologies for the South African mining industry; in order to maximise the potential of new technologies, the mining industry also needs to establish standardised processes and systems to enhance the technologies' delivery. PwC also states that the South African mining sector will continue to struggle in the next decade as the mining sector is transforming from unsustainable conventional mining method to a hybrid mode, where conventional and mechanised mining methods are carried out in parallel (Temkin, 2016). For instance, two major mining houses in South Africa expect that the revolutionised drilling technology that was developed by Peterstow Aquapower can help mining operations to reduce power requirements. According to the former CEO of Goldfields, this new digital technology is considered to be the most important technology that has been introduced into the mining industry in the last 50 years. This single piece of innovative technology has changed energy consumption in hard-rock mining operation, allowing mining companies to simultaneously boost productivity and reduce cost (Wyngaardt, 2010).

The increasing velocity of implementing digital technologies leads to a boom of data generated in mining operations, which is available for mining companies to utilize. Such data would not only provide accurate and real-time statuses of overall mining operations, but would also be capable of providing locations and statuses of individual workers and equipment in mining operations. Deloitte described digital technology as a stepping stone for the mining industry, stating that “digital technology has been changing businesses and operating models, reshaping completive differentiators and in some cases, completely altering the entire fabric of industry” (Walsh, et al., 2017).

2.3 Impact of digital technology on the mining industry

Mining companies around the globe have already gained the benefits of adopting new digital technologies in their operations. Accenture’s survey-result on digitalization in the mining operations indicates that six out of the top ten mining companies have clear strategic plans for their digital transformation. Although three out of ten companies have quantified revenue gained indirectly from the digital technologies in their operations, only one company has a direct benefit from the new digital technologies (Accenture Consulting-US, 2014).

Different mining companies have different approaches towards the utilisation of new technologies in their mining value chain and long-term strategic plan. Anglo American and Gold Fields are the two of the major mining houses in South Africa. Although parts of their businesses are similar, their perceptions on utilisation of new technologies differ. For over a century in mining, Anglo American has developed a culture of being a pioneer in innovation implementation. Anglo American introduced the concept of “future smart mining” to help the company stay at the top of leading-edge technology development (AngloAmerican plc, 2017). Such a concept allows Anglo American to develop the research capacity to address the challenges they are facing. Gold Fields’s approach is to pass the challenges to research partners to find solutions (which is a lesson learned from a failed project of mining robots development in 2007). Currently two companies, namely GlassTerra and Cyest, are collaborating with Goldfields in the research fields of geospatial information and visualisation of mining processes (Gold Fields Limited, 2016).

Accenture North America's digital mining survey reveals that mining companies are gaining benefits from new-technology utilisation in several aspects:

- Remote operating centres**:** Increased safety and productivity, as there are fewer people on site. The centres rely heavily on availability of remote-operations technology and data;
- Mobility**:** Using cutting-edge positioning technology to track people and machines and assets: not only does this increase safety and productivity, but it also creates distance between people and hazards, which, in turn, facilitates a better execution of the job assignment and safer working environment;
- Data analysis**:** Digitalization creates sudden increases in availability and volume of data. This requires mining companies to rethink ways that data is collected, stored, processed and used: the analytic process should be data-driven and primarily focused on real-time data across the mining value chain for better planning, decision-making and optimisation. Analysis of historical data is also critical, as it provides insights into trends, and patterns and review of defects for future operation (Accenture Consulting-US, 2014); and
- Other possible digital technologies identified include wearable technology, drones, and robotics/automation;

2.3.1 Future of the mining industry

The future of digital technology in the mining industry is crucially dependent on the attitude of the management in the commissioning entity, as the management sets the company's vision on using data to make decisions and to manage budgets. Accenture North America digital mining survey (2014) focuses on the perspective of C-level senior employees in digital mining in around 40 mining firms. The survey results indicate that there is a rising trend of capital investment in new technologies in the mining industry. During the period from 2011to 2014, 88 % of all senior employees reported an increase of budget toward digital technology. 95% of them confirmed that new employees were recruited to work on digital technology application (Accenture Consulting-US, 2014).

The survey results confirmed senior management's positive impression on the use of new technologies in the mining industry. 93 % of executives are satisfied with the performance of digital technology in operation. Over 96% of them consider continuing investment in the next three years.

2.3.2 Potential of digital technologies

According to Deloitte's report on new digital technology applied to the mining industry, the future application of such will not be limited to only the core operation. Applications will also extend into the entire mining value chain, including exploration, supply, processing, human resources and finance. The following are three identified areas in which new digital technology may potentially cause an impact in the mining industry (Steven, et al., 2017):

- Data analysis/big data;
- Cloud computing; and
- The mobility of personnel and equipment, etc.

Senior management in the Deloitte survey also identified aspects that are likely to be impacted by the new digital technology in the mining industry over the next five years. Such areas are:

- Operational productivity and organisation;
- Supply chain organisation; and
- Health and safety performance.

2.4 Resistance to new digital technology

Peitchinis (1983, pp.104-119) stats that:

> "*Technological changes were deemed to be a managerial prerogative and the prerogative was interpreted to constitute a right to implement technological changes without regard to their effects on workers.*"

Attitudes towards new digital technology are one of the major external forces that form barriers to adoption. Three key forces that need considerations are organisation (management and workers), trade unions, and government (legislative bodies).

McCarthy (2011) concludes that it is necessary for mining companies to adopt organisational management principles when mitigating problems occurred during the adoption process. McCarthy (2016) further studies how organisational management framework will affect adoption of new technologies in a mining context. The studies explore barriers to implementing new digital technology and look into solutions by adopting mine management systems which provide insights for management.

Peitchinis (1983) conducts a survey on the attitudes of trade unions towards technological changes. Peitchinis lists three reasons for trade union's opposition to the introduction of technologies, namely:

- Costly introduction processes destroy the potential advantage of new digital technology;
- Result in unemployment; and

- Union membership loss.

The National Union of Mineworkers (NUM) is one of the largest trade unions in South Africa. NUM represents over half of the total employees in the gold mining sector. NUM has expressed similar perspectives regarding the introduction and implementation of new digital technology into mining operations. The general secretary of NUM commented on the union's perspective about technology introduction in the mining sector as follows (Baleni, 2009).

> "*Massive job loss as the mining industry absorbing fewer workers, such a downward trend is caused by the employment shedding and shift in production methods.*"

The barriers to implementing new digital technology not only lie with individuals or organisations, but are also largely influenced by government legislation, for instance, political economy. A case study on the barriers to new digital technology adoption in Saharan salt mining reveals that the direction and rate of new digital technology adoption are influenced by the economic organisations and the environment established by the political organisation (Kuan, et al., 2015).

2.5 Traditional approach to acquiring new technologies

Macfarlane (2001) indicates that new digital technology, especially new digital technology, plays a vital role in the development and application of mining methods to enhance both mine safety and operational efficiency. The utilisation of new technologies in mining and ore processing provides new opportunities for the expansion of "new digital technology" to improve the revenue and efficiency of mining operations (Andrew, 1998). McCarthy (2016) commented that introduction of new digital technology allows modelling, control and tracking through the entire mining value chain. The latter is critical as the mining industry is currently operating under pressure of decreasing mineral deposit both in size and grade. Whereas mining companies are aware of the potential and availability of new digital technology, they are struggling to adopt the technology into the mining value chain and turn the new digital technology into overall productivity. The possible cause is the lack of a strategic plan for adopting new digital technology and a comprehensive understanding of all aspects that are involved in the technology adoption process.

McCarthy (2011) points out that the development of a strategic plan is key to a smooth transformation in adopting new digital technology in the mining value chain. Most digital technology related projects are only focusing on the technical part of the project rather than articulating the business value. It is recommended that digital technology related projects start with a requirement and capability analysis of that digital technology (Steven, et al., 2017).

CIMA (2010) states that an effective strategy is a proper planned procedure to help the organisation[6] to adopt new digital technology. CIMA also urges the organisation to be aware of the impact caused by new digital technology on both the internal culture and external environment of that organisation. CIMA further discusses three critical stages in an effective strategic procedure for the new digital technology adoption (CIMA, 2010):

- Understand the status and the potential benefits that new digital technology may offer after adoption;
- Analyse the possible impacts that may occur when the new digital technology has been adopted; and
- Consider the possibility of commercialisation.

The "Champion model" is one model that is used for the implementation[7] of new digital technology in the mining industry. In Andrew Scott's paper, the "Champion model" is described as a traditional model used for the implementation of new digital technology

[6] In this research, the organisation is referred to as the commissioning entity

[7] Implementation also refers to adoption or installation

(ranging from small mining machines to large-scale mining systems). In “Champion model”, “champion” refers to a single person or a group with an interest in new digital technology, probably creating concept or investment in new digital technology as development progress: the implementation phase can initiate once the conceptual development becomes mature enough to meet all the investment criteria. The implementation phase demonstrates the potential success of the new digital technology implementation, and it is dependent on the champion person (Andrew, 1998).

Christensen invented the term “disruptive innovation” and concludes that the disruption is caused by the impact of new digital technology, not the technology itself. There are several principles that have been developed to guide the adoption of disruptive technology (Christensen, 2019).

According to Chen and Ma (2017) individual users or organisations prefer to use a psychology-based acceptance method. It relies on social planning on the system level to meet the system objectives, not on the individual level (Chen & Ma, 2017).

There are three well-developed models for the psychology-based method in new digital technology adoption. These are:

- Technology adoption lifecycle model;
- Technology acceptance model (TAM); and
- Base diffusion model.

Nemoto, Vasconcellos and Nelson (2010) developed an innovation adoption model in 2010 to demonstrate the key factors needed for the implementation of RFID technology based on a real-time decision-making system in the manufacturing industry in Brazil. The research concluded that international cooperation is the key success factor in creating a desirable outcome during the adoption of disruptive technology (Nemoto, et al., 2010).

Furthermore, several research outcomes indicate the importance of distinguishing the right technology to adopt for mining companies to achieve the needs and desired outcome. Readett (2006) pointed out that disruptive technology itself does not guarantee the adoption success; a proper adoption is a key factor to release the potential of the technology. Macfarlane (2001) states that implementation failure is only linked to the system (i.e. organisation or commissioning entity)[8] which the technology is introduced to, i.e. the cause of failure is not inhabitant in the new digital technology itself (Macfarlane, 2001).

Based on the historical data of the development of the resource-based process plants, Readett (2006) discovered several influential factors which contribute to the failure of adoption. Readett has also developed guidelines for the selection and adoption of new digital technology in the mining project. Below is a brief summary of the guideline;

- Perform the requirement analysis;
- Select the right product/supplier;
- Create the business and implementation plan; and
- Project justification and management.

Dickerson (1997) concludes that the toughest question faced by resource companies is not only to choose a technology but also to choose the one that is mature enough and would fit in the company's existing value chain and long-term strategic plan. Dickerson develops a system to help resource companies categorise and understand a disruptive technology, as well as to assess the outcome of an implementation. Dickerson concludes that unproven technology is not suitable for full-scale mining operation as it requires high-quality development-support from the suppliers (Dickerson, 1997).

[8] System here is refers to the organisation or commissioning entity that adopts new digital technology

Several researchers also looked into the main influential factors that support successful implementation or cause implementation to fail. Obal (2017) showed that technology adoption strategies are a combination of the complex interplay of external pressures and internal motives.

There are several technological acceptance models that have been developed to help the organisation to understand how the individual user’s or the organisation's behaviour changes over time to adopt the technology (Surendran, 2012). In Long Li’s work, these models are (Li, 2015):

- Theory of Reasoned Action(TRA);
- Technology Acceptance Model (TAM);
- Unified Theory of Acceptance (UTA);
- Motivational Model;
- Theory of Planned Behaviour;
- Innovation Diffusion Theory; and
- Social Cognitive Theory.

Among these seven models, TRA and TAM are the two most frequently used models, particularly in the information technology field. TRA is the model that illustrates how users can accept and use technology (see figure 2-6). Perceived usefulness and ease are the two most influential factors that need consideration when making a decision on how the technology will be presented (Li, 2015).

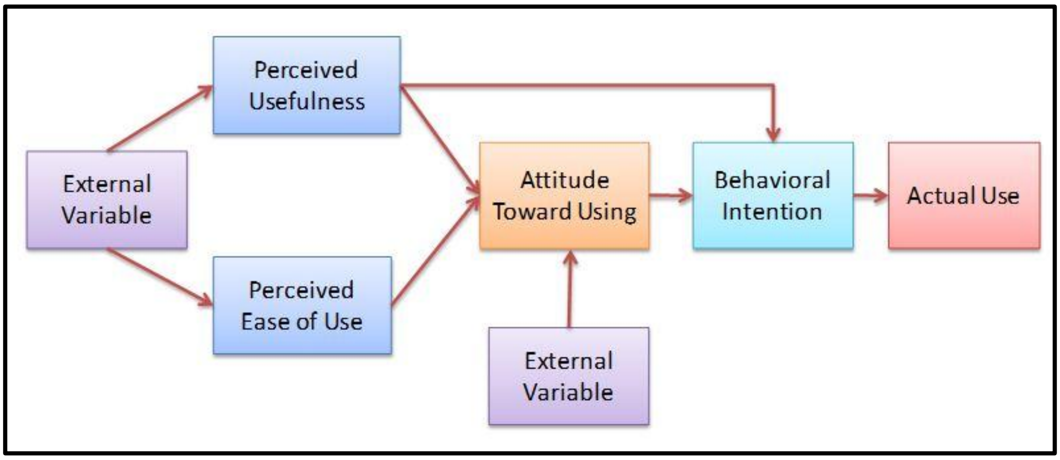


Figure 2-6 Technology Acceptance Model (Davis, 1989)

TRA was first developed in 1967 to study the human factor by predicting the behaviour of an individual based on the relationship between the intention of attitude and behaviour.

However, a recent publication shows that UTAUT becomes more popular to the information technology related adoption than other models. Samaradiwakara and Gunawardena (2014) conduct a conceptual review of existing technology acceptance theories and draw the conclusion that among all fourteen models, it is most likely that UTAUT is the model that could provide success for technology adoption (Samaradiwakara & Gunawardena, 2014).

Technology acceptance models are not the only solutions to enhance new digital technology adoption processes. McCarthy (2016) demonstrates the usefulness of the change management theory in the implementation of technology in a mining environment. McCarthy also suggests that the combination of project management and change management would accelerate and smooth the new digital technology adoption process, as the project manager manages the technical side, and human-related problems are responsible for the change management (McCarthy, 2016).

The complexity of new digital technology adoption rises exponentially as the data volume in the information technology increases. The commissioning entity therefore urgently requires a new methodology to manage the process of new digital technology adoption.

2.6 Systems thinking in new digital technology acquisition

Systems thinking is a holistic approach that focuses on the interactive relationship between system elements and system behaviour over time (Rouse, 2005). Systems thinking skills are essential for a systems engineer to utilise and perform deep analysis of the problems embedded in a complex environment (Walden, et al., 2015). Peter Senge is the pioneer of the systems thinking research; he defines systems thinking as follows (Senge, 1990):

> "*Systems thinking is a discipline of seeing wholes. It is the framework of seeing interrelationships rather than things; for seeing patterns of change rather than snapshots.*"

The objective of systems thinking study is to focus on the big picture through the interactive relationship between the parts within a system. Raza & Standing (2011) describes that the core principle of systems thinking, is systems' behaviour of the interactive parts within a system (Raza & Standing, 2011).

Raza & Standing (2011) argues that the traditional information technology adoption model is only based on the user's perspective and lacks the strategic perspective of the whole context of the organisation. Their initial hypothesis is to consider the barriers to the organisational progress of technology as systemic problems which are unable to be addressed by traditional TAM and TRA models. Such barriers need to be solved from a "systems thinking" perspective.

Senge (1990) discusses the rationale to use systems thinking; it is to provide that individual or organisation with a better understanding of the problem they are trying to address (Senge, 1990). The following four perspectives are the most important Systems Thinking Perspectives (STP) in the context of new digital technology adoption (Kasser & Mackley, 2008).

- Big pictorial;
- Operational;
- Functional; and
- Structural.

Systems thinking has become one of the most popular tools used in the adoption of the technology related project. Systems thinking has a wide application in the medical and defence industries. In medical science, doctors are using systems thinking techniques to perform the diagnostic more accurately for better decision making in the treatment plan (Goodman, 2016).

In this context, it is important to reiterate that the advantage of systems thinking over traditional technology acceptance models is the capability to obtain the whole picture of the system by looking at the relationship between different elements in them. Raza & Standing (2011) states that the complex amalgam caused by the various factors is impossible to identify in TAM. The justification is follows:

> "*TAM only consider the technology adoption from an individual user's viewpoint, which does not provide any solution to address the multiple users perspective in a holistic framework from a project management viewpoint*."

Raza & Standing believes that failure of technology adoption involves psychological, social and organisational issues. They suggests to treat the technology adoption at the organisational level and consider the issues as "systemic" problems (Raza & Standing, 2011).

2.7 Application of systems thinking in the mining industry

A systematic approach is critical for the mining industry when dealing with innovative technologies. According to the CEO of PwC Southern Africa, Dion Shango:

> *"Organisations that take a systematic approach are likely to get better results in the long term, and will ultimately be able to monitor and manage stakeholder relationship and risks more effectively."*

Mining companies need to understand the opportunities and risks associated with new digital technology adoption in the mining industry. The assumption that systems thinking will fit in the adoption process is justified by the fact that systems thinking is a macro-picture perspective. Goodman (2016) advises when systems thinking should intervene:

- Problem is critical and familiar;
- Problem with precedent history; and
- Problem with the previously failed attempt.

Issues that are related to technology adoption in the mining industry fit the requirement for applying systems thinking. This includes technology along with the other elements such as systems, structure, culture, and people from the commissioning entity. Unless proper adoption processes of technology are in place to bring all of the elements together, the commissioning entity will not produce the desired outcome for adoption (Panda & Upadhyay, 1998).

SDLC is a cyclical methodology that is traditionally used for systems development (see figure 2-7). Its core objective is conceiving, transferring and implementing the technology. SDLC's cyclical structure is less rigid than the linear methodology, but it allows changes in the sequential stages that are critical for any project development (Scroggins, 2014).

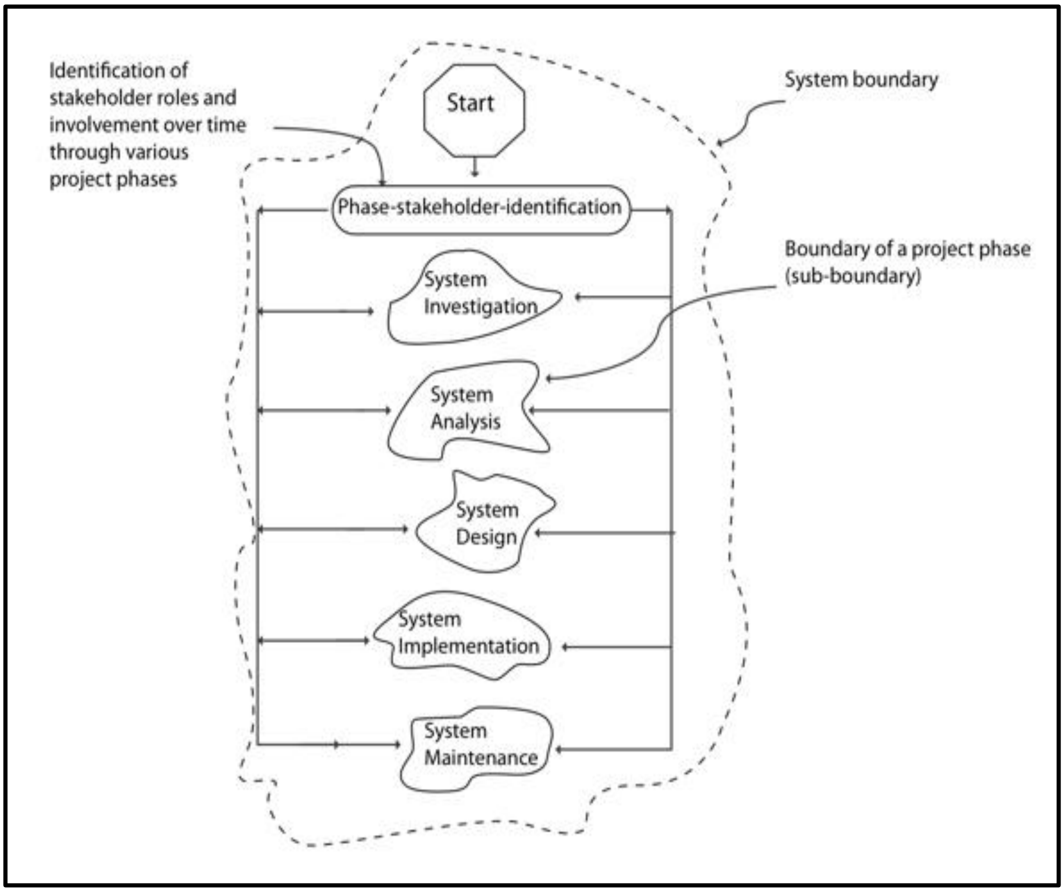


Figure 2-7 Modified systems development life Cycle (SDLC) (Raza & Standing, 2010)

A systems boundary is an imaginary line that separates what is inside and outside of the system (Lu, et al., 2010)(see figure 2-2). According to Checkland (1981), the boundary of the system is defined as:

> "a *distinction made by an observer which makes the difference between an entity he takes to be a system and its environment*."

According to Raza (2011), a systems boundary will lead to the identification of the roles of stakeholders who are involved and affected by the technology adoption process. Ulrich (2005) describes the term of boundary critique as the "*systemic effort of handling boundary judgements critically*." Ulrich develops the guidance to practice the boundary critique for each stage of the SDLC as the system development progress for better stakeholder identification and classification.

Stakeholders are the essential components in the formation of any commissioning entity and can be defined as individuals or groups who can cause effect or be affected by the objectives that the commissioning entity intends to achieve (Freeman, 2001). Stakeholder theory has been developed and used to understand how an individual stakeholder affects the entire commissioning entity by classifying the stakeholders into the pre-defined groups (Rowley, 1997). Stakeholder identification is critical for the mining project, as there are at least three parties[9] involved in the adoption process.

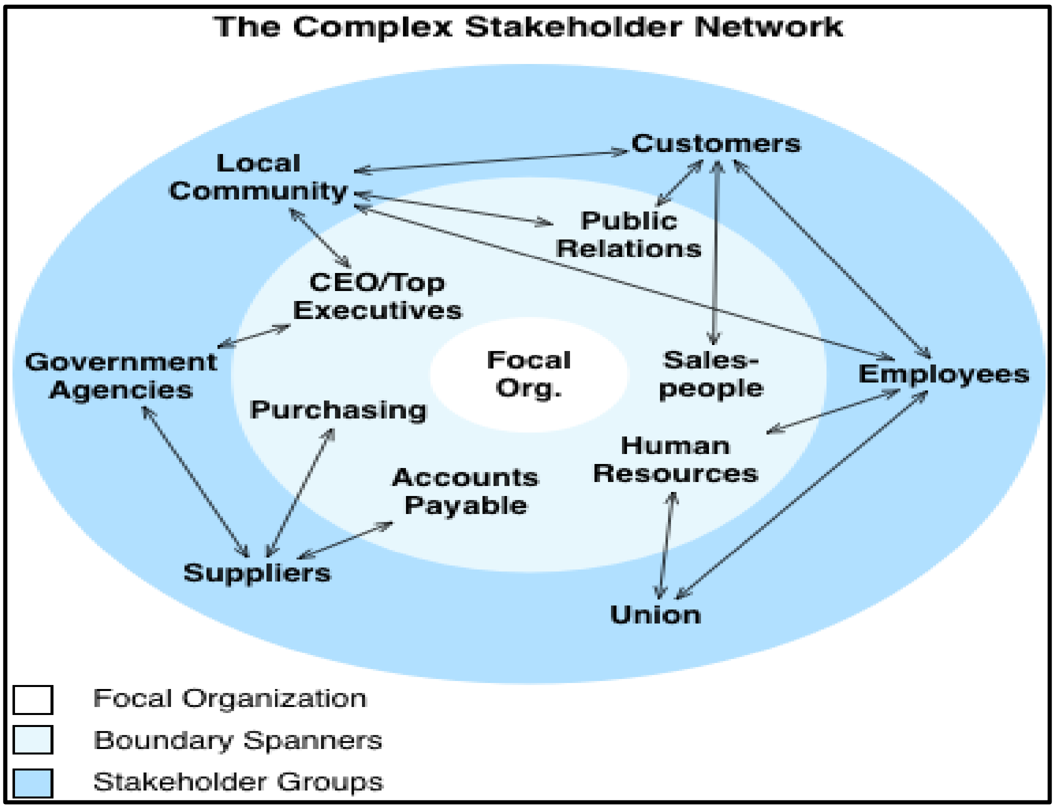


Figure 2-8 Typical complex stakeholder network (Lewis, 2011)

Figure 2-8 shows typical interactive relationships between stakeholders within an organisation. Lewis (2011) suggests that stakeholder interaction is a critical and extra caution needs to be taken as it may affect the outcome of commissioning entity activities.

---

[9] Three parties: commissioning entity, appropriate new digital technology and supplier of the new digital technology

2.8 Summary

In conclusion, the current situation is: the South African mining industry is struggling to utilise the potential benefits of new technologies to overcome the dilemma that the industry is encountering. Lack of motivations for new digital technology acquisition has reflected on the slow and painful transformation from traditional to mechanized mining. The root cause is not only the capital cost required by the digitalisation processes or the resistance posed by some trade unions, but also the managerial perspective towards the underrated performance of new technologies. In order to have a smooth, efficient and cost-effective digitalisation when dealing with new digital technology adoption, and to eventually ensure that the newly adopted technology reaches its full design-functionality, an appropriate roadmap for new digital technology acquisition is urgently required in the mining industry. This roadmap should be capable to guide and monitor the entire adoption process from beginning to end via a systems thinking (holistic) approach from a managerial perspective. A systems thinking (holistic) approach will increase the possibility of the overall integration of the newly adopted technology into the system within the commissioning entity. Managerial perspective will allow the selection, installation and integration of the new digital technology and the meeting of both short and long-term strategic plans of the commissioning entity. The adoption process requires collaborative efforts from not only the commissioning entity, but also the supplier of the new digital technology. Thus, the roadmap should cover all the affected parties.

However, the literature review conducted in this research has exposed a critical question: There is a gap of knowledge in the application of systems thinking (holistic) approach in new digital technology adoption processes within the mining industry. The reason for the gap is that only limited research has been done on the relevant topics. Hence this study is important to fill that gap of knowledge by developing a new blueprint (roadmap) using a systems thinking (holistic) approach from a managerial perspective. In the later stage, this new blueprint can be used to guide other commissioning entities in the processes of new digital technology adoption. The next chapter will be focusing on the general concepts of this research. Such concepts include the application of a systems thinking (holistic) approach for the development of the new blueprint that is capable to guide the new digital technology adoption.

3 General research concepts

3.1 Introduction

A systems thinking approach is selected to achieve the goal of developing a new blueprint in this research. Systems thinking is a holistic approach, which is different from the traditional TAM method that solely relies on empirical experience for new digital technology adoption. By using a holistic approach, the entire adoption process is divided into several phases (see figure 3-1). A detailed work plan is developed for each phase in terms of application of systems thinking skills. The application of systems thinking skills creates a big picture of the commissioning entity. A big picture perspective allows an insight into the interactive relationship between different systems in the commissioning entity. Systems thinking skills also provide capability to identify all the critical components that form the different level of systems hierarchy, such as systems boundary, stakeholders network and enabling elements to that support the SOI. The entire new blueprint consists of two critical sections, namely identification section and adoption section. The identification section includes the identification of the commissioning entity's issues, actual capacity, needs, expectations, as well as the identification of an appropriate new digital technology that is capable of addressing the issues, as well as to classifying all enabling elements of the SOI. The adoption phase includes activities such as preparation and installation of the identified new digital technology (see figure 3-1). Requirements for the post-installation phase are also included in the installation section. In the next chapter, a case study will be conducted on the Schauenburg MIMACS II system and current WMI vendor management system to provide crucial information for input into developing the new blueprint in chapter 7.

The final new blueprint consists of several critical components of the adoption process, such as risk assessments, contingency plans and training sessions. The new blueprint is capable to assist other commissioning entities to guide and monitor the processes of new digital technology adoption, as well as to assess the outcome of the adoption. The implementation of new blueprint aims to provide the commissioning entity with a smooth and speedy experience of new digital technology adoption and also to enhance the decision-making process for new digital technology identification.

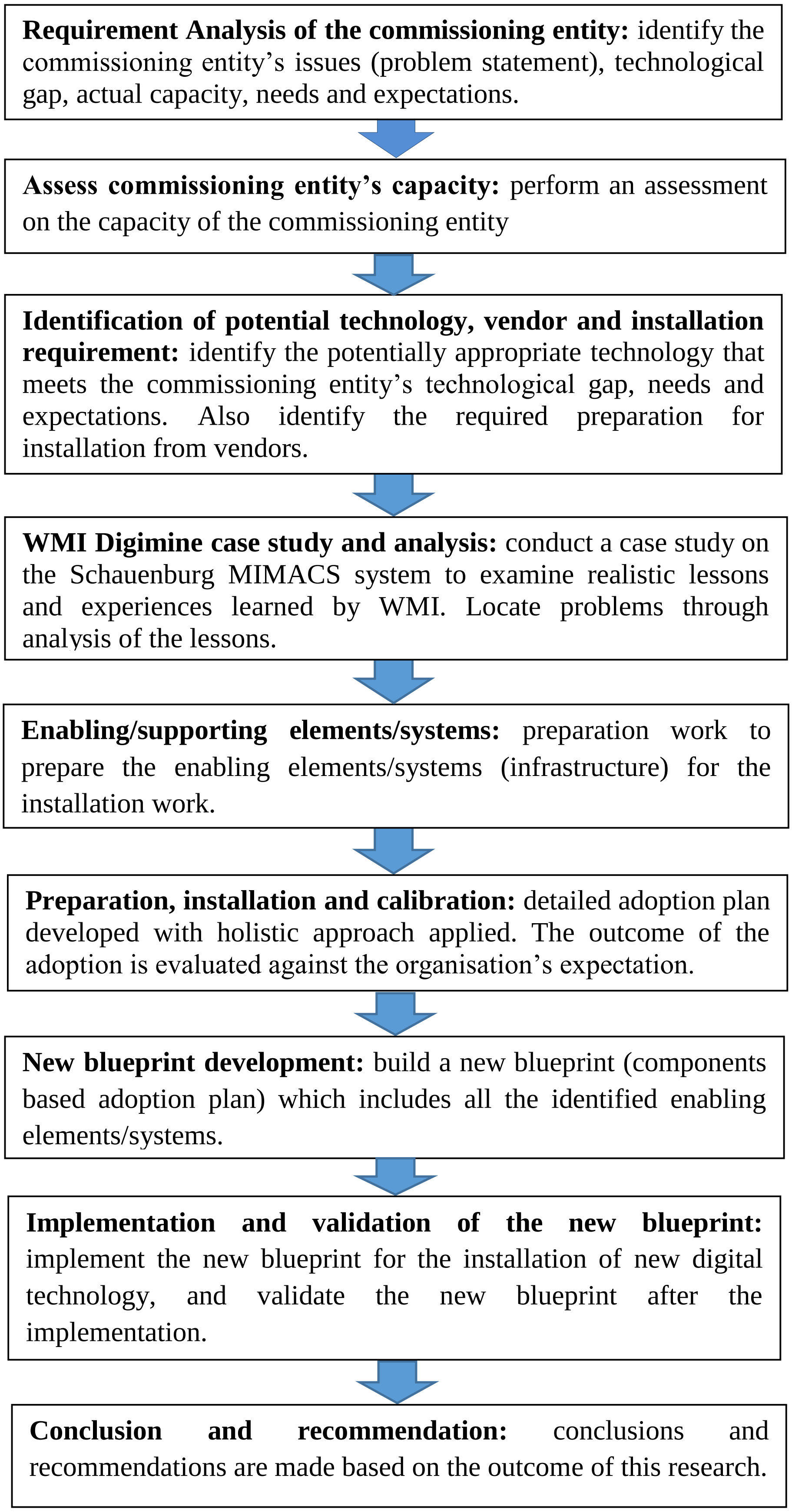


Figure 3-1 General research concept roadmap

3.1.1 Critical components of the research

Systems thinking is critical for this research in that systems thinking skill is a mental model that helps the commissioning entity to understand the complexity associated with new digital technology adoption. A system boundary is capable of providing a visualisation of where the external and internal factors are located in the system and how such factors affect the system functionality. Enabling systems with elements and new blueprint are the two most important components of this research. Enabling elements and systems will be identified first as they serve the foundation of the new blueprint. Once the enabling elements/systems are identified, they will become the input elements for the construction of the new blueprint.

Adoption rate and diffusion patterns are the two key parameters in the adoption processes of new technologies. Adoption rate is a parameter that measures the level of acceptance of new digital technology in a commissioning entity. Figure 3-2 illustrates the adoption rate of several important innovative technologies in recent human history:

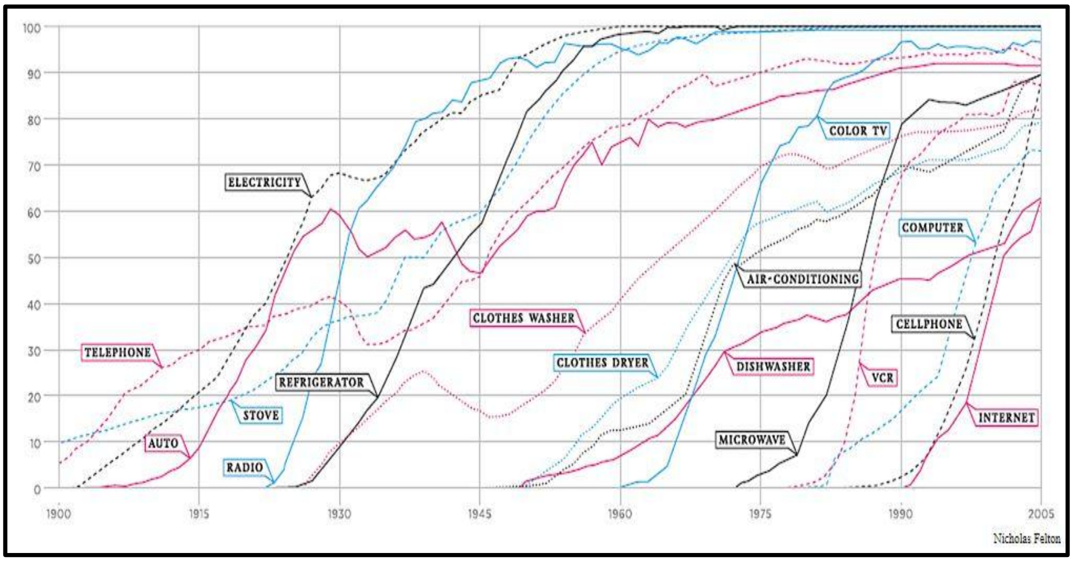


Figure 3-2 Adoption rate of various categories of product (Claessens, 2016)

Adoption rate together with the diffusion patterns represent the amount of time that is required for the system to be accepted and integrated into the existing systems in the commissioning entity. It can also be accounted as the time that it takes for the adoption process to complete. Diffusion patterns are the key indicators of how the technologies are diffused within a commissioning entity. The sequence is that the new technologies are introduced into the commissioning entity first, and that newly adopted technology then starts to diffuse within the commissioning entity. The diffusion patterns include but are not limited to the level of acceptance of the technology and the integration of newly adopted technologies into the currently existing systems in the organisation.

Different stages of new digital technology adoption require different enabling elements. The requirement of the enabling elements is in a chronological sequence. This chronological sequence allows the commissioning entity to prioritise the elements that are required for adoption. Thus less pressure is put on the commissioning entity in terms of capital, labour and other resources. This is due to the reason that resources required for adoption can be purchased and prepared as the adoption process proceeds. A case study on the Schauenburg MIMACS II system should provide insight into the chronological sequence of the enabling elements, and should have the same sequence in the new blueprint. However, the chronological sequence of the enabling elements varies between different commissioning entities since the situation of each commissioning entity is different.

3.1.2 Types and characteristics of the new blueprint

The level of the complexity of the mining operation has increased rapidly since the introduction of the digital technologies in the mining industry. Such complexity mainly occurs in the interaction between two major elements and the surrounding environment:

- Man (workers); and
- Machinery;

Figure 3-3 illustrates four most-widely used systems models that are based on the level of details of the system hierarchy. New digital technology adoption would normally have fallen into Figure 3-3's 'High Abstraction' level, where decisions are strategic and usually decided at managerial level.

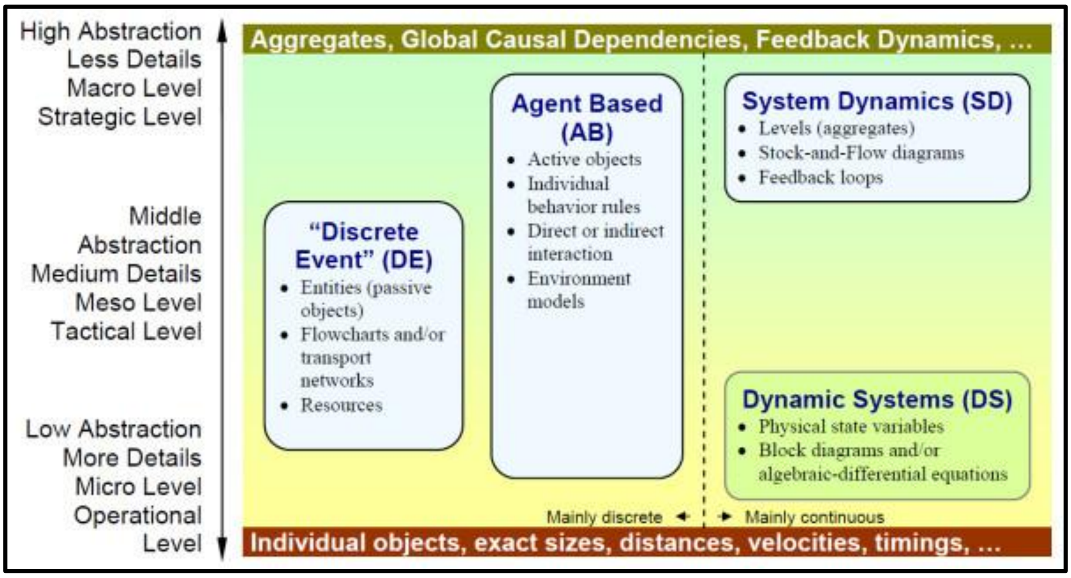


Figure 3-3 Systems model on different abstraction level (Bouarfa, et al., 2013)

However, not only have the perspectives of this research affected the level of the abstraction, but the details of the input of the systems model have also affected the level of the abstraction. The input of this research measures the macro-level of a commissioning entity from a managerial perspective. However, new digital technology adoption can also be at a Low Abstraction level with more details at the micro level when it comes to the technical part of the adoption (for instance, the bandwidth of the ICT of the commissioning entity). Based on the hierarchy of the adoption process and characteristic of this research, a combination of the systems dynamics model and the agent-based model is chosen to be the type of model for this research (see figure 3-3). There are four key components in the agent-based model, listed below (Bouarfa, et al., 2013):

- Active objects;
- Individual behaviour rules;
- Direct or indirect interactions; and
- Environment models.

All four critical components match the nature of the new digital technology adoption process and are described below.

- Active objects and individual behaviour rules

  Active objects are defined as the objects that are self-powered and have the capability of self-control. Most of the objects involved in new digital technology adoption are active objects; for instance: new digital technology suppliers, contractors and system operators. Behaviours of each agent pose influences on the adoption process.

- Direct or indirect interactions and environment models

  There are direct and indirect interactions between the objects involved in the adoption process. There are also interactions between the objects and the environment in the commissioning entity.

There are three key components in the system dynamic model (Bouarfa, et al., 2013):

- Levels;
- Stock-flow diagram; and
- Feedback loops.

A hierarchical new architecture is chosen for the new blueprint to properly manage the progression of the three critical phases contained in the adoption process. An influence diagram will be created based on the principle of the flow and stock diagram. The advantage of influence diagram is the visualisation of how the enabling elements within a commissioning entity affect the decision-making process. Such an influence diagram also allows the commissioning entity to evaluate the importance of a certain element and shift the resource onto the most critical agent to ensure successful adoption. One of the key features in the influence diagram is the feedback loops, which not only allow the commissioning entity to understand the impact of a new digital technology on the whole commissioning entity, but also provide a clear image on the functionality and position of a specific element in the entire adoption possess. It also enables understanding if the specific element affects the entire process positively or negatively. A study on the measurements for new digital technology adoption developed by WMI will also be carried out. The outcome of the study on these measurements provides crucial information to the model building and the new blueprint development.

3.2 Case study

In order to gain the insight into the problems that a commissioning entity may encounter during the new technologies adoption process, a case study on the digital technology systems that were installed at WMI Digimine will be performed. The focus of the case study is on lessons and experiences that cause delay and malfunction of systems during and following installation. Whereas the case study will be focusing on the Schauenburg MIMACS II system, other installations will also be briefed. The input data of the case study will be extracted from the historical data that is documented during the adoption and installation of digital technologies. The core data is the documented communication history between the organisation and the supplier of the system, including agreements, contracts, presentations, job cards, documents and emails. In the following chapter, the summarised WMI Digimine lessons and experiences are analysed. The objective of the analysis is to assess what could be improved in the adoption process. Thus in order to obtain a robust and reliable model, validation and correction are critical components of the case study, and the outcome of the case study provides several critical influential factors for input to the new blueprint development process.

3.3 A Systems thinking approach

Systems thinking is a useful tool to address complex problems, as it allows better practices such as problem identification, analysis and solutions to be carried out throughout the entire commissioning entity. Forrester described the benefits of using systems thinking in 1968; system thinking is capable of enhancing the decision-making process by focusing on the system feedback, not the single elements or the interactions among elements within the system (Foresster, 1968).

One of the biggest advantages of applying a systems thinking approach is gaining a big picture of the entire adoption processes of new technologies, not only to focus on individual influential factor from a view-angle of a technical expert, but also to promote the managerial perspective.

Systems thinking approach has been widely recognised and practised in addressing complex technology-related problems. Successful cases include innovative farming technology diffusion in agribusiness, and advanced ICT adoption in Thailand SCB banking system. In these two cases, systems thinking is not only used to smooth the adoption process, but also to study critical parameters such as adoption-rate and diffusion-patterns. The latter two parameters are the critical indicators of the progress of the technology adoption and diffusion within the commissioning entity. Technology itself will not be functional without proper support within the commissioning entity and the surrounding operating environment.

In the principles of systems thinking, the SOI is the core objective intended to be achieved by the system through a series of collaborative activities which involve all elements of the system. Supportive elements that are required by the collaborative activities to be carried out, are called “enabling elements”, with two or more enabling elements forming “enabling systems”.

INCOSE defined “enabling elements” as the key elements that support the SOI within the boundary of the system, and “enabling systems” as the systems and services that are presented within the boundary of the system. Both “enabling elements” and “enabling systems” are critical to the system as they form the foundation of the system and support the system to achieve its SOI (David, et al., 2015).

In this research, enabling elements are distinguished based on the requirements of adoption of new digital technology, and categorized into different groups based on the characteristics of the elements themselves. Systems thinking is selected for a better understanding of the enabling elements and systems required for the adoption. The enabling elements and systems are then categorized and processed for transfer into the new blueprint. A systems model is built by using the systems thinking techniques to visualise the importance of the individual enabling elements and systems in the whole adoption. The following section provide information on some critical system components and explanation of systems thinking terminologies.

3.3.1 Systems hierarchy

The hierarchy of the systems model for new digital technology adoption represents the relationships between new technologies and the commissioning entity. Based on the characteristics of new technologies and the property of the commissioning entity, there are four levels incorporated in a systems hierarchy (see table 3-1).

Table 3-1 Systems hierarchy of new digital technology adoption:

<table>
<tr><td>System Hierarchy</td><td colspan="6">Systems structure</td></tr>
<tr><td>Level 1</td><td colspan="6">Commissioning entity (organisational culture and factors)</td></tr>
<tr><td>Level 2</td><td colspan="3">Current existing technology systems</td><td colspan="3">New technologies</td></tr>
<tr><td>Level 3</td><td colspan="3">Suppliers/Vendors/Stakeholders</td><td colspan="2">Infrastructure (ICT)</td><td>Functionality</td></tr>
<tr><td rowspan="2">Level 4</td><td colspan="3">Post-adoption services</td><td rowspan="2">System champion
Human factors
Individual behaviour rules</td><td rowspan="2">Preparation work, Hardware
&
Software installation, future upgrade</td><td rowspan="2">Productivity and safety enhancement,
&
Real-time alert
notifications</td></tr>
<tr><td>Maintenance
(Self-maintain, regular/major)</td><td>Training
(operators/crews)</td><td>Recovery procedure for system
breakdown & malfunction</td></tr>
</table>

The system model that will be developed in this research is a combination of both a dynamic systems model and an agent-based model which cover all four levels of the system hierarchy. The systems hierarchy also represents the path of adoption of the new technologies within the commissioning entity. The activities carried out in level 1 are called identification: the commissioning entity first identifies the actual capacity of itself, and then identifies potential appropriate new technologies that match needs and fill the technological gap of the commissioning entity. Study at this level focuses on influential factors such as organisational culture and business model. Level 2 represents potential issues in merging the newly adopted technologies into the current existing technology systems. Level 3 shows all enabling systems that are needed for the new technologies to be adopted. Level 4 is the break-down of the enabling systems. All the enabling elements in level 4 are compulsory to maintaining the functionality of the newly adopted technologies. The input data that is required for developing the systems model will also be identified and categorized based on the systems hierarchy.

3.3.2 Systems boundary

Defining the systems boundary is critical for any system that involves multiple elements. INCOSE defines the systems boundary based on the concept of internal and external views. Internal view means all elements within the system; External view represents all elements that form the operating environment. The systems boundary is an imaginary line that separates the internal view and the external view of a system (David, et al., 2015). The system hierarchy discussed in the above section helps this research to set the system boundary (see figure 3-4). However, elements that lie above level 1, such as mining regulatory bodies, are not included in the research. Elements that lie below level 4's enabling-elements are also not considered in the research. Any elements in the operating environment that interact with the system are included in the research.

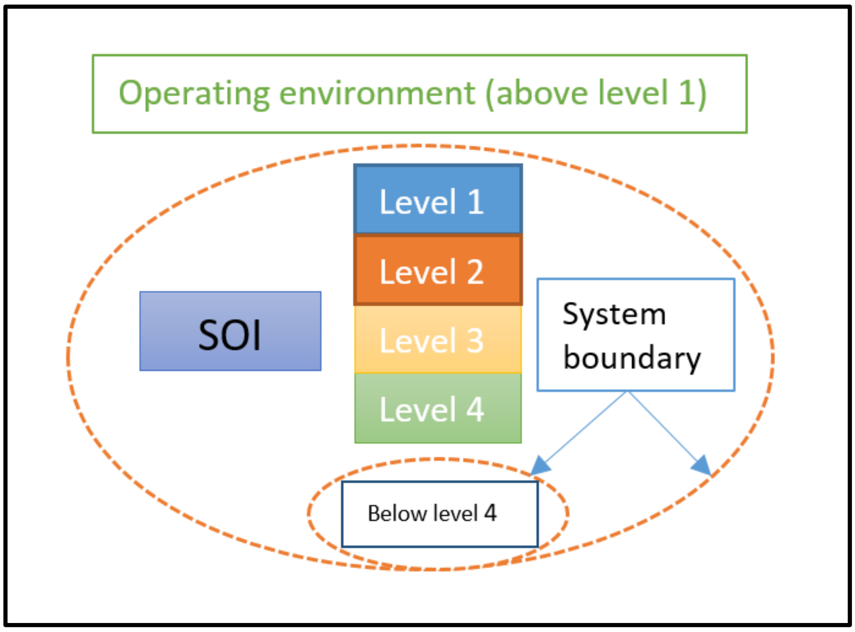


Figure 3-4 System boundary of research

3.3.3 Enabling systems

Level 3 and Level 4 consist of all the enabling elements and systems required for the new digital technology adoption process. Such enabling elements need to be considered extremely carefully as they set the foundation for the entire adoption process, as well the systems model.

The ultimate goal for any new digital technology adoption is to allow the newly adopted technology to reach its full functionality. Hence, the quality of enabling elements and systems are key influential factors in the adoption process. No technology system will be functional without the support of the enabling elements and systems.

Before the study on the enabling elements and systems can begin, the concepts of adoption rate and diffusion patterns need to be understood (refer to section 3.1.1). This is due to the fact that enabling elements and systems pose great impact on the adoption and diffusion rate. The study of the enabling elements and systems is therefore a key focus for both the case study and the systems model. The study on the critical elements covers the physical elements that facilitate the adoption process of new technologies within the commissioning entity, such as vendors and stakeholders. The study on the supporting systems will cover the agreement and technical management processes, for instance, preparation work and infrastructure development.

The following discussions will describe lifecycle processes.

3.3.4 Lifecycle process

The international standard for system engineering process is used to guide the building process of a robust and repeatable systems model. The following three standards are the most frequently used in this research.

- INCOSE systems engineering handbook: A guide for system life cycle processes and activities (INCOSE, 2012);

The entire adoption process can be considered as a lifecycle process from a systems thinking perspective. The lifecycle starts with the identification of the potential technologies. This is followed by the adoption and integration process to allow the newly identified technologies to fit into currently-existing systems in the commissioning entity. Eventually, the final phases are maintenance and closure of the system. Application of international standards will not only guide the building process of the systems model and new blueprint, but also help to standardise the procedures for new digital technology adoption.

Based on the principles of systems life cycle that are stated above, the entire adoption process in this research is divided into three phases, namely:

- Pre-installation;
- Installation phase; and
- Post-installation phase.

The justification for having three phases is to gain better control of the progression of the entire adoption process, in terms of budget, schedule and resources. The outcome of each phase needs to be assessed before the subsequent phases can start.

3.4 New blueprint development

The ultimate goal of this research is to develop a new blueprint to guide commissioning entities in new digital technology adoption. Two important properties of the new blueprint are *robustness* and *repeatability*. The building process of the new blueprint will combine the results of the case study and WMI Digimine learnings to ensure the robustness. International standards for systems life cycle and systems engineering are chosen to standardise each step of the new blueprint to ensure the model is repeatable and comprehensive to other commissioning entities.

3.5 Summary

A systems thinking approach is an effective method to handle the complex adoption process of new technologies in the mining industry. A case study on WMI Digimine installations will be carried out by examining the critical lessons learned from the adoption of new mining technologies. The outcome of the case study will be used as part of the input parameters for the new blueprint development. The case study is crucial to this research as the quality of the new blueprint is highly dependable on the quality of the input parameters. It also helps to identify critical components for the adoption process, such as systems boundary, stakeholders' network and enabling elements and systems. A hierarchical new architecture is chosen for the new blueprint to identify all the enabling elements and systems required for the adoption, and to further help the progression of the entire adoption process. This new architecture also allows the commissioning entity to monitor the progression and quickly detect any problems that occur during the adoption. Once all the critical components of the new blueprint are determined, a new blueprint will be developed. International standards are chosen as the backbone of the new blueprint development, and further ensure that a robust and repeatable new blueprint is built.

The following chapter will be the case study on the WMI Digimine's installation project of the Schauenburg MIMACS II system and other digital technology installations at WMI. Procedures developed by WMI for new digital technology adoption, such as WMI vendor management system, will also be studied. Outcomes from these studies will provide crucial information for the input resources needed for the development of the new blueprint.

4 An overview of the ICT system at WMI

4.1 Introduction

An overview of the ICT system at WMI is conducted in this chapter, firstly to demonstrate the usefulness of new digital technologies in the enhancement of productivity and safety for the mining industry, and secondly to understand the complexity associated with components and functionality of digital technologies in mining operations. The second point is familiar with the ICT system installed at WMI, particularly the Schauenburg MIMACS II system. The objective is to prepare for the case studies on such systems in chapter 5.

To begin this chapter, a critical question needs to be asked: Why should a systems thinking approach be applied to new technologies adoption in the mining industry? The question can be answered by examining why there is a demand for such technologies: For decades, the South African mining industry has been deeply inhibited by its unsustainable labour-intensive operating model. The mining industry has realized the situation and its need for solutions. In this context, the mining industry recognises the potential of new technologies, and the improvement that can be reached by implementing such technologies. However, the actual effectiveness of such new technologies is still debatable. In this context, Wits Mining Institute (WMI) was established with a mission to conduct 21st century research that includes technology development for the mining industry. WMI's research agenda includes smart, intelligent and safer mining with reduced risks. WMI has also developed an approach to achieve such objectives by utilising cutting-edge mining technologies. The following table illustrates the approach that WMI uses to reduce risks (Cawood, 2018b).

Table 4-1WMI's approach to mitigating mine risks

Risk Evaluation	Risk Control	Risk Management
Mining Technical	Visual Systems	System Integration
Mine Management	Technology RDI	Skills Development

Table 4-1 clearly indicates that new technologies have played a significant role in WMI research. They are also the core of WMI's approach to mitigating mining-related risks. Furthermore, such new technologies are mainly ICT coherent. Selection of such technologies is based on the R&D themes of WMI (see figure 4-1).

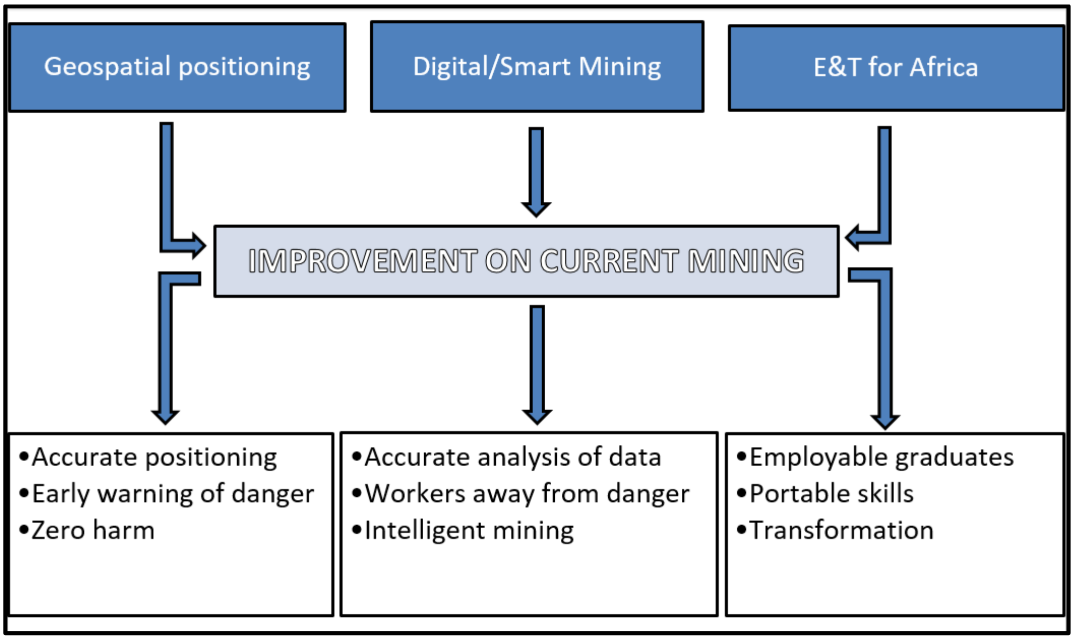


Figure 4-1 WMI R&D model (Cawood, 2018b)

Figure 4-1 shows that WMI's intent is producing desirable research outcomes by utilizing available technologies, e.g. geospatial positioning. These research outcomes are categorized into different groups based on research topics. The following is a list of research topics that WMI is currently conducting (Cawood, 2018b).

- Extend surface technologies to underground;
- Communication systems;

- Positioning, mapping and navigation;
- Real-time systems, e.g. Scheduling system;
- Action recognition;
- Detection of abnormalities;
- Visual environmental and rock monitoring;
- Distancing people from risk; and
- Installation, Testing and Certification of systems.

The above list expose that WMI research requires a multi-disciplined knowledge body. Four main research themes are selected based on concerns regarding problems in the mining industry. The following is a brief discussion of these four main research themes (Cawood, 2018a).

Theme 1 - Communications

1) Reliable underground communication (ICT) systems;
2) Extend surface technologies to underground; and
3) System testing.

ICT technologies have changed communication in smart mining. The associated rapid increase in data volume demands a faster and reliable communication system for data processing. The communication system therefore needs to be prioritized in the smart mining project. As such, WMI has set communication as foundamental to its research work.

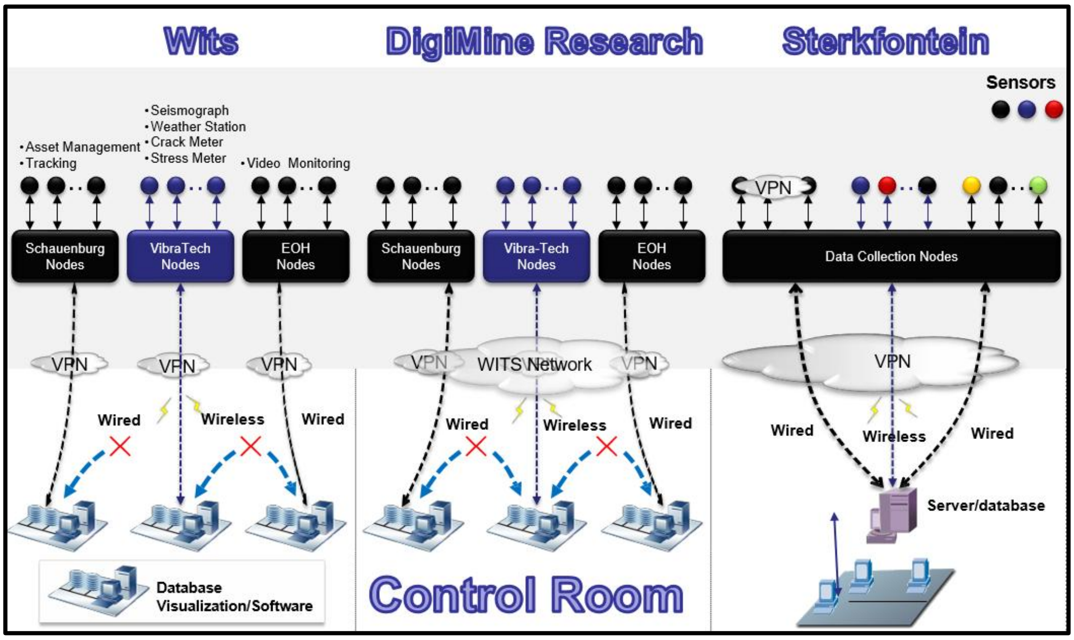


Figure 4-2 WMI Communication System (Cawood, 2018a)

Figure 4-2 provides an overview of the WMI communication system, which includes three subsystems:

- Wits network;
- Digimine Research network; and
- Sterkfontein system (a simulated mine build inside the Sterkfontein cave).

WMI researchers have conducted several ICT technology-related studies. One of these studies is research into the correlation between tunnel geometry, antenna position and signal strength in an underground mining environment. Another study uses available wireless communication technology to locate missing miners in mine-accident scenarios.

Theme 2 - Surveying, Mapping and Navigation

1) From Roof to Sidewall networks;
2) From Indoor to Underground navigation; and
3) From Point-Cloud to Automation.

WMI research theme 2 includes research into geospatial positing technologies within the smart mining framework, i.e. surveying, mapping and navigation technology. Such technologies rely heavily on the communication system and form the foundation of the 21st-century mining industry. As such, they are capable of having impact on both current mining operation and the future of the mining industry.

Surveying and mapping technologies have been applied at each stage of the life cycle of the mining operation, from exploration to mine closure. Navigation technology is one of the fundamental technologies required for mine mechanisation and automation. WMI has several ongoing research projects under this research theme; one of which is using Geo-informatics technology to improve the accuracy of the underground navigation system by introducing above-ground satellite-like signals into underground environments.

Theme 3 - Health, Safety and Security

1) ANSYS[10] modelling of air flow;
2) 3DEC: mine stress build-up; and
3) Mine access: Abnormalities.

Mine health and safety has been a core subject of WMI research from its outset. It covers a wide range of topics in the mine, from occupational health to daily operation. WMI believes that advanced technology makes the ultimate aim of 'zero harm' achievable. The following is the basis of WMI's approach to the mine health and safety.

- Create distance between hazards and people;
- Use machines instead of people to execute dangerous work; and
- Use technology to detect abnormalities and to warn people of such.

[10] ANSYS and 3DEC are the names of supplier for products of such simulation software

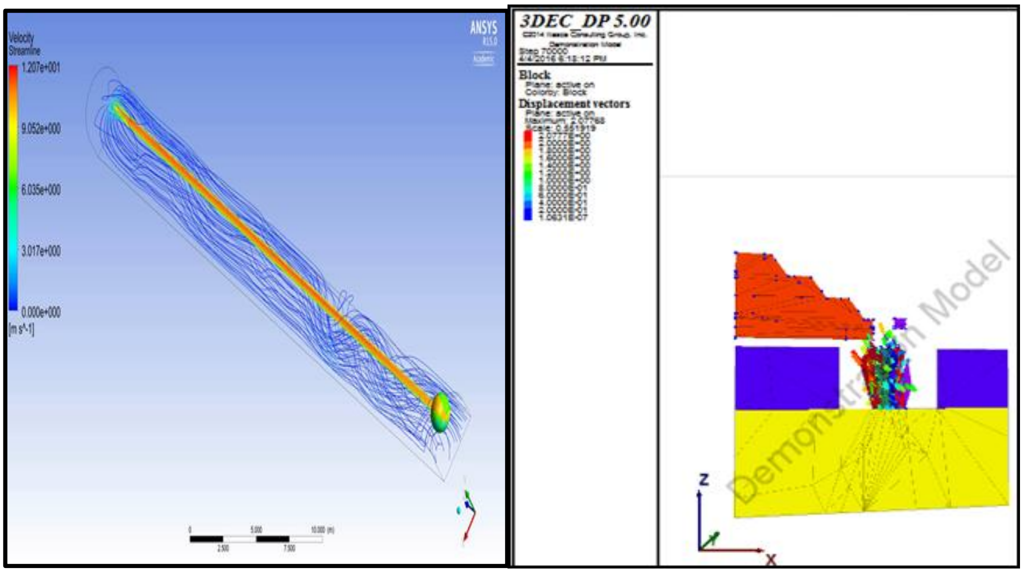


Figure 4-3 Modelling for ventilation and rock engineering by WMI (Cawood, 2018a)

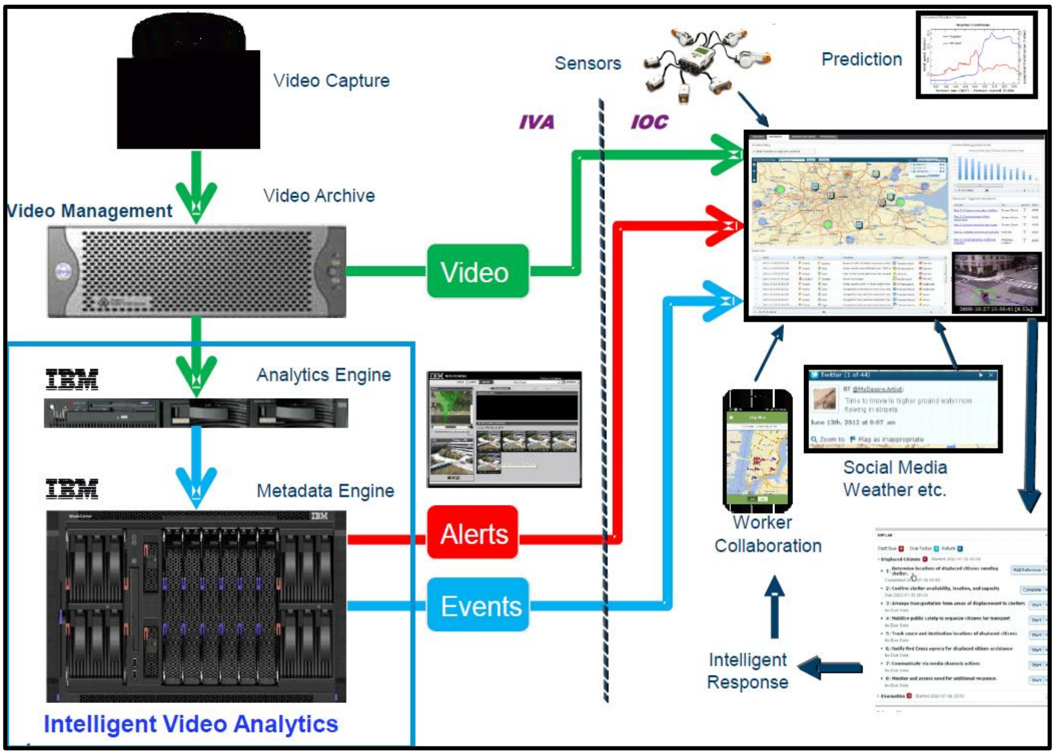


Figure 4-4 Smart mine access system (IBM)

WMI has dedicated multiple areas of research into both software and hardware to mitigate risks. Figure 4-3 shows the advanced software modelling in ventilation and rock engineering. Figure 4-4 is smart-mine access system developed by WMI and IBM. WMI has researched and acquired several technologies that integrate multiple safety features into one system. This includes Schauenburg MIMACS II which combines asset management, gas and fire detection and access control.

Theme 4 – Visualization for smart mining

1) Real-time systems;
2) Material tracking;
3) System integration;
4) Smart economics; and
5) Lightning density maps.

Mining operations normally cover wide areas, thus related data is scattered. This causes significant challenges in locating, gathering and storing such data. Thus data mining techniques are required to extract relevant data to be stored in a database. Analytical and optimization processes are carried out once the data is ready. The purpose of the data analysis and optimization is to interpret the data and present it in a format that can be easily understood, i.e. visual.

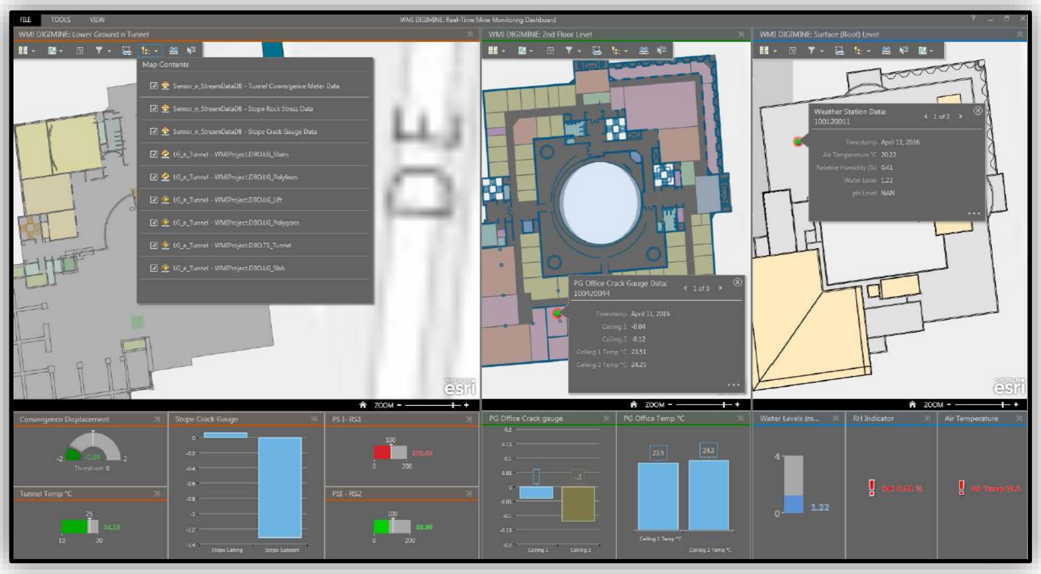


Figure 4-5 WMI-developed GIS-based mine visualization platform

Figure 4-5 shows the interface of a GIS-based mine-visualization platform developed by WMI. The interpretation of the data was achieved by using a dashboard-like display platform, which shows processed data in the form of graphics and charts. Another example is Vibra-Tech's seismicity monitoring platform (see figure 4-6).

Figure 4-6 Real-time rock-engineering information display system (Vibra-Tech)

Advanced technologies are therefore a major support-pillar to the research at WMI. The types of technology selected and installed directly affect WMI research work. Such technologies therefore not only need to meet WMI's organisational needs but also need to fit into the overall structure of WMI.

4.2 Overview of ICT system at WMI

WMI has developed its own approach for the identification and adoption of ICT technologies. Figure 4-7 illustrates the approach that WMI uses to acquire ICT systems. WMI has taken a different route to most organisations: WMI has built an external partner network based on the mutually beneficial agreement.

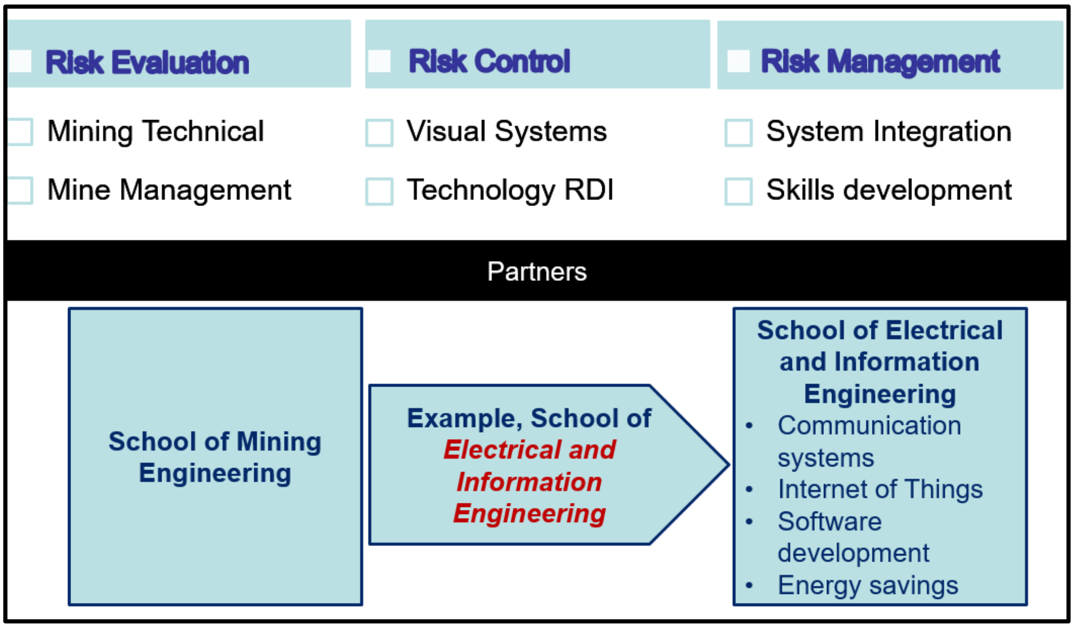


Figure 4-7 WMI approach to partner network development

Based on the four themes of the research plan, WMI has identified the following vendors and partners.

- NCM, VUMA, MineRP, Schauenburg, Vibra-Tech, Esri-SA, IBM, Mine-Tech

Guided by agreements, identified vendors provide their systems to WMI. WMI installs and tests the systems in their mock-up mine as part of their research. Both parties have access to data that is generated by the systems.

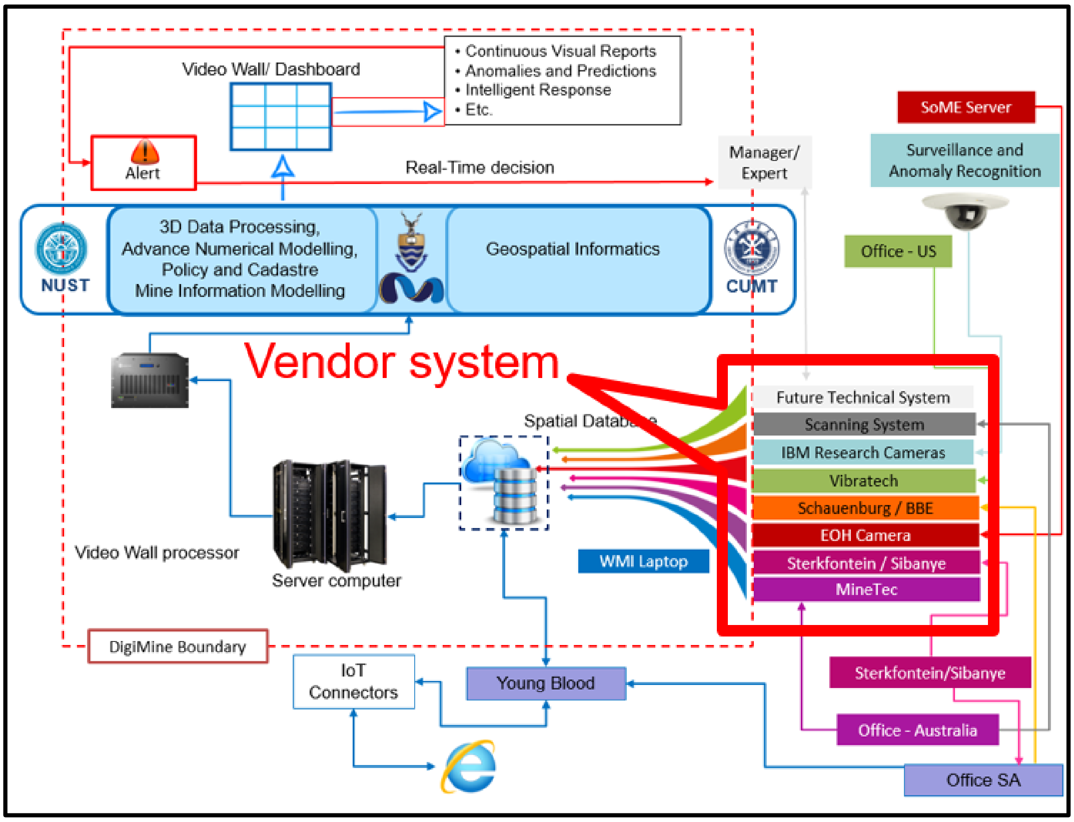


Figure 4-8 Overall WMI structure (Cawood, 2018b)

Figure 4-8 shows the overall new architecture of WMI. As may be seen, it consists several subsystems and components. The figure also shows the direction of data flow within WMI. Vendor systems and video wall are two technology groupings within the WMI digital mining system. The initial stage of WMI data chain starts at the vendor systems. The data chain ends with the display of visual information on the video wall. The following sections describe the ICT subsystem that forms the WMI vendor system.

4.2.1 WMI Digimine mock-up mine

The WMI mock-up mine is part of the WMI research laboratory that was constructed in 2015. Its located in the basement of the Chamber of Mines building on the West Campus of Wits University. The mock-up mine features the following components (see figure 4-9 and figure 4-10): Seventy-metre tunnel; cross-cut; lamp room; vertical shaft; stope; ventilation system; several digital sensors.

Figure 4-9 WMI mock-up mine

Figure 4-10 WMI mock-up mine tunnel (Source: Faiq Javaid)

The mock-up mine serves as a research laboratory for WMI. It simulates an actual underground mining environment. Students use the simulated mining environment as a testing ground for gathering data on their research.

4.2.2 Vibra-Tech system

The main functionality of the Vibra-Tech system is seismicity vibration monitoring. The system uses a series of sensors that are placed at strategic locations for data collection.

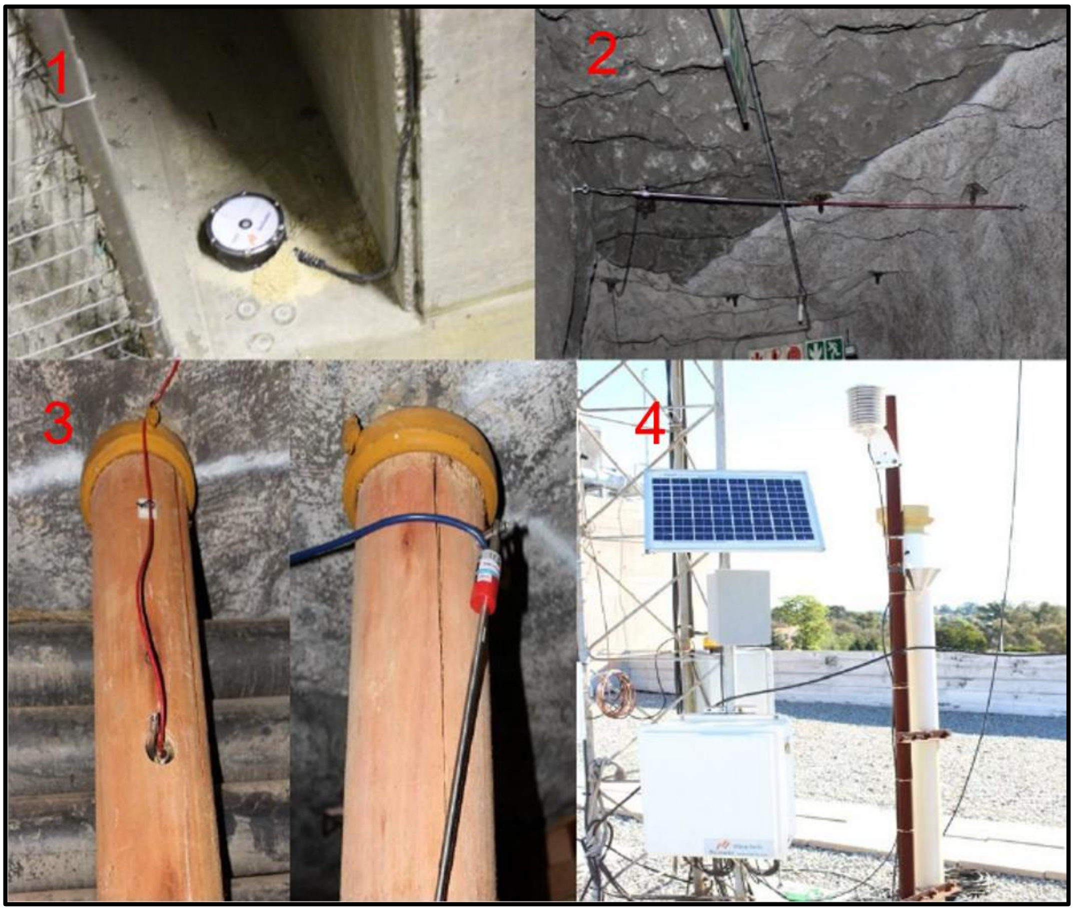


Figure 4-11Vibra-Tech sensors at WMI mock-up mine (Source: Faiq Javaid)

Figure 4-11 shows key locations of Vibra-Tech sensors in the WMI mock-up mine. The following are the functions and installation details of Vibra-Tech sensors in the WMI mock-up mine:

1) Seismometer sensors are placed on the floor of the stope to detect seismicity;
2) Extensometer sensors are placed on the roof of the stope to detect rock movement;
3) Crack meter sensors are placed at the permanent support to detect deformation; and
4) The weather station is installed at the surface of the mock-up mine to collect critical weather information, e.g. precipitation.

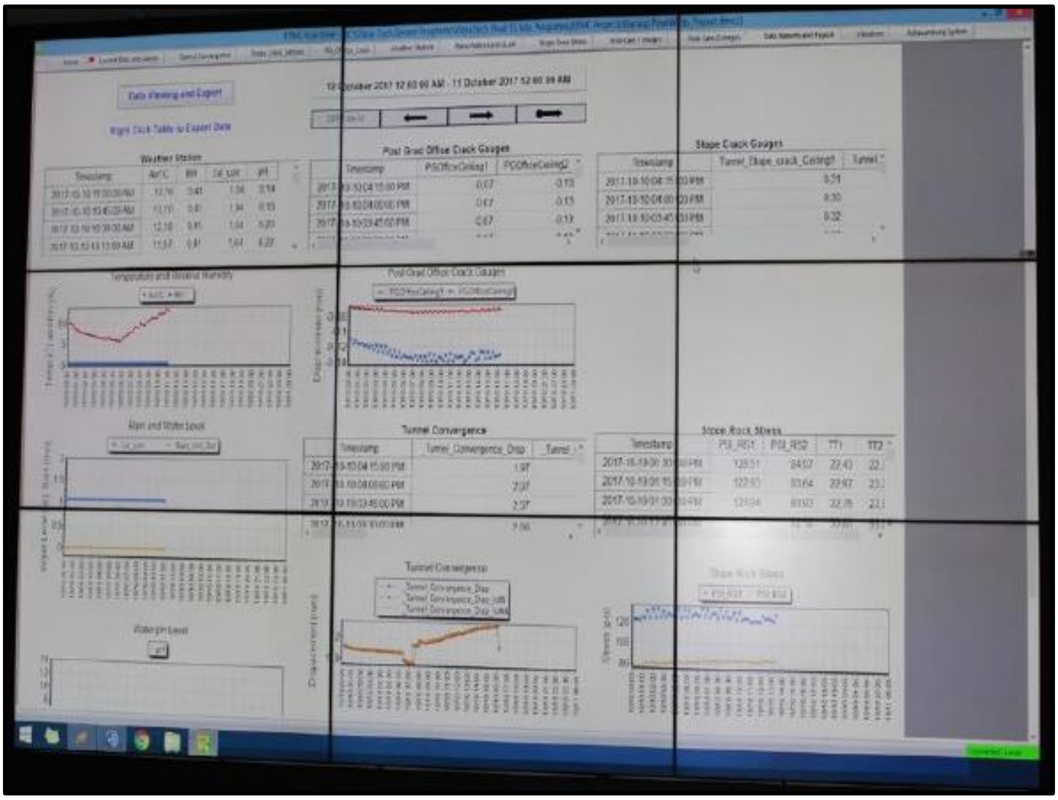


Figure 4-12 Vibra-Tech information on the WMI video wall

Data is processed via Vibra-Tech software and then displayed on the video wall (see figure 4-12). Thresholds set by Vibra-Tech are designed to detect abnormality. Any unusual readings that exceed thresholds will trigger alarms designed to alert the operator in the control room.

4.2.3 Camera system

At present, two camera systems are installed at WMI, namely IBM intelligent system and EOH camera system (see figure 4-8). The main functionality of the two camera systems is continuous surveillance. Data collected by the camera systems is sent to the WMI server for analyses and optimization. All processed data is then displayed for visualisation on the-control room video wall (see figure 4-13).

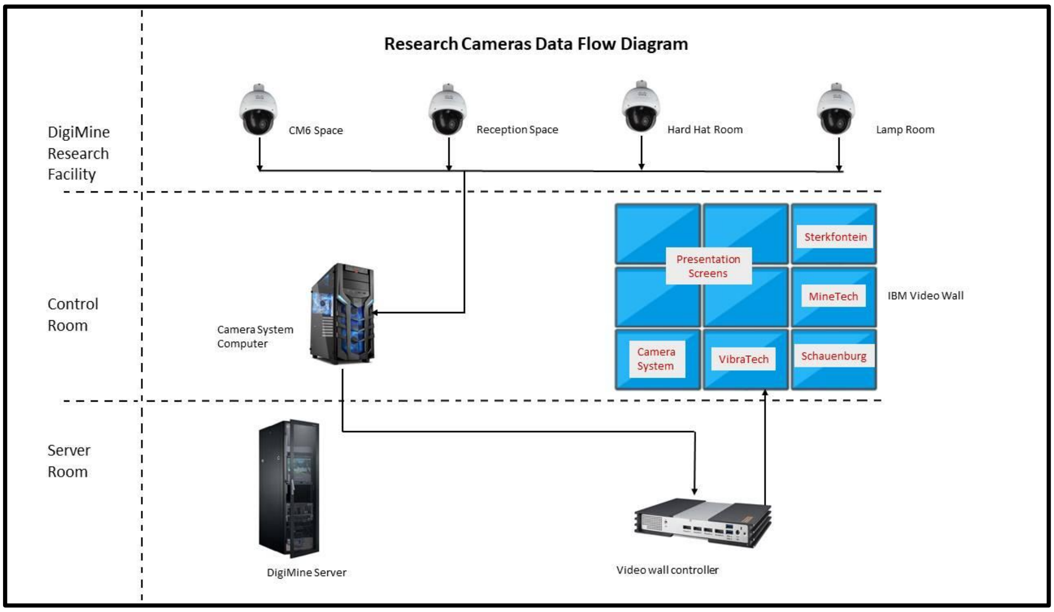


Figure 4-13 Structure of camera system at WMI (Hlatswayo & Kelvin, 2017)

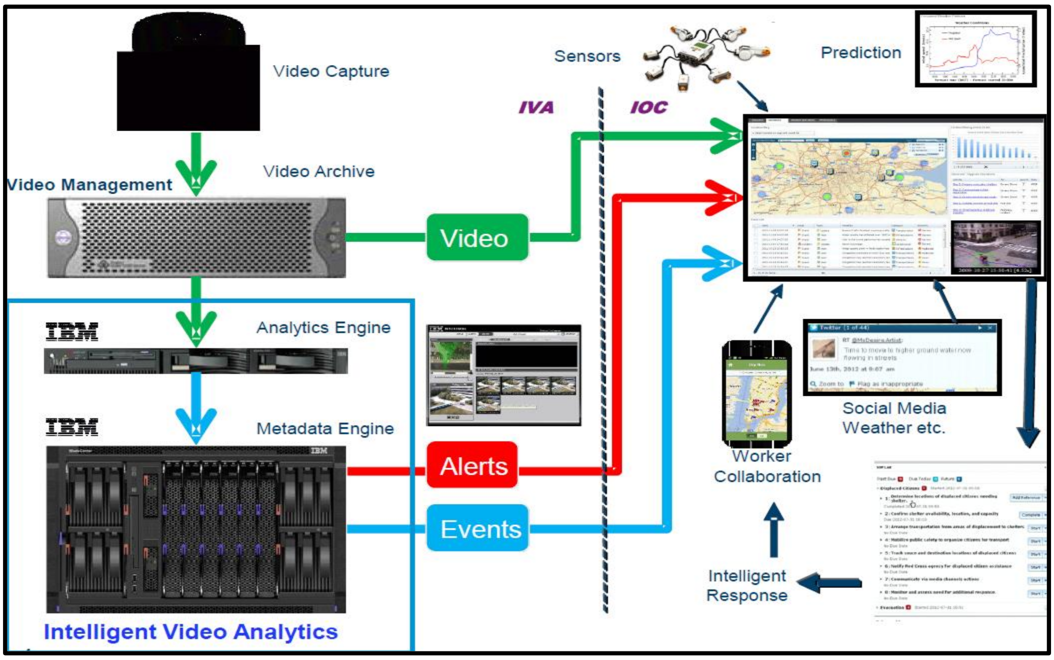


Figure 4-14 Structure of IBM intelligent camera system

However, complex security problems cannot be simply addressed by only having surveillance on the premises. IBM has developed an intelligent camera system that processes the data via software. The IBM processed data can then be used for advanced safety and security measurement (see figure 4-14). The following list states some of the advanced functionalities of this IBM system (Hlatswayo & Kelvin, 2017):

- Real-time data communication and abnormality alert;

- Intelligent mine access control, e.g. counting people;
- Detect personnel that are in a horizontal rather than vertical position, i.e. accident-victims, sleeping, etc.; and
- Facial recognition, i.e. detect unwanted personnel access to mine premises.

As may be seen, such integrated camera systems provide extensive mine-access, control and security solutions for the mining industry.

4.2.4 Schauenburg MIMACS II system

Schauenburg is a company specialized in integrated industrial systems. MIMACS II is a system that Schauenburg specifically designed for the underground mining operation. MIMACS II stands for 'Mine Wide Integrated Monitoring and Control System'. This integrated system provides the following functionalities (Schauenburg System, 2015):

- Mine access control;
- Asset management;
- Environmental monitoring;
- Lamproom asset management;
- Ambient environment monitoring; and
- Personnel and equipment position tracking and management.

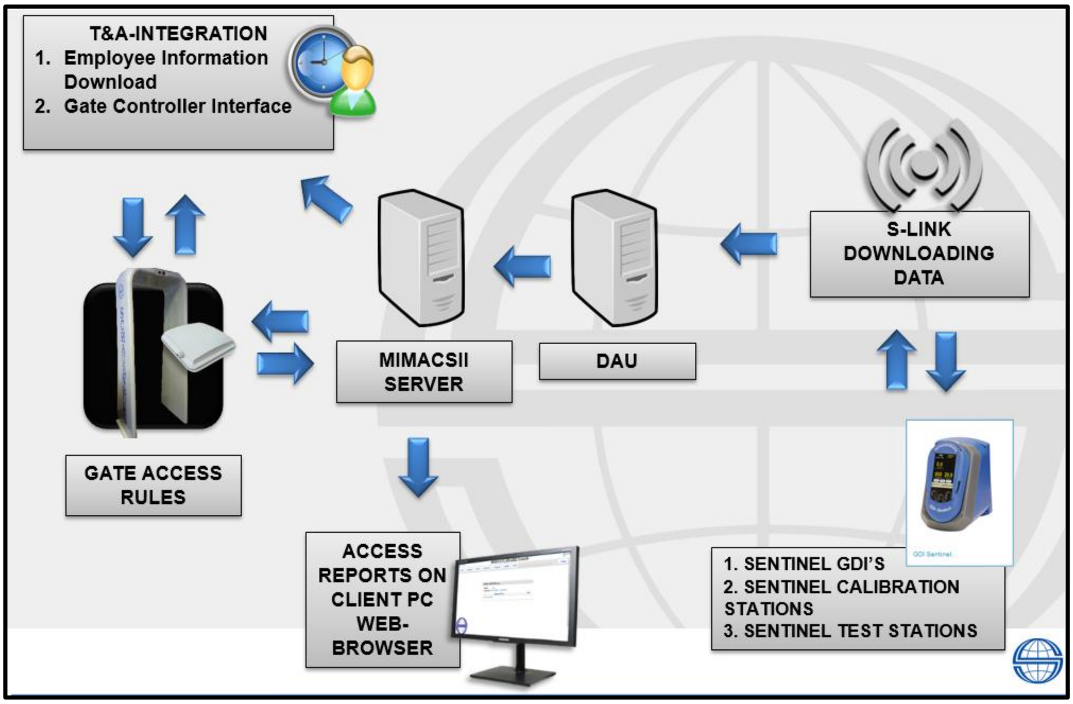


Figure 4-15 Schauenburg MIMACS II system overview

Figure 4-16 Schauenburg installation at WMI mock-up mine (Source: Faiq Javaid)

Schauenburg has taken a somewhat different route to IBM in the context of smart-mine access control: Schauenburg utilised the employee information database to achieve secured mine access control. Mandatory equipment needs to be carried by the workers, namely Gas

Detective Instrument (GDI), cap lamp and self-rescue pack. Schauenburg has developed special gate access rules that require the worker to carry all three pieces of equipment (see figure 4-15 and figure 4-16). Illegal miners would not have such equipment, thus would be entry-prohibited by the system and reported. As an integrated system, MIMACS II systems also includes the following features to assist the mine (Schauenburg System, 2015).

- Assets and personnel assignment and management;
- Report generation, download and viewing capability;
- Personnel tracking and paging function;
- Equipment repair and maintenance log history;
- Employee attendance register; and
- SCAS-Schauenburg Collision Avoidance System.

However, WMI has experienced multiple malfunctions and breakdowns since installation of the MIMACS II system and has therefore struggled to maintain full functionality.

4.2.5 Mine-Tech system

Mine-Tech is a company that offers tailor-made technological solutions to the mining industry. WMI's Mine-Tech installation uses a real-time communication system to track personnel and assets in an underground mining operation (Mine-Tech Limited, 2017). The two-way communication in WMI's mock-up mine is via a cable network (see figure 4-17 and figure 4-18).

Figure 4-17 Mine-Tech installation at WMI mock-up mine (Source: Faiq Javaid)

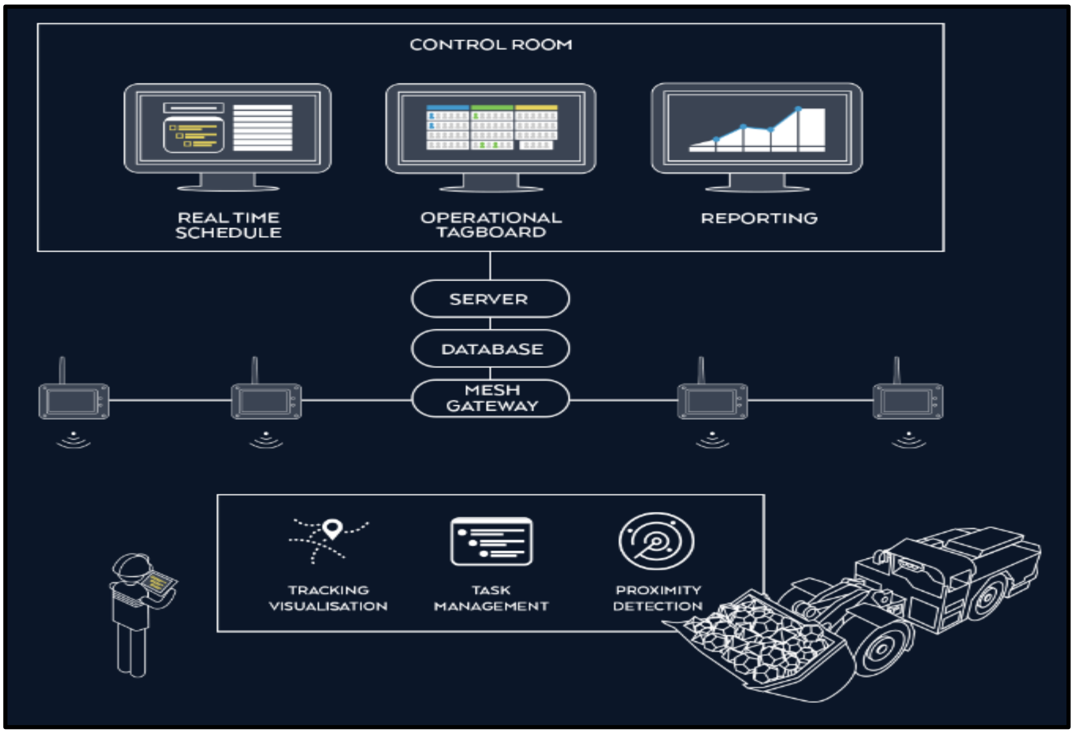


Figure 4-18 Overview of Mine-Tech system (Mine-Tech Limited, 2017)

4.2.6 youngBlood system

youngBlood is a consulting company that has special skills in database management. youngBlood IoT reporting platform was acquired to manage data generated in the WMI mock-up mine. This data management platform converts data into visual-format reports (see figure 4-19).

Figure 4-19 youngBlood IoT reporting platform (Source: Faiq Javaid)

4.2.7 WMI Video wall

WMI's intent is to utilise all of its gathered data to generate value for research. WMI has constructed an intelligent operations centre to manage all its vendor systems together with data provided by these systems (see figure 4-20).

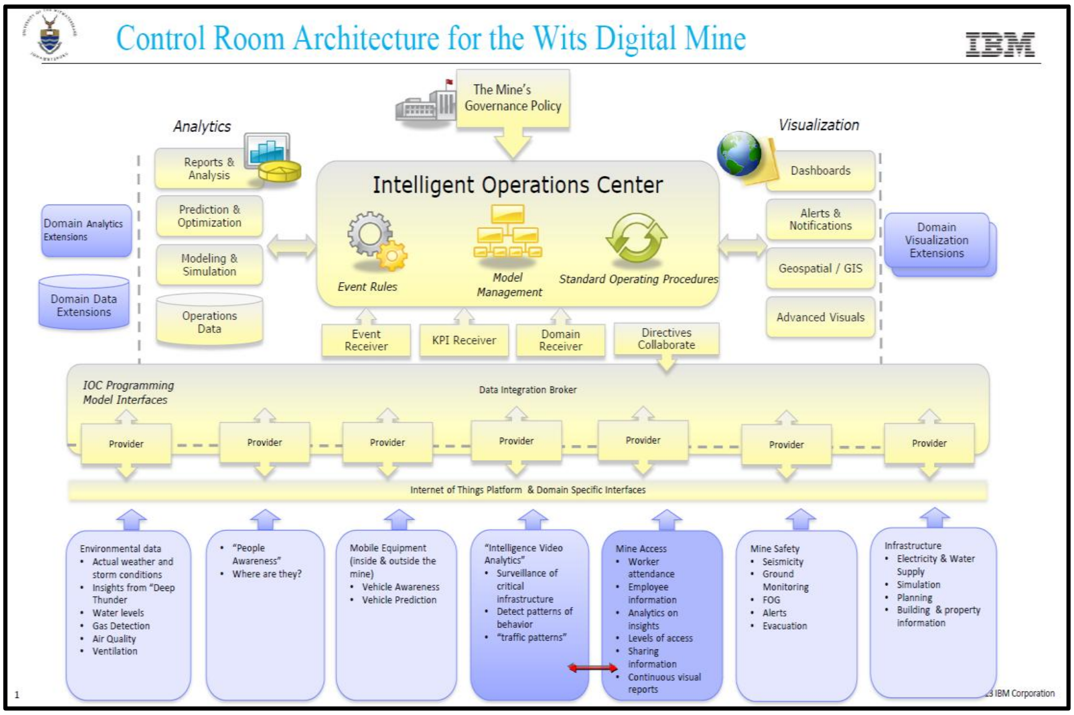


Figure 4-20 Overview of WMI Intelligent Operations Centre

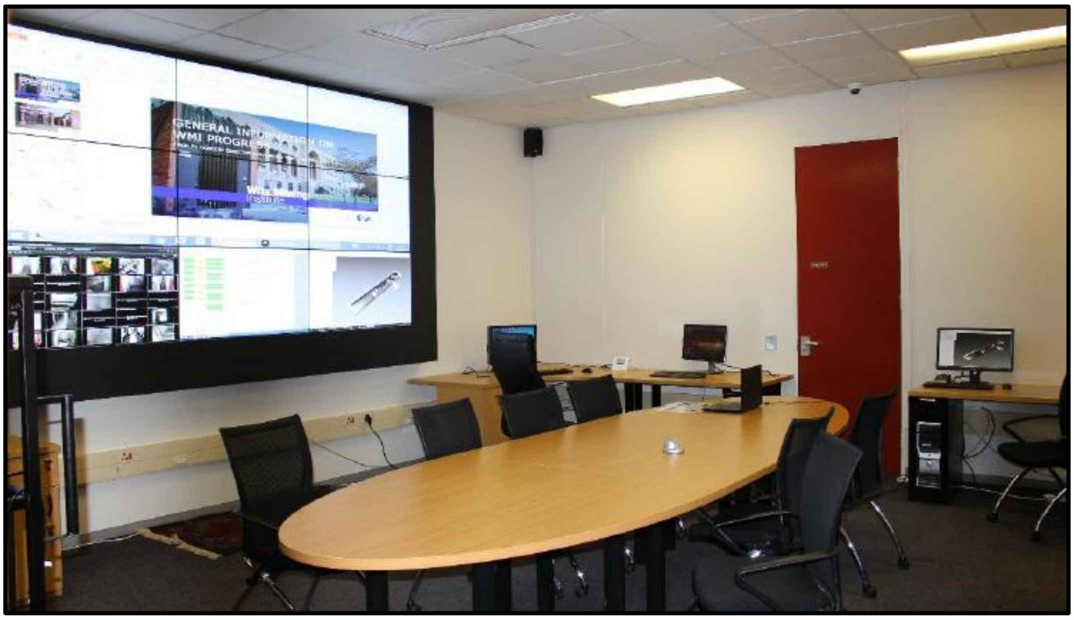


Figure 4-21 Control room at WMI (Source: Faiq Javaid)

In the case of emergency, this operations centre is capable of reacting faster than a traditional mine setup. In the WMI mock-up mine, abnormality is first detected by vendor system sensors. The basic information is then categorized based on the nature of the abnormality. Following this, categorized information is feed into the Data Integration Broker for further processing. Processed data is then fed into associated domain receivers. Finally, the domain extension decides the format in which the data needs to be displayed on the video wall, e.g. analytics charts or visual images (see figure 4-21). Thus the original abnormality that occurred in the mock-up mine has now been transformed into visual information. Properly-trained control room operators are thus enabled to take speedy action according to the SOP. In summary, this set-up allows dangerous events that occurred underground to be simultaneously visually analysed at the surface.

4.3 Summary

Identification and adoption of new digital technology that are marketable and reliable is not an easy task. Such technology needs to fit into the commissioning entity. Preparation work is required for the technology to reach its full designated performance and functionality. WMI developed its own system to ensure that it receives the latest technology as well as support from the mining industry. In this context, complicated technology requires collaborative effort to maintain its full functionality. The next chapter reveals the importance of a holistic approach when dealing with the adoption process of such technologies. This is done via case studies on the installation project of the Schauenburg MIMACS II system and other digital technologies installed at WMI. The practice and procedures for new digital technology identification and adoption developed by WMI will also be discussed.

5 A case study on the WMI Schauenburg MIMACS II System installation project

5.1 Introduction

(Note: Schauenburg MIMACS II system has been abbreviated to MIMACS in following discussions).

An important part of this chapter is to carry out a case study on the 2016 installation project of the Schauenburg MIMACS system at WMI. (MIMACS system is a fully-integrated, safety-enhancement platform for surface and underground mining operations.) The major objective of this case study is to investigate what WMI experienced during the installation of MIMACS system in its mock-up mine. The investigation focuses on the main causes of installation delay and system malfunction problems. The investigation includes both external and internal factors that could have caused the above mentioned problems. (Internal factors are factors that occurred within WMI. External factors are factors in the operating environment surrounding WMI.) Mitigation processes for these factors have been considered as lessons for WMI. WMI recognises the value of such lessons and their importance for new digital technology adoption in the future. Findings of the case study are thus classified and analysed. The outcome of the analysis reveals aspects that could cause project delay and system malfunction. Information and data gained in this chapter will be used for developing the new blueprint to guide other commissioning entities through new digital technology adoption. The outcome of this chapter will also provide critical information for the following chapter 6.

5.2 The approach followed

As introduced in chapter 2's literature review, systems thinking is ideal for analysing interactive relationships between multiple components in a system. Thus systems thinking techniques have also been applied in the case study to ensure functionality. System boundary is also established to define the SOI (system of interest) and system scope. The usage of systems thinking techniques means that all influential factors will be looked at the organizational level of WMI (an organizational level perspective will also provide insight into all the components that form WMI). The interactive relationship between influential factors will be studied, as well as the correlation between influential factors and the environment. The case study is divided into three sections according to the structure of the new blueprint.

- Pre-installation phase;
- Installation phase; and
- The post-installation phase.

Data that was originally documented during the installation will be used for this case study. The latter data includes multiple aspects, the core for this case study being records of project delay and system malfunction. The section below is a detailed work plan for the case study.

The first step is to establish a system boundary by analysing the MIMACS system using a systems map method. This step is aimed at understanding the organisational structure of WMI and the operating environment of MIMACS system. In addition, key components and enabling elements that support the achievement of the SOI are identified. The intent of this step is to break down the MIMACS system and installation project into its individual components and influential factors, in order to allow fast-track analysis of associated problems.

The second part of the case study is to investigate the problems that occurred during the installation project. Such problems are analysed to find the cause of the system malfunction.

5.3 Systems map of WMI

As discussed in chapter 2, systems boundary is a conceptual line rather than a physical boundary. Figure 5-1 is a systems map created based on the overall new architecture of WMI.

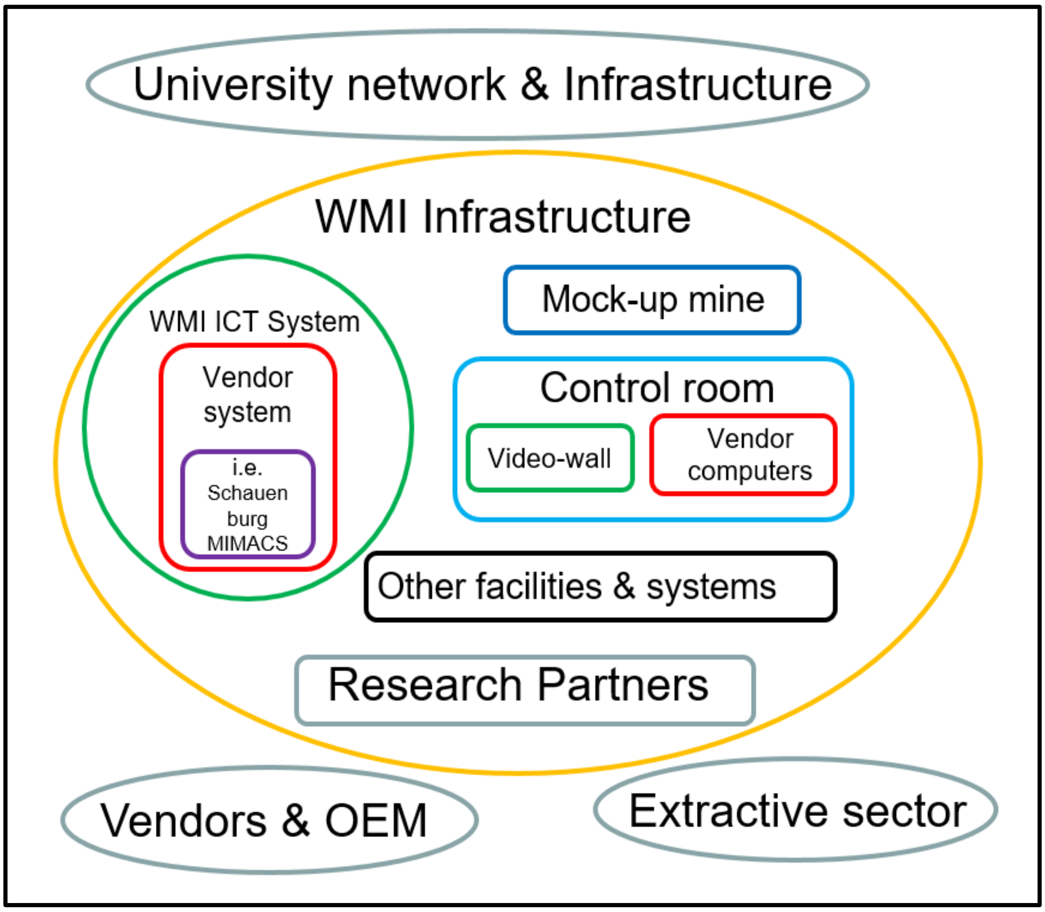


Figure 5-1 Systems map of WMI and MIMACS system

The systems map clearly shows main components in both WMI and the operating environment. The following three principles are used to identify the system boundary.

- Components that are required by the MIMACS system to ensure that the system is functional;
- Components that are required to form WMI's infrastructure, e.g. ICT system; and
- Components that form the environment for MIMACS and WMI ICT system to be functional.

The yellow line is the boundary that separates WMI from the operating environment on figure 5-1. Components within the boundary are controllable by WMI, and components outside of the boundary are not controllable by WMI, but can still pose an impact on the SOI. The contents of the yellow oval represent the WMI infrastructure, which consists of four main components:

- WMI ICT system;
- Mock-up mine;
- Control room; and
- Other facilities and infrastructure such as WMI database and computer servers.

These components are also the key enabling-elements to support the purpose of the system, also called SOI. In the installation project, SOI represents a successful adoption of the MIMACS system and achievement of its full designated performance and functionality.

Outside of the yellow oval in figure 5-1, there are three main components in the operating environment. These components form three individual subsystems that could impact the contents of WMI infrastructure. The following is a brief description of these individual subsystems.

- University network and infrastructure;

  WMI relies heavily on the university infrastructure to achieve its functionality, especially the network service that is required by the WMI ICT systems. The university network configuration and capacity have restricted new digital technology selection for WMI research.
- Vendor and OEM; and

The technology system is manufactured by an OEM and supplied by a Vendor. Hence, OEMs and Vendors have a direct influence on WMI's research direction, as they determine the type and availability of such technologies in the region.

- Extractive sector.

  WMI is a research-oriented organisation. Its research direction is driven by the problems occurring in the mining industry and its research outcome is intended to address such problems.

5.3.1 Systems map of MIMACS system

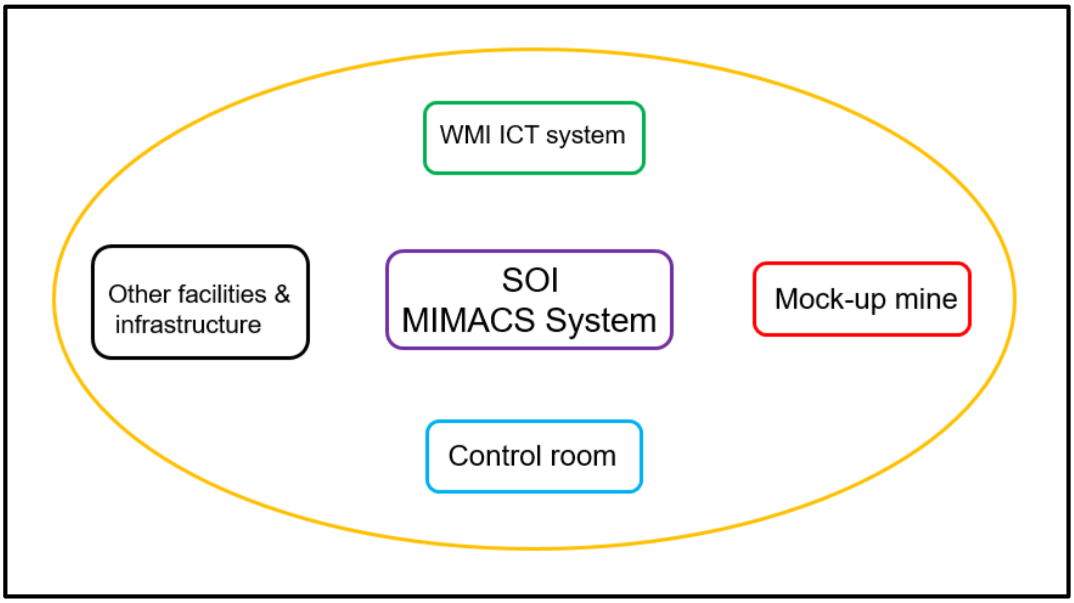


Figure 5-2 Systems map of Schauenburg MIMACS installation

The major functionality of components in the system boundary has been discussed in chapter 4. Each component is designed to achieve specific functionality on its own. However, the interaction between components and SOI usually occurs when there is more than one element in the system. MIMACS system is no exception to this rule.

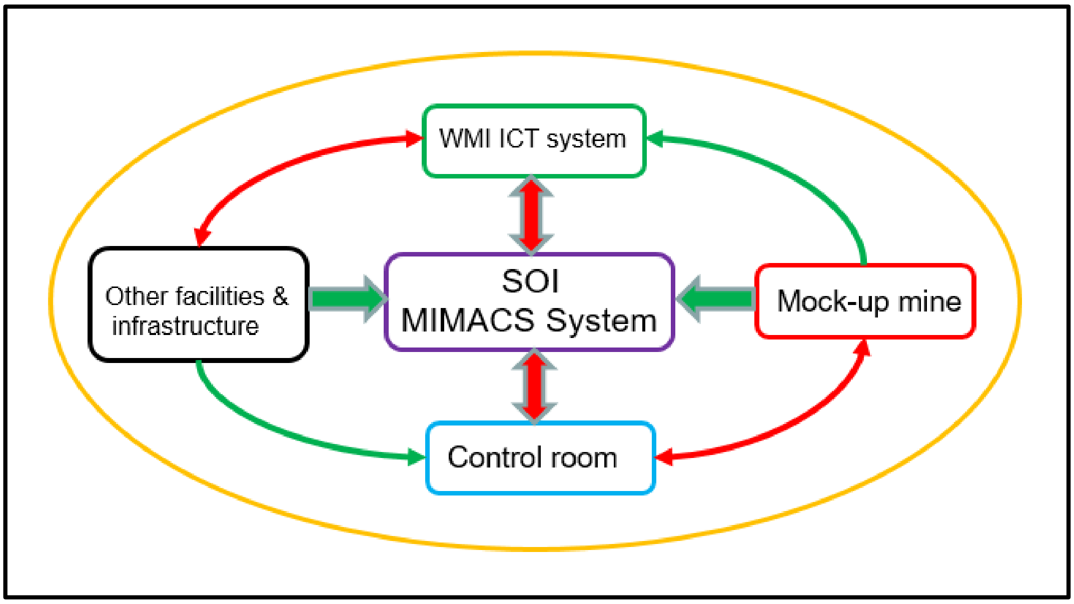


Figure 5-3 System map with interaction indications

Figure 5-3 shows how the SOI and system components interact with each other. The red arrows represent the bidirectional interaction between SOI and system components, indicating that two elements pose impacts upon each other. For example, data collected by the MIMICS system is processed in the control room, and the control room can send commands back to the MIMACS system based on decisions made from the data received. The green arrows represent unidirectional impacts caused by one element upon another. For example, the MIMACS system needs support from other infrastructure (e.g. stable power supply from the power grid), but its activities do not have a direct impact on other infrastructure. The systems maps shown above provide understanding regarding the new architecture of the system. However, they are incapable of providing any detailed information, e.g. system configuration or hardware requirement. The following section will illustrate findings of the case study, particularly in answering questions on how the system failed.

5.4 Findings of the case study

The case study has revealed issues related to WMI's MIMACS deployment and its surrounding environment. WMI has encountered many struggles with overall performance and reliability. Malfunction is the most frequently-occurring problem from WMI's side, and the institute has continuously struggled to maintain full system functionality. Such problems are a combined result of several influencing factors in and outside of the system boundary shown in the previous section. Findings of this case study are utilised to seek the cause of system malfunction. The following key problems were discovered during the case study.

5.4.1 Main cause to project delay

System malfunction remains as one of the most frequently occurring issues in WMI's MIMACS installation and its surrounding environment. The reliability of the Wits network and linked connections is one of the major problems among them. This is due to the fact that the MIMACS system is heavily reliant on reliable network connectivity. A study of the Schauenburg files reveals the importance of the network connectivity to the system. In 2016, the MIMACS system installation project encountered a ten-month delay due to a variety of issues, including support and Wits Wi-Fi network preparation. Other major issues included failure of switches; fly-leads, sockets, data points, power, gas instruments, miner caps, rescue-pack hooks; gas-detection unit, monitors, hardware, software.

The fact is that WITS university I.T. department does not allow any third party to manage the university ICT network. Any ICT network request needs to be approved by the IT department first before actual network installation take place. Such arrangement automatically delays the preparation and increases the amount of time required to complete an installation. Furthermore, Wits university I.T department has raised concerns regarding cybersecurity, therefore it is unlikely the university will allow any third parties to manage the university network. This means that WMI's system performance is potentially limited by external network supply and support.

5.4.2 System malfunction

As introduced above, besides the network issue, several other possible influential factors have also been identified. Such factors are also capable in causing system malfunction. The following is a brief description of these factors.

- **Typical malfunction**

The whole MIMACS system consists of several modules. The functionality of the MIMACS system is only achievable when all the modules are working in order. Even failure of a single module could cause the MIMACS to lose its functionality. Based on records, the following list indicates the general status of the network connectivity of modules when MIMACS system malfunction occurs.

- **LMS/AMS Server: Network not connected**
    - S-Link Tunnel: Network not connected;
    - Tunnel Adams Module: not connected;
    - S-Link Lamproom: not connected;
    - Allocation Bin Lamproom: not connected; and
    - Walkthrough Frame Lamproom: not Connected.

Once the module is disconnected from the network, the module automatically stops providing service and data to the MIMACS system, hence, system malfunction occurs. The case study findings also reveal that WITS network is another issue that causes MIMACS system malfunction.

There are also mainly two types of malfunctions with MIMACS system, namely hardware and software:

- **Faulty hardware**

The functionality of the MIMACS system is achieved through a series of sensors (tags) installed by Schauenburg system technicians. The control system collects data from the sensors (tags) to detect the status of the system. However, system malfunction occurred if the sensors (tags) failed to provide the right information. In this case, the lamp-room control system encountered a typical scenario: lamp room access controller often failed and needed to be de-activated. This was due to the access card reader being non-responsive. Such failures caused access-denial for personnel to the mock-up mine, hence, manual operation needed to be activated.

- **Signal interference**

Signal interference between different components needs to be considered when designing a digital system with multiple components. System scope and system boundary need to be set prior to clarification. A holistic approach should be taken to eliminate faulty design that could cause interferences. The design of the lamp room at WMI mock-up mine has demonstrated what happens if a holistic approach is not used in design: After the MIMACS installation was completed in 2016, technicians struggled to find the problem that caused access denial at the turnstile. The cause was finally identified in 2017, as signal-interference between passive cap-lamp tags and turnstile antenna. The underlying cause was faulty lamp-room design. Eventually, the lamp-room layout was redesigned in such a way to enable sensors (tags, antenna, etc.) to be placed at optimized locations.

- **Software issues**

The functionality of MIMACS system relies on the software packages installed on the vendor computer. Schauenburg systems source software from other software developers and incorporate such into MIMACS system solutions. However, this relationship structure tends to create longer response times when problems occur. The software package required to interact with equipment to execute system functionality often does not work as expected. In order to overcome this issue, Schauenburg has developed a script file to restore system functionality.

According to the systems map (see figure 5-1), faulty hardware and software mentioned above belong to the components in the system boundary, which operates under the ICT system within the frame of WMI infrastructure. As discussed above, components within the system boundary are controllable by WMI, hence amendments need be made by WMI to improve the performance of both hardware and software.

5.4.3 Disruption to MIMACS system functionality

However, outside of the system boundary (yellow line in figure 5-1), lie uncontrollable components in the operating environment. Such components are also capable of negative impact on the SOI. Several key influential factors have been identified during the case study, which could disrupt the functionality of MIMACS system:

- **Power outages**

  Unsteady power supply[11] has posed a threat to the MIMACS system: Disruptions in power supply have resulted in loss of system functionality. When the vendor computer interface is restarted after the power supply has recovered, some software programs do not launch successfully. Schauenburg system technicians have developed several script files to help the system to restore functionality after power outages. However, the power outages are not the only influential factor that poses threats to system functionality. Upgrades of the university network also became an accountable influential factor that disrupts MIMACS system functionality:

[11] WMI receive its supply from ESKOM mainly, in the case of load shedding, WMI receive power from Wits generators, but it is unstable. WMI has installed several UPS for backup power.

- **Network upgrades**

Network upgrades are frequently carried out by the university's IT department as part of the process of network modernisation. Changes to the university network infrastructure can lead to a loss of the system functionality. Script files have also been developed to keep the system running after network upgrades. However, constant upgrades of the university network have led to the continuous adjustment of the script files to maintain system functionality. Such upgrade also includes need to obtain hardware items from the university IT department which are required by the Schauenburg system, such as data-point and IP address. This problem is inevitable as the university has to ensure the cybersecurity for both the university network and user privacy.

- **System upgrades**

Several upgrades have been made to the MIMACS system since installation in 2016. Each upgrade has featured improvements to address issues found in previous versions. For example, system upgrade of MIMACS 2.2.48 corrected atomic log-out when the system was idle. However, not all the system upgrades boosted system functionality. Some records show loss of system functionality and crucial records after system upgrade.

- **Add-on function**

As an integrated platform, the MIMACS system is capable of expanding system functionality by adding new modules. However, such additional modules on existing platforms may involve third-party-developed hardware and software. WMI experienced loss of system functionality after a fire and gas detection-module was added to the existing system.

5.4.4 Post-installation phase

The installation phase officially ends with the completion of the installation work of the identified technology. Thereafter, the project moves to the next post-adoption phase. Training is a key element in the post-adoption phase, particularly in the case of the MIMACS system, as it is a complicated installation that requires multi-levels of knowledge. According to the case study, inadequate training was provided in the post-installation phase, despite it being the primary item that was requested by WMI. Schauenburg suggested that a dedicated person (system champion) needed to be properly trained to oversee the whole MIMACS system. However, this was only carried out two years after the MIMACS system was installed at WMI.

5.5 Summary

The outcome of the case study has confirmed that the MIMACS and associated systems installation at WMI have produced relatively poor overall performance and reliability. In complex systems such as MIMACS, many influential factors can cause system malfunction or loss of functionality. Some of them are caused by faulty hardware, and some are purely software-related problems. Some of the problems can be resolved by WMI alone, and some require collective effort between all stakeholders. Malfunction has compromised system functionality, causing loss of confidence in the entire MIMACS system. However, the case study has located both actual and potential problems that cause malfunction. Amendments can be made for each of the problems to eliminate the possibility of system malfunction: for the problems that occurred under the framework of WMI infrastructure, the institute needs a better understanding of the functionality and performance of each of the vendor systems. A better understanding of the vendor system will help WMI to eliminate the possible interaction and interference between different system components and subsystems. For the problems that occurred outside of the system boundary, a collective effort is required between WMI and all stakeholders to address such problems. In the latter case, formal agreements are required to clarify the obligation and responsibility of each party and stakeholder. The agreements need to ensure that system functionality is delivered in a timely and an efficient manner. The most important process to managing these influential factors is a holistic approach, which does not restrict focus to one component at a time, but instead, examines all system components from a system perspective. The outcome of this case study provides a good foundation for development of the new blueprint. The next chapter will examine measurements that have been developed and implemented by WMI to mitigate the problems identified in this chapter and associated with other vendor system adoptions. Such measurements will provide critical input information for development of the new blueprint in chapter seven.

6 WMI learnings on new digital technology adoption

6.1 Introduction

The case study conducted in the previous chapter shows the problems experienced by WMI during the adoption of the MIMACS system. Such problems resulted in negative impacts, such as system breakdown, and malfunction on the MIMACS system. Yet WMI considers these problems as important lessons learnt which will prove useful in terms of mitigation-process research. In this context, the findings of the case study have identified the defective system components, as well as the impact factors that may have caused such problems. The findings also conclude that improvements can be made by mitigating the defective components and impact factors. However, the findings only discover parts of the problems WMI experienced during the installation project, and more impact factors are likely to be discovered. WMI believes that a holistic approach is therefore needed for future projects in terms of new digital technology adoption. WMI has developed a vendor management system to guide the institute through adoption processes, based on the lessons learned from the MIMACS system installation project and also experiences gained from the adoption of other vendor-systems at WMI. The WMI vendor management system consists of a series of pre-determined processes to guide the institute in identifying potential risks throughout all phases of new digital technology adoption. This chapter will firstly examine lessons WMI learned from other vendor systems installed at the institute. Secondly, the focus of the study will then shift to questions on how the vendor management system will mitigate risks associated with impact factors. The study carried out in this chapter is critical for the following chapter, as it provides parts of knowledge required for developing the final new blueprint.

6.2 Typical problems of the WMI system

The case study in the previous chapter identified that low reliability of hardware and software was the major intervening factor that caused the MIMACS system's malfunction. However, the limits of the previous case study could not be ignored as the MIMACS system does not represent the whole WMI. Currently, there are nine digital technology systems installed at WMI, each of which has a unique requirement for adoption which is distinct from others

Some of the system's functionality is only achievable with sufficient service and data received from other systems. The new blueprint of new technologies adoption should therefore not only focus on one system, but should apply lessons gained from that subsystem to the overall system in the commissioning entity. From a systems thinking perspective, the new blueprint needs to be inclusive and have broad applicability, thus incorporate as many lessons as possible. The finalised new blueprint needs to be applicable to commissioning entities which share similar system installation and operating environments as WMI. In order to fulfil such requirements, an overview of all the lessons experienced by WMI is crucial. Each phase of the new digital technology adoption needs to be treated differently, as different system components and stakeholders are involved. All lessons will be discussed chronologically, according to the sequence in which the lessons appeared during the development of the installation project. Information and data used in this chapter are sourced from archives saved during the adoption and installation of all the digital technology systems at WMI. The following is a brief description of the lessons WMI gained from the adoption and installation of all its digital technology systems (Cawood, 2017d).

6.2.1 Pre-installation phase

Problems that appeared in the pre-installation phase could firstly help understanding of the true capacity of the system and its installation, and then help to identify the appropriate new digital technology for the commissioning entity. This phase can therefore also be called the identification phase. Another focus in this phase is the preparation-work required for new digital technology adoption.

1) Appropriate technology identification and selection

There are often several newly developed technologies available for addressing the commissioning entity's problems. The main goal of selecting the appropriate technology is to utilise the advantage of such technologies to benefit the commissioning entity. Technology selection is considered as the most important process in the adoption phase. This is based on the consequence caused by inappropriately selected technology. The most common mistake a commissioning entity can make is to purchase the most advanced technology and expect to get the best out of it. In general, two important intervening factors could cause the occurrence of such problems:

a. Possible misdirection of suppliers

As mentioned previously, some suppliers may emphasize the designed capacity of their products and services while missing the impact that the actual environment may have on the products and services. Furthermore, it is difficult for a commissioning entity to know the true performance of a vendor's products without testing the products within their own environment. Unless a case study conducted in a similar installation is available, an inappropriate technology will definitely disrupt the commissioning entity's ongoing operations. Furthermore, it would also cause financial stress on the commissioning entity.

It should be noted that WMI also works closely with vendors who wish to be part of the WMI research agenda by voluntarily donating their technologies to the institute. General identification and selection criteria are not applicable to such donated technologies. Instead, the selection criteria for such donated technologies is mainly driven by mutual interest between WMI and the vendors.

b. Too little knowledge by the commissioning entity about itself

Another factor which could also misdirect the commissioning entity is the commissioning entity knowing too little about itself in terms of its vision, business model, new architecture, culture, problems, needs and expectations. The newly identified technology needs to match all of the abovementioned aspects in order to achieve successful adoption, otherwise, the commissioning entity will repeatedly fail in technology adoption.

2) Budget overspending

WMI notices that overspending is another common problem when installing technology systems. Overspending may occur within all the phases of the adoption process. However it appears differently in each phase: Overspending in the identification phase generally concerns decision-making skills on technology identification and selection. In contrast, when the project reaches implementation and installation phases, the overspending problem will mainly be related to poor site preparation, budget control and project management skills. The following are the factors found which may cause the overspending problem in the identification phase of new digital technology adoption.

a. Duplication of system functionalities

This problem may be related to poor decision-making in technology identification and selection caused by inadequate knowledge of new technologies. Many newly-developed technologies that are available in the market provide similar functionalities. For example, both the Schauenburg MIMACS system and the Mine-Tec system are capable of tracking personnel in the underground-situations. However, the Mine-Tec system is more accurate than the MIMACS system. Since WMI has both systems, this could cause the MIMACS system’s personnel-tracking module to be considered redundant in WMI. However removal of the underperformance personnel-tracking module from the already-installed MIMACS system could cause loss of functionality. Some of MIMACS system's functionalities need support from its tracking module to be functional. Thus potentially, this problem becomes broader and more concerning considering the fact that integrated platforms may include a combination of several technologies in one installation.

b. High unit cost

Electronic or digital-related products cost more in South Africa than overseas. This is a direct consequence of weak South African currency, high import taxes and poor local-manufacturing capability. The products that WMI requires are no exception. Generally speaking, if the budget is set based on local-unit standard prices, it will be over budget once the unit is purchased from overseas. Such high unit cost and associated long-waiting periods for logistics automatically delay the progress of WMI Digimine project.

c. Insufficient preparation work

Site preparation work needs to be in place ahead of the installation phase. Preparation work also serves the purpose of smoothing the gap created by the introduction of new technologies in a commissioning entity. WMI research discovered that preparation work must include vendor system requirements. For example, vendor system requirements may include ICT-related specifications, such as hardware configuration, network bandwidth and software compatibility, and failure to pre-assess such can lead to increased expenditure at later stages. Another important part of the preparation work is to identify and design any civil works that may be required. WMI discovered that required civil works are sometimes not ready for installation when needed, thus causing project delays in the installation phase, and increased costs.

6.2.2 Installation phase

The entire project only moves to the installation phase once the required preparation work has been completed. According to WMI's experience, most problems associated with the adoption process occur in this phase. This phase will reveal the commissioning entity's decision-making abilities relevant to technology identification and selection during the previous identification phase. Furthermore, problems that occurred before will carry on in this phase but in different forms, e.g. overspending and civil works related issues. The following section is a summary of problems WMI has experienced in the installation phase.

1) Overspending

Overspending that occurs in this phase is mainly related to poor planning, project overrunning and inadequate project management. These problems may be internally interlinked, for example, poor project management skills may cause the project schedule to overrun.

2) Civil works construction delay

Problems associated with the civil works construction may be related to required civil works not being ready for installation when needed, or the need to rectify inadequate design carried out in the previous phase. Signal interference that occurred on MIMACS system in the WMI lamp room is a typical example of inadequate design. The MIMACS system required construction of the lamp room before system installation could begin. However, it was later found that access-control functionality of the MIMACS system was being affected by signal interferences. This revealed that the lamp room's layout-design was faulty. As a result, the entire project was delayed due to the lamp room having to be re-configured.

Once the installation work is complete, the entire project moves to the integration phase. The objective of this phase is to ensure that the newly-adopted technology reaches its full designated functionality. The following are the problems that WMI encountered in the installation phase's integration process.

3) Poor system compatibility

System compatibility is the most frequently occurring problem in the installation phase's integration process. According to WMI documents, compatibility problems usually occur between the vendor system and WMI ICT systems, as well as between the WMI ICT system and the university network. Based on the WMI experience, repairing such compatibility issues is time-consuming as it requires approvals from the university's ICT department.

4) System malfunction

During integration, WMI discovered that system malfunction is a major threat to the reliability of the vendor system. WMI also realised that system malfunction is usually caused by the failure of an individual module or component. The following is a brief description of the system malfunction and how system malfunction occurs.

a) Long lead-time to system functionality

Long delivery time delays the adoption process and results in long-lead time to achieve system functionality. According to WMI files, it took three years to complete the MIMACS system adoption before full functionality was reached.

b) Equipment malfunction

As discussed in the previous chapter, component malfunction is one of the major problems causing system malfunction at WMI. WMI systems consist of multiple components to support their functionality. Thus even a single faulty component could directly result in system malfunction. WMI has discovered that in most cases, problems associated with system-component failure are addressed in the system's user-manual. As such, a Schauenburg technician is only required if the problem cannot be resolved by WMI.

5) Unreliable communication system

WMI has experienced a communication problem with almost every vendor system installed. The most frequent communication problem experienced by WMI is reliability of the wireless network. The vendor system requires a reliable communication system for consistent data streaming to maintain system functionality. WMI recognises that communication reliability problems are mostly associated with ICT product design and system maintenance, and not with vendor components. This is based on the fact of that many of the reliability-related problems can be detected and eliminated by proper ICT product design and regular system maintenance checks.

6) Faulty hardware design

Some of the problems that contributed to system malfunction are embedded in the design and manufacturing process of the hardware. Such problems are not under direct control of WMI, but pose a direct impact on WMI vendor systems' functionality. A typical example is the short lifespan of batteries mounted in sensors (tags). This directly reduces the durability and reliability of the sensors (tags), with further impact on data collection. This also increases the workload of regular maintenance, especially if there is a significant number of batteries that need to be replaced in multiple vendor systems at WMI.

7) Restrictions on remote access

However, embedded hardware problems only represent parts of problems associated with faulty system design. WMI has discovered that the vendor system has a limited capability of remote access. Such a design eliminates the possibility of remote diagnosis of component- or vendor-system malfunction. Thus, when such component or system malfunction occurs, onsite diagnosis needs to be conducted by a Schauenburg technician. Such an arrangement stretches the time required to restore system functionality.

8) Interruptions on overall system functionality

The faulty design of the hardware is not considered as destructive as the failure of infrastructure support. Such factors not only affect MIMACS system functionality, but also affect other vendor systems. Infrastructure-related problems are not controlled by WMI yet directly impact the WMI vendor systems. Thus, a collective effort is required among all stakeholders to address infrastructure related problems.

9) System integration problem

WMI believes that a key action needs to be taken to mitigate problems associated with system integration. Generally speaking, different systems have different functionalities and characteristics since they are designed and manufactured by different OEMs on different platforms for varying purposes. However, they are no longer isolated systems once they have been adopted at WMI. All vendor systems share the same infrastructure at WMI, and interact with each other within the WMI environment. WMI encountered the following system integration problems, which depleted precious infrastructure resources and overall system's efficiency.

a. Integration with WMI ICT system

Multiple vendor systems rely on the WMI ICT system to achieve their functionality. The interfaces of vendor systems may vary as different OEMs use different platforms to develop their systems. Integration of these platforms can therefore become problematic concerning system compatibility. Although there are certain industry standard protocols for both development and manufacture of ICT systems, WMI has struggled to make all the vendor systems work together, especially in cases where the system or equipment was developed in other countries.

b. Hardware duplication leading to associated redundancy

As mentioned in the previous section, each vendor system has its own requirements for configuration of its hardware. This has resulted in vendors supplying similar hardware to perform configuration, maintenance and processing. The excessive number of servers installed at WMI reflects this problem.

c. Software interoperability problem

Low software interoperability is another serious problem that WMI has experienced. This problem causes unreliable and ineffective control of all software. Other software-related problems include reliability issues caused by the excessive number of outsourced software developers, as well as system functionality disruptions caused by regular software updates.

d. Silo approach

WMI notices that each system's solutions are independent and are aimed at addressing single problems. Thus a significant number of solutions are needed to address all problems. To resolve this, solutions need to be categorized based on similarity and nature of the problem. For example, all systems' IP address solutions could be grouped under "ICT related problems". Such an arrangement will allow a universal solution to be developed to tackle a group of similar problems.

The following are other significant problems discovered in the installation phase:

- Poor provision on integration of manual processes in the digital system;
- Lack of data transfer and security protocols;
- Inadequate computing capability for systems;

- Delays when integrating vendor systems with Wits network; and
- Lack of a proper new architecture for the sensor network.

6.2.3 Post-installation phase

The post-installation phase is the final stage of new digital technology adoption after the completion of the installation phase. The main objective of the post-installation phase is to carry out supporting activities such as training, system debugging, optimizing, upgrading and maintenance. According to WMI documents, this phase ensures that the vendor system is working optimally and that all its designated functionalities are being achieved. WMI has identified the following problems in the post-installation phase:

1) Poor after-sales support

The complexity of new digital technology adoption requires comprehensive user-training which not only covers how to operate the technology, but also relevant technical functions and maintenance. However, some suppliers only provide training on how to use their systems. This has caused multiple issues when system malfunction has occurred, such as WMI being unable to restore system functionality without calling in supplier-technicians. This is not only due to the fact that WMI has not been provided with sufficient training to assess how the system malfunction occurred, but also due to the time it takes for supplier-technicians to be located and to then conduct onsite diagnosis and correction.

2) Inadequate provision for system maintenance and future upgradability

The above discussions expose the fact that insufficient provisions exist to guide WMI through standard/regular maintenance work required by vendor systems. WMI has found that such maintenance is key to the system functionality of all vendor systems. This is based on the fact that regular minor maintenance work has needed to be conducted. A comprehensive maintenance provision can therefore guide the commissioning entity to carry out minor maintenance work and detect abnormalities. Furthermore, it can also reduce the cost of having a designated technician conducting minor maintenance work onsite.

6.2.4 Inflated system capability expectations

WMI documents conclude that the frequent system malfunction is only a part of an unsatisfactory experience in digital technology adoption. Inflated expectations of systems' capacity have caused unreasonable expectations of actual capacity of digital technologies at WMI.

The following is the summary from WMI on unsatisfactory experiences in terms of adoption of vendor systems.

- Long lead-time to full system functionality;
- Lack of proper provision for installation and maintenance;
- Disappointment regarding system performance, primarily caused by low system reliability, system break-down and malfunction;
- Lack of knowledge concerning external 'technical jargon';
- Inadequate sensor precision; and
- Inadequate training support.

6.3 WMI's answer to the problems

WMI has developed a vendor management system to help the institute to mitigate the problems encountered during the course of new digital technology adoption. This management system is based on lessons learned by WMI. Its core objective is to ensure that the institute understands its true capacity, identifies appropriate new technologies, successfully adopts the identified technology, and ultimately utilises the new technologies' advantages. Based on its lessons learnt, WMI understands the importance of having a formalised approach to guide the adoption of new technologies. The WMI vendor management system consists of seven sub-phases which expand on aspects of the three adoption-process phases discussed above (Cawood, 2017d).

6.4 WMI vendor management system

The objective of the WMI vendor management system (see appendix I) is to assign a specific task for each sub-phase as the adoption process proceeds. After completing development of the WMI vendor management system, WMI has begun applying it as a roadmap to guide every stage of the new digital technology adoption process. This has included Minetec and youngBlood adoption. The outcome of these adoptions is inspiring.

The WMI vendor management system identifies the objectives and stakeholders involved in each phase in order to clarify the purpose of each step by setting boundaries correctly.

1) Pre-installation phase

There are two main activities conducted in this phase; namely technology identification and agreement drafting. In total, three major stakeholders are involved, namely WMI, vendors and the university.

2) Sub-phase one: WMI's statement

The objective of this sub-phase is to prepare a detailed statement file that outlines WMI's expectations in the new digital technology. The statement contains details on WMI's background, problems, infrastructure, and communication protocols, as well as security and legal liabilities. The statement is used to help WMI to identify appropriate technology by classifying both WMI's capacity and WMI's needs. Such a statement could also assist WMI in not overestimating its capacity, thus avoid misleading itself in the process of technology identification.

3) Sub-phase two: New digital technology identification

The second sub-phase is to identify suitable technology based on the statement developed in the previous phase. WMI recommends that instead of only identifying the technology, it is more important to identify a suitable vendor supplying the technology. This arrangement is aimed at reducing workload caused by purchasing technology piece by piece instead of a package. Such a package should include all required installation and training work, as well as a proper plan for after-sales support. Vendor experience is the key consideration factor in this phase. WMI recommends that meetings be set up with vendors, and that the statement file be presented in-person to the vendors.

4) Sub-phase three: Vendor identification and selection

WMI recommends that at least two potential vendors should be identified in order to create a comparable reference. Vendors are required to provide a detailed quotation and supporting documents to WMI for reviewing. This needs to include comprehensive information about the vendor's products and services. Furthermore, to enable WMI to choose an appropriate vendor, vendor documents also need to include all aspects underlying the new digital technology, such as infrastructure requirements, system configuration, and subcontractors. WMI should then make decisions by comparing vendor-supplied information against WMI's capacity-and-need statement files which were created in sub-phase one.

5) Sub-phase four: Legal agreement drafting

Wits legal office is called into the process once the vendor has been identified by WMI. The main task assigned to the legal office in this sub-phase is to draft a formal agreement between WMI and the vendor. Successful adoption of technology relies on these legal agreements. Thus the legal agreements need to include the following four key aspects.

- Assurance of project delivery within the schedule and budget;
- Correct management of taxes and project budget in the purchase;

- Protection of vendor- and WMI-interests in terms of intellectual property and product quality;
- Assurance that vendor-claimed functionality is achievable;

6) Sub-phase five: System installation

The installation of the technology may commence after concluding an agreement that will guide the installation. As discussed in the previous chapter, preparation work is mandatory for achieving smooth installation. WMI requires that vendor-supplied systems-requirement-documents specify all installation-requirements, including detailed plans for civil works and infrastructure upgrades. Vendors need to also send system-requirement-documents to the Wits legal office for reviewing.

7) Sub-phase six: Official handover

Sub-phase six's purpose is to define after-sales support. Two core activities need to be performed in this sub-phase.

- Examine the quality of the system-installation;
- Prepare maintenance and training manuals;
- Conduct training to the commissioning entity.

The installation will only be considered as satisfactory after the above activities are performed and the documents are in place. The objective of having such documents is to eliminate the possibility of maintenance problems occuring in the post-installation stage.

8) Sub-phase seven: Exit strategy

WMI has developed an exit strategy to review the overall project, and if the review proves negative, to also seek possible alternative options to advance the system to an acceptable level. Such options include upgrades to software and hardware to enhance system-functionality. WMI needs to decide when to initiate this exit strategy, and if needed, to request vendors to complete corrective work before the exit strategy is initiated. However, even if WMI is satisfied with the system-installation, for the purpose of quality assurance, WMI still need to perform an additional review on the system's performance by comparing WMI's statement file to the vendor's supporting documents. This procedure is to ensure that WMI has received what was expected and that vendors have delivered what they claim. Once both WMI and vendor are satisfied with the work performed by both parties, the two parties can discuss the way forward, namely, to continue with the cooperation or terminate it.

6.5 Discussion

The vendor management system was applied in the Minetec project. The following positive outcomes proved the effectiveness of the system: shortened installation time; overall system performance improved by better system reliability.

Such positive outcomes are not unexpected. This is due to the fact that the WMI vendor management system is designed to address specific adoption-related problems. Furthermore, the development philosophy of the WMI vendor management system was based on well-defined problems that were discovered in similar operating environments. This automatically increased the effectiveness of the WMI vendor management system.

The advantage of using well-defined problems to develop a solution is that it provides effective criteria to address such problems. However, the applicability of such a solution is limited to particular problems only. Thus it is important to examine root causes of the problems and to seek solutions from experiences gained while trying to address such causes. These experiences are also considered as key parts of WMI lessons-learnt.

A vendor management system with limited applicability is therefore also limited in capability in providing a comprehensive guideline for new digital technology adoption. Therefore, it is necessary to develop a new blueprint with wide applicability to guide new digital technology adoption.

6.6 Summary

The findings of this chapter are critical for follow up work in this research. Not only do this chapter's findings supplement what is missing from MIMACS system case-study findings, it also it makes all problems better defined. Despite the fact that the main component of WMI technology is ICT-related, some lessons-learnt from the technologies' adoptions differ. The study of the lessons has provided a big-picture view of how intervening factors cause system malfunction. Based on this, this research develops a vendor management system to mitigate such factors. However, this system has limited applicability as it only covers a portion of the full spectrum of lessons learnt at WMI. The development of a new blueprint has therefore become necessary for both WMI and other commissioning entities in the extractive sector. The next chapter will focus on the development of the new blueprint. WMI lessons-learnt will serve as parts of information required for the development of this new blueprint. Additional systems thinking skills will be employed to ensure applicability and integrity of the new blueprint.

7 New blueprint development for the adoption of new technologies

7.1 Introduction

Note: Following sections refer to new digital technology which is potential, and also to “existing new digital technology”: “Existing new digital technology” refers to new digital technology that was previously purchased and is already installed at WMI or commissioning entity site. All other references to “new digital technology (i.e. narrative that does not include “existing”) refers to potential new digital technology that is to be investigated and managed as part of a current new blueprint.

An overview was conducted in the previous chapter on major problems posed by new digital technology installations at WMI. The overview also examined lessons that WMI learnt when addressing the problems, as well as identified negative impacts posed by such problems on overall systems functionality. WMI developed a vendor management system to guide the institute through new digital technology adoption by utilising such lessons. The system has proven effective. However, limited representativeness narrows its applicability, thus a new blueprint with broader applicability and representativeness is required for guiding the commissioning entity[12] in new digital technology adoption. The main objective of this chapter is to fulfil such requirements by developing such a new blueprint. Data used to develop this new blueprint is collected from the findings of the case study on the Schauenburg MIMACS adoption project, lessons that WMI gained from new digital technology adoption, and a study of the WMI vendor management system. Systems thinking techniques are applied to broaden the applicability of the new blueprint. A holistic approach with a managerial perspective is also used to ensure the representativeness of the new blueprint. Tools used to develop the new blueprint include Mindjet software for new blueprint contents development. The new blueprint contents illustrate all the critical activities

[12] Commissioning entity in this new blueprint refers to user/organization that is willing to use this new blueprint for new digital technology adoption

that need to be performed by the commissioning entity[1] prior to and during new digital technology adoption. A checklist is also developed to assess the outcome of the adoption by measuring the compliance and quality of the adoption process. A properly-developed new blueprint provides an effective guideline for new digital technology adoption, not only to WMI but also the extractive sector. Work carried out in this chapter will be verified, assessed and discussed in the next chapter. The final complete new blueprint can be found in Appendix III

7.2 New blueprint development

WMI recognised dilemmas faced by the mining industry when adopting new digital technology. The institute is also deeply aware of the urgent demand for a universal solution that both the institute and the mining industry can use to address such dilemmas. The new blueprint developed in this chapter is designed to tackle these dilemmas. With this in mind, this research has the objective of:

- Developing a new blueprint that is capable of providing guidance for the commissioning entity through the identification and adoption of new digital technology.

The quality of the contents of the new blueprint is key to achieving the above goal. The new blueprint contents involve development of a series of pre-determined activities that need to be performed in different stages of new digital technology adoption. This arrangement utilises systems thinking to manage the complexity associated with the adoption process, as well as to increase the applicability and representativeness of the new blueprint. Figure 7-1 shows the basic new architecture of the new blueprint.

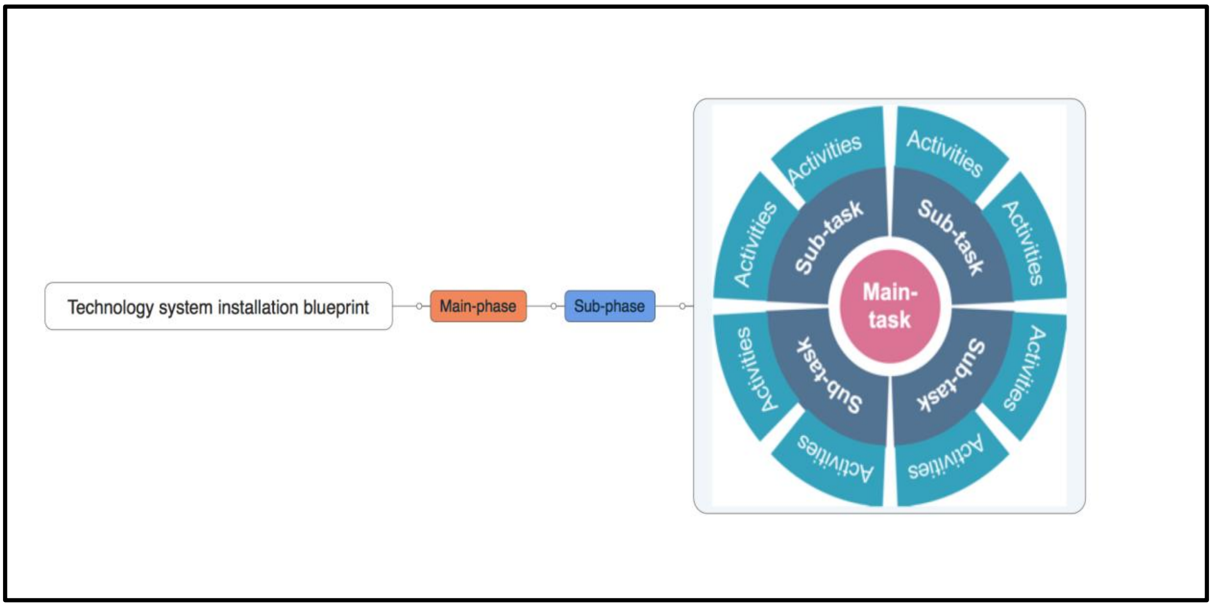


Figure 7-1 Basic new architecture of the new blueprint

The following colour-convention has been applied in the new blueprint to enable a clear illustration:

- Orange: main-phase
- Blue: sub-phase
- Red: main-task
- Deep blue: sub-task
- Cyan: activities

A hierarchical new architecture with multiple phases is selected for the new blueprint. Each main-phase contains several sub-phases that are formed by several main-tasks. The new architecture of the main-task is illustrated via an onion diagram (see figure 7-1). The main-task is broken down into several individual sub-tasks. Each individual sub-task is assigned several activities to complete. The adoption process only proceeds to the next main phase when all sub-phases in the previous main-phase are completed (see figure 7-2).

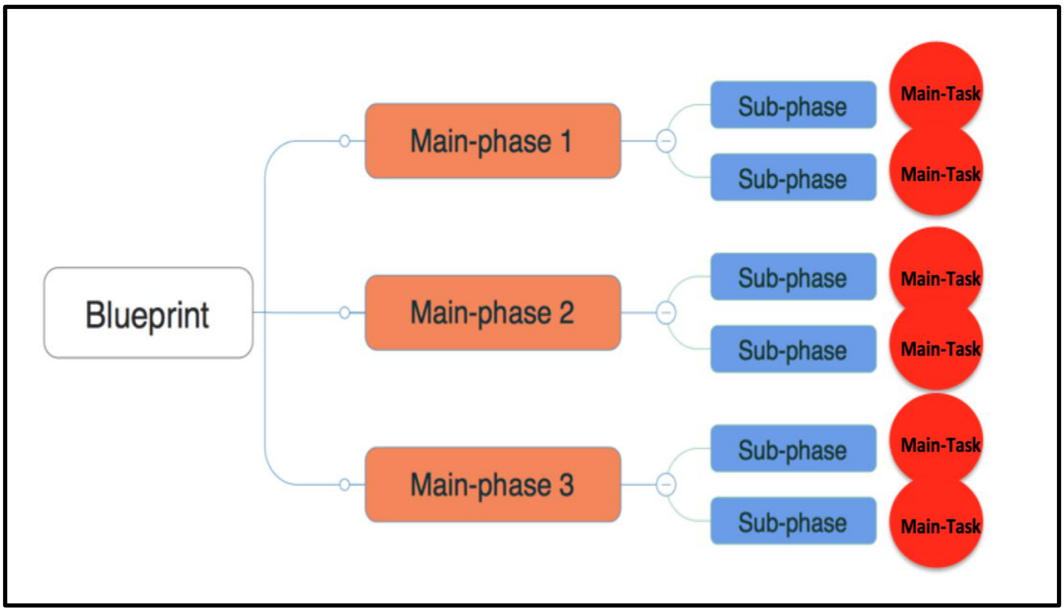


Figure 7-2 Basic new architecture of the main phase in the new blueprint

This new architecture allows the commissioning entity to complete the entire adoption phase by phase. Another noticeable advantage of this new architecture is ensuring that quality of work performed during adoption is properly monitored. Yet another major consideration for selecting the new architecture is to widen the representativeness and applicability of the original blueprint. Each commissioning entity could face different problems during the adoption process. This new architecture allows the commissioning entity to mitigate the problems by modifying the sub-phases during the adoption process. More sub-phases are included in each main phase, more flexibility is provided to the commissioning entity to adjust the course of the adoption process. However, there are two important considerations that need to be taken for determining the number of sub-phases included in the main-phase:

- From the perspective of systems thinking, it is impractical to include every possible situation that may be encountered by different commissioning entities in one new blueprint. In order to ensure the applicability and the representativeness of the new blueprint, systems thinking is applied to ensure that the most common questions are included in the new blueprint. This also ensures that the arrangement of the main-phases and sub-phases is logical and that they do not contradict each other.

- The fundamental requirement for the design of the new blueprint is to ensure the smooth progression of the adoption process. In order to fulfil this requirement, the commissioning entity needs to follow the direction of progression of the main-phases defined in the new blueprint (see figure 7-3). A guided progression will help the commissioning entity to avoid overspending of resources in just one main phase. In order to maintain the integrity of the new blueprint, only the individual sub-phases are adjustable by the commissioning entity (see figure 7-4).

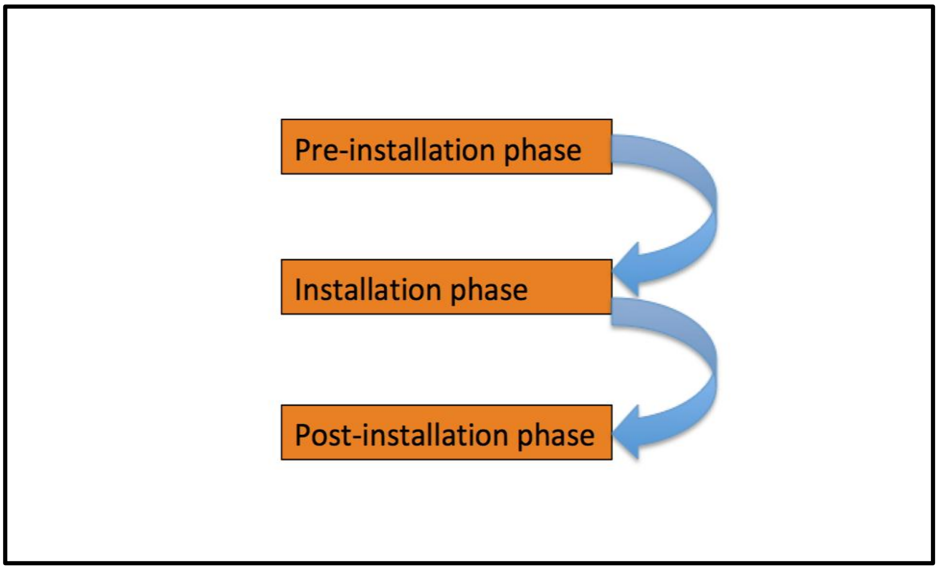


Figure 7-3Sequence of progression of the new blueprint

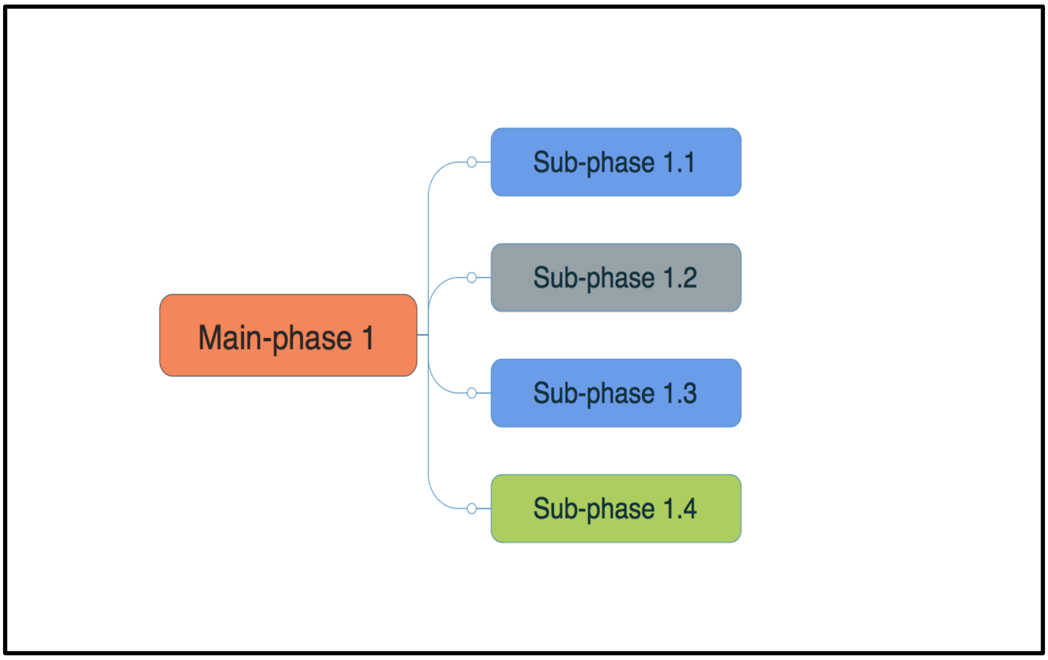


Figure 7-4 Adjustable sub-phase 1.2 and sub-phase 1.4

The commissioning entity cannot alter or skip any of the main phases, as these set the course of the adoption process and affect the entire adoption process going forward. Hence, only the sub-phases are editable. Per figure 7-4, the commissioning entity can either add a sub-phase (e.g. sub-phase 1.2) or remove a sub-phase (e.g. sub-phase 1.4) under a main-phase. Such adjustment will not influence the main course of the adoption process, but will create a certain level of flexibility for the commissioning entity to deal with the unforeseen problems. Another noticeable property of the main-phase is that it is irreversible. Each of the main phases has to be accomplished before the adoption process can proceed to the next phase. Another major concern for having this new architecture is the cost associated with the project schedule and budget for redoing any of the main-phases.

The functionality of the sub-phases is to support the main-phase by defining the objective of the main-phase and outlining the activity that has to be accomplished. Well-outlined work will help the commissioning entity to precisely plan and monitor the progress of each individual sub-phase, thus minimise the possibility of problem occurrence. The following are the main functionalities of such new architecture;

- The main-phase sets the course and ensures the real progress of the whole adoption process;
- The sub-phases further define contents that need to be developed in the main-phase, as well as outline activities that need to be executed under the main phase to develop such contents; and
- The combination of main phases and sub-phases ensures the successful adoption of new digital technology for the commissioning entity.

Table 7-1 Example of the new blueprint contents and checklist

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (click)**	**Remarks**
Name of main-task				
	Name of sub-task	Activity	Y	
		Activity	N	
		Activity	Y	
	Name of Sub-task	Activity	N	
		Activity	Y	
		Activity	Y	

Table 7-1 is an example of the new blueprint contents and checklist table that is used in this chapter. New blueprint contents include the main-task, sub-task and activities. The Check column is used to confirm whether the activity was completed. The Remarks column includes any additional comments on the execution of the activity. The following section is a discussion of all the contents considered in the new blueprint. This discussion also includes the justification for selecting such contents.

7.2.1 Pre-adoption phase

The new blueprint starts with the pre-installation phase. The major objective of this phase is to obtain a comprehensive understanding of the background of the commissioning entity, as well as to identify the potential suitable new digital technology for the commissioning entity to install. (Note: in this chapter, the commissioning entity refers to the user of the new blueprint). Two main stakeholders are identified in this phase:

a. Commissioning entity that requires new technologies; and

b. Potential technologies that fit the Commissioning entity's requirements.

Sub-phases under this main-phase are processed once stakeholders have been identified (see sub-phase 1.1 and sub-phase 1.2 in figure 7-5).

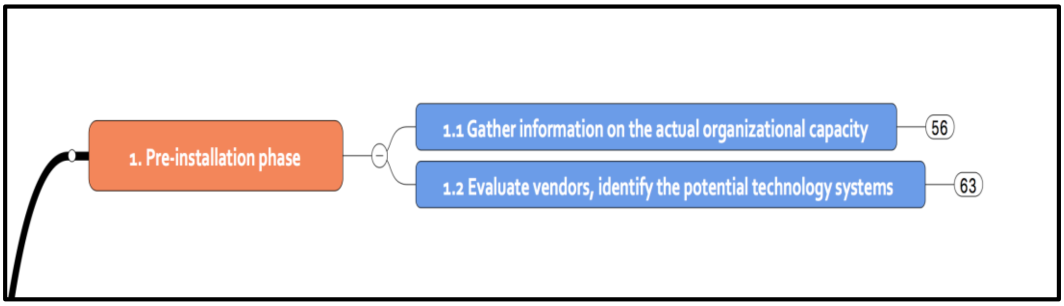


Figure 7-5 Sub-phases 1.1 and 1.2 in the pre-installation phase

7.2.2 Sub-phase 1.1: Gather information on commissioning entity's capacity

Sub-phase 1.1 is gathering information that reflects the actual capacity of the commissioning entity. This sub-phase is aimed at gathering as much information about the commissioning entity as possible, including actual functionality and technological maturity of the potential new digital technology.

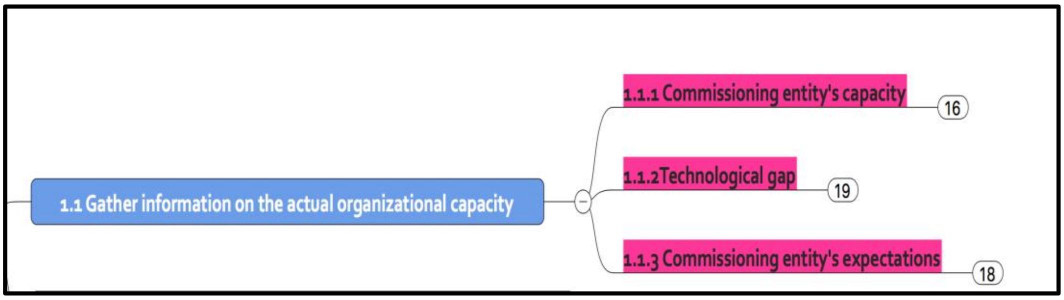


Figure 7-6 Sub-phase 1.1 and main-tasks

Three main-tasks (see figure 7-6) are included in the sub-phase 1.1 to investigate the commissioning entity's information. Each main-task covers an important aspect of the commissioning entity. Table 7-2 shows the focus of each sub-task and aspects of the commissioning entity that should be studied.

Table 7-2 Main-task 1.1.1 commissioning entity's capacity

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.1.1 Commissioning entity's capacity				
	1.1.1.1 Commissioning entity's vision, culture, new architecture & budget	Check commissioning entity's background, vision and strategy		
		Check commissioning entity's business model, culture & interest		
		Check commissioning entity's funding and planned budget		
	1.1.1.2 Commissioning entity's infrastructure and new architecture	Check commissioning entity's communication system (ICT)		
		Clarify commissioning entity's data collection, transfer and storage		
		Obtain detailed ICT system new architecture, including data flow and sensor network of the commissioning entity		
		Clarify the commissioning entity's requirement for system integration		
		Clarify commissioning entity's system expandability		

Sub-task 1.1.1.1 focuses on fundamental information that includes the vision, culture, new architecture and budget (finance) of the commissioning entity. Such information needs to be collected via three activities that are listed below.

- Commissioning entity's background, vision and digitalisation strategy;
- Commissioning entity's business model, culture and interest; and
- Commissioning entity's capital, funding and planned budget.

Information collected here reveals the commissioning entity's potential interest in acquiring new digital technologies. Particularly important is information gathered on the commissioning entity vision, culture and planned budget. Such information indicates the appetite and capability of the commissioning entity for technology acquisition.

Sub-task 1.1.1.2 gathers the information that describes the physical state of the commissioning entity. The purpose of having such descriptions is to clarify the capacity of the existing infrastructure and new architecture of the commissioning entity. The focus of the study is on the physical state of the hardware and software that support the new digital technology adoption, e.g. ICT system. The following list shows activities that need to be performed on the commissioning entity's infrastructure and new architecture.

- Clarify communication system (ICT) and network type used by the commissioning entity;
- Clarify bandwidth requirement, path of data collection and data transfer, and storage capacity;
- Obtain detailed ICT system new architecture with data flow and sensor network;
- Clarify requirement for system integration and upgrade; and
- Clarify system compatibility with other systems and system expandability.

Information collected above is critical for the entire adoption process as it provides a comprehensive understanding of the physical state of the existing infrastructure. Two key questions are answered by obtaining such information.

- What is the capacity of the existing infrastructure in the commissioning entity?
- What kind of new digital technology can the existing infrastructure accommodate?

The answers to these two questions reflect true capability and potential of the commissioning entity for adopting the new digital technology. They may indicate another digital technology that may suitable for the commissioning entity. Information gathered in sub-task 1.1.1.1 also provides critical information that supports the decision-making process in sub-phase 1.2. Once the physical state of the commissioning entity is clarified, the adoption process can proceed to the next sub-task.

The following main-task 1.1.2 is investigating the technological gap within the commissioning entity. It focuses on the current status and problems faced by the commissioning entity. It also looks at the best practice for addressing similar problems in the mining industry. Four sub-tasks are included in the main-task 1.1.2 (see figure 7-7).

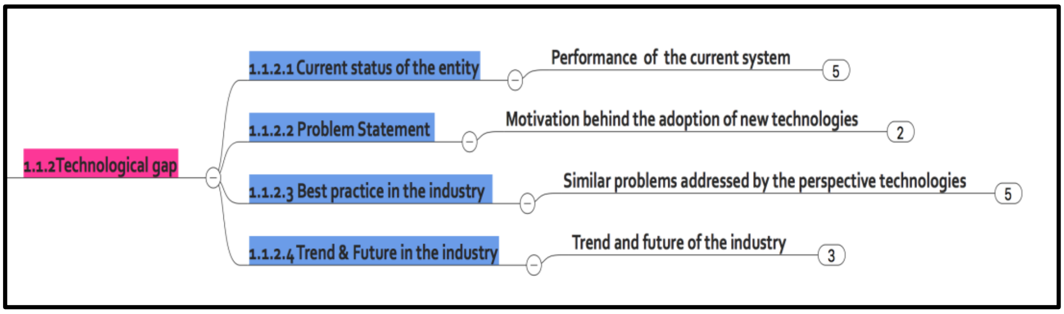


Figure 7-7Main-task 1.1.2 technological gap and four sub-tasks

The sequence of progression for the sub-tasks is set chronologically. Firstly the performance of any existing new digital technology in the commissioning entity is reviewed in sub-task 1.1.2.1 and five activities need to be performed (see table 7-3).

Table 7-3 Main-task 1.1.2 Technological gap

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.1.2 Technological gap				
	1.1.2.1 Current status of the commissioning entity	Check current status of existing new digital technology installed in the commissioning entity		
		Clarify the approach used for the new digital technology adoption in the commissioning entity		
		Check outcome of the adoption		
		Check lessons learned from other adoptions		
		Check employees' level of skills (qualification & experience)		
	1.1.2.2 Problem Statement	Clarify the type and nature of the problem that is facing the commissioning entity		
		Check possible solutions that are related to utilizing new technologies		
	1.1.2.3 Best practice in the industry	Check similar problems occurred in the industry		
		Check solutions used to address such problems		
		Clarify the role of technologies in such solutions		
		Check outcome of the solutions		
		Check lessons learnt from such problems and solutions		
	1.1.2.4 Trend & Future in the industry	Check general practice and trend in the industry		
		Seek new digital technology that may apply in the future of the industry		
		Clarify differentiation between commissioning entity's version and industry's future		

The outcome of sub-task 1.1.2.1 indicates how the existing WMI new digital technology was installed and what was encountered during the adoption process. The most important two aspects are lessons learnt from the adoption and the level of employees' skills. Qualification and experience of the employees are used to measure the capacity of the skills.

The next sub-task 1.1.2.2 is a problem statement which looks at the problem being faced by the commissioning entity. It is compulsory for the commissioning entity to produce a detailed description of the problem. This description should include the type, nature and the possible cause of the problem. Addressing the problem is the motivation behind the new digital technology adoption. Detailed information collected from this sub-task is critical for reflecting the current status of the commissioning entity. Information gathered from the previous sub-task 1.1.2.1 and this sub-task combined provides an answer to the question, "what is the current status of the commissioning entity?"

Once the problem of the commissioning entity is clearly understood, the next step is to look at possible solutions in the mining industry. Sub-task 1.1.2.3 studies the best practise in the industry (see table 7-3). The objective is investigating similar problems that occurred in the mining industry and the effectiveness of solutions applied to address such problems. Effective new digital technology solutions will be considered as potentials for the commissioning entity to adopt. As may be seen in table 7-3, five activities are required in sub-task 1.1.2.3 to obtain such information.

The final step of the main-task 1.1.2 is to look at trends of the mining industry. The purpose of this step is to gather information for identification and selection of potential new technologies. Such information is gathered via three activities that relate to general trend and future of new digital technology in the mining industry (see table 7-3). It is important to align the commissioning entity's vision with the future trend of the industry, as it will maximise future system upgrades.

Main-task 1.1.2 is vital for the overall adoption process. Information gathered at this stage is critical for the following sub-phase 1.2 - potential technology identification process. Main-task 1.1.3 discusses the commissioning entity's expectation for the new digital technology. It is critical for identifying and selecting appropriate new digital technology for the commissioning entity. In the main-task 1.1.3, the commissioning entity's expectation is divided into three sub-tasks (see figure 7-8).

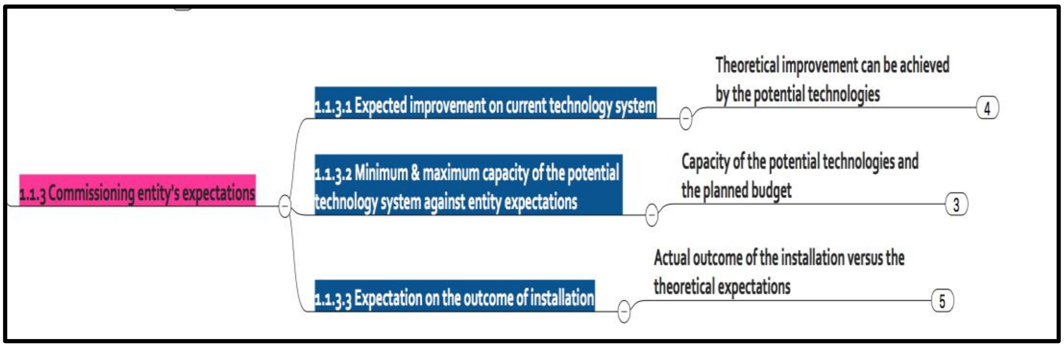


Figure 7-8Main -task 1.1.3 and three sub-tasks

Table 7-4 represents the full picture of the main-task 1.1.3. Three sub-tasks are included in this main-task and each one represents a portion of the commissioning entity's expectations (see table 7-4). Systems thinking is applied to ensure that the contents of the new blueprint are logical. The following questions show the logic-flow of main-task 1.1.3.

- What problem in the existing system needs to be addressed by adopting the new digital technology?
- What should the potential technology look like? Or what type of technology should the commissioning entity install?
- What has to be achieved after the potential technology is installed?

Table 7-4 Main-task 1.1.3 Commissioning entity's expectations

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.1.3 Commissioning entity's expectations	**1.1.3.1 Expected improvement on existing new digital technology**	Clarify commissioning entity's expectations in terms of planned budget, cost, functionality etc.		
		Check impact on the existing new digital technology in the commissioning entity		
		Clarify timeframe for installation, adoption and integration		
		Clarify employees' skills deficiency (compare to the capacity of skills in 1.1.2.1)		
	1.1.3.2 Minimum & maximum functionality of the potential new digital technology against commissioning entity expectations	Clarify minimum & maximum functionality required for commissioning entity to be satisfied		
		Check redundancy that may be created by the maximum functionality based on the commissioning entity requirement		
		Clarify extra budget required for system upgrading to achieve the minimum or maximum functionality		
	1.1.3.3 Expectation on the outcome of the adoption	Clarify method to measure the improvement, achievement		
		Check improvement, achievement (actual outcome) versus commissioning entity's expectations		
		Clarify measurement required to measure functionality		
		Check for possible future upgrade and integration (e.g. real-time decision, notification, and alert)		

The first sub-task 1.1.3.1 expresses the commissioning entity's expectations on the improvement of its existing new digital technology. The commissioning entity's intent is to utilize potential new digital technology to achieve the improvement. Four activities are required in sub-task 1.1.3.1 to fully understand the support required and the impact that may be caused by the improvement (see table 7-4).

Sub-task 1.1.3.2 reviews the functionality of the potential new digital technology (see table 7-4). It looks at the minimum and maximum functionality that the potential new digital technology can provide in terms of planned budget. This step is critical for understanding if the functionality of the potential new digital technology applied in the industry meet the requirement and expectations of the commissioning entity. Three activities are developed to clarify the limitation of the potential new digital technology and to determine minimum and maximum functionality. These activities also cover the budget required for installing the new digital technology with minimum or maximum functionality. They help to determine how the functionality of the technology and the planned budget are correlated. Any redundancy that may be created by technology with maximum functionality is also reviewed, so that it can be avoided or catered for if needed. Such correlations provide key information for identifying and selecting the new digital technology.

Sub-task 1.1.3.3 (see table 7-4) discusses the expected outcome of adoption of the new digital technology from a perspective of systems thinking. This sub-task also looks at support that may be required by the new digital technology to maintain its functionality, and the method to measure the improved functionality after the adoption. The final activity of sub-task 1.1.3.3 covers the commissioning entity's expectations on the upgradability of the new digital technology. This is part of the requirement that the commissioning entity keeps up with future trends of digitalization in the mining industry.

The completion of the main-task 1.1.3 marks the end of the sub-phase 1.1. As has been seen, sub-phase 1.1 focuses on investigating information that reveals the true capacity of the commissioning entity. Three main-tasks and nine sub-tasks are defined to gather information for the investigation. Information gathered in sub-phase 1.1 is part of the identification process for the new digital technology. Such information covers a wide range of aspects about the commissioning entity, ranging from its business culture to its expectations. The outcome of the investigation indicates the possible suitable type of new digital technology for the commissioning entity to adopt.

7.2.3 Sub-phase 1.2 Vendor and potential technology identification

Sub-phase 1.2 begins by identifying possible channels to source potential new digital technology for the commissioning entity. Information and data required for this come from the documents provided by identified vendors and precedent adoption-cases at other mines. Furthermore, the investigation conducted in the previous sub-phase 1.1 provides key information for sub-phase 1.2, enabling the objective of sub-phase 1.2, namely to identify an appropriate technology and choose an appropriate vendor to supply the identified new digital technology. This objective is achieved by comparing the functionality of potential new digital technology to the capacity and the expectations of the commissioning entity. (Assessment of actual capacity and technological gap within the commissioning entity was also conducted in previous sub-phase 1.1. Potential new digital technology type is identified based on the outcome of the assessment.)

After completing all the activities in sub-phase 1.2, the commissioning entity will be capable of identifying a suitable vendor, as well as a new digital technology to help it to tackle the problems. Sub-phase 1.2 is therefore critical to the entire adoption process. Any mistake made in this phase (e.g. selection of inappropriate technology), could lead to total failure of the adoption process.

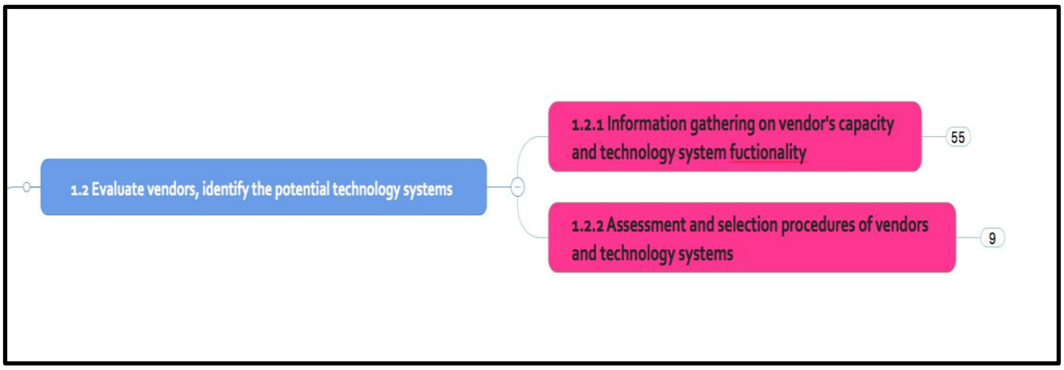


Figure 7-9 Sub-phase 1.2 evaluate vendors and new digital technology identification

The objective of this sub-phase, namely the identification of suitable vendors and new digital technology, is achieved through a series of assessments. As may be seen in figure 7-9, there are two main-tasks in sub-phase 1.2: Main-task 1.2.1 focuses on gathering information on vendors and new digital technology, together with the procedures for assessing the functionality of new digital technology. Main-task 1.2.2 works on the assessment and selection of the vendors and new technologies. After completing sub-phase 1.2, the commissioning entity will capable in identifying the appropriate vendor and the new digital technology that addresses the problems faced by the commissioning entity.

Table 7-5 Main-task 1.2.1 channel to source the new digital technology

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.1 Information gathering on vendor's capacity and new digital technology's functionality				
	1.2.1.1 Channel to acquire vendor and new digital technology	Check the general practice to acquire new digital technology in the industry.		
		Evaluate the possible channel to acquire the new digital technology from a local supplier, OEM, Service package from the vendor		

Due to the fact that several of parties are available to supply new digital technology, sub-task 1.2.1 in table 7.8 shows aspects that need to be considered by the commissioning entity to enable identification of the possible channel for acquiring the new digital technology. It is critical for the commissioning entity to decide where to get the new digital technology. Such decision is made mainly based on the commissioning entity's actual capacity and expectations. Other factors, such as availability of the technology in the region, should also be considered. Generally, three channels are available through which new digital technology can be acquired:

a. Supplier: an organization or individual that supplies the new digital technology with the capacity of local technical support, but without new-technology-related services such as customised design of components or devices.
b. OEM: an original equipment manufacturer, who generally excludes marketing, branding and full service for their products (e.g. local technical support etc.); and
c. Vendor: an organization or individual that supplies the new digital technology and required services as a package. Such a package usually includes pre-sale initiation and after-sales support services.

Experience gained from the WMI vendor and technology management system shows that the Vendor is the best option in the above channels. Vendors normally provide a full package of new digital technology and required services. However, some vendors provide services and not technologies. In such cases, technology and vendor would need to be identified separately, thus requiring multiple vendors.

The following is a list of indications provided by information gathered in sub-phase 1.1 on the commissioning entity's actual capacity and expectations:

- Commissioning entity's expectations indicate the preferable channel to acquire the new digital technology for the commissioning entity; e.g., if the commissioning entity lacks self-support capability and requires local after-sales technical support, then Vendor is the appropriate channel; and

- Commissioning entity's actual capacity (e.g. planned budget and infrastructure) indicates restrictions in the commissioning entity's new digital technology selection options.

Thus the commissioning entity needs to carefully examine the channel for supplying the new digital technology by balancing it with the commissioning entity's expectations and the commissioning entity's capacity. Once the commissioning entity has made its decision on the channel, the adoption process can proceed to the next sub-task, namely information exchange between the commissioning entity and vendors.

Table 7-6 Sub-task 1.2.1.2 Information exchange between commissioning entity and vendors

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.1 Information gathering on vendor and new digital technology				
	1.2.1.2 Information exchange between commissioning entity and vendors	Ensure that the commissioning entity has requested multiple bids from vendors and arranged meetings with them. Commissioning entity present all the requirements and expectations to vendors		
		Ensure that the commissioning entity presents all sub-phase 1.1-investigation-outcomes to the vendors, especially problem statement, capacity and expectations.		
		Receive detailed background information relating to the vendors and their available new technologies		
		Receive detailed information regarding new technologies that the vendors need to provide: marketability, commercialization, availability in the region, precedent successful adoption cases, etc.		
		Receive detailed technical documents covering functionality, specification, configuration, system compatibility, total cost with unit price, and adoption requirement for infrastructure (versus vendor's capacity) of the new digital technology from vendors		
		Compare the documents that were received in the above activity to the template which defines "*general contents*		

		for vendor's supporting documents" (Cawood, 2017) see Appendix IX		

It is important for the commissioning entity to assess both the vendor's capacity and the functionality of the new digital technology. As may be seen in table 7-6, sub-task 1.2.1.2 includes six key activities which are designed to guide the commissioning entity and the vendors through their exchange of vital information. Commissioning entity should call for multiple bids to increase the number of participating vendors and create a fair competing environment. The commissioning entity needs to give vendors all relevant aspects covering the commissioning entity's actual capacity, requirements and expectations. Vendors need to provide information with good coverage and representativeness, to help the commissioning entity to gain a comprehensive understanding of their products and services. The following list shows general topics that should be covered in information provided by vendors.

- Products and services;
- Marketability and commercialization;
- Regional availability; and
- Precedent successful adoption cases.

The last activity in sub-task 1.2.1.2 ensures that documents supplied by the vendors fulfil all requirements listed in the following template: "*general content for vendor's supporting documents*" (see appendix I). The latter template was developed as part of the WMI vendor management system, and provides information on how the vendors should prepare a comprehensive report about themselves for the commissioning entity. This template has proven useful in several new digital technology adoptions at WMI.

Table 7-7 Sub-task 1.2.1.3 Information required by commissioning entity from vendors on new digital technology

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.1 Information gathering on vendor and new digital technology	**1.2.1.3 Information required for assessing vendor's capability and new digital technology functionality**	Ensure vendors provide detailed description and demonstrations of their capability and functionality of the new digital technology		
		Obtain documents for all requirements, including full specifications of required infrastructure (for both software and hardware)		
		Obtain a full list of equipment required for adoption, including a description of all equipment, working principle of all instruments, detailed system new architecture and data flow		
		Obtain detailed requirement for system integration between the new digital technology and the existing new technologies installed at the commissioning entity		
		Obtain detailed plan for add-on functionality (e.g. Real-time alert and notifications)		
		Obtain emergency procedures: e.g. auto-restart function in power outage		
		Ensure that the vendor provides after-sale support documents and plan		
		Ensure that the vendor provides a comprehensive quotation (including cost of all services)		
		Check integrity of all the information received by the commissioning entity as well as information sent to vendors		

Per table 7-7, the commissioning entity needs to obtain comprehensive information from vendors about the vendor's capability and the functionality of the new digital technology. Sub-task 1.2.1.3 includes eight activities that are designed to help the commissioning entity to obtain sufficient information. The commissioning entity will rely on the information to determine if the vendor's service fulfils the commissioning entity's expectations. Information provided by vendors needs to cover the following technical related topics.

- Full functionality of the new digital technology;
- System specification and configuration;
- System compatibility to other systems;
- Total cost with a detailed breakdown on unit cost; and
- Adoption requirement for infrastructure, which includes both hardware and software.

The commissioning entity should carefully examine the integrity of all the information received from vendors, as well as information sent to vendors by the commissioning entity. This activity is critical for both the commissioning entity and vendors. It not only ensures that the commissioning entity received all required information from vendors, but also ensures that sufficient information has been obtained by the commissioning entity for the future assessment. This integrity check also eliminates the possibility of miscommunications and misunderstanding on the information-exchange between the commissioning entity and vendors. Once all the eight activities in sub-task 1.2.1.3 have been completed, the adoption process can move on to the next assessment and identification phase:

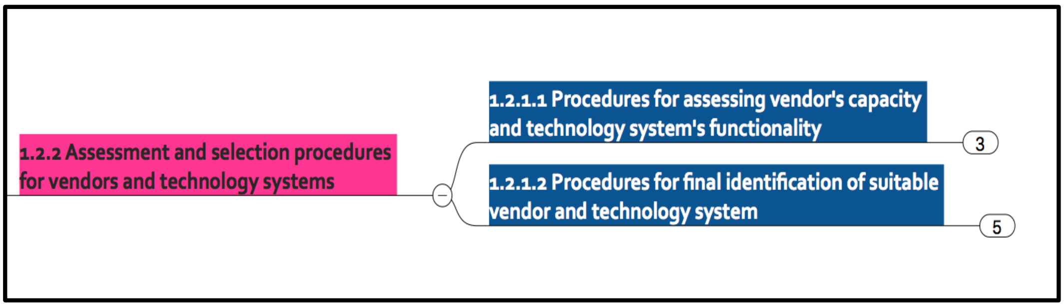


Figure 7-10 Main-task 1.2.2 Assessment and selection procedures

The procedures for identifying the suitable vendor and new digital technology begin with commissioning entity receiving the above-mentioned information from the vendors. The objective of main-task 1.2.2 is to identify a suitable vendor and new digital technology. A series of assessments on vendors and new digital technology was developed to carry out this final identification. Figure 7-10 shows them as two sub-tasks included in main-task 1.2.2.

Table 7-8 Sub-task 1.2.1 procedures for assessing vendors and new digital technology

New blueprint contents			Checklist	
Main-task	**Sub-task**	**Activities**	**Check (tick**	**Remarks**
1.2.2 Assessment and selection procedures for vendors and new digital technology	**1.2.1.1 Procedures for assessing vendor's capability and new digital technology's functionality**	Ensure that more than one vendor was required to provide detailed information and that more than one vendor needed to be assessed by the commissioning entity to create a competitive reference		
		Ensure that the commissioning entity assess the vendors by comparing vendor-provided information to the commissioning entity's capacity and expectations. Commissioning entity needs to conduct the following five assessments.		
		a). Vendor and vendor new digital technology versus commissioning entity vision, culture and business model		
		b). Vendor new digital technology functionality versus problems stated in commissioning entity problem statement and commissioning entity expectations		
		c). Vendor new digital technology adoption requirement versus commissioning entity's capacity in terms of infrastructure		
		d). Vendor's total cost of all services versus commissioning entity's funding and planned budget		
		e). Cross-comparisons between different vendors (not only commissioning entity versus vendor, also vendor versus vendor)		
		Select the most appropriate vendor and new digital technology based on the outcome of the above assessments		

Sub-task 1.2.1.1 in table 7-8 focuses on the development of procedures for assessing the vendor's capability and the new digital technology's functionality. In order to select the most appropriate vendor and new digital technology that matches the commissioning entity's capacity and expectations, seven activities need to be performed by the commissioning entity (see table 7-8). Since the commissioning entity has called an 'invitation for bids', it is important for the commissioning entity to create a competitive reference for assessing more than one vendor.

The commissioning entity will identify the suitable vendor by comparing the information provided by different vendors against information gathered in sub-phase 1.1, namely commissioning entity capacity, problem statement and expectations. When conducting the assessment, the commissioning entity should always use the commissioning entity's capacity and expectations as the benchmark. The following five comparisons need to be conducted by the commissioning entity to obtain sufficient proof for the final identification of the suitable vendor and new digital technology.

1. Vendor and new digital technology versus commissioning entity vision, culture and business models;
2. Vendor new digital technology functionality versus problems stated in commissioning entity's problem statement and expectations;
3. Vendor new digital technology adoption requirement versus commissioning entity's capacity in terms of infrastructure;
4. Vendor's total cost of all services versus commissioning entity's funding and planned budget; and
5. Cross-comparisons between different vendors (not only commissioning entity versus vendor, also vendor versus vendor).

The outcome of these comparisons provides strong substance to the commissioning entity to enable choosing the most suitable vendor and new digital technology to install. There could be more than one vendor left at this stage. The following procedures will help the commissioning entity to make the final decision based on several selection-criteria that may have been missing in the assessment conducted above.

Table 7-9 Sub-task 1.2.1.2 Selection procedures for suitable vendor and new digital technology

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.2 Assessment and selection procedures for vendors and new digital technology	**1.2.2.2 Criteria for final selection of the most suitable vendor and new digital technology**	Capability for the future upgrade and integration with other existing systems in the commissioning entity's environment is the key consideration		
		Choose appropriate vendor and new digital technology; avoid selection of the most expensive or cheapest option, or one that provides the most system functionality, without proper review.		
		The ultimate one to choose is the one that most-meets the commissioning entity's vision, organizational culture and business model, and that is most likely to be successfully adopted and achieve continuous/full functionality		
		Commissioning entity makes the final decision based on the documents and outcomes of assessments mentioned above		

Sub-phase 1.2.2.2 includes the criteria that need to be considered for the final selection of the most suitable vendor and new digital technology (see table 7-9). Such criteria will not only assist the commissioning entity in performing the assessment, but will also ensure that the new digital technology will ultimately fit into the commissioning entity. The first criterion is the capability for the future upgrade and integration with other existing systems installed at the commissioning entity. The commissioning entity needs to consider this criterion seriously as it further affects the continuous functionality of the new digital technology after adoption. The commissioning entity needs to avoid purchasing the most expensive or the cheapest new digital technology without extensive review and assessment of the functionality of that new digital technology. The final criterion shows that the commissioning entity needs to go back to the fundamental criteria even though it has performed all the required assessments. Such fundamental criteria include the vision, organizational culture and business model. This consideration is based on the fact that they are critical for the new digital technology to reach its full functionality, not only technically, but also at the level of organizational culture and business model.

Main-phase 1, namely pre-adoption phase, ends with the completion of main-task 1.2.2. The two major objectives of this phase were to understand the commissioning entity's capacity and expectations, and based on this, to have a desirable vendor and new digital technology in place, ready for the adoption. The entire project then moves to the adoption phase:

7.2.4 Adoption phase for new digital technology

The second part of the new blueprint is main-phase 2- adoption phase. The objective of this phase is to develop the strategy that guides the commissioning entity through the new digital technology adoption. The logic flow of this phase is to draft legal documents first, then prepare for the adoption, and then carry out the adoption. Three sub-phases are therefore defined to achieve the goal (see figure 7-10).

Table 7-10 Main-phase 2 Adoption phase

New blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
2. Adoption phase for new digital technology	**2.1. Legal documents drafting**	2.1.1 Agreement drafting		
		2.1.2 Contracts drafting		
	2.2 Preparation work for adoption	2.2.1 Documents required for running the system		
		2.2.2 System requirement documents need to be prepared by vendors (Cawood, 2017)		
		2.2.3 Requirement for infrastructure upgrade for adoption		
	2.3. Adoption of new digital technology	2.3.1 Ensure implementation of legal documents		
		2.3.2 Measurements for budget control, project management		
		2.3.3 Design and quality of civils work		
		2.3.4 Support & cooperation (communication)		

7.2.5 Sub-phase 2.1 Legal documents drafting

Sub-phase 2.1's legal-documents-drafting focuses on the development of all the legal-related documents for the new digital technology adoption. Such legal documents regulate the duty and responsibility of both the commissioning entity and vendors. Two main-tasks, namely 2.1.1 and 2.1.2, are included (see figures 7-11 and 7-12).

Table 7-11 Main-task 2.1.1 Agreement drafting

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.1.1 Agreement drafting				
	2.1.1.1 Drafting constitutional agreement (e.g. Wits agreement (Appendix X)	Develop the commissioning entity's constitutional agreement		
		Implement the commissioning entity's constitutional agreement		
		All drafted legal documents have to refer to the commissioning entity's constitutional agreement for all the activities take place in the commissioning entity (refer to the Wits/vendor's agreement)		
	2.1.1.2 Drafting Intellectual property agreement	Ownership of data generated by the new digital technology		
		Collection, transfer and storage of data generated		
		Utilization of data generated (i.e. analysis, research purpose)		
		Security of data generated (cyber security, access control to server, etc.)		
	2.1.1.3 Drafting purchase agreement	Develop detailed plan for purchasing goods, equipment, material and labor, and all required items for adoption		
		Logistics arrangement for purchased goods, equipment and material delivery		
	2.1.1.4 Agreement of mutual acknowledge-ment	Clarification on outcome of the adoption		
		Clarification on vendor-claimed functionality		
		Clarification on the limitation of the new digital technology		

Table 7-11 illustrates the contents and new architecture of main-task 2.1.1, which is focused on drafting the following four key agreements between the commissioning entity and vendors.

a. Drafting constitutional agreement for the commissioning entity

Sub-task 2.1.1.1 is illustrated by the Wits agreement that has been used by WMI for new digital technology adoption (see Appendix II). The Wits agreement is a good demonstration of how the commissioning entity should draft such agreement and serves as a constitution for all agreements between WMI and vendors. The commissioning entity should therefore also develop such constitutional agreement. All the agreements and contracts in the commissioning entity need to then be drafted under the constitutional agreement. This is to avoid any conflicts between different technology systems in the commissioning entity.

b. Purchase agreement

Sub-task 2.1.1.2 contains a detailed plan for purchasing the goods and equipment for the adoption. Due to the lack of local manufacturing capability, some goods and equipment need to be acquired from international sources. Hence a logistic agreement also needs to be developed.

c. Intellectual property agreement

Sub-task 2.1.1.3 shows that the commissioning entity needs to consider ownership and copyright of data that may be generated by the new digital technology. This intellectual property agreement should include the plan for data collection, storage and transfer after the new digital technology is installed. Data utilisation and security should also be stated in the agreement.

d. Agreement of mutual acknowledgement

Sub-task 2.1.1.4 focuses on the clarification of the outcome of the adoption and vendor-claimed functionality, as well as the limitation of the new digital technology. The purpose is to avoid any misunderstanding of the achievable functionality of the new digital technology when the adoption is completed.

After the commissioning entity and the vendors reach agreement, the next step is to draft the contract to clarify and formalise the activities between the commissioning entity and the vendors during the adoption:

Table 7-12 Main-task 2.1.2 contracts drafting

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.1.2 Contracts drafting				
	2.1.2.1 Drafting contracts	Preparation work for commissioning entity (state the support required)		
		Project plan for adoption work (including schedule and budget)		
		Pricing, payment and labour arrangement, (e.g. import tax)		
		System integration with the existing installed system		
		Deliverable outcome and achievable functionality after the adoption		
		Detailed plan for after sale services from vendors		
		Exit strategy (conditions re. termination of contracts, or further cooperation)		

Table 7-12 illustrates the items in the contract. The contract needs to clarify the preparation work to be done by the commissioning entity. Meanwhile, the vendor needs to develop a detailed plan for the adoption, which includes schedule and budget. Other considerations such as system integration and deliverable outcome should also be included in the contract. The vendor also needs to clarify services required to maintain system functionality after adoption. The exit strategy indicates conditions and circumstances that will allow the commissioning entity and vendor to terminate the contract or further corporation.

7.2.6 Preparation work for adoption

Table 7-13 Sub-phase 2.2 Preparation work for new digital technology adoption

New blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
2. Adoption phase for new digital technology				
	2.1. Legal documents drafting	2.1.1 Agreement drafting		
		2.1.2 Contracts drafting		
	2.2 Preparation work for adoption	2.2.1 Documents required for running the system		
		2.2.2 System requirement documents need to be prepared by vendors (Cawood, 2017)		
		2.2.3 Requirement for infrastructure upgrade		
	2.3. Adoption of new digital technology	2.3.1 Ensure implementation of legal documents		
		2.3.2 Budget control		
		2.3.3 Design and quality of civils work		
		2.3.4 Support & cooperation (communication)		

Sub-phase 2.2 represents preparation work that has to be done by both the commissioning entity and the vendor (red box in table 7-13). Three main-tasks with several activities ensure that sufficient work is carried out before the adoption commences.

Table 7-14 Preparation work for the adoption

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.2.1 Documents required for running the system				
	2.2.1.1 System operation documents	Develop system new architecture with data flow		
		Apply SOP (Standard Operation Procedures) for all the activities		
		Apply health and safety measurements and procedures		
		List of possible sub-contractors for adoption and operation		
	2.2.1.2 Technical support documents	Clarify system update & upgrade (include both hardware and software)		
		Check system debug & system functionality recovery during system malfunction		
		Develop a schedule for System maintenance		
		Develop a reporting system between commissioning entity and vendor		

Two sub-tasks are included in main-task 2.2.1 to describe the documents required by the commissioning entity for enabling the new digital technology adoption (see table 7-14). Sub-task 2.2.1.1 focuses on documents required for system operation. System new architecture and SOP helps the commissioning entity to understand the functionality of each component in a system and how they fit together. Health and safety provides measurements and procedures that need to be adhered to during and after adoption. The vendor also needs to provide a list of the possible sub-contractors required for the adoption work, as well as for the operation of the new digital technology. Sub-task 2.2.1.2 focuses on documents that cover technical support after adoption. Such support includes system upgrade, system debug, system maintenance and reporting system. Such support is extremely important for maintaining functional new digital technology. Main-task 2.2.2 describes the system requirement documents developed by WMI:

Table 7-15 Main-task 2.2.2 WMI's system requirement documents

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.2.2 System requirement documents need to be prepared by vendors (Cawood, 2017)				
	2.2.2.1 Contents of key topics	Obtain system description (e.g. system operation documents, COP, SOP)		
		Obtain a detailed list of system items		
		Clarify enabling elements/items required for adoption (e.g. civils work upgrade)		
		Clarify vendor deliverables (itemized)		
		Obtain software-related information/plans		
		Commissioning entity and vendor meet to get clarity on everything mentioned above		

Table 7-15 shows the contents of key topics in this document. It provides a good example of the template and contents of system requirement documents that have to be drafted by the vendor.

Main-task 2.2.3 in table 7-16 shows the document needed for requirements for infrastructure upgrade. This is one of the most important documents that need to be prepared for the adoption.

Table 7-16 Main-task 2.2.3 requirement for infrastructure upgrade

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.2.3 Requirement for infrastructure upgrade				
	2.2.3.1 Civils work, hardware	Time consuming, need to plan in advance for preparation (construction, logistics, etc.)		
		Ensure a holistic design of the civils work (influence to other systems)		
	2.2.3.2 Network, communication system, software and ICT system	Network and I.T. system capability (bandwidth, storage capacity, computing power and number of servers, etc.)		

Such infrastructure upgrade includes both hardware and software, such as civils work and the ICT system. Both of the latter aspects are time-consuming and need to be planned in advance. Design of civils work can influence the functionality of both hardware and software, and eventually impact the entire new digital technology (e.g. antenna signal interference). Other important requirements that also need to be considered include bandwidth, storage capacity, computing power and numbers of servers. Each is capable of posing significant threats to overall system functionality.

Once the preparation work has been completed, the entire adoption process can proceed to the adoption phase. It is recommended that experienced personnel with project management skills to be appointed to supervise the whole adoption work.

Table 7-17 Sub-phase 2.3 Adoption of new digital technology

New blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
2. Adoption phase for new digital technology				
	2.1. Legal documents drafting	2.1.1 Agreement drafting		
		2.1.2 Contracts drafting		
	2.2 Preparation work for adoption	2.2.1 Documents required for running the system		
		2.2.2 System requirement documents need to be prepared by vendors (Cawood, 2017)		
		2.2.3 Requirement for infrastructure upgrade		
	2.3. Adoption of new digital technology	2.3.1 Project management		
		2.3.2 Focusing areas for budget control		
		2.3.4 Communication mechanism		

Sub-phase 2.3 in table 7-17 shows three main-tasks that need to be carried out in the adoption phase. The objective of this sub-phase is to ensure that a successful adoption project is achieved within schedule and budget. These three main-tasks cover three major aspects of the adoption, ranging from project management, through budget control, to communication mechanism.

Table 7-18 Main-task 2.3.1 Project management

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.3.1 Project management of adoption				
	2.3.1.1 Appointment of system champion to supervise the progress of the adoption	System champion appointed to oversee the entire adoption project behalf of the commissioning entity		
		Communication/liaison with vendors on behalf of the commissioning entity		
		System champion is required to have comprehensive understanding of the new digital technology, and preferably to have been involved from the initial stage of identification/selection procedures		
	2.3.1.2 System champion supervise the adoption project	Ensure the implementation and execution of all legal documents		
		Monitor the implementation/execution of all the agreements and contracts in different phases (schedule)		
		Monitor of the quality of implementation/execution (documenting and reporting)		
		Ensure the requirement of infrastructure upgrade is in place and is sufficient to accommodate the requirement of adoption		
		Adhere to all the regulations, standards, COP, SOP during adoption, such as wiring standards, emergency procedures and health and safety act, etc.		
	2.3.1.3 Apply Key principles to managing all the resources for each phase of the adoption	Initiation and planning		
		Execution of the plan		
		Adoption of project monitoring and control		
		Adoption project completion and handover		

Three sub-tasks are developed under the main-task 2.3.1 for managing the adoption project (see table 7-18). The commissioning entity is required to appoint an experienced system champion to communicate with the vendors and oversee the entire adoption project on behalf of the commissioning entity. The basic requirement for appointing the system champion includes that he/she have comprehensive understanding of the new digital technology and have had involvement in identification and selection of the new digital technology. Sub-task 2.3.1.2 discuss the activities for ensuring the quality of the adoption. Such activities include the monitoring, documenting and reporting processes required for implementation of all the legal documents and contracts developed in sub-phase 2.1. Proper documenting and reporting ensures that the progress and quality of the implementation is properly monitored. Activities in sub-task 2.3.1.2 also require the system champion to ensure the readiness of the required infrastructure before the adoption, as well as to adhere to all standards, regulations and COP during the adoption. The design and quality of civils work needs to be rechecked according to any civils work upgrade requirements that may have been defined in main-task 2.2.3. Sub-task 2.3.1.3 in table 7-18 includes four principles that illustrate the general stages of an adoption project. The system champion should closely monitor the progress of the adoption against these four stages to ensure that the project is carried out according to the plan and completed in time.

Meeting the project schedule is only part of successful adoption. A successful adoption also requires attention on the project budget. Table 7-19 shows four focus-areas of budget control in the adoption project.

Table 7-19 Main-task 2.3.2 budget control of adoption project

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.3.2 Focusing areas for budget control				
	2.3.2.1 Labor	The arrangement of labour during adoption needs to follow the labour agreement drafted in 2.1.1.1		
	2.3.2.2 Material	Purchase of the material for adoption should strictly follow the purchase agreement signed in 2.1.1.1		
	2.3.2.3 Logistics	The requirement for logistics should be done according to the guidance written by vendors in logistics agreement in 2.1.1.1		
	2.3.2.4 Hardware and software	Hardware and software purchase: Strictly implement the purchase agreement in 2.1.1.1 and only listed items should be purchased		
		Hardware and software upgrade: based on the assessment of the existing hardware and software before going for the upgrade		

Budget control is a key focus in the adoption phase. It has a direct link to the planned budget of the commissioning entity. The appointed system champion is required to focus on the following four areas for budget control.

a. Labour;
b. Material;
c. Logistics; and
d. Hardware and software purchase.

The system champion needs to ensure that purchases of labour, material and logistics are done according to the agreements and contracts signed between the commissioning entity and vendors in main-task 2.1.1.1. Decisions made on purchase or upgrade of both hardware and software should be based on the actual needs of the adoption project. For example, instead of purchasing new software, the system champion needs to first review the possibility of purchasing add-on modules to existing software to achieve the same system functionality. This is also for the consideration of cost control.

Table 7-20 Main-task 2.3.3 communication mechanism

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.3.3 Communication mechanism				
	2.3.3.1 Support & cooperation between the commissioning entity and vendors	Create multiple channels for efficient communication, documenting and reporting between system champion and vendors for the lifespan of the system		
		System champion and vendor support/cooperate with each other during the adoption		
		Sufficient communications between system champion and vendor on progress and feedback during the adoption		

Main-task 2.3.3 in table 7-20 shows that the system champion must ensure that a communication mechanism is established between the commissioning entity and vendor to enhance communication, documenting and reporting. It is also important that the commissioning entity and the vendor cooperate with each other by providing sufficient support. Such cooperation is key to creating a harmonious environment for successful adoption of the new digital technology, as well as to maintain a continuous functional technology system after adoption.

The outcome of the adoption varies between different entities. It could be influenced by several other factors, such as the size of the new digital technology, the capability of the vendors and human factors etc. The commissioning entity needs to ensure that the whole adoption project is properly monitored and guided according to the requirements mentioned above.

Main-task 2.3.3 marks the end of the sub-phase 2-adoption phase. The adoption process then proceeds to the final phase to address problems encountered in the post-adoption phase.

7.2.7 Post-adoption phase

Sub-phase 3 is the post-adoption phase and it is also the final phase for the newly developed blueprint in this research. The objective of this phase is to clarify the activities that need to be performed to maintain the system functionality after the adoption. The main activities that need to be carried out in this phase are system testing, after-sales support services and assessment for an exit strategy. In total, there are two sub-phases and five main-tasks in main-phase 3 (see table 7-21).

Table 7-21 Main-phase 3 post-adoption phase for new digital technology

New blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
3. Post-adoption phase for new digital technology	**3.1 System calibration, testing, and integration**	**3.1.1 System calibration**		
		3.1.2 System testing		
		3.1.3 System integration		
	3.2 After sale services	**3.2.1 Activities required to maintain continuous system functionality**		
		3.2.2 Exit strategy		

Sub-phase 3.1 includes work that needs to be done by the commissioning entity after the adoption to achieve a continuously-functional new digital technology through system calibration, testing and integration (see table 7-21).

The purpose of sub-phase 3.1 is to ensure that the new digital technology achieves its full functionality after adoption. It also helps to maintain a functional system in the long term through system malfunction testing. The following is a brief discussion of the three main-tasks in sub-phase 3.1.

a. Main-task 3.1.1: System calibration (see figure 7-22).

The system champion needs to ensure that all hardware is constantly calibrated to specifications. He/she further needs to ensure accuracy of data collected by such hardware, especially from sensors and measuring equipment. All certificates of calibration need to be regularly checked and kept up to date.

Table 7-22 Main-task 3.1.1 system calibration

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.1.1 System Calibration	**3.1.1.1 System calibration**	Calibrate all the hardware such as sensors, equipment and devices to their required specifications, especially sensors and measuring instruments		
		System champion to ensure that setting-requirements of all software matches associated hardware requirements, and that software receives correct and sufficient data from hardware		
	3.1.1.2 Certification of calibration	Obtain calibration certificates for individual equipment/device, and the overall system		
		Document all records for calibration and update the certificates accordingly		

b. Main-task 3.1.2: System test

Main-task 3.1.2 in table 7-23 shows system functionality testing and system malfunction testing that are required to be conducted. The noticeable fact is that system calibration and system testing are preparatory-work for the final step in system integration.

Table 7-23 Main-task 3.1.2 system testing

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.1.2 System testing	**3.1.2.1 System functionality testing**	Test individual and overall system functionality against the claimed functionality stated in the contract in main-task 2.1.2		
	3.1.2.2 System malfunction testing	Recognize and record any system malfunction		
		Identify the major cause of system malfunction		
		Identify any disruption to the continuous functionality of the system during testing		
		Debug and make corrections; Document all the findings		

The outcome of those two tests reveals whether the new digital technology has reached the claimed functionality. The system champion should pay extra attention to the results of the malfunction testing. Any system malfunction encountered during this testing phase should be properly documented and reported to the vendor for solutions. An emergency plan to restore system functionality under circumstances such as power failure needs to be prepared by the vendor.

c. Main-task 3.1.3: System integration

Main-task 3.1.3 in table 7-22 discusses system integration between the newly installed new digital technology and the existing system in the commissioning entity. Two critical activities are included in this main-task and are required to be conducted by the system champion (see table 7-24).

Table 7-24 Main-task 3.1.3 system integration

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.1.3 System integration	**3.1.3.1 Apply appropriate integration method**	Perform system compatibility test between newly installed new digital technology and the existing technology systems in the commissioning entity		
		Identify and apply the appropriate integration method to integrate all the sub-systems in the commissioning entity according to their functionalities		

The entire integration is divided into two sections. The first section is to conduct system compatibility tests to determine whether the platform in the commissioning entity is proficient enough for the new digital technology to perform its functionality. The second section requires the system champion to identify an appropriate integration method and apply it to integrate the newly installed new digital technology into the overall existing system in the commissioning entity.

Once the system champion is satisfied with the outcome of the system testing, the entire adoption project can move to final stage sub-phase 3.2.

Table 7-25 Sub-phase 3.2 After-sales support services

New blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
3. Post-adoption phase for new digital technology				
	3.1 System calibration, testing, and integration	**3.1.1 System calibration**		
		3.1.2 System testing		
		3.1.3 System integration		
	3.2 After-sales support services;	**3.2.1 Continuous system operation after adoption**		
		3.2.2 Exit strategy		

Two main-tasks are included in the sub-phase 3.2 (red box in table 7-25). Main-task 3.2.1 is aimed at developing activities required to support system-operation after adoption.

Table 7-26 Main-task 3.2.1 system operation after adoption

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.2.1 System operation after adoption	**3.2.1.1 Activities requires to maintain the continuous system functionalit y**	System maintenance & system debug		
		Emergency procedures for system functionality recovery after system malfunction		
		Regular system and hardware upgrade and software update		
		Documenting & Reporting system		

Four important activities are included in main-task 3.2.1 (see table 7-26). Sub-task 3.2.1.1 covers the major problems that the new digital technology may encounter after it has been installed. The vendor is required to develop a comprehensive document for regular system maintenance, as well as emergency procedures to cater for system malfunction. System upgrades and update information are also required for keeping all the system features up to date, such as system security features.

Table 7-27 Main-task 3.2.2 exit strategy

New blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.2.2 Exit strategy				
	3.2.2.1 Commissioning entity conduct an assessment to review the performance of the new digital technology	Two questions should be answered by the assessment: 1. Did the performance meet the commissioning entity's expectations? And:		
		2. Did the new digital technology address the problem faced?		

Main-task 3.2.2 is an exit strategy and is also the final task of the entire new blueprint (see table 7-27). System champion needs to conduct an assessment to review the performance of the newly installed new digital technology against the commissioning entity's expectations. Two key questions need to be answered before the system champion can declare the completion of the whole adoption project.

a. Does the performance meet the commissioning entity's expectations?

b. Did the new digital technology address the problem faced?

If positive answers are obtained for those two questions, then the system champion can declare the completion of the adoption and consider possible exits such as: Either terminate the agreements and contracts or seek further cooperation between the commissioning entity and vendors.

If the answers are negative, the system champion needs to review the entire adoption to locate the problems.

The completion of the main-task 3.2.2 marks the end of the main-phase 3, as well as the completion of all the phases, tasks and activities defined in the new blueprint.

7.3 Summary

The objective of this chapter was to create a new blueprint from WMI lessons that can be used to guide a commissioning entity to achieve smooth adoption of new digital technology. An empirical model and holistic approach were used to develop this new blueprint. The following three aspects provide crucial information for the development process.

a. WMI vendor management system; vendor supporting documents template;
b. A case study on Schauenburg MIMACS system installation project and other digital technology systems installed at WMI; and
c. Systems thinking skills.

The new architecture of the new blueprint is designed chronologically and hierarchically, to simplify the adoption process and reduce the workload associated with each phase. A series of pre-determined phases is designed to guide the commissioning entity through the entire adoption process. The following table 7-28 shows the total hierarchy of the new blueprint.

Table 7-28 Hierarchy and the total number of hierarchy in the new blueprint

Hierarchy	Total number in the new blueprint
Main-phase	3
Sub-phase	8
Main-task	18
Sub-task	35
Activities	119

The new blueprint's main-phase and sub-phase together set the course of the adoption process, and guide the commissioning entity through three critical phases of the entire adoption of new digital technology.

- Identification of new digital technology in pre-adoption;
- Adoption of new digital technology in the adoption phase; and
- Continuous functionality achievement in the post-adoption phase.

The main-task and sub-task combined, define the work needed to be done in each sub-phase. Activity in each sub-task represents the actual work that the commissioning entity needs to perform. Such new architecture provides flexibility to the commissioning entity: The commissioning entity can skip or add certain tasks to accommodate individual situations within the commissioning entity.

However, the main purpose of the new blueprint is to provide a guideline for new digital technology adoption to any commissioning entity. In such cases, effort is also required from the commissioning entity to ensure quality of the adoption process, e.g. project management skills are required in the adoption phase to ensure that the project is completed within schedule and budget.

The completion of all activities in the new blueprint will only enable the commissioning entity to complete adoption. The commissioning entity's satisfaction on the outcome will indicate the effectiveness and quality of the new blueprint. The following list represents several indications when examining the outcome of the adoption:

- Execution of the full agreement;
- Achievement of claimed system-functionality;
- Smooth adoption meeting schedule and budget;
- Continuous functional system; and
- Quality-contents of support-documents.

The complexity of the adoption process requires that the new blueprint covers as many of the aspects as possible. Yet the applicability of the new blueprint requires that its size be practical. Application of systems thinking skills is essential to balance such contradictions. It helps to gain a big picture of the whole adoption when designing individual phases. However, the actual adoption process can be influenced by many factors. For example, cooperation between commissioning entity and vendors is key to ensuring successful adoption.

The new blueprint's verification will be carried out in the next chapter. In this context, the new blueprint developed in this chapter was modified to measure WMI's performance during the MIMACS system installation.

8 Blueprint verification and discussion

8.1 Introduction

A blueprint was developed in chapter 7 to assist the commissioning entity during the adoption process of new digital technology systems. The objective was to create a logical and flexible structure that is capable of guiding the commissioning entity through the entire adoption process. The final blueprint consists of three main phases, each of which represents a critical segment in the adoption process. The commissioning entity needs to perform a number of tasks to achieve the goals defined for each phase of the adoption process. A series of pre-determined steps in the blueprint was developed to guide the commissioning entity through identification and selection of an appropriate new digital technology. The ultimate goal of applying the blueprint is to help the commissioning entity to achieve the functionality of the new digital technology.

Key stakeholders were identified for clarifying the correlations and responsibilities of different parties in different phases during the adoption process, which will facilitate verification of the blueprint.

The WMI vendor management system provided a good example when developing this blueprint: The case study conducted in chapter 5 showed that the system is effective. Both the blueprint and the WMI vendor management system are empirical models. However, systems thinking skills were applied in developing the blueprint, making it more comprehensive and more applicable. The first part of chapter 8 discusses the verification process of the blueprint. The second part of this chapter focuses on improvements that can be made to the blueprint by identifying missing parts and limitations in the blueprint. The last part of this chapter covers influential factors that could affect new digital technology adoption experiences, as well as the final outcome of the adoption process.

8.2 Verification of the blueprint

Verification of the blueprint is carried out in this chapter to test the effectiveness and practicality of the blueprint. The Schauenburg MIMACS II system adoption project is selected as a sample for testing the blueprint. The case study conducted on the MIMACS system in chapter 5 revealed major problems that were experienced by the WMI during the installation project. One of the possible causes of these problems was lack of proper guidance. The blueprint developed in the previous chapter thus includes compulsory tasks and activities needed for successful system adoption. The commissioning entity is required to complete all the compulsory tasks and activities before completing the adoption project. Non-completion of the tasks and activities may cause a variety of problems for the commissioning entity, both during and after adoption. WMI experienced such problems within each adoption phase of the MIMACS II system project, e.g. lack of proper guidance caused project delay, inadequate after-sales services caused system malfunction, etc. The following is an illustration of the scope of the testing method:

- The object that is tested is the WMI adoption project of the Schauenburg MIMACS II system.
- The testing sequence strictly follows the structure and logical flow of the blueprint.
- The activities defined in the blueprint set the benchmark for the MIMACS system adoption project and measure the compliance of the work carried out by WMI in the project.
- All work carried out by WMI during the project is compared against work that is required by the blueprint[13].
- Work carried out by the WMI is furthermore compared to corresponding sections of the blueprint and then assessed in percentage of compliance.

[13] To measure what WMI has done against what is required to be done.

- A checklist is added to the blueprint to facilitate the measurement of WMI work.
- In order to gather realistic data regarding WMI work during the MIMACS II adoption project, 10 persons were invited to participate in a survey. The full record of the survey can be found in Appendix XI.
- Data gathered by the survey is analysed to ascertain correlations between level of compliance and problems experienced by WMI during MIMACS system adoption (e.g. project delay and system malfunction).
- Conclusion can be drawn based on the findings of the correlations. Recommendations can also be made for improving the quality of the blueprint.

8.2.1 Scope of data collection

The objective of the data collection was to accumulate data that correctly reflects work carried out by WMI during the MIMACS system adoption project. Figure 8-1 below illustrates a checklist that is linked to each task in the blueprint to ensure fulfilment of its associated requirements.

Table 8-1 Example of the blueprint with the checklist

Blueprint contents			Checklist		
Main-task	**Sub-task**	**Activities**	**Risk Scale**	**Compliance (%)**	**Remarks**
Main-task					
	Sub-task	Activity			
		Activity			
		Activity			
	Sub-task	Activity			
		Activity			
Total and average compliance					

Four components are included in the checklist:

- Risk-scale, gathered from a 5 x 5 risk-assessment matrix for each hierarchy of the blueprint.
- Percentage of compliance for the activities performed. This is measured on a scale from 0 to 100%, and reflects the quality of work performed by WMI; and
- Remarks include comments that were made by individuals on each activity.
- Row for calculating total and average compliance.

The survey contains 18 tables in total (each table follows figure 8-1's template format). In addition to inclusion of the above four components into Chapter 7's blueprint, the following text has been modified in the blueprint: "Commissioning entity" has been replaced with "WMI"; "New digital technology system" has been replaced with "MIMACS system"; "Vendor/supplier" has been replaced with "Schauenburg". The full record of the survey is attached in the Appendix XI.

The checklist will be used to gather data from relevant persons[14]. The advantage of using this checklist is that it provides information on every item of work that was carried out during the adoption project. A further reason for selecting this structure is that the adoption project was completed in 2016, and thus dated-information that is based solely on memory of relevant persons is insufficient.

A coding system is used in the survey record to name the 10 persons: Person A, person B, etc.

[14] Relevant person: people who participated in the adoption project of the MIMACS system installation.

Qualitative method is chosen for data collection, since the source of data is relatively small. This is mainly due to the limited size of the focus group[15], since only ten persons were available to participate in the survey for data collection.

Telecommunication is chosen as the main channel for data collection and communication. In order to obtain realistic data, each person is required to have an actual experience and participation in the MIMACS system adoption project. The survey was sent to all persons via emails, together with a consent letter. Sufficient time was then given to each individual to complete the survey. This arrangement was based on the fact that most persons invited to participate in this research are unavailable for personal-interview.

All completed surveys were gathered and sorted to extract the data that became be the source for data analysis and interpretation. The objective of the data analysis and interpretation is to look for correlations between compliance of tasks or activities and problems faced by WMI during system adoption. The entire process covers all three key stages of system adoption, namely pre-adoption, adoption and post-adoption.

8.2.2 Outcome of data collection

Nine out of the ten persons who were invited to participate in the questionnaire accepted the invitation and fully completed the survey. All the data was carefully classified and archived for analysis.

8.2.3 Data analysis and interpretation

The objective of the data analysis is to attempt to find what may have caused unsatisfactory outcomes in the MIMACS system adoption project. Focus of the data collection and interpretation is on identifying correlations between compliance of activities and unsatisfactory outcomes (lessons learned) in the adoption project. The percentage of

---

[15] Focus group for the source of data: it refers to the relevant person.

compliance and confirmation of the performance of each activity provides a critical indication of the quality of work that was carried out during the adoption project. Included are remarks made by other individuals that could improve the quality of the blueprint.

A risk assessment tool is used to rate the risk scale for each main-task and main-phase (see table 8-2). Each main-task and main-phase is allocated an individual risk level to calculate the cumulative risk. The outcome of the risk assessment provides a clear indication of the importance of each main-task and main-phase. This, in turn, provides the commissioning entity with the ability to plan its resources wisely when implementing the blueprint.

Table 8-2 Risk-assessment 5 x 5 matrix of risk scale for main-tasks and main-phases

	Consequence to the final outcome of adoption				
Threats likelihood	**Insignificant (1)**	**Minor (2)**	**Significant (3)**	**Major (4)**	**Severe (5)**
Almost certain (5)	Medium 5	High 10	Very high 15	Extreme 20	Extreme 25
Likely (4)	Medium 4	Medium 8	High 12	Very High 16	Extreme 20
Moderate (3)	Low 3	Medium 6	Medium 9	High 12	Very high 15
Unlikely (2)	Very Low 2	Low 4	Medium 6	Medium 8	High 10
Rare (1)	Very Low 1	Very Low 2	Low 3	Medium 4	Medium 5

Vertical scale (threat-likelihood to a successful adoption in this research), rates the threat-likelihood to overall adoption if a main-task (including all its activities) did not perform, or partially performed. This rate is inversely proportional to compliance percentage:

- Higher compliance equals lower threats;
- Lower compliance equals higher threats.

The horizontal scale (severity of consequence to a successful adoption in this research), rates the consequence to overall adoption if a main-task (including all its activities) did not perform, or partially performed. This rate is inversely proportional to compliance percentage:

- Higher compliance means lower risk;
- Lower compliance means higher threats.

Data analysis: Pre-adoption phase

The entire evaluation process starts with the pre-adoption phase. Two sub-phases and five main-tasks are required to be performed by WMI in this main-phase (see table 8-3).

Table 8-3 Main-phase 1 - Pre-adoption phase

Blueprint contents			Checklist		
Main-phase to perform	**Sub-phase to perform**	**Main-tasks to perform**	**Risk scale (ratings)**	**Average Compliance (%)**	**Remarks**
1. Pre - adoption phase for Schauenburg MIMACS II System					
	1.1 Gather information on the WMI's capacity	**1.1.1 Clarify WMI'S capacity before adoption start**	Extreme (20)	51%	Moderate
		1.1.2 WMI Technological gap	High (12)	62%	Moderate
		1.1.3 WMI's expectations	Extreme (20)	55%	Moderate
	1.2 Evaluate vendors, identify the potential technology systems (Schauenburg and MIMACS II system)	**1.2.1 Information gathering on Schauenburg and MIMACS II system**	Extreme (20)	54%	Moderate
		1.2.2 Assessment and selection procedures for selecting Schauenburg and MIMACS II system	Very high (15)	61%	Moderate

Sub-phase 1.1's purpose is to understand three key aspects of WMI by studying key information that is related to WMI. Main-task 1.1.1 gathers information for comprehensive understanding of the actual capacity of WMI. Risk scale of extreme (20) is determined as it is extremely important for the overall adoption. Poor performance of this main-task may result in severe consequences, such as total failure of the adoption. According to the collected data, an overall compliance of 51 % is scored for this main-task during the MIMACS system adoption project (see Appendix XI table 1). Such low compliance indicates that WMI did not spent adequate effort on gathering information. Only two out of nine WMI Digimine personnel members were aware of the funding for this adoption project. However, the case study on the Schauenburg MIMACS II system shows no sign of funding shortage, with overspending only being observed in adoption and post-adoption phases. Table 8-3's checklist reveals that WMI's vision, culture and business model was reasonably understood by WMI personnel before the adoption, based on an average compliance of 51 %. However, table 8-4's low average compliance of 42 % shows poor knowledge about WMI's existing infrastructure, especially table 8-4's "Obtain detailed ICT system architecture with data flow and sensor network of WMI" activity:

Table 8-4 WMI's actual capacity

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
1.1.1.1 Clarify WMI's vision, culture, structure & budget	Check WMI's background, vision and strategy	52
	Check WMI's business model, culture & interest	50
	Check WMI's funding and planned budget	23
1.1.1.2 Clarify WMI's existing infrastructure	Check WMI's communication system (ICT)	42
	Clarify WMI's data collection, transfer and storage route	50
	Obtain detailed ICT system architecture with data flow and sensor network of WMI	40
	Clarify the WMI's requirement for system integration	35
	Clarify WMI's system expandability	43
	Average compliance	**42**

In addition, table 8-4's checklist also demonstrates ignorance of possible system integration and system expandability via low compliance achieved by related activities.

Main-task 1.1.2 focuses on the review of the technological gap at WMI. The risk scale is rated as high (12), as it includes the critical problem-statement that covers all the problems faced by WMI which are expected to be addressed by suitable technology systems. A moderate level of 63 % overall compliance was voted by WMI (see table 8-5 and Appendix table-2).

Table 8-5 Existing technology system at WMI

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
1.1.2.1 **Current status of technology system installed at WMI**	Clarify current status of all technology systems installed at the WMI	66
	Check adoption approach used for all the technology systems in the WMI (before the Schauenburg MIMACS system installed)	33
	Review the outcome of the precedent adoption cases at the WMI	55
	Study all the lessons learned from those adoption cases	54
	Clarify WMI employees' capacity of skills (qualification & experience)	60
	Average compliance	**53**

This indicates WMI was performing well on main-task 1.1.2. This is backed up by the high 67 % level of compliance that sub-task *1.1.2.2 WMI's problem statement* achieved in below table 8-6. This also proves that WMI was well aware the problems they were facing. A 67 % compliance on the motivation to acquire Schauenburg's MIMACS system further shows WMI's clarification on the problem statement (see table 8-6).

Table 8-6 WMI's problem statement

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
1.1.2.2 **WMI's Problem Statement** **(Motivation to acquire Schauenburg's MIMACS system)**	Clarify/justify WMI's need/motivation to acquire Schauenburg's MIMACS system (e.g. require better mine access control)	69
	Clarify type and nature of the problems faced by WMI that can be addressed by Schauenburg MIMACS system	65
	Check possible solutions that are related to utilizing Schauenburg MIMACS system	67
	Average compliance	**67**

However, similar to main-task 1.1.1 and sub-task 1.1.1.1, WMI showed inadequate knowledge on existing technology and infrastructure at WMI, as a low level compliance of 42 % was voted. In contrast, WMI personnel demonstrated strong foresight regarding potential technology that was capable in addressing WMI's problems (see table 8-7). In sub-task 1.1.2.2 and 1.1.2.3, WMI scored an average compliance of 67% and 66 % on best current technology system and future trend in the mining industry respectively.

Table 8-7 Best practice in mining industry

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
1.1.2.3 **Best practice in the industry to address similar problems**	Check similar problems that occurred in the mining industry (e.g. mine access control problem)	72
	Check solutions used to address similar problems in the mining industry	74
	Clarify role of new technologies in such solutions	56
	Review outcome of the solutions	65
	Study lessons learned from such problems and solutions	63
	Average compliance	**66**

Main-task 1.1.3 focuses on WMI's expectations of the potential technology system's[16] capability in addressing the problems listed in the problem statement. This is rated as 'extreme (20) severe consequence' on the risk scale, since wrong technology selection could occur if this main-task is mishandled. According to checklists filled by WMI personnel, a moderate level of 55 % compliance was achieved by WMI during the adoption project on this particular main-task (see Appendix – table 3). The main-task includes three sub-tasks, which need to be performed to clarify WMI's expectations on potential technology system. First sub-task 1.1.3.1 defines the improvement WMI expects to gain through the adoption of the MIMACS system. An average compliance of 64 % was voted by WMI personnel (see table 8-8).

Table 8-8 WMI's expectations on the improvement for adoption

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
1.1.3.1 Expected improvement on current technology system's functionality at the WMI	Clarify WMI's expected improvement in terms of planned budget, cost, functionality, etc.	**71**
	Clarify possible impact caused by Schauenburg MIMACS system on other existing technology systems installed at WMI	**60**
	Clarify timeframe for transition, adoption and integration for Schauenburg MIMACS system	**48**
	Clarify WMI's employee skills deficiency (compare to the required capacity of skills in 1.1.2.1)	**76**
	Average compliance	**64**

This indicates that WMI was very clear on what improvement it could expect through the adoption. Second sub-task 1.1.3.2 set the maximum and minimum functionality of the Schauenburg MIMACS System that would fulfill WMI's expectations as set out in sub-task 1.1.3.1. Due to inadequate knowledge on its existing infrastructure, WMI did not do well in

[16] The potential new digital technology in this phase is referring to the MIMACS system.

setting the expectations on maximum and minimum capacity of the system: WMI only managed to score a low level compliance of 43% for sub-task 1.1.3.2 (see table 8-9).

Table 8-9 Schauenburg MIMACS system functionality versus WMI expectations

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
1.1.3.2 **Minimum & maximum functionality of the Schauenburg MIMACS system against WMI's expectations**	Clarify minimum & maximum capacity of Schauenburg MIMACS System required for WMI to be satisfied	**70**
	Check redundancy created by the maximum capacity of Schauenburg MIMACS System based on the WMI requirement	**45**
	Clarify extra budget required for Schauenburg system upgrading to achieve the maximum capacity of MIMACS system	**16**
	Average compliance	**43**

A noticeable activity in sub-task 1.1.3.2 is the clarification of the extra budget required for upgrading the Schauenburg MIMACS system. WMI only managed to achieve an extremely low compliance of 16%. This will certainly affect WMI when maximum system capacity is required.

The third sub-task 1.1.3.3 discusses WMI expectations on the final outcome after the Schauenburg MIMACS system has been installed at WMI. A moderate compliance level of 56 % achieved in sub-task 1.1.3.3 indicates that WMI has clear expectations on the outcome of the adoption of Schauenburg MIMACS System (see table 8-10). This achievement is a direct result of the well-prepared problem statement in sub-task 1.1.2.2.

Table 8-10 WMI's expectations on the adoption

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
1.1.3.3 **WMI's expectations on the outcome of adoption of Schauenburg MIMACS System**	Clarify WMI's expectation on the improvement after the Schauenburg MIMACS System is installed	**56**
	Clarify the method for measuring the improvement after Schauenburg MIMACS System is installed	**49**
	Check possible future upgrade and integration for Schauenburg MIMACS System (e.g. real-time decision and alert)	**62**
	Average compliance	**56**

Main-task 1.1.3 marks the completion of gathering information on WMI. Sub-phase 1.1 is critical for the entire adoption project as the result of it sets the foundation. It not only reveals the true capacity of WMI, but it also provides crucial information for the rest of the adoption project. An overall compliance of 56% indicates insufficient WMI-effort in sub-phase 1.1. Furthermore, low level of compliance resulted in overall risk being rated as extreme (20) for sub-phase 1.1. This means that the likelihood of occurrence of inadequate information gathered on WMI is high, and the consequence of impact is severe.

Sub-phase 1.2 is another important task that is needed to be completed in the pre-adoption phase. Main-task 1.2.1 evaluates potentially-suitable technology systems, including the Schauenburg MIMACS system. Main-task 1.2.2 then justifies that MIMACS system is the most suitable system to meet WMI's needs. The latter two main-tasks are included in sub-phase 1.2. The following is the analysis of data collected from WMI on main-tasks 1.2.1 and 1.2.2 (see Appendix-table 4):

Main-task 1.2.1 contains three sub-tasks to help WMI gather information on the potential technology systems after the invitation for bids was sent (including the Schauenburg MIMACS System). The overall risk rate is determined as extreme (20). Sub-task 1.2.1.1

reviews the possible channel to gather information on acquiring the MIMACS system. An average compliance of 74 % indicates that WMI was well aware of the channels to access information on the MIMACS system and acquire their products and services (see table 8-11).

Table 8-11 Channel to acquire MIMACS system

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
1.2.1.1 Channel to acquire MIMACS system	WMI check the general practice to acquire a technology system in the mining industry	**75**
	WMI evaluate the possible channel to acquire a technology system from local supplier, OEM, or vendor (e.g. where to acquire Schauenburg MIMACS System?)	**73**
	Average compliance	**74**

Such high compliance could be a result of the fact that Schauenburg has a well-established business in South Africa. Information on their products and services is easily accessible for potential customers. The second sub-task 1.2.1.2 regulates the process for exchanging supporting documents between WMI and Schauenburg after the invitation for bids was sent. This process is crucial for both WMI and Schauenburg: Schauenburg need to fully understand the problems faced by WMI. WMI need to evaluate the Schauenburg MIMACS System against WMI's expectations. Quality of the WMI problem statement prepared in sub-task 1.1.2.2 poses great impact on the outcome of this information-exchange process. Hence if the WMI problem statement is determined as well prepared, WMI should have no problem in this information exchange process, and an average of 69% overall compliance has further proved it (see table 8-12).

Table 8-12 Information exchange between WMI and Schauenburg

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
1.2.1.2 Information/ documents exchange between WMI and Schauenburg	Ensure WMI sends 'invitation for bids' and arranges meetings between WMI and Schauenburg. WMI is to present all the requirements and expectations to Schauenburg	70
	Ensure WMI presents WMI's problem statement and expectations to Schauenburg	68
	WMI receive detailed background information on the Schauenburg MIMACS System and available technology systems	68
	Schauenburg provides detailed information to WMI: marketability, commercialization, availability in the region, precedent successful adoption cases, etc.	66
	WMI receive detailed technical documents about the functionality, specification, configuration, system compatibility, total cost with unit price and adoption requirement for infrastructure (versus WMI's capacity) of the Schauenburg MIMACS System	70
	Refer to the WMI's general contents for vendor's supporting documents	68
	Average compliance	**69**

However, an average of 39 % compliance in sub-task 1.2.1.3 shows that WMI failed to obtain key documents from Schauenburg, particularly documents that are required for continuous functionality of the MIMACS system in the post-adoption phase (see table 8-13).

Table 8-13 Information required for assessing MIMACS system

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
1.2.1.3 Information required by WMI for assessing Schauenburg's capability and MIMACS systems functionality	Ensure Schauenburg provide detailed description and demonstrate the functionality of the technology system	**72**
	Schauenburg provides all the documents for infrastructure upgrade required by the adoption project (both software and hardware)	**62**
	Schauenburg provide full list of equipment required for adoption, including description of all equipment, working principle of all instruments, detailed system architecture and data flow	**72**
	Schauenburg provide detailed requirement for system integration between the Schauenburg MIMACS System and existing technology systems installed at WMI	**34**
	Schauenburg provide detailed plan for add-on functionality (e.g. real-time alert and notifications)	**25**
	Schauenburg provide emergency procedures: (e.g. auto-restart function in power outage)	**18**
	Schauenburg provide after-sale support documents and plan	**22**
	Schauenburg provide comprehensive quotation (include cost of all services)	**25**
	WMI check receipt of all the information received and sent to Schauenburg	**23**
	Average compliance	**39**

Low compliance indicated in table 8-13 shows inadequate documents-exchange between WMI and Schauenburg. As a result, WMI overestimated the true capacity and functionality of the MIMACS system, eventually leading to questioning of inappropriate selection of new digital technology. The impact and consequence of such failure will only emerge late when WMI needed such services in the later stage of the adoption process.

Work of main-task 1.2.2 is the final identification and selection of the MIMACS systems, which includes all the information about the MIMACS system gathered in the previous main-task 1.2.1. The main activity is to assess the information provided by Schauenburg in the main-task 1.2.1 against WMI’s expectations prepared in main-task 1.1.3. The overall average compliance and overall risk scale are 52 % and very high (15) respectively (see Appendix X).

Two sub-tasks are included in the main-task 1.2.2. Both of them focus on assessment and selection of the most suitable potential technology systems, in this case the MIMACS system. Sub-task 1.2.2.1 provides four important assessment procedures that have to be performed by WMI to assess the MIMACS system. WMI personnel managed to achieve a high level of compliance of 74 % for this sub-task (see table 8-14).

Table 8-14 Procedures for assessing MIMACS system

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
1.2.2.1 Procedures for assessing MIMACS system	WMI to assess other potential vendors’ technology systems with similar functionality as MIMACS system for competitive reference	**66**
	Ensure WMI assess the Schauenburg-provided documents against the WMI's capacity and expectations: WMI need to conduct the following four assessments.	**57**
	1. MIMACS system’s functionality versus problems stated in WMI’s problem statement	**79**
	2. MIMACS system requirement for adoption versus WMI’s capacity	**81**
	3. MIMACS system’s total cost versus WMI planned budget	**75**
	4. MIMACS system’s property versus WMI vision, culture and business model	**83**
	WMI review the outcome of these assessments (review the overall performance of the MIMACS system)	**80**
	Average compliance	**74**

Due to the fact that only one technology system will eventually be selected, sub-task 1.2.2.2 focuses on further assessment criteria if more than one technology system has been identified in previous sub-task 1.2.2.1 (see table 8-15).

Table 8-15 Final assessment of MIMACS system

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average complianc e
1.2.2.2 **Criteria for final assessing the MIMACS system**	Ensure MIMACS system meet WMI's vision, organizational culture and business model, and is most likely to be successfully installed and achieve the continuous functionality	**62**
	Clarify MIMACS system's future upgradability with different platform	**33**
	Ensure WMI makes final decision based on the documents and the outcome of the assessment mentioned above	**65**
	Average compliance	**53**

However, a low-level average compliance of 53 % demonstrates that WMI personnel were not familiar with this step. The possible explanation is that MIMACS system was the only candidate-system remaining after earlier assessment, and WMI therefore did not have A chance to perform sub-task 1.2.2.

The final selection of the MIMACS system marks the completion of the entire pre-adoption phase. WMI has provided adequate feedback on the adoption project through the questionnaire. An overall compliance of 57 % was achieved by WMI for this main-phase 1.0. The overall risk scale is rated as very high (15). This means that this pre-adoption phase is extremely critical for the entire adoption project. Meanwhile, it is also very likely to go wrong and cause severe consequences. The following items are discovered from the outcome of the data analysis and interpretation of the main-phase 1.0 – pre-adoption phase:

- WMI did not spend adequate effort on main-task 1.1.1, thus incomplete information on WMI's true capacity was gathered. This certainly posed threats to the rest of the adoption project;
- A well-prepared problem statement in main-task 1.1.2 shows that WMI was aware of the existing technological gap and the problems within the institute;

- WMI had a clear plan to fill the technological gap and to address all the problems faced by the institute through the utilisation of new digital technology systems. WMI put their plan and requirement through main-task 1.1.3 via WMI expectations files;
- WMI's performance in main-task 1.2.1 shows that WMI lacks capability in gathering adequate information on a particular object. This problem was evidenced in main-task 1.1.1. WMI also under-performed in gathering information on potentially suitable vendors, including identifying MIMACS system in main-task 1.2.2; and
- Despite underperformance in information gathering, WMI still managed to carry out well-planned assessment procedures for final selection of a suitable technology system in main-task 1.2.2. In this case, Schauenburg MIMACS system was selected by WMI.

The entire adoption project for the MIMACS system moves into second main-phase 2.0 after Schauenburg was selected as the vendor to supply the MIMACS system to WMI. The objective of second main-phase 2.0 is to successfully adopt the MIMACS system at WMI. A series of activities and tasks needs to be performed by WMI to achieve such an objective. The main-activity WMI needs to perform is to complete three sub-phases and eight main-tasks (see table 8-16).

Table 8-16 Main-phase 2.0 - Adoption phase of MIMACS system

Blueprint contents			Checklist		
Main-phase	**Sub-phase**	**Main-tasks**	**Risk scale (Ratings)**	**Average Compliance (%)**	**Remarks**
2. Adoption phase for MIMACS system					
	2.1. Legal documents drafting	**2.1.1 Agreement drafting between WMI and Schauenburg**	**Extreme (20)**	52%	Moderate
		2.1.2 Contracts drafting process between WMI and Schauenburg	**Extreme (20)**	58%	Moderate
	2.2 Preparation work for MIMACS adoption	**2.2.1 Documents required for running the MIMACS system**	**Extreme (20)**	41%	Low
		2.2.2 System requirement documents need to be prepared by Schauenburg (Cawood, 2017)	**Extreme (20)**	68%	Moderate
		2.2.3 Requirement for infrastructure upgrade for installation	**Extreme (20)**	72%	Moderate
	2.3. Installation of MIMACS system	**2.3.1 Project management of installation of MIMACS system**	**Extreme (20)**	58%	Moderate
		2.3.2 Focusing areas for budget control during installation	**Extreme (20)**	20%	Very low
		2.3.3 Communication mechanism during installation and adoption	**Extreme (20)**	75%	High

According to the blueprint developed in the previous chapter, the entire adoption needs to start with the drafting of legal documents between WMI and Schauenburg covering adoption. Two types of documents need to be drafted, namely agreement and contracts. An overall compliance average of 52% was scored by WMI on agreements drafting (see appendix XI – table 6). Such low compliance is a combined result of relatively low score in several activities, namely 39% compliance for constitutional agreement (see table 8-17), 49% compliance for purchasing agreement drafting (see table 8-19) and only 13% compliance on clarification on the limitations of MIMACS system (see 8-20).

Table 8-17 Constitutional agreement (e.g. Wits agreement)

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance
2.1.1.1 Drafting constitutional agreement for all MIMACS adoption	Develop and implement the WMI's constitutional agreement (E.g. WMI vendor system adoption agreement)	**55**
	Ensure all the legal documents are drafted and are referred to WMI's constitutional agreement (refer to the Wits/vendor's agreement)	**23**
	Average compliance	**39**

Table 8-18 Intellectual property agreement drafting

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.1.1.2 Drafting Intellectual property agreement between WMI and Schauenburg	WMI and Schauenburg clarify ownership of the data generated by the MIMACS system	**83**
	WMI clarify collection, transfer and storage of data generated by MIMACS system	**81**
	WMI clarify the utilization of data generated by MIMACS system (i.e. analysis, research purpose)	**85**
	Schauenburg ensures the security of data generated by MIMACS system (e.g. cyber security, access control to server, etc.)	**62**
	Average compliance	**78**

Table 8-19 Purchasing agreement drafting

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.1.1.3 Drafting purchase agreement between WMI and Schauenburg	WMI and Schauenburg develop detailed agreement for purchasing goods, equipment, material and labour; all the required items for the adoption	**34**
	WMI and Schauenburg draft logistics arrangement for transport goods, equipment and material delivery	**64**
	Average compliance	**49**

Table 8-20 Agreement on MIMACS system functionality

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.1.1.4 Agreement of mutual acknowledgement on system functionality	WMI and Schauenburg clarify the expected outcome of the adoption and system functionality	**79**
	Schauenburg clarify on the limitation of the MIMACS II system	**13**
	Average compliance	**46**

Such low score indicates that the adoption project of the MIMACS system was guided by inadequate contract caused by oversight of key adoption issues. Missing key agreements will certainly affect the rest of the adoption process. An overall risk scale of extreme (20) is scored for this main-task. However, WMI still managed to achieve a high compliance of 78% in the activity of agreement drafting on intellectual property of generated data. Such agreement is key to WMI, since a large portion of WMI's research work is data dependent (see table 8-18).

Another important part of legal documents drafting is contracts drafting. WMI performed moderately in this sub-task with a score of 57% for overall average compliance (see Appendix XI-table 7). Despite the moderate overall compliance, WMI actually performed well in several contracts-drafting activities: 66% compliance achieved for project plan for preparation and installation; 63% compliance achieved for the labour and logistics arrangement; and 56% compliance scored for after-sales services (see table 8-21).

Table 8-21 Contracts drafting for MIMACS system adoption

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.1.2 Contracts drafting for the MIMACS system adoption	WMI develop project plan for both preparation and adoption work (e.g. project Schedule and budget)	**66**
	WMI Clarify pricing, payment and labour arrangement for the adoption (e.g. import tax)	**63**
	Schauenburg develop the plan for overall system integration after adoption	**31**
	WMI and Schauenburg clarify deliverable outcome and achievable functionality after the adoption	**66**
	Schauenburg develop detailed plan for after-sale services required for maintaining the functionality of MIMACS system	**56**
	Average compliance	**57**

An interesting fact is that although WMI only scored 13% on clarifying MIMACS system limitations (in the previous sub-task), WMI still managed to achieve 66% compliance on clarification of the outcome of MIMACS system adoption and achievable functionality after the adoption.

Such result means that WMI agreed on the outcome of the adoption of MIMACS system with Schauenburg, without knowing the actual limitation of the MIMACS system. In addition, WMI only achieved 31% compliance on contracts drafting for overall system integration (see table 8-21). Such low-level compliance on clarification of system limitation and integration will affect successive phases such as system testing and calibration, as well as the final outcome of the MIMACS system adoption.

Once both WMI's and Schauenburg's duties and responsibilities have been clearly defined via legal documents, the adoption process moves on to the next sub-task, namely preparation-work for the installation of MIMACS system. Main-task 2.2.1 is the last main-task that needs to be completed in legal-documents-drafting. Its purpose is to draft documents that are required for continuous operation of the MIMACS system. The first sub-task WMI is required to complete under main-task 2.2.1 is sub-task 2.2.1.1, namely drafting of MIMACS system operation documents. Low overall compliance of 41% has been voted on WMI's performance in this sub-task 2.2.1.1 (see Appendix XI – table 8).

Table 8-22 System operation documents drafting

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.2.1.1 System operation documents drafting	Schauenburg develop system architecture with data flow	**80**
	WMI ensure Schauenburg apply SOP (Standard Operation Procedures) for all the activities during adoption	**44**
	Schauenburg implement health and safety measurements	**23**
	Schauenburg produce a list of all possible sub-contractors	**24**
	Average compliance	**43**

Per table 8-22, the main contributor to such low compliance includes low compliance in the following sub-task 2.2.1.1 activities: 24% compliance to listing all possible contractors during installation, 44% in ensuring application of SOP during adoption, only 23% compliance achieved on implementing health and safety measurements, and 24% compliance in listing all possible contractors during installation. Such low level of compliance indicates that inadequate effort was spent by Schauenburg to create a safe environment for the MIMACS adoption project.

Sub-task 2.2.1.2 deals with the drafting of after-sales support documents that define the full support that the MIMACS system will require to be continuously functional after the adoption.

Table 8-23 After-sales support documents drafting

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.2.1.2 After-sales support documents drafting	Schauenburg clarify MIMACS system update & upgrade (include both hardware and software)	**63**
	Schauenburg ensure MIMACS system debug & system functionality recovery during system malfunction	**48**
	Schauenburg develop MIMACS system maintenance plan and schedule	**13**
	WMI and Schauenburg create reporting system for better communications	**33**
	Average compliance	**39**

The moderate 63% compliance-level in table 8-23's first activity shows that WMI has reasonable understanding of updates and upgrades that may be required by the MIMACS system in after-sales services. In contrast, an extremely low compliance of 13% demonstrates that both WMI and Schauenburg place very limited effort into development of a post-adoption maintenance plan and schedule for the MIMACS system. In addition, WMI also performed poorly on the system debug and system functionality recovery. Such inadequate preparation is further indicated by chapter 6's case study findings on WMI's MIMACS adoption problems, such as inadequate or poor quality maintenance work which could cause system malfunction and thus impact availability of the MIMACS system. The findings of the case study also expose that poor communication and reporting cause delays in system-functionality recovery. Poor communication after adoption may have been caused by omission of a plan for creating a good communication-mechanism between WMI and

Schauenburg. Substantiating this is a low compliance of 33% scored by WMI on creating a communication mechanism.

The next main-task requires Schauenburg to provide WMI with a system requirements document that includes at least four critical aspects (see table 8-24).

Table 8-24 MIMACS system requirement document

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.2.2.1 Contents of key topics in MIMACS system requirement document	Schauenburg provide system description to WMI	**78**
	Schauenburg provide list of required system items to WMI	**63**
	Schauenburg provide enabling elements required for installation to WMI (include both software and software)	**63**
	Schauenburg and WMI to meet to obtain clarity and get feedback on topics gathered above	**71**
	Average compliance	**68**

An overall compliance of 68% was achieved by WMI, which indicates that adequate information about the MIMACS system was provided to WMI (see Appendix XI table-9). One possible explanation for such a high level of compliance is that MIMACS is a mature and commercialized system, thus abundant information is available regarding the system. This is further substantiated by the 78% compliance achieved by Schauenburg in providing system description documents to WMI (see table 8-24). Schauenburg was also required to provide detailed information about required system items and enabling systems, namely systems that are critical for achieving a functional MIMACS system. An average compliance of 63% shows Schauenburg is well-prepared for providing such documents.

Once the paperwork that is required for adoption of the MIMACS system is ready, WMI moves on to infrastructure-upgrade that is required by Schauenburg for adopting the MIMACS system (see figure 8-25).

Table 8-25 Preparation required for MIMACS system adoption

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.2.3.1 WMI prepare civils work, hardware	WMI need to plan/execute in advance for civils work preparation (construction, logistics, etc.), as such is time-consuming,	**80**
	WMI need to use holistic approach for the design of the civils work to avoid affecting other systems, (e.g. antenna signal interference)	**70**
2.2.3.2 WMI prepare network, communication system, software and ICT system	WMI to ensure sufficient network and ICT system capability to support the installation (e.g. bandwidth, storage capacity, computing power and number of servers, etc.)	**66**
	Average compliance	**72**

The high-level compliance of 72% achieved in table 8-25 shows that WMI had strong knowledge regarding preparation work needed for adopting the MIMACS system, especially for the preparation of civils work. WMI shows its awareness of impacts that faulty civils design could bring to the overall adoption process. This corresponds to findings of Chapter 6's case study, where antenna signal interference caused malfunction of MIMACS system's mine-access control. This was despite the fact that WMI scored low compliance on sub-task 1.1.1.2 for understanding WMI's existing ICT infrastructure. WMI also shows strong awareness of the importance for preparing the ICT system for the adoption (high compliance of 66%). Completion of the civils work marks the end of the preparation phase for installation. The next task is to install the MIMACS system at WMI.

The findings of Chapter 6's case study indicate that installation is not a simple process and requires multiple levels of knowledge for adequate execution. The overall risk scale is rated as extreme (20) for the sub-phase 2.3, thus reflecting the importance of MIMACS system installation to the entire adoption process of the MIMACS system. A moderate level of 58% was achieved by WMI for overall compliance (see Appendix XI table 11). Per the blueprint, a system champion is required for overseeing the installation project of the MIMACS system. An average compliance of 79% shows WMI is extremely aware of the importance of appointing such a system champion (see table 8-26).

Table 8-26 WMI appoint system champion to supervise the installation

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.3.1.1 WMI appoint system champion to supervise the installation	WMI appoint system champion: People who oversee the entire installation project	**79**
	WMI system champion required to have general understanding of the technology system, and preferably to be involved from the initial stage of the identification/selection procedures	**68**
	WMI system champion responsible for communication/liaison with the vendors on behalf of the entity	**70**
	Average compliance	**72**

Furthermore, based on average compliances of 68% and 70% respectively, WMI demonstrated awareness of the basic criteria for identifying a suitable MIMACS system champion, together with the duties of the system champion.

Sub-task 2.3.1.2 outlines aspects that need special attention from the system champion. Despite the strong awareness demonstrated by WMI on the importance of the system champion, WMI performed moderately on outlining the duties of the system champion. Only

39% compliance is achieved for implementation of legal documents drafted in sub-phase 2.1 (see table 8-27).

Table 8-27 MIMACS system champion supervise system installation

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.3.1.2 WMI system champion supervise the installation project	WMI MIMACS system champion to ensure implementation and execution of all legal documents	**39**
	WMI MIMACS system champion to monitor implementation/execution of all agreements and contracts in different phases	**38**
	WMI MIMACS system champion to ensure quality of documenting and reporting	**67**
	WMI system champion to adhere to all the regulations, standards, SOP, COP during installation, such as wiring standards, emergency procedures and health and safety rules, etc.	**66**
	WMI system champion to ensure that the requirement of infrastructure upgrade is in place and that it is sufficient to accommodate the requirement of installation	**59**
	Average compliance	**54**

WMI also attempts to create a safe and secure adoption-environment for the MIMACS system, and also to standardize the installation of the MIMACS system by applying SOP and COPs.

In order to complete the installation project within schedule and budget, sub-task 2.3.1.3 requires WMI to apply key actions to manage all resources in each phase of the installation project (see table 8-28).

Table 8-28 Key principles for system champion to manage the installation project

Sub-task to perform	Activities that need to be performed by the system champion/WMI	Average compliance (%)
2.3.1.3 **WMI system champion conduct actions to managing all the resources for each phase of the installation**	Initiation and planning	39
	Execution of the plan	35
	Installation project monitoring and control	73
	Installation project completion and closing	69
	Average compliance	**54**

Sub-task 2.3.1.3 in table 8-28 contains four critical actions that WMI is required to execute for adequate resources management during each phase of the MIMACS system installation project. An average compliance of 54% indicates that WMI did not adequately apply such actions during installation. Furthermore, low compliance of the initiation (39%) and execution (35%) of the plan indicates poor installation planning by WMI.

Main-task 2.3.2 represents focus-areas for budget control. Chapter 6's case-study findings expose overspending issues during MIMACS system adoption. Survey results of main-task 2.3.2 in table 8-29 support the findings, and correspond to sub-task 2.1.1.3's survey results. Low compliance in table 8-29 shows that WMI did not use the arrangement that was drafted in sub-task 2.1.1.3 to manage labour, material and logistics required for the installation of MIMACS system. The possible cause is that WMI was not aware of the importance of drafting an agreement to manage resources required during installation. Low compliance of 34% achieved by WMI on agreement drafting proves such possible cause. The logical chain is: WMI's poor planning on resources management leads to poor resources management, which eventually causes overspending-problems during the MIMACS system installation (see table 8-29).

Table 8-29 Focusing area for budget control of installation project

Sub-task to perform	Activities that need to be performed by the system champion	Average compliance (%)
2.3.2.1 Labour	WMI system champion ensure that arrangement of labour during installation follows the labour agreement drafted in 2.1.1.3	5
2.3.2.2 Material	WMI system champion ensure purchase of the material for installation strictly follows the purchase agreement signed in 2.1.1.3	8
2.3.2.3 Logistics	WMI system champion ensure requirement for logistics be done according to the guidance written by vendors in logistics agreement in 2.1.1.3	4
2.3.2.4 Hardware and software	WMI system champion ensure hardware and software purchase: Strictly implement the purchase agreement in 2.1.1.3 and only approved items should be purchased	14
	WMI system champion ensure hardware and software upgrade: based on the assessment of the existing hardware and software before going for upgrade	68
	Average compliance	**20**

Main-task 2.3.3 is the last task to complete in main-phase 2.0. It refers to the creation of a communication and cooperation mechanism between WMI and Schauenburg (see table 8-30). An overall compliance of 76% shows WMI's awareness of importance for creating communication and cooperation for the MIMACS system installation (see Appendix XI table -13).

Table 8-30 Communication and cooperation mechanism between WMI and Schauenburg

Sub-task to perform	Activities that need to be performed by the system champion	Average compliance (%)
2.3.3.1 Communication & cooperation between the WMI and Schauenburg	WMI and Schauenburg create multiple channels for efficient communication, documenting and reporting between WMI system champion and Schauenburg for the lifespan of the MIMACS system	79
	WMI system champion and Schauenburg support/cooperate with each other during the installation of MIMACS system	78
	Sufficient communications between system champion and Schauenburg on progress of installation and feedback during the installation	71
	Average compliance	**76**

The completion of the sub-task 2.3.3.1 marks the end of installation of MIMACS system, as well as the end of the entire phase 2.0 – MIMACS system adoption phase. The next phase is the post-installation phase of the MIMACS system adoption, where WMI will be focusing on tasks and activities that maintain the continuous functionality of the MIMACS system (see table 8-31).

Table 8-31 Main-phase 3.0 post-adoption phase

Blueprint contents			Checklist		
Main-phase	**Sub-phase**	**Main-tasks**	**Risk scale (Ratings)**	**Average Compliance (%)**	**Remarks**
3. Post - installation phase for technology system	**3.1 System calibration , testing, and integration**	**3.1.1 MIMACS System calibration**	**Extreme (20)**	48%	Low
		3.1.2 MIMACS System testing	**Extreme (20)**	53%	Moderate
		3.1.3 MIMACS system integration	**Extreme (20)**	21%	Very low
	3.2 After-sale support services	**3.2.1 After sale services for continuous operation of MIMACS system after installation**	**Extreme (20)**	44%	Low
		3.2.2 Exit strategy	**Extreme (20)**	59%	Moderate

Main-task 3.1.1 requires WMI to carry out system calibration on the MIMACS system after it has been installed at WMI. An overall average compliance of 48%, indicates that inadequate effort was spent by WMI on MIMACS system calibration (see Appendix XI table-14). Schauenburg is required to calibrate all components of the MIMACS system. However, an average compliance of 41% indicates inadequate calibration work (see table 8-31). Sub-task 3.1.1.1 also requires Schauenburg to calibrate software in addition to hardware. However, 51% compliance exposes inadequate work in this sub-task.

Table 8-32 MIMACS system calibration and certification of calibration

Sub-task to perform	Activities that need to be performed by the system champion	Average compliance (%)
3.1.1.1 System calibration	Schauenburg calibrate all the hardware such as sensors, equipment and devices to their required specifications, especially the sensors and measuring instruments	41
	WMI system champion ensure the setting of all software matches the hardware and software, and that WMI receive correct and sufficient data from the MIMACS system	51
3.1.1.2 Certification of calibration	WMI system champion obtain calibration certificates for the overall system	52
	WMI system champion document all the record for calibration and update the certificates accordingly	51
	Average compliance	**48**

Sub-task 3.1.1.2 requires all calibrated components of MIMACS system to be certified by Schauenburg or other third parties, and certification of calibration to be updated accordingly. However, since inadequate calibration was conducted in sub-task 3.1.1.1, certification of calibration is also inadequate.

Main-task 3.1.2 requires WMI and Schauenburg to carry out system testing to assess the outcome of installation and actual functionality of the MIMACS system (see Appendix XI table -15). WMI and Schauenburg need to complete two sub-tasks that are collaboratively included in main-task 3.1.2 (see table 8-32). Sub-task 3.1.2.1 tests the actual functionality of the MIMACS system against the agreed outcome of installation signed in sub-task 2.1.1.4. A 53% compliance indicates that WMI and Schauenburg did not perform adequate work on system testing.

Table 8-33 System testing of MIMACS system

Sub-task to perform	Activities that need to be performed by the system champion	Average compliance (%)
3.1.2.1 System functionality testing	Schauenburg test individual and overall system functionality against claimed functionality stated in the contract defined in main-task 2.1.2	53
3.1.2.2 System malfunction testing	WMI system champion identify and record any system malfunction	56
	Schauenburg identify the major cause of any system malfunction	60
	Schauenburg system identify any disruption to the continuous functionality of the MIMACS system during testing	51
	Schauenburg debug and make corrections; WMI system champion documents all the findings	51
	Average compliance	**53**

Sub-task 3.1.2.2 requires the WMI system champion and Schauenburg to perform system testing to identify and eliminate any aspects that could lead to system malfunction. The findings of the case study in chapter 6 indicate that system malfunction is a frequently-occurring problem. Sub-task 3.1.2.2's 54% compliance results correspond to the findings of Chapter 6's case study.

The last sub-task 3.1.3 – system integration, requires the WMI system champion to carry out a system compatibility test on MIMACS system with application of appropriate integration methods (see table 8-34). WMI achieved a low compliance of 21% in the compatibility test between the MIMACS system and existing technology systems at WMI.

Table 8-34 MIMACS system integration

Sub-task to perform	Activities that need to be performed by the system champion	Average compliance (%)
3.1.3.1 Apply appropriate integration method	WMI perform system compatibility test between MIMACS system and the existing technology system installed at WMI	21
	WMI system champion identify and apply the appropriate integration method to fully integrate MIMACS system into WMI	26
	Average compliance	**23**

Another activity in sub-task 3.1.3.1 is system integration. The WMI system champion achieved 26% compliance, which shows that inadequate integration was done. Such low compliance corresponds to the findings of Chapter 6's case study, where compatibility problems occurred as a result of multi-platform technology being installed at WMI. Once WMI has completed system integration, the adoption process moves to the next sub-phase 3.2.

Sub-phase 3.2 outlines services that are required by the MIMACS system for maintaining continuous operation after installation. Four activities are required to be completed by the WMI and Schauenburg (see table 8-35).

Table 8-35 Activities to maintain MIMACS system functionality

Sub-task to perform	Activities that need to be performed by the system champion	Average compliance (%)
3.2.1.1 Activities require to maintain continuous system functionality	Schauenburg perform regular system maintenance & system debug for MIMACS system	43
	Schauenburg develop emergency procedures for system functionality recovery after system malfunction for MIMACS system	43
	WMI and Schauenburg perform regular system upgrade and update for MIMACS system	46
	WMI and Schauenburg create regular-system-maintenance documenting & reporting system	45
	Average compliance	**44**

An overall average compliance of 44% achieved for sub-task 3.2.1.1 shows that both WMI and Schauenburg failed to provide adequate activities to maintain MIMACS system functionality. This is reflected in all four activities: 43% for both regular system maintenance and procedures for system functionality recovery; 46% for system upgrade/update; 45% for documenting & reporting system. This survey result corresponds to Chapter 6's case study findings on causes of system malfunctions.

The adoption proceeds to the final main-task once activities required for continuous MIMACS functionality are initiated.

The final sub-task 3.2.2 is the exit strategy that both WMI and Schauenburg need to consider. WMI needs to conduct an assessment on the overall outcome of the MIMACS system adoption. The results of the assessment need to answer two questions in table 8-36.

Table 8-36 Assessment on final outcome of overall adoption; exit strategy

Sub-task to perform	Activities that need to be performed by the system champion	Average compliance (%)
3.2.2.1 WMI conduct an assessment to review the performance of the technology system	Outcome of the assessment needs to answer the following two questions:	
	1). Did the performance of the technology system meet the WMI's expectations?	51
	2). Did the technology system address the problems faced?	56
Exit Strategy	Based on the personal experience and knowledge, System champion to provide recommendations to WMI for the way forward, namely to either further cooperation or terminate the contract.	60
	Average compliance	**55**

An achievement of 51% compliance for the first question means that at that stage, WMI barely understood the overall performance of the technology system. Furthermore, 56% compliance for the second question indicates that the final assessment did not provide enough information to enable WMI to properly assess the overall outcome of the MIMACS system adoption project.

The last step in the entire MIMACS adoption project is the exit strategy. The WMI system champion needs to consider the way forward after the adoption, based on the outcome of the adoption and the actual performance of the MIMACS system. Possible ways-forward include contract termination or further cooperation. The entire adoption project of MIMACS system officially ends once WMI completes the decision on the exit strategy.

8.3 Improvement on the blueprint

Verification of the blueprint has revealed that the blueprint contains some shortcomings. Primary causes of the shortcomings were limited time, resource, experience and knowledge during development of the blueprint (ref. Chapter 7). Since the shortcomings were embedded in separate aspects of the blueprint, they were not immediately evident while the blueprint was being developed. Thus it has been necessary to identify shortcomings by reviewing the blueprint from the perspective of system-integration. The following aspects were identified during this subsequent review. These include a breakdown of shortcomings according to categories that they belong to. (Note that the review may not expose all shortcomings, thus proper implementation should also be applied to assist further exposure).

8.3.1 Contents

The contents of the blueprint play a key role in ensuring the representativeness and applicability of the blueprint. The blueprint's contents guide the commissioning entity through the adoption process by passing key information, i.e. the commissioning entity has direct interaction with the blueprint's contents. The quality of the contents therefore has fundamental influence upon the outcome of the adoption. The following are some aspects of the basic requirement for creating quality contents of a blueprint. Shortcomings discovered during the review are grouped under the following lists.

- **Comprehensiveness**

The contents of the blueprint should cover a wide range of adoption-process aspects and provide easy understanding of such. The review revealed a possible coverage-imbalance in different parts of the blueprint: Whereas main-phase 1 needs more than half of the resources from the commissioning entity, main-phase 2 and 3 share the other half (this can be seen in the final blueprint – see Appendix X). In the latter context, 'resources' mainly refer to time and budget required to complete the adoption project. Yet such resources do not necessarily need to be evenly distributed across different sections of the adoption process. This is due to the fact of that different stages of the adoption process require different amount of resources to complete. Under ideal circumstances, resources would be suitably allocated relative to the demands of each stage of the adoption process, to develop a balanced blueprint. However, the commissioning entity needs to consider differing situations in each adoption process as well as the actual capacity of the commissioning itself. This allows the commissioning entity to prioritise their resources for different stages of the adoption process. For example, if the commissioning entity is inexperienced in identifying appropriate technologies (in main-phase 1), yet has sufficient capacity to maintain system-functionality (in main-phase 3), then it should dedicate more resources to main-phase 1 than main-phase 3. However, the commissioning entity still needs to be aware of such imbalanced distributions of resources. Such imbalances could cause budget overspending and project-schedule delays, which could, in turn, could lead to project failure.

- **Informative and compact**

The total contents of the blueprint are automatically limited by the practical size of the blueprint. This means that only a limited number of phases, tasks and activities can be included in the blueprint. Furthermore, the contents of the blueprint should be simple yet informative, unambiguous yet compact.

The review revealed that the contents of the developed blueprint are fairly informative. It has fulfilled the purpose of guiding the commissioning entity to accomplish all phases, tasks and activities in the adoption process. Information extracted from the contents of the blueprint is critical for the quality and progression of the adoption process. For example, such contents provide a detailed guideline for the commissioning entity to gather information on the commissioning entity's actual capacity in main-phase 1. The quality of the contents in this main-phase has a direct impact on the following sub-phase 1.2, namely evaluating the potential technology supplier. Examples also include the full template of the vendor support documents in activity 1.2.2.5, and the list of enabling elements required for implementation in main-task 2.2.2.

However, informative contents have potentially created an oversized blueprint. This issue is linked to the problem discussed in the previous bullet point. An oversized blueprint is likely to cause imbalanced resource-distribution and unevenly-developed elements within the blueprint.

- **Logicality**

As discussed in the previous section, logical flow is one of the most basic requirements when developing a blueprint. This requirement ensures smooth progression of the adoption process by having the correct structure and contents. Logical flow also helps the commissioning entity to avoid conducting repetitive work and improves conjunction between different phases of the adoption process. Certain measurements were brought in to ensure the quality of the logical flow. One of them is systems thinking skills, which helps to minimise conflicts between elements in a blueprint by identifying influential factors and system boundary, as well as key stakeholders. Systems thinking skills should be applied during drafting of legal documents in order to avoid conflicts between different agreements and contracts. For example, sub-phase 2.3 represents the actual installation phase, and required labour-arrangements for this sub-phase have already been determined in sub-phase 2.1's legal documents-drafting process. Hence, systems thinking skills provides a comprehensive view, not only from the perspective of the commissioning entity, but also from the labour requirements of different stakeholders. The review has revealed that systems thinking provided a key role in the development of this blueprint, especially in the pre-implementation phase. The application of systems thinking has ensured both the quality and the coverage of the information that reflects the true capacity of the commissioning entity. However, the obvious shortcoming that is related to the logical flow in this blueprint is that the actual adoption process may deviate from the blueprint. This is due to the fact that the blueprint is developed in an optimistic state. There should be measurement to allow the commissioning entity to perform adjustment and correction when the actual course of the adoption process deviates from the blueprint. This shortcoming has brought another challenge, namely providing extra room for the commissioning entity to conduct self-adjustment and correction.

- **Flexibility**

The above challenge can be grouped into the problem of flexibility. This issue is caused by the nature of the blueprint. The objective of this blueprint is to guide the commissioning entity through the adoption process. Quality contents are created to ensure the representativeness and applicability of the blueprint. However, representativeness is based on the careful selection of common issues discovered in Chapter 6's case study. On the one side, this has enabled creation of a representative blueprint that accommodates such common issues for different commissioning entities. Yet on the other side, this has caused the blueprint to be less flexible in accommodating uncommon issues encountered by individual commissioning entities during the adoption process. This issue has already been highlighted during development of the blueprint in the chapter 7. Measurement has been brought into the design to enable identification of situations in the adoption, thus enabling the following flexibility: Depending on the individual situation, the commissioning entity is provided capability to adjust the adoption process by either adding or skipping certain steps in the blueprint. However, such flexibility only allows the individual commissioning entity to perform minor adjustment to the course of adoption process. As discussed in the previous chapter, minor adjustment only refers to changes to designated activities in the blueprint. Major adjustments, such as changes to main-phase, sub-phase, main-task and sub-task in the blueprint are not recommended. This is because insufficient information may be gathered when such a major adjustment is made. Such insufficient information may cause complete misdirection in successive parts of the adoption process. However, the flexibility of the blueprint still can be improved through the following channels.

8.3.2 Approach

The level of flexibility that a blueprint can provide is dependent on the approach that is used to develop it. The approach further determines the structure of the blueprint. Different approaches used in developing a blueprint give different levels of flexibility.

In summary of previous sections:

The approach used to develop this study's blueprint is of a natural empirical. Data and information used to construct the model include a case study on the MIMACS system and studies on WMI's approach for new technologies adoption. The objective of this study, namely to develop a blueprint that is capable of guiding the commissioning entity through the adoption process, has direct impact on the design of the blueprint. Hence, an objective orientated structure was selected to accommodate such requirement. The blueprint is developed in a chronological order, which simulates an actual adoption process from identification of technology through to final adoption of the identified technology. This blueprint design has its own inevitable limitations, namely low level of flexibility. Such drawback is caused by the role of the blueprint, namely that it acts as guidance to the commissioning entity during the adoption process. This means it has to have a wide coverage over all aspects of the adoption process. Consequently, there is little room left for the commissioning entity to perform self-adjustment/correction to address uncommon issues encountered during the adoption process. Another cause of low level of flexibility was discussed in section 8.3.1, under the bullet point of flexibility, namely that all the contents are arranged in a chronological order. Hence, this arrangement has created a strong link between the adjacent steps of the adoption process. Two important facts are included in such links:

- Information and data required by successive steps sometimes has to be collected and prepared by preceding steps. For example, sub-phase 1.2 (potential technology identification) requires critical commissioning entity information collected in sub-phase 1.1; and
- The progression of the adoption process is dependent on completion of adjacent steps, which include all phases, tasks and activities in the blueprint.

This means any major-adjustment or correction of the contents in the blueprint could cause links to fail due to loss of vital information or incomplete information being collected. A failed link between the adjacent steps automatically holds back the progression of the adoption process. Thus the empirical model has significant advantage in creating a blueprint with wide-covering contents and practical size, but it is not an ideal tool to develop a blueprint with a high level of flexibility.

Thus, other alternative approaches need to be considered for developing the blueprint. One of the considered models to develop a blueprint with a high level of flexibility is analytical model. Unlike the traditional empirical model, the analytical model does not have a fixed route for the commissioning entity to follow. Instead, it allows the commissioning entity to evaluate every aspect that is related to the adoption process, and based on the outcome of such analysis, it indicates shortcomings of the aspects. It also allows the commissioning entity to train an experienced individual to oversee the entire adoption (ideas: give you everything in the pot, you decide which one to pick).

8.4 Summary

The blueprint developed in chapter 7 is verified in chapter 8. The blueprint is part of the survey used to assess WMI's performance during its adoption of the Schauenburg MIMACS system. The blueprint is modified to enable assessment of WMI's performance by measuring the percentage of compliance for each activity that WMI carried out during the adoption. A 5x5 risk assessment matrix is used to determine the risk scale for each sub-phase. The risk scale is an indication of the severity of incompletion for each sub-phase. The outcome of the survey suggests that WMI achieved relatively poor performance due to low percentage of compliance in several key activities. Strong correlations between WMI lesson-findings in Chapter 6's case study and WMI's performance during adoption have been discovered. The hierarchical structure and chronological order of the adoption process can result in each activity performed during adoption affecting subsequent activities. For instance, poor system integration during the installation phase will certainly cause compatibility issues in the system-operation of a multi-platform technological environment. Shortcomings in the blueprint were later identified. Identification of such design shortcomings focused on two aspects in the blueprint, namely contents and approach. Possible-improvement of such aspects was also discussed. Work that has been done in this chapter demonstrates a critical fact: Adoption of new digital technology requires a holistic approach. Every activity performed during adoption is important. Poor performance in even one adoption activity may affect the final outcome of the adoption.

The next chapter will provide final discussions on the entire dissertation. Conclusions will be drawn based on the work that has been done in this dissertation. Recommendations will also be made for future improvement of new digital technology adoption and the quality of the blueprint.

9 Conclusion and recommendations

Utilization of new digital technology is crucial for the South African mining industry, as it allows the industry to use key advantages provided by such technology to address mining stagnation caused by drop of operational efficiency and rise of operational cost. However, in order to fully utilize the potential of a new digital technology, smooth adoption of such into existing operations of commissioning entities is crucial. In this context, this dissertation includes a case study that was conducted on WMI's approach and management during digital technology installation at WMI. The main focus of the case study is WMI's Schauenburg MIMACS II system installation project. WMI learned significant lessons from this project. Such lessons included project delay, system malfunction, faulty hardware, signal interference, and disruptions to MIMACS system functionality caused by various factors including load shedding. Analysis of the case study's findings and lessons learned by WMI reveal that the underlying causes of such problems included poor planning/execution and lack of a holistic approach in the adoption process. The case study's findings, together with typical new-technology adoption problems and consequences that WMI encountered, provided good input for this research's ultimate objective, namely: Address all problems that a commissioning entity may encounter during new-technology adoption by developing a blueprint that can be used to delineate and guide the adoption process.

Systems thinking skills were used as part of a holistic approach to gain big-picture perspective when developing the blueprint. Special attention was given to representativeness and applicability of the blueprint to ensure its robustness and repeatability. The blueprint is presented through a hierarchical structure of five levels, namely main-phase, sub-phase, main-task, sub-task and activities. The progression of these levels follows a chronological order that matches the actual progression of new digital technology adoption. The following three main-phases are defined in the blueprint:

- Pre-installation phase;
- Installation phase; and
- Post-installation phases.

The above includes 119 activities, which represent all the work that has to be done to complete all three main-phases in new-technology adoption.

After developing the blueprint, verification was carried out to assess its usefulness and comprehensiveness. The assessment was based on the Schauenburg MIMACS II system installation-project at WMI. The objective of the assessment is to identify the correlation between the outcomes of the MIMACS-adoption (as revealed in the case-study's findings) and the poor planning and execution during the adoption.

Ten personnel participated in a survey. The blueprint was modified to include realistic data supplied by the ten personnel, which reflected the true performance of WMI and the vendor during the MIMACS system adoption. A checklist was added to the blueprint to enable the personnel to determine performance and percentage of compliance within each individual activity. Assessments made by the personnel were based on their individual experiences during MIMACS system adoption. Data gathered from the survey was then sorted and analysed to fulfil the objective of verification by identifying correlations discussed above. This further proved that the blueprint is a useful tool for new-technology adoption.

The outcome of the survey reveals the following low-compliance problems in key activities within every main-phase:

- Pre-installation phase: Low compliance in WMI's self-awareness and identification of new digital technology;
- Installation phase: Low compliance in legal documents drafting, preparation work, and installation of the new digital technology; and

- Post-installation phase: Low compliance in system calibration, testing and integration, and after-sales services.

The outcome of the data analysis shows strong correlation between the above problems and WMI's lessons, as well as between the above problems and the findings of the case study. The following table shows correlations that were discovered during verification of the blueprint:

Table 9-1 Correlation between WMI lessons and findings of blueprint verification

WMI lessons/problems	Cause found in blueprint verification
Installation project delay	Poor project preparation and project management in the adoption phase
System malfunction	Inadequate support from the infrastructure (e.g. power supply, network connectivity, etc.) Poor system debug, system maintenance, system integration, and most importantly: inadequate after-sales services in the post-adoption phase.
Faulty hardware/software issues	Poor self-awareness, inappropriate new-technology and vendor identification, poor legal documents drafting (e.g. sale and purchasing agreement, etc.) in pre-adoption and adoption phases.
Signal interference, civils work preparation delay/problems	Poor self-awareness in pre-adoption phase. Poor knowledge of civils design in preparation in adoption phase.
Disruption of system functionality, e.g. power outage, network connectivity.	Inadequate support from the infrastructure (e.g. power supply, network connectivity, etc.) Poor preparation in the pre-adoption and adoption phase.
System/network/ICT update and upgrade	Poor self-awareness in pre-installation phase. Inadequate system maintenance and system integration, as well poor after-sales services
Continuous functional system, Training, maintenance and exit strategy	Poor legal documents drafting in adoption phase and inadequate after-sales services in post-adoption.

During the verification, several problems related to the development of the blueprint were discovered. Such problems mainly occurred within the contents, structure and approach of the blueprint. Amendment of such problems in the blueprint could improve the quality of the blueprint. The following describes aspects of the blueprint that should be improved.

- Contents;
- Comprehensiveness;
- Informatics and compact;
- Logicality;
- Flexibility; and
- Approach.

It should be noted that the following four critical aspects need to be addressed when developing or adjusting a blueprint for new-technology adoption.

- Representativeness;
- Applicability;
- Robustness; and
- Repeatability.

The outcome of both the survey and the data analysis shows that the blueprint is a useful tool: Not only is it capable in guiding commissioning entities through new-technology adoption, but it is also capable in assessing commissioning entities' performance during new-technology adoption and identifying causes of problems that occurred during adoption. The outcome further proved that a systems thinking (holistic) approach is an appreciate method to develop a blueprint that is complex and consists of multiple components.

9.1 Recommendations

Based on the work that has been done in this research and conclusions drawn above, following recommendations can be made regarding blueprint development and implementation for guiding new-technology adoption:

- Big picture perspective and systems thinking skills are always needed for new digital technology adoption.
- A holistic approach is essential for new digital technology adoption.
- A hierarchical structure of blueprint is crucial for easy monitoring of progress, reducing workload and evenly-distributing resources;.
- Consider interaction between all elements within the system boundary that could impact the SOI.
- Always have a blueprint for new digital technology adoption.
- Pay special attention to the self-awareness of the commissioning entity and properly-understand the true capacity of the commissioning entity.
- Understand the true capacity of the infrastructure, not only for the commissioning entity, but also for the environment surrounding the new digital technology, e.g. power supply and network connectivity.
- ICT is the backbone of new digital technology adoption, thus priority should be given to it together with associated back-up plans.
- Always plan the task first before actually starting to carry out the task, eg. properly plan the adoption phase before starting adopting the technology.
- Human factors need to be considered for the full duration of new digital technology adoption.
- A System champion must be appointed in the early stage of the adoption, and must apply project management skills during adoption and installation.

- After-sales support is key to continuous functionality of new digital technology after adoption.
- Proper training needs to be provided to ensure achievement of continuous functionality and dealing with emergency situations.
- The Commissioning entity needs to carefully consider and execute the exit strategy.

References

Accenture Consulting-US, 2014. *Accenture Global Digital Mining Survey,* California: Accenture Consulting-US.

Andrew, S., 1998. *Implementing and Managing New Technologies in Mining.* Mount Isa, AusIMM.

AngloAmerican plc, 2017. *Welcome to Futuresmart Mining.* [Online]
Available at: http://www.angloamerican.com/futuresmart
[Accessed 17th February 2018].

Antin, D., 2013. *The South African Mining Sector: An Industry at Crossroads,* Johannesburg: Hanns Seidel Foundation.

Baleni, F., 2009. *MINTEK 75-A Collabration of Technology "NUM and Technology".* Johannesburg, Mintek, SA, Johannesburg.

Baxter, R., 2013. *Role of the South African Mining Industry in South Africa's Growth and Development.* Johannesburg, Chamber of Mines of South Africa.

Bouarfa, S., Curran, R., Blom, H. A. P. & Everdij, M. H., 2013. *Agent-Based Modeling and Simulation of Emergent Behavior in Air Transportation.* Los Angeles, American Institute for Aeronautics and Astronautics (AIAA).

Breytenbach, B., 2014. *Schauenburg Systems Installed In the Mock-up Tunnel,* Johannesburg: Schauenburg Systems.

Cawood, F., 2017d. *WMI DigiMine Installation Lessons,* Johannesburg: Wits Mining Institute.

Cawood, F., 2018a. *General Information on WMI Progress,* Johannesburg: Wits Mining Institute.

Cawood, F., 2018b. *The WITS MINING INSTITUTE-General Information 2018,* Johannesburg: Wits Mining Institute.

Cawood, F., 2018c. *Wits Mining Institute.* [Online]
Available at: https://www.wits.ac.za/wmi/
[Accessed 15th February 2019].

Chamber of Mines, 2016. *Mine SA 2016 Facts and Figures,* Johannesburg: Chamber of Mines.

Chamber of Mines, 2017. *Mine SA Facts and Figures 2016,* Johannesburg: Chamber of Mines.

Checkland, P., 1981. *Systems Thinking, Systems Practice,.* Chichester: Wiley.

Chen, H. & Ma, T., 2017. Optimizing systematic technology adoption with heterogeneous agents. *European Journal of Operational Research,* Issue 257, pp. 287-296.

Christensen, C., 2019. *Clayton Christensen.* [Online]
Available at: www.claytonchristensen.com/key-concepts/
[Accessed 15th August 2018].

CIMA, 2010. *A strategic approach to disruptive technologies.* [Online]
Available at: http://www.cimaglobal.com/Research--Insight/A-strategic-approach-to-disruptive-technologies/
[Accessed 24th May 2017].

Claessens, M., 2016. *PRODUCT CHARACTERISTICS THAT INFLUENCE THE ADOPTION RATE.* [Online]
Available at: https://marketing-insider.eu/product-characteristics-adoption-rate/
[Accessed 28th October 2017].

David, W. et al., 2015. *Systems Engineering Handbook.* 4th ed. San Diego: International Council On Systems Engineering (INCOSE).

Davis, F., 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly,* 13(3), pp. 319-340.

Dickerson, A., 1997. *Utilising New digital technology.* Sydney, Mindev 97 Conference.

Dijk, M. . v., 2016. *JSE Management Supplement.* [Online]
Available at: http://www.jsemagazine.co.za/jse-supplement/full-value/
[Accessed 23rd August 2017].

Foresster, J., 1968. *PRINCIPLES OF SYSTEMS.* Second ed. Massachusett: Wright-Allen Press.

Freeman, E., 2001. *A Stakeholder Approach to Strategic Management,* Virginia: University of Virginia - Darden School of Business.

Glau, S., Constantino, S. & Alexander, C., 2016. *Disruptive Innovation in Digital Mining.* Sao Paulo, SYMPHOS 2015.

Gold Fields Limited, 2016. *Technology and innovation.* [Online]
Available at: https://www.goldfields.co.za/reports/annual_report_2015/integrated/bus-technology.php
[Accessed 25th August 2017].

Goodman, M., 2016. *Systems Thinking: What,Why,When,Where,And,How?.* [Online]
Available at: https://thesystemsthinker.com/systems-thinking-what-why-when-where-and-how/
[Accessed 10th June 2017].

Hlatswayo, N. & Kelvin, O., 2017. *Mine Surveillance and Video Analytics for Risk Management,* Johannesburg: Wits Mining Institute.

Hugn, D.-W., Ryan, G., Ferran, P. & Richard, S., 2015. *How didital technology innovation can improve mining productivity,* s.l.: McKinsey&Company.

INCOSE, 2012. *INCOSE systems engineering handbook: A guide for system life cycle processes and activities.* version 3.2.2 ed. San Diego: John Wiley and Sons, Inc.

Kasser , J. & Mackley, T., 2008. *Applying systems thinking and aligning it to.* Utrecht, 18th INCOSE International Symposium.

Kuan, J., Shulman, S. R. & Shittu, E., 2015. The political economy of technology adoption: The case study of Saharan salt mining. *The Extractive Industries and Society,* 2(2), pp. 328-338.

Lala, A., Moyo, M., Rehbach, S. & Sellschop, R., 2015. *Productivity in mining operations: Reversing the downward trend.* [Online]
Available at: http://www.mckinsey.com/industries/metals-and-mining/our-insights/productivity-in-mining-operations-reversing-the-downward-trend
[Accessed 20th July 2017].

Lewis, L. K., 2011. *rganizational Change: Creating Change through Strategic Communication.* 1st ed. London: John Wiley & Sons, Inc.

Li, L., 2015. *A critical review of technology acceptance literature ,* Los Angeles: Grambling State University.

Lu, Q., Byrne, S. & Maani, K., 2010. *Unfolding Systems Boundary:Evolution and Implication.* Auckland, MSIS Department, University of Auckland .

Macfarlane, A. S., 2001. The implementation of new digital technology in Southern African mines:Pain or Panacea. *The Journal of The South African Institute of Mining and Metallurgy,* 3(223), pp. 115-126.

McCarthy, B., 2016. *Successfully Implementing Technology-driven Change in the Mining Environment.* Brisbane, International Mine Management Conference/Brisbane,QLD.

Mine-Tech Limited, 2017. *Mine-Tech Products.* [Online]
Available at: www.minetec.com.au
[Accessed 25th January 2018].

Nemoto, M., Vasconcellos, E. & Nelson, R., 2010. The Adoption of New digital technology: Conceptual Model and Application. *Journal of Technology Management & Innovation,* 5(4), pp. 96-107.

Obal, M., 2017. Investigating the negative and positive antecedents of disruptive technology continuous adoption intentions.. *Industrial Marketing Management,* Volume 63, pp. 42-52.

O'Callagham, J., Rossouw, A., Michal, K. & Makhetha, N., 2016. *PwC SA Mine 8th edition,* Johannesburg: PwC South Africa.

Omarjee, L., 2016. *SA to exhaust gold reserves in 38 years.* [Online]
Available at: https://www.fin24.com/Companies/Mining/sa-to-exhaust-gold-reserves-in-38-years-20161120-2
[Accessed 25th January 2019].

Panda, M. R. & Upadhyay, S. K., 1998. *Challenges in effective implementation of systems.* Kharagpur, International Conference on Systems Dynamics.

Peitchinis, S., 1983. The Attitude of Trade Unions Towards Technological Changes. *Relations industrielles,* 38(1), pp. 104-123.

Raza, S. A. & Standing, C., 2010. Towards a systemic model on information systems' adoption using critical systems thinking. *Journal of Systems and Information Technology,* 12(3), pp. 196-209.

Raza, S. A. & Standing, C., 2011a. *A Critical Systems Thinking Perspective for IS Adoption,* Collombo: Edith Cowan University.

Raza, S. A. & Standing, C., 2011b. *Systemic Problems in Information Technology Adoption and Use: A Systems Thinking Perspective.* Perth, Edith Cowan University.

Readett, D., 2006. *Selecting and Implementing the Right Technology.* Kalgoorlie, AusIMM.

Rossouw, M. & Baxter, R., 2011. Subject concepts and issue outline. *Journal of the Southern African Institute of Mining and Metallurgy (SAIMM),* 111(11), pp. 511-516.

Rouse, M., 2005. *systems thinking-Definition.* [Online]
Available at: http://searchcio.techtarget.com/definition/systems-thinking
[Accessed 6th June 2017].

Rowley, T. . J., 1997. Moving beyond Dyadic Ties: A Network Theory of Stakeholder Influences. *The Academy of Management Review,* 22(4), pp. 887-910.

Samaradiwakara, G. D. M. N. & Gunawardena, C. G., 2014. COMPARISON OF EXISTING TECHNOLOGY ACCEPTANCE THEORIES AND MODELS TO SUGGEST A WELL IMPROVED THEORY/MODEL. *International Technical Sciences Journal (ITSJ) ,* 1(1), pp. 21-36.

Schauenburg System, 2015. *Schauenburg MIMACS II Product Training Manual,* Johannesburg: Schauenburg System.

Schwikkard, G., 2016. *Declining productivity in South African Mining – how bad is it?.* [Online]
Available at: http://www.dbassociates.consulting/single-post/2016/1/14/Declining-productivity-in-South-African-Mining-%E2%80%93-how-bad-is-it
[Accessed 24th July 2017].

Scroggins, R., 2014. SDLC and Development Methodologies. *Global Journal of Computer Science and Technology: C Software & Data Engineering,* 14(7), pp. 21-22.

Senge, P. M., 1990. *The fifth discipline-The art and practice of the learning organizatio.* 1st ed. New York: Doubleday.

Steven, W. et al., 2017. *The digital revolution-Mining starts to reinvent the future,* Sydney: Deloitte Touche Tohmatsu Limited.

Surendran, P., 2012. Technology Acceptance Model: A Survey of Literature. *International Journal of Business and Social Research (IJBSR),* 2(4), pp. 175-178.

Temkin, S., 2016. *SA's mining industry continues to face tough times.* [Online]
Available at: https://www.pwc.co.za/en/press-room/sa-mining-face-tough-time.html
[Accessed 20th July 2017].

Temkin, S., 2016. *Technological advances set to drive SA's mining industry forward: PwC Africa Mining.* [Online]
Available at: https://www.pwc.co.za/en/press-room/technological-advances-set-to-drive-sas-mining-industry-forward-.html
[Accessed 25th August 2017].

Ulrich, W., 2005. *ECOSENSUS project websit, The open university , Milton Keynes,UK.* [Online]
Available at: http://projects.kmi.open.ac.uk/ecosensus/publications/ulrich_csh_intro.pdf
[Accessed 14th June 2017].

Walden, D. D., Roedler, G. J., Forsburg, K. J. & Shortell, T. M., 2015. Systems Thinking. In: *SYSTEMS ENGINEERING HANDBOOK.* San Diego: John Wiley & Sons,Inc, pp. 17-19.

Walsh, S. et al., 2017. *The digital revolution-Mining starts to reinvent the future,* Sydney: Deloitt Touche Tohmatsu..

Wyngaardt, M., 2010. *New drilling system uses 60% less water than existing systems - manufacturer.* [Online]
Available at: http://m.miningweekly.com/article/greener-and-more-efficient-drilling-system-seen-as-breakthrough-2010-09-10/rep_id:3861
[Accessed 15th February 2018].

Appendix I

WMI vendor management system (Cawood, 2018a)

- **Pre-installation phase**
- **Sub-phase one: WMI's Statement**
- **Sub-phase two: New digital technology identification**
- **Sub-phase three: Vendor identification and selection**
- **Sub-phase four: Legal agreement drafting**

- **Installation phase**
- **Sub-phase five: System installation**
- **Sub-phase six: Official handover**
- **Sub-phase seven: Exit strategy**

Appendix II

Wits Agreement

MEMORANDUM OF AGREEMENT

Between

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

THE UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

and

[redacted]

TABLE OF CONTENTS

MEMORANDUM OF AGREEMENT

1. PARTIES

1.1. [redacted]

1.2. [redacted]

2. OBJECTIVES

2.1. The University, through its Mining Institute, aspires to produce quality academics and graduates in the field of mining engineering.

2.2. [redacted]o collaborate with the University by providing the University with use of the Equipment and delivering Services to the University at no cost to the University for the purpose of supporting the effective and efficient implementation of the[redacted]

3. DEFINITIONS

Unless the context clearly indicates otherwise, the following terms will bear the following meanings:

3.1.	"Agreement"	this agreement together with all annexures and schedules hereto
3.2.	"Background Intellectual Property"	all Intellectual Property rights in existence before the commencement date of this Agreement as well as Intellectual Property developed by a Party to this Agreement after its commencement and which does not fall within the scope of the definition of Foreground Intellectual Property
3.3.	"Business Day"	any day which is not a Saturday, Sunday or official public holiday in South Africa
3.4.	"Confidential Information"	information that (a) relates to the Disclosing Party's past, present or future research, development, business

activities, products, services, technical knowledge and personal information regarding any person, and (b) either has been identified in writing as confidential or is of such a nature (or has been disclosed in such a way) that it should be obvious to the other Party that it is claimed as confidential. (As used herein, the Party Disclosing Confidential Information is referred to as the "Disclosing Party" and the Party receiving the Confidential Information is referred to as the "Recipient" or the Receiving Party

3.5. "Control Room" — the operations centre of the University's Digital Mining Laboratory

3.6. "Data" — any data developed as a result of using the Equipment in research projects

3.7. "Equipment" — [redacted] more fully described in Annexure A attached hereto

3.8. "Foreground Intellectual Property" — means such IP as may be created or developed by a Party or the Parties in the course and scope of any project undertaken using the Equipment and arising directly therefrom

3.9. "Party" — [redacted]

3.10. " Services" — the installation, maintenance and training services [redacted]re fully described in Annexure A

3.11. "University Rules" — [redacted] and standing orders as may be amended from time to time

3.1[redacted] a software system which monitors, visualises and reports on ventilation conditions in mines as more fully describ[redacted]

4. INTERPRETATION

4.1. In this Agreement:

4.1.1. an expression which denotes -

4.1.1.1. any gender includes the other genders;

4.1.1.2. a natural person includes a juristic person and *vice versa*;

4.1.1.3. the singular includes the plural and *vice versa*; and

4.1.1.4. a Party includes a reference to that Party's successors in title and assigns allowed at law;

4.1.2. the clause headings appearing in this Agreement are for reference purposes only and will not affect the interpretation of the subject matter of this Agreement;

4.1.3. the annexures to this Agreement form an integral part of the Agreement and will be read as if incorporated herein, provided that if there is any conflict between the body of the Agreement and the annexures the meaning contained in the body of the Agreement will take precedence, unless the context expressly indicates otherwise;

4.1.4. any reference to any agreement, annexure or schedule will be construed as including a reference to any agreement, annexure or schedule amending or substituting that agreement, annexure or schedule;

4.1.5. any word or expression related to a word or expression defined in this Agreement bears a corresponding meaning;

4.1.6. any reference to the provisions of law and any similar reference of general application will be construed to include both legislation and the common law, and any reference to legislation includes any statute, any regulations passed under any statute, as well as any public notice, ruling or similar legislative instrument passed or approved by a relevant authority with the requisite authority;

4.1.7. save where specifically provided otherwise, references to statutory provisions are to be construed as references to those provisions as amended or re-enacted or as their application is modified by other provisions (whether before or after the Signature Date) from time to time and will include any provisions of which they are re-enactments (whether with or without modification);

4.1.8. the words "include" and "including" mean "include without limitation" and "including without limitation". The use of the words "include" and "including" followed by a specific example or examples will not be construed as limiting the meaning of the general wording preceding it;

4.1.9. wherever provision is made for the giving or issuing of any notice, application, submission, request, decision, consent, permission, acceptance, agreement, expression of satisfaction, endorsement, approval, certificate, information, instructions or determination by any person, unless otherwise specified, such notice, decision, consent, permission, acceptance, agreement, expression of satisfaction, endorsement, approval, certificate, information, instruction or determination must be in writing and the words "notify", "apply", "submit", "request", "decide", "consent", "permit", "accept", "agree", "endorse", "approve", "certify", "inform", "instruct" or "determine" and other related expressions are to be construed accordingly;

4.1.10. references to materials, information, data and other records are to materials, information, data and other records whether stored in electronic, written or other form;

4.1.11. when any number of days is prescribed, it will be calculated exclusively of the first and inclusively of the last day unless the last day falls on a day which is not a Business Day, in which case the last day will be the first Business Day thereafter;

4.1.12. where figures are referred to in numerals and in words, if there is any conflict between the two, the words will prevail.

4.1.13. expressions defined in this Agreement will bear the same meanings in schedules or annexures to this Agreement which do not themselves contain their own definitions.

4.2. If any provision contained in this Agreement is inconsistent with any document relevant to the Agreement issued by either Party this Agreement will prevail.

4.3. If any definition contains a substantive provision conferring rights or imposing obligations on a Party, notwithstanding that it is only in the definition clause, effect will be given to it as if it were a substantive provision in the body of the Agreement.

4.4. Each Party must ensure that any decision, determination, instruction, inspection, examination, testing, consent, approval, expression of satisfaction, acceptance, agreement, exercise of discretion (whether sole or otherwise) or similar act required by it from another Party in respect of this Agreement must be applied for or requested promptly;

4.5. Whenever this Agreement provides for approvals, consents or expressions of satisfaction by any one of the Parties, that Party may not unreasonably withhold or delay that approval, consent or expression of satisfaction.

4.6. The expiry or termination of the Agreement will not affect such of the provisions of the Agreement as expressly provide that they will operate after any such expiry or termination or which of necessity must continue to have effect after such expiry or termination, notwithstanding that the clauses themselves do not expressly provide for this.

4.7. The rule that an agreement will be interpreted against the party who drafted it will not apply to this Agreement.

5. PERIOD OF AGREEMENT

5.1. This Agreement will come into effect on the date of last signature hereof and, subject to the provisions set out in this Agreement, will continue for a period of [redacted]

5.2. The Parties may renew this Agreement for a further [redacted] "the [redacted] bject to the approval of the Parties' respective executive management bodies and provided that none of Parties are in breach of any of the terms of this Agreement.

5.3. All the terms of this Agreement will continue to apply during the Renewal Period

5.4. If any of the Parties wishes to exercise the option to renew this Agreement as provided in clause 5.2 it must do so by giving notice to the other Parties which must be received by the other Parties no later than 6 (six) Months before the expiry of the initial period, failing which the option *ipso facto* lapses.

5.5. If this Agreement does not endure for the initial period of 4.5 (four and a half) years, the right of renewal will lapse and any notice of exercise thereof given before such lapsing will be null and void.

6. RESPONSIBILITIES OF THE PARTIES

6.1 [redacted]

6.1.1. [redacted]

6.1.1.1. transport the Equipment to the University;

6.1.1.2. employ, qualified technicians to install the Equipment in the Control Room within three months after signing of this agreement;

6.1.1.3. allocate an appropriately qualified engineer, [redacted] to be competent in the proper maintenance of the Equipment, to maintain the Equipment throughout the term of this Agreement;

6.1.1.4. bear all risk in the Equipment at all times before delivery to and installation at the University and after termination of the Agreement regardless of whether the Equipment has been removed [redacted]

6.1.1.5. provide equipment assistance, training, and engineering service assistance in order to ensure that the University's students and staff fully understand how to operate the Equipment.

6.1.1.6. promptly repair or make good all damage occurring to the Equipment from time to time during the term of the Agreement, unless the cause of such damage is through misuse or negligence on the part of University students and/or staff.

6.2. **The [redacted]sponsibilities**

6.2.1. [redacted]

6.2.1.1. nominate a Project Director to supervise any projects to be undertaken by the University using the Equipment;

6.2.1.2. provide an environment appropriate for the installation of the Equipment;

6.2.1.3. supply the appropriate infrastructure, utilities and resources necessary to run the Equipment;

6.2.1.4. insure the Equipment against loss and damage for the duration of the Agreement;

6.2.1.5. carry out research on the Data;

6.2.1.6. on the termination of this Agreement, howsoever and whenever it terminates, return the Equipment and all such parts there[redacted]condition and repair, fair wear and tear excepted.

6.2.2. If the [redacted]writing within 7 (seven) days after having taken possession of the Equipment of the need for any repairs to the Equipment or of the fact that any part of the Equipment, is damaged, missing, or o[redacted]romptly cause the necessary repair or replacement to be[redacted]wn expense.

6.3. **Joint Responsibilities**

6.3.1. The Parties will ensure that the proper protocols for the acknowledgement of the contributions of all participants in any projects and subsequent publications undertaken in terms of this Agreement will be followed. Neither Party may publish any material which may cause reputational harm to the other Party without first providing such Party with written notice thereof and a reasonable opportunity to consider and agree or object to the contents of such publication. The publishing Party may proceed to publish should they not receive any objection from the other Party within 7 (seven) days of transmitting the written notice referred to above.

7. ACCESS

7.1. The [redacted] will provide access to the Control [redacted] clientele for the purposes [redacted] monstrating the functionality of the Equipment to such clientele. Such visits must be pre-arranged a week in advance and restricted to not more than once a month.

7.2. [redacted] appointed by the University in terms of this Agreement in order to make suitable arrangements for access to the Control Room.

7.3. Whenever [redacted] personnel or invitees are present on the University's [redacted] is required to ensure that all these persons abide by all the University's Rules.

8. INTELLECTUAL PROPERTY

8.1. Ownership of Background Intellectual Property remains unaffected hereby.

8.2. Foreground Intellectual Property in all work produced by the University or its staff, students, employees or assigns, including work produced as a result of the use of the Equipment by the University or its staff, students, employees or assigns will remain the property of the [redacted] provided that where the Parties have jointly created intellectual property it will be shared proportionate to their contributions.

8.3. The [redacted]he owner of all rights in the Data. The Data will be stored by the University.

8.4. [redacted] Data to undertake research provided that the University is properly acknowledged.

8.5. The ownership of the intellectual property directly related to the design of the Equipment will remain tha[redacted]

9. CONFIDENTIAL INFORMATION

9.1. The Parties shall with respect to the Confidential Information:

9.1.1. Ensure that its consultants, employees or agents exercise care appropriate for the protection of the Confidential Information.

9.1.2. Upon request by the other Party promptly deliver any and all records containing Confidential Information which is in its, its consultants' or agents' possession or control.

9.1.3. Neither Party, their consultants, employees or agents will acquire any proprietary or any other rights to any of the other Party's Confidential Information

10. DISPUTE RESOLUTION

10.1. All disputes between the Parties will be dealt with in accordance with the provisions of this clause 10.

10.2. Within a period of fourteen (14) days after the date on which the dispute arose ("the Dispute Date") the Parties will meet to discuss the dispute and will endeavour to resolve the dispute amicably.

10.3. If the Parties are unable to resolve the dispute in terms of 10.2 within thirty (30) days from the Dispute Date the dispute will be referred to the Vice-Chancellor or a Deputy Vice-Chancellor of the University and the Managing Director or Vice-

Presider[redacted]presentative/s, who will use their best endeavours to resolve the dispute. Their determination will in the absence of manifest error, be final and binding and will be carried into effect by the Parties.

10.4. If the individuals described in 10.3 are unable to resolve the dispute within a period of thirty (30) days after it has been referred to them, either Party may institute action in the South Gauteng High Court, Johannesburg, unless the Parties agree to resolve such dispute by arbitration in terms of a separate arbitration Agreement.

11. LIMITATION OF LIABILITY

The Parties record that each of them has insured itself against its liability in law for the acts and omissions of persons acting on its behalf, and their respective personnel (and, in the case of the University, its students) are insured during the course and scope of the Party's business, where fault can be attributed to one of the Parties or its personnel. Each Party's maximum liability in respect of any damage to property or death of or injury to any person or any other cause resulting or arising from or in connection with any act or omission in terms of this Agreement will be limited, whether for a single event or multiple events, to the extent of its insurance cover herein

12. BREACH AND TERMINATION

12.1. An event of a material breach will occur should either Party breach any of the material terms or conditions of this Agreement and fail to remedy that breach within a period of 14 (fourteen) days of being called upon in writing to do so.

12.2. Upon the occurrence of an event of breach the aggrieved party will be entitled, in addition to any other rights which it may have in law, to cancel this agreement on written notice to the defaulting party.

12.3. Any termination of this agreement will not absolve the Parties from the obligation to observe the confidentiality measures and other restraints as set out herein.

13. FORCE MAJEURE

13.1. The Parties are not responsible for failure to perform, for defective performance or for any delay in performing any obligation under the Agreement, if and to the extent that such failure or delay is caused by force majeure, save to the extent that such liability is covered in terms of appropriate insurance cover.

13.2. For the purpose of this Agreement force majeure means any circumstance which is beyond the reasonable control of the Party giving notice of force majeure ("the Affected Party"), including war (whether declared or not), revolution, invasion, insurrection, riot, civil commotion, sabotage, blockade, boycott, the exercise of military or usurped power, fire, explosion, storm, flood, rain, drought, wind lightning or any other adverse weather condition, epidemic, quarantine, accident, acts or restraints of government imposition, or restrictions of or embargoes on imports or exports.

13.3. The Affected Party must give notice thereof to the other Party immediately upon the occurrence of an event of force majeure and again immediately on the cessation thereof.

13.4. If force majeure is of such nature that it will result in impossibility of performance of an obligation going to the root of the Agreement, the Party not so affected ("the Other Party") is entitled, on receipt of notice of the force majeure event, to terminate the Agreement upon notice to the Affected Party but is not entitled to recover any damages which it may suffer as a result of such premature termination.

13.5. If the force majeure is of such a nature that it will not result in impossibility of performance of the obligation in question but will delay the performance thereof, the Affected Party is entitled to such extension of time in which to perform that obligation as may be reasonable in the circumstances, taking into account the interests of the Parties, provided that if such force majeure situation persists for a period in excess of 90 (ninety) days the Other Party will be entitled to terminate the Agreement but is not entitled to recover any damages which it may suffer as a result of such premature termination.

14. MISCELLANEOUS MATTERS

14.1. Address for correspondence

14.1.1. Any correspondence (other than a notice contemplated in 0) in connection with this Agreement may be addressed:

14.1.1.1. in the case of the University, to:

[redacted]

[redacted]

[redacted]

14.1.1.2. [redacted]

[redacted]

Address for Service of Legal Documents

14.1.2. The Parties choose the following physical addresses at which documents in legal proceedings in connection with this Agreement may be served (i.e. their *domicilia citandi et executandi*):

14.1.2.1. The University :

[redacted]

14.1.2.2. [redacted]

14.2. The notice will be deemed to have been duly given on delivery, if delivered to the Party's physical address set out in 14.1.1 unless the addressor is aware, at the time the notice would otherwise be deemed to have been given, that the notice is unlikely to have been received by the addressee through no act or omission of the addressee.

14.3. A Party may change its address for this purpose to another address in the Republic of South Africa, by notice to the other Party.

14.4. Notwithstanding anything to the contrary herein contained a written notice or communication actually received by a Party will be an adequate written notice or communication to it notwithstanding that it was not sent to or delivered at its chosen address in terms of 14.1.1.

14.5. All notices and correspondence in connection with this Agreement will be in the English language.

14.6. A Party may change its address for this purpose to another physical address in the Republic of South Africa at which legal process can be served, by notice to the other Party.

14.7. **Entire Agreement**

This Agreement contains all the express provisions agreed on by the Parties with regard to the subject matter of the Agreement and the Parties waive the right to rely on any alleged express provision not contained in the Agreement.

14.8. **No Representations**

No Party may rely on any representation which allegedly induced that Party to enter into this Agreement, unless the representation is recorded in this Agreement.

14.9. **Variation, Cancellation and Waiver**

No addition to or variation of any clause of this Agreement (including this clause 14.9), consensual cancellation or novation of this Agreement and no waiver of any right arising from this Agreement or its breach or termination will be of any force or effect unless reduced to writing and signed by both Parties or their duly authorised representatives.

14.10. **Indulgences**

If either Party at any time breaches any of its obligations under this Agreement, the other Party ("the Aggrieved Party"):

14.10.1. may at any time after that breach exercise any right that became exercisable directly or indirectly as a result of the breach, unless the Aggrieved Party has expressly elected in writing or by clear and unambiguous conduct, amounting to more than mere delay, not to exercise the right. In particular, acceptance of late performance will be provisional only, and the Aggrieved Party may still exercise that right during that period;

14.10.2. will not be estopped (i.e. precluded) from exercising its rights arising out of that breach, despite the fact that it may have elected or agreed on one or more previous occasions not to exercise the rights arising out of any similar breach or breaches.

14.11. **Applicable Law**

This Agreement will be interpreted and implemented in accordance with the law of the Republic of South Africa.

14.12. **Jurisdiction**

The Parties consent to the jurisdiction of the South Gauteng High Court, Johannesburg.

14.13. **Successors in title**

Without prejudice to any other provision of this Agreement, any successor-in-title, including any executor, heir, liquidator, curator or trustee, of a Party will be bound by this Agreement.

14.14. **Severability**

If any provision of this Agreement is invalid, unenforceable or illegal, the remaining provisions of this Agreement will be deemed to be severable therefrom and will continue in full force and effect unless such invalidity, unenforceability or illegality goes to the root of this Agreement.

14.15. **Counterparts**

This Agreement may be executed in any number of counterparts and by the Parties hereto on separate counterparts, each of which when executed and delivered will be an original and each of the counterparts will together constitute one and the same instrument.

14.16. **Costs**

Each Party will bear its own costs relating to the negotiation, preparation and signature of this Agreement.

Signed on behalf of the University:

Name: [redacted]

Designation: [redacted]

Date: [redacted]

Place: [redacted]

Witness: [redacted]

Signed on beha[redacted] [redacted]

Name: [redacted]

Designation: [redacted]

Date: [redacted]

Place: [redacted]

Witness: [redacted]

Executive Summary

[redacted] has a long-standing relationship with Wits mining school and is committed to the continued partnership in allowing students access to world leading developments and skills in the mine ventilation and refrigeration environment.

This agreement outlines the infrastructure, hardware and communication requirements in order to allow the successful implementation of VUMA3D-live. The agreement elaborates on [redacted]s well as [redacted] contribution to the VUMA3D-live implementation at the [redacted]

[redacted]

CONTENTS

TABLES

FIGURES

ANNEXURES

Annexure 1: Paper on VUMA3D-live system

[redacted]

1 General Overview of BBE

[redacted]s the international leader in mine ventilation, refrigeration, cooling; modelling, using all available software packages for mine ventilation and cooling networks; energy optimisation and energy management; applied mining and energy research and development

Many years of experience in the world's deepest and hottest mines have developed [redacted] as global specialists in ventilation, refrigeration, cooling and energy management in mines. [redacted] capabilities range from conceptual design and modelling to detailed engineering, implementation and commissioning. [redacted] has built an international reputation since its inception in 1989. The team comprises refrigeration and thermo-flow engineers specializing in design, installation and operation of all elements of mine ventilation, refrigeration and cooling systems.

[redacted] total staff complement is 120 [July 2017] of which some 80% are specialised professionals [generally with multiple degrees]. The back-up support team includes administrators and design draftsmen [design drawing office has eight experienced individuals]. [redacted] professionals are made up of mechanical engineers, mining engineers, chemical [process] engineers and electrical engineers. Many o[redacted] professionals have more than 30 years individual experience at a high level in this specific field. [redacted] have published hundreds of technical and scientific papers and authored and co-authored standard text books - these have attracted a variety of awards for engineering and scientific achievement.

[redacted] and experience covers a wide range of activities including:

- Analysis of all alternative ventilation, refrigeration and cooling systems and optimisation.
- Surveys and audits and diagnostic work with ventilation and cooling networks and systems.
- Modelling of ventilation systems and mine heat load prediction with associated state-of-art software development and application
- Conceptual and pre-feasibility life-of-mine designs, investigations, scheduling and estimates in field of ventilation, cooling and energy management.
- High level ['bankable'] Feasibility studies with life-of-mine designs, scheduling, estimates, capital and power profiles in the field of ventilation, cooling and energy management.
- EPCM type project execution in this specific field.
- Preparation of detailed specifications for ventilation, cooling and energy recovery equipment.
- Cooling ultra-deep hot mines including ventilation and cooling on demand.
- Project management in this specific field.
- Training courses in terms of ventilation, cooling and energy management aspects.
- Third party and due diligence investigations and competent person reports in this field.
- Applied mining research in this specific field and development of new technologies.

2 System Overview

The integrated VUMA3D-live system allows:

- Monitor, visualize and report ventilation conditions on a quasi-real time basis
- Alarm when abnormal conditions are detected in the control room (air flow, temperature, etc.)
- Monitor vent control status (doors open/closed, fans on/off)
- Predict abnormal ventilation conditions within the ventilation environment (constant forward prediction)
- Allow for the future addition of other monitoring and control requirements (e.g. fire and blasting fumes, personnel tracking.)

2.1 Description

Please refer to Appendix 1 for a paper presented at an international conference that describes the system in detail.

2.2 Architecture

The basic system architecture is shown in the image below

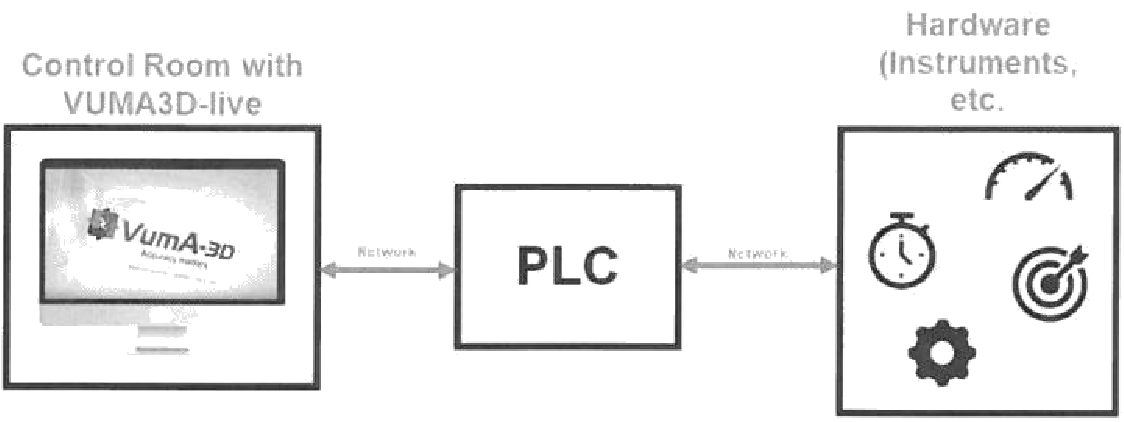


Figure 1: Basic system architecture

3 Infrastructure requirements

The following infrastructure is required

1. Standalone PC with the following specifications:

   a. Minimum:
   1. Intel I3 or equivalent processor
   2. 4 GB RAM or more
   3. 2 GB of available hard disk space
   4. Windows 7/8.1/10
   5. DirectX 9 graphics device [NVIDIA 7 Series or higher]
   6. Available USB port
   7. Internet access for online activation
   8. Admin rights (installation only)

   b. Recommended:
   1. Intel I5/I7 equivalent processor
   2. 8 GB RAM or more

iii. 23" Screen
iv. NVIDIA GTX Series, Intel 4000 or equivalent dedicated graphics hardware

2. Power supply for the PC
3. Network connection
4. The required hardware is installed and linked on the network
5. The instrument values are readily available via the network
6. Necessary permissions to access the data is in place
7. Remote access to PC running VUMA3D-live

4 Commercial aspects

[redacted]ontribute the following to WMI:

- VUMA3D-live license, this includes updates to latest upgrades and versions?
- 8 man-hours per month for the installation and maintenance of the VUMA3D-live system on an ongoing basis renewable each year
- Training and knowledge transfer as work is conducted

[redacted]s acknowledgement by [redacted]ontribution in marketing documents. Feedback on errors and possible improvements are requested.

[redacted]

Appendix III

Final new blueprint (in tables)

Main-phase 1, Pre-installation phase, sub-phase 1.1 and 1.2

Blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
1. Pre - installation phase for technology system				
	1.1 Gather information on the actual entity's capacity	1.1.1 Commissioning entity's capacity		
		1.1.2 Commissioning entity's technological gap		
		1.1.3 Commissioning entity's expectations		
	1.2 Evaluate vendors, identify the potential technology systems	1.2.1 Information gathering on vendors and technology systems		
		1.2.2 Assessment and selection procedures for vendors and technology systems		

Main-phase 2, Installation phase, sub-phase 2.1, 2.2 and 2.3

Blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
2. Adoption phase for new digital technology	**2.1. Legal documents drafting**	2.1.1 Agreement drafting		
		2.1.2 Contracts drafting		
	2.2 Preparation work for adoption	2.2.1 Documents required for running the system		
		2.2.2 System requirement documents need to be prepared by vendors (Cawood, 2017)		
		2.2.3 Requirement for infrastructure upgrade		
	2.3 Adoption of new digital technology	2.3.1 Ensure implementation of legal documents		
		2.3.2 Budget control		
		2.3.3 Design and quality of civils work		
		2.3.4 Support & cooperation (communication)		

Main-phase 3, Post installation phase, sub-phase 3.1 and 3.2

Blueprint contents				
Main-phase	**Sub-phase**	**Main-tasks**	**Check (tick)**	**Remarks**
3. Post-adoption phase for new digital technology				
	3.1 System calibration, testing, and integration	3.1.1 System calibration		
		3.1.2 System testing		
		3.1.3 System integration		
	3.2 After sale services	3.2.1 Activities required to maintain continuous system functionality		
		3.2.2 Exit strategy		

Risk assessment tool, 5X5 matrix to determine risk scale

	Consequence of impact				
Threats likelihood	**Insignificant (1)**	**Minor (2)**	**Significant (3)**	**Major (4)**	**Severe (5)**
Almost certain (5)	Medium 5	High 10	Very high 15	Extreme 20	Extreme 25
Likely (4)	Medium 4	Medium 8	High 12	Very High 16	Extreme 20
Moderate (3)	Low 3	Medium 6	Medium 9	High 12	Very high 15
Unlikely (2)	Very Low 2	Low 4	Medium 6	Medium 8	High 10
Rare (1)	Very Low 1	Very Low 2	Low 3	Medium 4	Medium 5

Sub-phase 1.1, Main-task 1.1.1

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.1.1 Commissioning entity's capacity	**1.1.1.1** **Commissioning entity's vision, culture, architecture & budget**	Check commissioning entity's background, vision and strategy		
		Check commissioning entity's business model, culture & interest		
		Check commissioning entity's funding and planned budget		
	1.1.1.2 Commissioning entity's infrastructure and architecture	Check commissioning entity's communication system (ICT)		
		Clarify commissioning entity's data collection, transfer and storage		
		Obtain detailed ICT system architecture, including data flow and sensor network of the commissioning entity		
		Clarify the commissioning entity's requirement for system integration		
		Clarify commissioning entity's system expandability		

Sub-phase 1.1, Main-task 1.1.2

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.1.2 Commissioning entity's Technological gap				
	1.1.2.1 Current status of the commissioning entity	Check current status of existing new digital technology installed in the commissioning entity		
		Clarify the approach used for the new digital technology adoption in the commissioning entity		
		Check outcome of the adoption		
		Check lessons learned from other adoptions		
		Check employees' level of skills (qualification & experience)		
	1.1.2.2 Problem Statement	Clarify the type and nature of the problem that is facing the commissioning entity		
		Check possible solutions that are related to utilizing new technologies		
	1.1.2.3 Best practice in the industry	Check similar problems occurred in the industry		
		Check solutions used to address such problems		
		Clarify the role of technologies in such solutions		
		Check outcome of the solutions		
		Check lessons learnt from such problems and solutions		
	1.1.2.4 Trend & Future in the industry	Check general practice and trend in the industry		
		Seek new digital technology that may apply in the future of the industry		
		Clarify differentiation between commissioning entity's version and industry's future		

Sub-phase 1.1, Main-task 1.1.3

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.1.3 Commissioning entity's expectations				
	1.1.3.1 Expected improvement on existing new digital technology	Clarify commissioning entity's expectations in terms of planned budget, cost, functionality etc.		
		Check impact on the existing new digital technology in the commissioning entity		
		Clarify timeframe for installation, adoption and integration		
		Clarify employees' skills deficiency (compare to the capacity of skills in 1.1.2.1)		
	1.1.3.2 Minimum & maximum functionality of the potential new digital technology against commissioning entity expectations	Clarify minimum & maximum functionality required for commissioning entity to be satisfied		
		Check redundancy that may be created by the maximum functionality based on the commissioning entity requirement		
		Clarify extra budget required for system upgrading to achieve the minimum or maximum functionality		
	1.1.3.3 Expectation on the outcome of the adoption	Clarify method to measure the improvement, achievement		
		Check improvement, achievement (actual outcome) versus commissioning entity's expectations		
		Clarify measurement required to measure functionality		
		Check for possible future upgrade and integration (e.g. real-time decision, notification, and alert)		

Sub-phase 1.2, Main-task 1.2.1, Sub-task 1.2.1.1

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.1 Information gathering on vendor's capacity and new digital technology's functionality				
	1.2.1.1 Channel to acquire vendor and new digital technology	Check the general practice to acquire new digital technology in the industry.		
		Evaluate the possible channel to acquire the new digital technology from a local supplier, OEM, Service package from the vendor		

Sub-phase 1.2, Main-task 1.2.1, Sub-task 1.2.1.2

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.1 Information gathering on vendor and new digital technology	**1.2.1.2 Information exchange between commissioning entity and vendors**	Ensure that the commissioning entity has requested multiple bids from vendors and arranged meetings with them. Commissioning entity present all the requirements and expectations to vendors		
		Ensure that the commissioning entity presents all sub-phase 1.1-investigation-outcomes to the vendors, especially problem statement, capacity and expectations.		
		Receive detailed background information relating to the vendors and their available new technologies		
		Receive detailed information regarding new technologies that the vendors need to provide: marketability, commercialization, availability in the region, precedent successful adoption cases, etc.		
		Receive detailed technical documents covering functionality, specification, configuration, system compatibility, total cost with unit price, and adoption requirement for infrastructure (versus vendor's capacity) of the new digital technology from vendors		
		Compare the documents that were received in the above activity to the template which defines "*general contents for vendor's supporting documents*" (Cawood, 2017) see Appendix IX		

Sub-phase 1.2, Main-task 1.2.1, Sub-task 1.2.1.3

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.1 Information gathering on vendor and new digital technology	**1.2.1.3 Information required for assessing vendor's capability and new digital technology functionality**	Ensure vendors provide detailed description and demonstrations of their capability and functionality of the new digital technology		
		Obtain documents for all requirements, including full specifications of required infrastructure (for both software and hardware)		
		Obtain a full list of equipment required for adoption, including a description of all equipment, working principle of all instruments, detailed system architecture and data flow		
		Obtain detailed requirement for system integration between the new digital technology and the existing new technologies installed at the commissioning entity		
		Obtain detailed plan for add-on functionality (e.g. Real-time alert and notifications)		
		Obtain emergency procedures: e.g. auto-restart function in power outage		
		Ensure that the vendor provides after-sale support documents and plan		
		Ensure that the vendor provides a comprehensive quotation (including cost of all services)		
		Check integrity of all the information received by the commissioning entity as well as information sent to vendors		

Sub-phase 1.2, Main-task 1.2.2, Sub-task 1.2.2.1

Blueprint contents			Checklist	
Main-task	**Sub-task**	**Activities**	**Check (tick**	**Remarks**
1.2.2 Assessment and selection procedures for vendors and new digital technology				
	1.2.2.1 Procedures for assessing vendor's capability and new digital technology's functionality	Ensure that more than one vendor was required to provide detailed information and that more than one vendor needed to be assessed by the commissioning entity to create a competitive reference		
		Ensure that the commissioning entity assess the vendors by comparing vendor-provided information to the commissioning entity's capacity and expectations. Commissioning entity needs to conduct the following five assessments.		
		a). Vendor and vendor new digital technology versus commissioning entity vision, culture and business model		
		b). Vendor new digital technology functionality versus problems stated in commissioning entity problem statement and commissioning entity expectations		
		c). Vendor new digital technology adoption requirement versus commissioning entity's capacity in terms of infrastructure		
		d). Vendor's total cost of all services versus commissioning entity's funding and planned budget		
		e). Cross-comparisons between different vendors (not only commissioning entity versus vendor, also vendor versus vendor)		
		Select the most appropriate vendor and new digital technology based on the outcome of the above assessment s		

Sub-phase 1.2, Main-task 1.2.2, Sub-task 1.2.2.2

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
1.2.2 Assessment and selection procedures for vendors and new digital technology	**1.2.2.2 Criteria for final selection of the most suitable vendor and new digital technology**	Capability for the future upgrade and integration with other existing systems in the commissioning entity's environment is the key consideration		
		Choose appropriate vendor and new digital technology; avoid selection of the most expensive or cheapest option, or one that provides the most system functionality, without proper review.		
		The ultimate one to choose is the one that most-meets the commissioning entity's vision, organizational culture and business model, and that is most likely to be successfully adopted and achieve continuous/full functionality		
		Commissioning entity makes the final decision based on the documents and outcomes of assessments mentioned above		

Sub-phase 2.1, Main-task 2.1.1

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.1.1 Agreement drafting	**2.1.1.1 Drafting constitutional agreement (e.g. Wits agreement (Appendix II)**	Develop the commissioning entity's constitutional agreement		
		Implement the commissioning entity's constitutional agreement		
		All drafted legal documents have to refer to the commissioning entity's constitutional agreement for all the activities take place in the commissioning entity (refer to the Wits/vendor's agreement)		
	2.1.1.2 Drafting Intellectual property agreement	Ownership of data generated by the new digital technology		
		Collection, transfer and storage of data generated		
		Utilization of data generated (i.e. analysis, research purpose)		
		Security of data generated (cyber security, access control to server, etc.)		
	2.1.1.3 Drafting purchase agreement	Develop detailed plan for purchasing goods, equipment, material and labor, and all required items for adoption		
		Logistics arrangement for purchased goods, equipment and material delivery		
	2.1.1.4 Agreement of mutual acknowledge-ment	Clarification on outcome of the adoption		
		Clarification on vendor-claimed functionality		
		Clarification on the limitation of the new digital technology		

Sub-phase 2.1, Main-task 2.1.2

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.1.2 Contracts drafting				
	2.1.2.1 Drafting contracts	Preparation work for commissioning entity (state the support required)		
		Project plan for adoption work (including schedule and budget)		
		Pricing, payment and labour arrangement, (e.g. import tax)		
		System integration with the existing installed system		
		Deliverable outcome and achievable functionality after the adoption		
		Detailed plan for after sale services from vendors		
		Exit strategy (conditions re. termination of contracts, or further cooperation)		

Sub-phase 2.2, Main task 2.2.1

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.2.1 Documents required for running the system	**2.2.1.1 System operation documents**	Develop system architecture with data flow		
		Apply SOP (Standard Operation Procedures) for all the activities		
		Apply health and safety measurements and procedures		
		List of possible sub-contractors for adoption and operation		
	2.2.1.2 Technical support documents	Clarify system update & upgrade (include both hardware and software)		
		Check system debug & system functionality recovery during system malfunction		
		Develop a schedule for System maintenance		
		Develop a reporting system between commissioning entity and vendor		

Sub-phase 2.2, Main-task 2.2.2

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.2.2 System requirement documents need to be prepared by vendors (Cawood, 2017)				
	2.2.2.1 Contents of key topics	Obtain system description (e.g. system operation documents, COP, SOP)		
		Obtain a detailed list of system items		
		Clarify enabling elements/items required for adoption (e.g. civils work upgrade)		
		Clarify vendor deliverables (itemized)		
		Obtain software-related information/plans		
		Commissioning entity and vendor meet to get clarity on everything mentioned above		

Sub-phase 2.2, Main-task 2.2.3

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.2.3 Requirement for infrastructure upgrade				
	2.2.3.1 Civils work, hardware	Time consuming, need to plan in advance for preparation (construction, logistics, etc.)		
		Ensure a holistic design of the civils work (influence to other systems)		
	2.2.3.2 Network, communication system, software and ICT system	Network and I.T. system capability (bandwidth, storage capacity, computing power and number of servers, etc.)		

Sub-phase 2.3, Main-task 2.3.1

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.3.1 Project management of adoption				
	2.3.1.1 Appointment of system champion to supervise the progress of the adoption	System champion appointed to oversee the entire adoption project behalf of the commissioning entity		
		Communication/liaison with vendors on behalf of the commissioning entity		
		System champion is required to have comprehensive understanding of the new digital technology, and preferably to have been involved from the initial stage of identification/selection procedures		
	2.3.1.2 System champion supervise the adoption project	Ensure the implementation and execution of all legal documents		
		Monitor the implementation/execution of all the agreements and contracts in different phases (schedule)		
		Monitor of the quality of implementation/execution (documenting and reporting)		
		Ensure the requirement of infrastructure upgrade is in place and is sufficient to accommodate the requirement of adoption		
		Adhere to all the regulations, standards, COP, SOP during adoption, such as wiring standards, emergency procedures and health and safety act, etc.		
	2.3.1.3 Apply Key principles to managing all the resources for each phase of the adoption	Initiation and planning		
		Execution of the plan		
		Adoption of project monitoring and control		
		Adoption project completion and handover		

Sub-phase 2.3, Main-task 2.3.2

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.3.2 Focusing areas for budget control				
	2.3.2.1 Labor	The arrangement of labour during adoption needs to follow the labour agreement drafted in 2.1.1.1		
	2.3.2.2 Material	Purchase of the material for adoption should strictly follow the purchase agreement signed in 2.1.1.1		
	2.3.2.3 Logistics	The requirement for logistics should be done according to the guidance written by vendors in logistics agreement in 2.1.1.1		
	2.3.2.4 Hardware and software	Hardware and software purchase: Strictly implement the purchase agreement in 2.1.1.1 and only listed items should be purchased		
		Hardware and software upgrade: based on the assessment of the existing hardware and software before going for the upgrade		

Sub-phase 2.3, Main-task 2.3.3

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
2.3.3 Communication mechanism				
	2.3.3.1 Support & cooperation between the commissioning entity and vendors	Create multiple channels for efficient communication, documenting and reporting between system champion and vendors for the lifespan of the system		
		System champion and vendor support/cooperate with each other during the adoption		
		Sufficient communications between system champion and vendor on progress and feedback during the adoption		

Sub-phase 3.1, Main-task 3.1.1

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.1.1 System Calibration				
	3.1.1.1 System calibration	Calibrate all the hardware such as sensors, equipment and devices to their required specifications, especially sensors and measuring instruments		
		System champion to ensure that setting-requirements of all software matches associated hardware requirements, and that software receives correct and sufficient data from hardware		
	3.1.1.2 Certification of calibration	Obtain calibration certificates for individual equipment/device, and the overall system		
		Document all records for calibration and update the certificates accordingly		

Sub-phase 3.1, Main-task 3.1.2

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.1.2 System testing				
	3.1.2.1 System functionality testing	Test individual and overall system functionality against the claimed functionality stated in the contract in main-task 2.1.2		
	3.1.2.2 System malfunction testing	Recognize and record any system malfunction		
		Identify the major cause of system malfunction		
		Identify any disruption to the continuous functionality of the system during testing		
		Debug and make corrections; Document all the findings		

Sub-phase 3.1, main-task 3.1.3

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.1.3 System integration	**3.1.3.1 Apply appropriate integration method**	Perform system compatibility test between newly installed new digital technology and the existing technology systems in the commissioning entity		
		Identify and apply the appropriate integration method to integrate all the sub-systems in the commissioning entity according to their functionalities		

Sub-phase 3.2, Main-task 3.2.1

Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.2.1 System operation after adoption	**3.2.1.1 Activities requires to maintain the continuous system functionality**	System maintenance & system debug		
		Emergency procedures for system functionality recovery after system malfunction		
		Regular system and hardware upgrade and software update		
		Documenting & Reporting system		

Sub-phase 3.2, Main-task 3.2.2

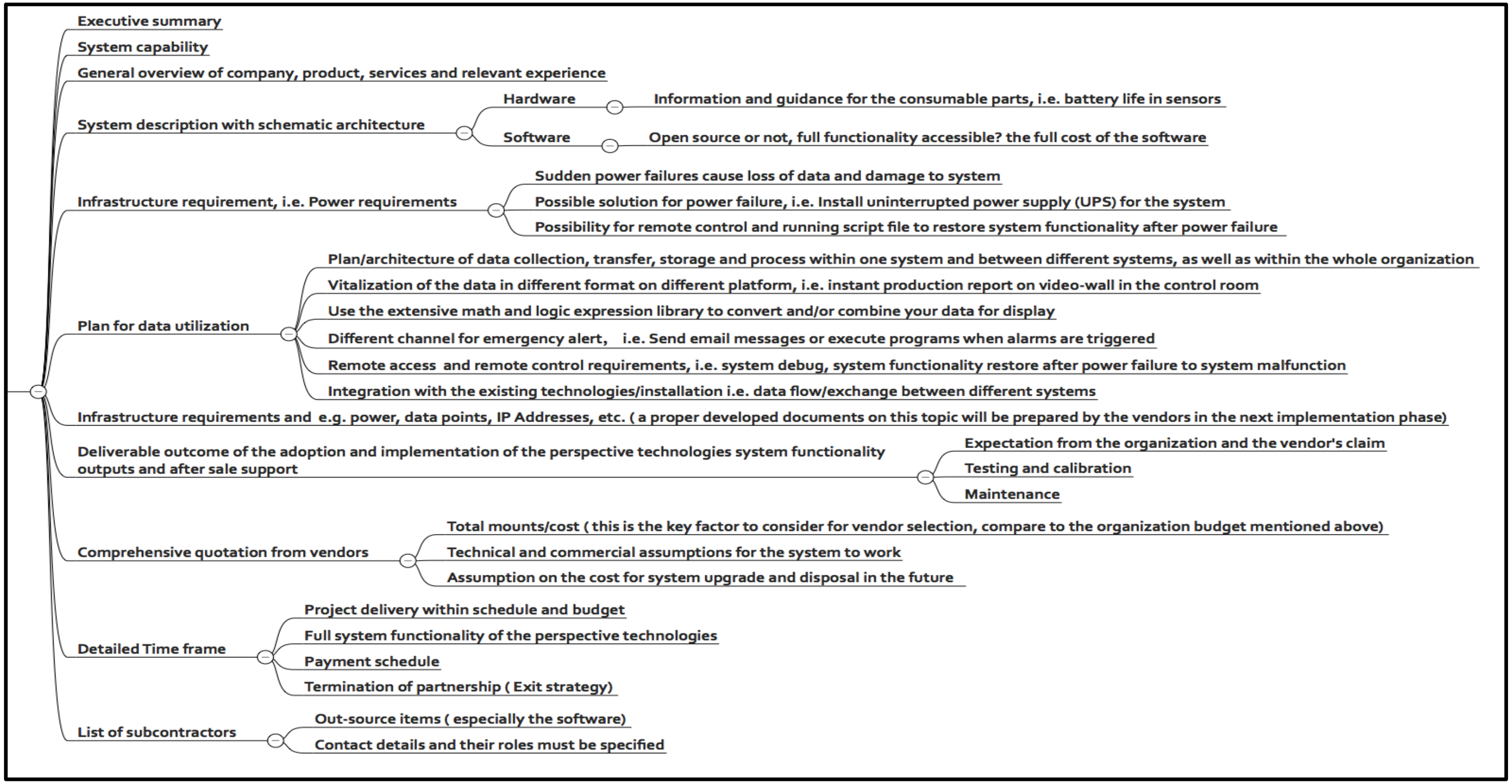
Blueprint contents				
Main-task	**Sub-task**	**Activities**	**Check (tick)**	**Remarks**
3.2.2 Exit strategy				
	3.2.2.1 Commissioning entity conduct an assessment to review the performance of the new digital technology	Two questions should be answered by the outcome of the assessment: 1. Did the performance meet the commissioning entity's expectations? And:		
		2. Did the new digital technology address the problem faced?		
		Based on the personal experience and knowledge System champion provide recommendations to the entity for the way forward. Either furthers the corporation and terminates the contract.		

Hierarchy and the total number of hierarchy in the blueprint

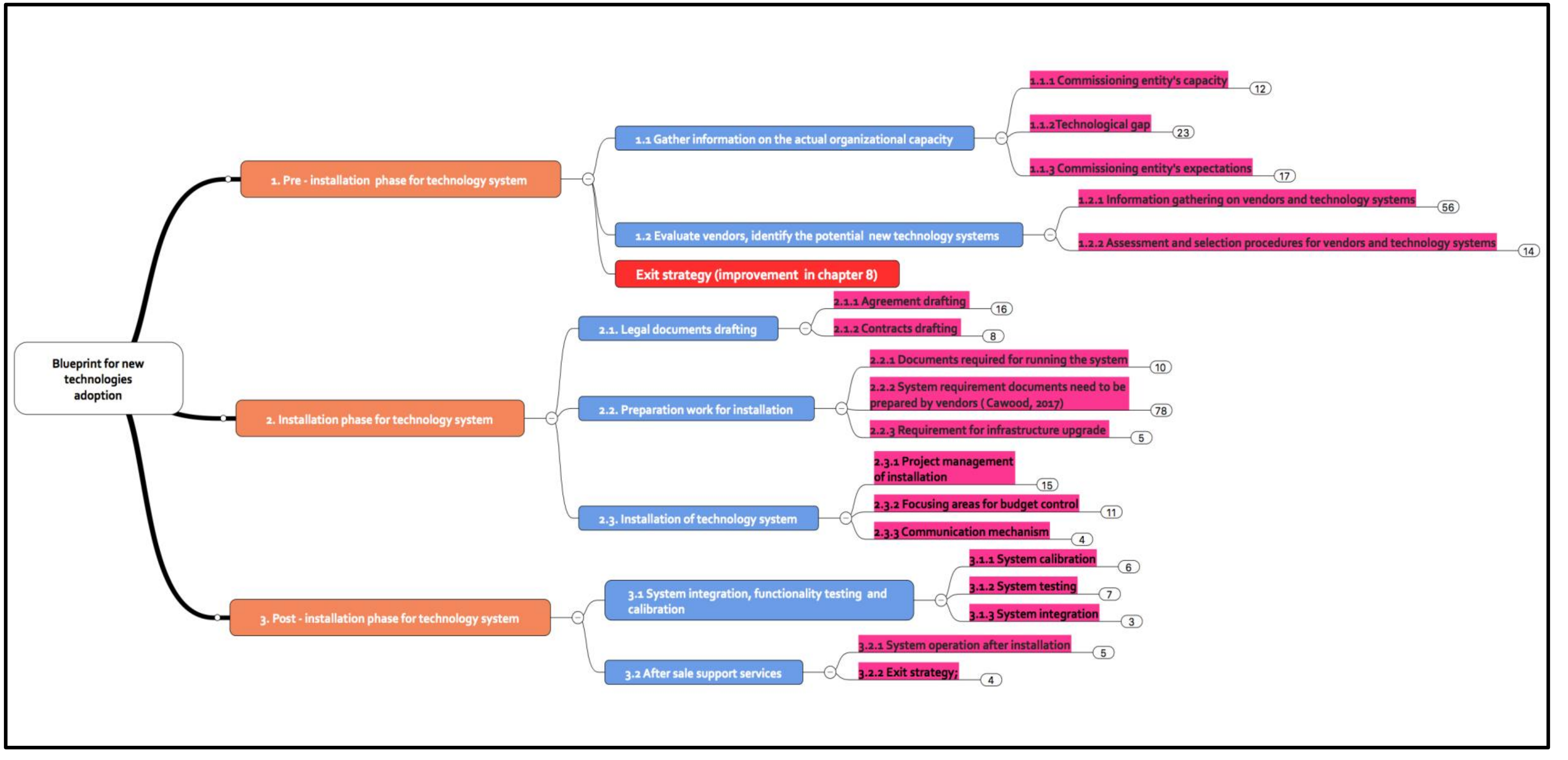
Hierarchy	Total number in the blueprint
Main-phase	3
Sub-phase	8
Main-task	18
Sub-task	35
Activities	119

Appendix IX

WMI vendor supporting document template (Cawood, 2017d)



Appendix X



Blueprint for new technologies adoption
1. Pre - installation phase for technology system
1.1 Gather information on the actual organizational capacity
1.1.1 Commissioning entity's capacity
12
1.1.2Technological gap
23
1.1.3 Commissioning entity's expectations
17
1.2 Evaluate vendors, identify the potential new technology systems
1.2.1 Information gathering on vendors and technology systems
56
1.2.2 Assessment and selection procedures for vendors and technology systems
14
Exit strategy (improvement in chapter 8)
2. Installation phase for technology system
2.1. Legal documents drafting
2.1.1 Agreement drafting
16
2.1.2 Contracts drafting
8
2.2. Preparation work for installation
2.2.1 Documents required for running the system
10
2.2.2 System requirement documents need to be prepared by vendors (Cawood, 2017)
78
2.2.3 Requirement for infrastructure upgrade
5
2.3. Installation of technology system
2.3.1 Project management of installation
15
2.3.2 Focusing areas for budget control
11
2.3.3 Communication mechanism
4
3. Post - installation phase for technology system
3.1 System integration, functionality testing and calibration
3.1.1 System calibration
6
3.1.2 System testing
7
3.1.3 System integration
3
3.2 After sale support services
3.2.1 System operation after installation
5
3.2.2 Exit strategy;
4

Appendix XI

Data of survey results

Table 1

Blueprint contents				Checklist: Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		Average compliance of each activity
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed	Compliance	Remarks	Compliance %	Remarks	Compliance %	Remarks	Compliance %	Remarks	Compliance %	Remarks	Compliance %	Remarks	Compliance %	Remarks	Compliance %	Remarks	Compliance %	Remarks	
1.1 Clarify Commissioning entity's (WMI) actual capacity before the adoption started	1.1.1.1 Clarify WMI's vision, culture, structure & budget	Check WMI's background, vision and strategy	Y	25	N/A	80	N/A	90	N/A	50	N/A	50	N/A	50	N/A	0	N/A	70	N/A			52
		Check WMI's business model, culture & interest	Y	30	N/A	80	N/A	70	N/A	40	N/A	50	N/A	60	N/A	0	N/A	70	N/A			50
		Check WMI's funding and planned budget	Y	70	N/A	90	N/A	0	I was not involved but I am sure this was done by Prof Cawood	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A			20
	1.1.1.2 Clarify WMI's existing infrastructure	Check WMI's communication system (ICT)	Y	40	N/A	50	N/A	40	N/A	50	N/A	75	N/A	40	N/A	0	N/A	40	N/A			42
		Clarify WMI's data collection, transfer and storage route	Y	50	N/A	50	N/A	40	N/A	75	N/A	75	N/A	50	N/A	40	N/A	20	N/A			50
		Obtain detailed ICT system architecture with data flow and sensor network of WMI	Y	10	N/A	40	N/A	40	N/A	50	N/A	80	N/A	70	N/A	30	N/A	0	N/A			40
		Clarify WMI's requirement for system integration	Y	10	N/A	40	N/A	40	N/A	40	N/A	80	N/A	30	N/A	30	N/A	10	N/A			35
		Clarify WMI's system expandability	Y	20	N/A	30	N/A	40	N/A	30	N/A	50	N/A	40	N/A	40	N/A	70	N/A			43

Overall compliance	41
Overall risk scale	Extreme (20)

Table 2

Blueprint contents				Checklist: Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		Average of each activity
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed (Y or N)	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	
1.1.2 WMI's technological gap	1.1.2.1 Current status of technology system installed at WMI	Clarify current status of all technology systems installed at WMI	Y	100	N/A	80	N/A	50%	Schauenburg MIMACS system was probably the second system installed at WMI, the first though not similar was the ducted fan (if we exclude the construction of the tunnel). There was not much deliberation / time to review the previous systems in a systematic manner, but of course the lessons learnt were naturally implemented to some extent.	50	N/A	80	N/A	50	N/A	90	N/A	80	Details in system documents			66
		Check adoption approach used for all the technology systems in WMI (before the Schauenburg MIMACS system is installed)	N	0	Schauenburg was the second system to install at WMI.	50	The Schauenburg MIMACS system was installed along with Vbra-Tek as the first systems	50%		60	N/A	50	N/A	40	N/A	0	N/A	60	Schauenburg MIMACS systems was the first digital sensors system to be installed at WMI			33
		Review the outcome of the precedent adoption cases at WMI	Y	100	After installing Schaueburg	0	Actually it was not possible, being the first system	50%		70	N/A	50	N/A	40	N/A	98	N/A	80	Precedent adoptions were dissimilar to sensor network			55
		Study all the lessons learned from those adoption cases	Y	100	After installing Schaueburg	20		50%		50	N/A	50	N/A	50	N/A	98	N/A	60	Documenting and updating of system documents			54
		Clarify WMI employee's capacity of skills (qualification & experience)	Y	100	Skills are considered before appointing a system champion	10	We thought we were ready but in fact was hopelessly unprepared for a sohjisticated system like Schauenburg	40%		50	N/A	70	N/A	60	N/A	98	N/A	90	Champions' minimum requirement are BSc in a relevant application area			60

53

Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed (Y or N)	Person A Compliance (%)	Person A Remarks	Person B Compliance (%)	Person B Remarks	Person C Compliance (%)	Person C Remarks	Person D Compliance (%)	Person D Remarks	Person E Compliance (%)	Person E Remarks	Person F Compliance (%)	Person F Remarks	Person G Compliance (%)	Person G Remarks	Person H Compliance (%)	Person H Remarks	Person I Compliance (%)	Person I Remarks	
	1.1.2.2	Clarify/justify WMI's need/motivation to acquire Schauenburg MIMACS system (e.g. require better mine access control)	Y	100	At that time, Schauenburg was the best	80	N/A	80%	N/A	60	N/A	50	N/A	70	The purpose of adoption, i.e. what intended results are we expecting, shall be discussed in advance with system vendor and TORs must be set in [illegible]	100	N/A	92	Study safety compliance and asset tracking underground management			69
	WMI's Problem Statement	Clarify type and nature of the problems faced by WMI that can be addressed by Schauenburg MIMACS system	Y		Integration of Schauenburg's internal system packages	80	N/A	80%	N/A	50	N/A	50	N/A	80	I think the system/ data compatibility issues are the greatest that we had, so they must be discussed in advance and incorporated in the implementatio[illegible]	100	N/A	94	Access control, asset and people tracking, safety compliance			65
	(Motivation to acquire Schauenburg MIMACS system)	Check possible solutions that are related to utilizing Schauenburg MIMACS system	Y	100		80	N/A	80%	N/A	40	N/A	80	N/A	60		98	N/A	80	Location tracking, integrated networks, Artificial intelligence,			67
	1.1.2.3	Check similar problems that occurred in the mining industry (e.g. mine access control problem)	Y	100	Mines are still using Schauenburg MIMCAS	75	N/A	70%	N/A	60	N/A	80	N/A	70	I think all the systems are good in a particular area of utilization, we must identify that right at the outset and design our project adoption according to [illegible]	98	N/A	92	Asset tracking, asset control, safety compliance, environmental control			72
	Best practice in the industry to address similar problems	Check solutions used to address similar problems in the mining industry	Y	100	Mines are still using Schauenburg MIMCAS	100	It including mine and factory visits with several meetings	70%	N/A	70	N/A	80	N/A	50	Identify the problem of industry and workshop it.	98	N/A	96	Schauenburg MIMACS system is widely adopted in [illegible]			74
		Clarify role of new technologies in such solutions	Y	100	N/A	50	N/A	70%	N/A	90	N/A	80	N/A	60	N/A	0	N/A	70	Communications technology for safety compliance			56
		Review outcome of the solutions	Y	100	N/A	50	N/A		N/A		N/A	80	N/A	80	N/A	0	N/A	80	Problems and solutions updated in [illegible]			65
		Study lessons learned from such problems and solutions	Y	100	N/A	100	It led to this research	50%	N/A	80	N/A	75	N/A	70	N/A	0	N/A	82	Lessons and solutions documented in systems			63
	1.1.2.4	Check general practice and trend for using other digital mining technology systems in mining industry	Y	100	N/A	80	N/A	60%	N/A	60	N/A	85	N/A	70	N/A	98	N/A	74	Apply solutions adopted from other systems			71
	Trend & future of WMI and the mining industry	Seek technology system that may applicable for the future of WMI and mining industry	Y	100	N/A	80	N/A	60%	N/A	50	N/A	90	N/A	60	N/A	98	N/A	89	Artificial intelligence and internet of things			71
		Clarify differentiation between WMI's vision/strategy and mining industry's future	Y	100	N/A	75	N/A	0.6	N/A	40	N/A	50	N/A	50	N/A	100	N/A	64	Multi-disciplinary collaboration focused research			60

67

66

67

Overall average	63
Overall risk scale	High (12)

Table 3

Blueprint contents				Checklist																	
				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I	
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed (Y or N)	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks

Main-task	Sub-task	Activity	Performed (Y or N)	Person A Compliance (%)	Person A Remarks	Person B Compliance (%)	Person B Remarks	Person C Compliance (%)	Person C Remarks	Person D Compliance (%)	Person D Remarks	Person E Compliance (%)	Person E Remarks	Person F Compliance (%)	Person F Remarks	Person G Compliance (%)	Person G Remarks	Person H Compliance (%)	Person H Remarks	Person I Compliance (%)	Person I Remarks	Average compliance of each activity
1.1.3																						
WMI's expectations on the new technology system	1.1.3.1 Expected improvement on current technology systems' functionality at WMI	Clarify WMI's expected improvement in terms of planned budget, cost, functionality etc.	Y	90	N/A	75	N/A	80	N/A	100	N/A	50	N/A	60		30	I only clarified functionality	82	Plans for improvements outlined in system document			71
		Clarify possible impact caused by Schauenburg MIMACS system on other existing technology systems installed at WMI	Y	80	N/A	10	We did not enough to understand this, resulting in significant compatability and functionality problems	80	N/A	20	From communication perspective there is the issue of interference which I think needs addressing	70	N/A	50	Including ICT	80	Work still in progress	90	Details in system document			60
		Clarify timeframe for transition, adoption and integration for Schauenburg MIMACS system	Y	80	N/A	5	It took much, much longer than what was expected. In fact, two years to reach adequate functionality	50	N/A	100	This I believe was done to perfection at WMI but lacked commitment from the vendor	65	N/A	40	A good option is to make a project implementation plan in coordination with system vendor and implement it as per the plan	0	N/A	40	Delays are common due involvement of many parties			48
		Clarify WMI's employee skills deficiency (compare to the required capacity of skills in 1.1.2.1)	Y	80	N/A	10	Our skills turned out to be inadequate, despite 'high'	90	Proper training sessions were arranged for WMI students	80	N/A	85	N/A			98	N/A	92	Contracts set out minimum requirement			76
																						64
	1.1.3.2 Minimum & maximum functionality of the Schauenburg MIMACS system against WMI's expectations	Clarify minimum & maximum capacity of Schauenburg MIMACS system required for WMI to be satisfied	Y	50	We only came to know these after adoption	10	It took too long to get adequate functionality	80	N/A	100	WMI provided these but I am not sure if the vendor delivered	70	N/A	60	Bandwidth/ space/ memory capacity must also be included.	98	N/A	90	Described in system document			70
		Check redundancy created by the maximum capacity of Schauenburg MIMACS system based on the WMI requirement	Y	50	Never worked on its max. capacity	0	Not considered	80	N/A	0	N/A	45	N/A	50	N/A	98	N/A	35	Evaluating integration requirements			45
		Clarify extra budget required for Schauenburg MIMACS system upgrading to achieve the maximum capacity	N	0	N/A	0	These came as 'surprises' of necessary expense on the road to functionality	0	Cannot comment	0	N/A	5	N/A	30	N/A	0	N/A	92	Obtain quotations from another vendor			16
																						43
	1.1.3.3	Clarify WMI's expectation on the improvement after the Schauenburg MIMACS system is installed	N	0	N/A	60	We had to commission several improvements to make the system work	80%	N/A	100	N/A	55	N/A	50	Exact TORs must be set at the outset of the project.	100	N/A	85	Described in system document			56
	WMI's expectations on the outcome of adoption of Schauenburg MIMACS system	Clarify the method for measuring the improvement after Schauenburg MIMACS system is installed	Y	60	N/A	40	Reliability and continuity of system performance	75%	N/A	100	I believe as we were using the system shortfalls were identified and communicated	45	N/A	60	N/A	0	N/A	86	Continuous systems operation check			49
		Check possible future upgrade and integration for Schauenburg MIMACS system (e.g. real-time decision and alert)	Y	50	N/A	60	By means of a workshop. Must still be actioned	80%	N/A	100	This will require integration with other systems	80	N/A	50	N/A	60	In progress	96	Discussions with vendor partners for integration options			62
																						56

Overall compliance	55
Overall risk scale	Extreme (20)

Table 4

				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
Blueprint contents			Checklist																			
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed (Y or N)	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Average compliance of each activity

	1.2.1.1	WMI check the general practice to acquire a technology system in the mining industry	Y	90	N/A	50	N/A	70	N/A	40	N/A	95	N/A	70	N/A	90	N/A	95	Partnership with vendors are structured similarly to industry agreements			75	
	Channel to acquire MIMACS system	WMI evaluate the possible channel to acquire a technology system from local supplier, OEM, or vendor (e.g. where to acquire Schauenburg MIMACS system?)	Y	100	N/A	70	N/A	50	N/A	30	N/A	95	N/A	60	N/A	90	N/A	92	Supplier contacts outlined in system documents			73	74
	1.2.1.2	Ensure WMI sets 'invitation for bids' and arranges meetings between WMI and Schauenburg. WMI present all the requirements and expectations to Schauenburg	Y	80	N/A	60	N/A	40	N/A	50	On the part of invitation for bids I am not sure if this process was followed but I do know that meetings were arranged after the fact	88	N/A	80	N/A	80	N/A	82	Regular meetings take place between WMI and Schauenburg			70	
1.2.1	Information / documents exchange between WMI and Schauenburg	Ensure WMI presents WMI's problem statement and expectations to Schauenburg	Y	80	N/A	50	N/A	60	N/A	60	N/A	90	N/A	50	N/A	70	N/A	87	Regular communication, documentation and meetings			68	
WMI gather information on Schauenburg and the MIMACS system		WMI receive detailed background information on Schauenburg and their available technology systems	Y	90	N/A	50	N/A	50	N/A	40	To the best of my knowledge, I am only aware of the information being presented after the adoption	95	N/A	70	N/A	60	N/A	89	Through contact with company, websites and events			68	
		Schauenburg provides detailed information to WMI: Marketability, commercialization, availability in the region, precedent successful adoption cases, etc.	Y	90	N/A	70	N/A	40	N/A	50	This is rated for post-adoption	82	N/A	80	N/A	50	N/A	68	Presentations at WMI events			66	
		WMI receive detailed technical documents about the functionality, specification, configuration, system compatibility, total cost with unit price and adoption requirement for infrastructure (versus WMI's capacity) of the Schauenburg MIMACS system	Y	70	This is now being considered	60	N/A	50	N/A	40	On the costing I do believe that the presented figures could be heavily biased due to company marketing strategies	100	N/A	80	N/A	70	N/A	92	Information provided by Schauenburg			70	
		Refer to WMI's general contents for vendor's supporting documents	Y	80	N/A	80	N/A	30	N/A	0	N/A	100	N/A	80	N/A	80	N/A	95	Duties of system champion			68	69
	1.2.1.3	Ensure Schauenburg provide detailed description and demonstrate the functionality of the technology system	Y	80	N/A	50	N/A	50	N/A	50	Demos were presented to WMI	95	N/A	60	N/A	90	N/A	98	Information provided			72	
	Information required by WMI for assessing Schauenburg's capability and technology systems functionality	Schauenburg provides all the documents for infrastructure upgrade required by the adoption project (both software and hardware)	Y	50	The documentation came with the passage of time	60	N/A	40	N/A	40	I am not sure if these were provided	100	N/A	50	N/A	70	N/A	82	All software and hardware specifications provided with each upgrade			62	
		Schauenburg provide full list of equipment required for adoption, include description of all equipment, working principle of all instruments, detailed system architecture and data flow	Y	50	The documentation came with the passage of time	60	N/A	30	N/A	100	N/A	100	N/A	70	N/A	80	N/A	89	Information provided			72	

		Schauenburg provide detailed requirement for system integration between the Schauenburg MIMACS system and the existing technology systems installed at WMI	Y	50	N/A	50	N/A	40	N/A	0	N/A	50	N/A	0	N/A	0	N/A	78	Integration only covers communications backbone and Vuma 3D-live			34
		Schauenburg provide detailed plan for the add on functionality (e.g. real time alert and notifications)	Y	0	N/A	30	N/A	0	N/A	0	N/A	80	N/A	0	N/A	0	N/A	86	Information available in manuals			25
		Schauenburg provide emergency procedures (e.g. auto-restart function in power outage)	Y	0	N/A	0	N/A	0	N/A	0	N/A	50	N/A	0	N/A	0	N/A	97	Scripting code developed for this purpose			18
		Schauenburg provide after-sale support documents and plan	Y	0	N/A	0	N/A	0	N/A	0	N/A	85	N/A	0	N/A	0	N/A	87	Documents and technical serviced provided by Schauenburg			22
		Schauenburg provide comprehensive quotation (include cost of all services)	Y	0	N/A	0	N/A	0	N/A	O	N/A	100	N/A	0	N/A	0	N/A	76	Cost provided with contact			25
		WMI check receipt of all information received and sent to Schauenburg	Y	0	N/A	0	N/A	0	N/A	0	N/A	100	N/A	0	N/A	0	N/A	82	Detailed asset record kept and digitally and in hard copy			23

39

Average compliance	54
Risk scale	Extreme (20)

Table-5

Blueprint contents				Person A		Person B		Person C		Person D		Person E (Checklist)		Person F		Person G		Person H		Person I		Average compliance of every activity
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed (Y or N)	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	
1.2.2																						
Assessment and selection procedures for MIMACS system	1.2.2.1	WMI to assess other potential vendor's technology systems with similar functionality to MIMACS system for competitive reference	Y	90	N/A	70	N/A	80	N/A	0	N/A	50	N/A	70	N/A	90	N/A	80	Ramjack and Mintec have similar functionality and are being assessed for competitiveness			66
	Procedures for assessing Schauenburg MIMACS system	Ensure WMI assess the MIMACS-provided documents against WMI's capacity and expectations, WMI need to conduct the following four assessments			N/A	60	N/A	0	N/A	0	N/A	90	N/A	70	N/A	90	N/A	86	Updates system documents			57
		1. MIMACS system's functionality versus problems stated in WMI's problem statement	Y	100	N/A	50	N/A	70	N/A	100	N/A	80	N/A	60	N/A	90	N/A	82	Updates system documents			79
		2. MIMACS system requirement for adoption versus WMI's capacity	Y	100	N/A	60	N/A	80	N/A	70	I think there were many issues related to ICT infrastructure that were of concern on WMI's capacity	80	N/A	80	N/A	90	N/A	84	Updates system documents			81
		3. MIMACS system's total cost versus WMI planned budget	Y	100	N/A	70	N/A	70	N/A		N/A	90	N/A	60	N/A	100	N/A	32	Contract agreement in Schauenburg file			75
		4. MIMACS system's property versus WMI vision, culture and business model	Y	90	N/A	50	N/A	80	N/A	80	I think the two aligned very well to some degree	95	N/A	80	N/A	100	N/A	87	Updates system documents - exit strategy			83
		WMI review the outcome of these assessments, (review the overall performance of the Schauenburg MIMACS system)	Y	100	N/A	80	N/A	90	N/A	70	N/A	50	N/A	70	N/A	90	N/A	86	Updates system documents			80

74

				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I			
	1.2.2.2	Ensure MIMACS system meets WMI's vision, organizational culture and business model and most likely will be successfully installed and achieve continuous functionality	Y	50	N/A	70	N/A	60	N/A	0	N/A	90	N/A	70	N/A	80	N/A	76	Constant contact with vendor and university support, training			62	
	Criteria for final assessing the Schauenburg MIMACS system	Clarify MIMACS's future upgradability with different platform	N		N/A	0	N/A	0	N/A	0	N/A	50	N/A	30	N/A	80	N/A	72	Evaluate possibility of integrating useful functionality			33	
		Ensure WMI makes final decision based on the documents and the outcome of the assessments mentioned above	Y	80	N/A	80	N/A	90	N/A	0	N/A	60	N/A	70	N/A	70	N/A	71	System updates discussed in weekly meeting and decided upon			65	53

Overall compliance	68
Overall risk scale	Very high (15)

Table-6

Blueprint contents			Checklist	Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		Average compliance of each activity	
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed (Y or N)	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks		
2.1.1 Agreements drafting between WMI and Schauenburg	2.1.1.1 Drafting constitutional agreement for all system adoption at WMI (e.g. Wits agreement used)	Develop and implement WMI's constitutional agreement (E.g. WMI vendor system adoption agreement)	Y	50	N/A			0	Not aware cannot comment, I think this was not done	80	N/A	100	N/A	90	N/A	0	N/A	60	N/A	60	N/A	55	
		Ensure all the legal documents drafted are referred to WMI's constitutional agreement (refer to the Wits/vendor's	Y	0	N/A			100	I am sure this was done	0	N/A	80	N/A	0	N/A	0	N/A	0	N/A	0	N/A	23	39
	2.1.1.2	WMI and Schauenburg clarify ownership of the data generated by the MIMACS system	Y	100	N/A			80	N/A	80	N/A	100	N/A	70	N/A	90	N/A	60	N/A	80	N/A	83	
	Drafting intellectual property agreement between WMI and Schauenburg	WMI Clarify collection, transfer and storage of data generated	Y	100	N/A			80	N/A	90	N/A	90	N/A	60	N/A	90	N/A	50	N/A	90	N/A	81	
		WMI clarify the utilization of data generated (i.e. analysis, research purpose)	Y	100	N/A			90	N/A	90	N/A	90	N/A	80	N/A	90	N/A	70	N/A	70	N/A	85	
		Schauenburg ensures the security of data generated (e.g. cyber security, access control to server, etc.)	Y	90	N/A			0	N/A	80	N/A	75	N/A	90	N/A	0	N/A	80	N/A	80	N/A	62	78
	2.1.1.3 Drafting purchase agreement between WMI and Schauenburg	WMI and Schauenburg develop detailed agreement for purchasing goods, equipment, material and labor, all the required items for the adoption		0	N/A			80	I am not 100% sure whether it was in writing or not, but Schauenburg almost always	0	N/A	100	N/A	0	N/A	90	N/A	0	N/A	0	N/A	34	
		WMI and Schauenburg draft logistics arrangement for transport goods, equipment and material	Y	100	N/A			0	took care of these aspects. They were slow at times.	90	N/A	100	N/A	80	N/A	0	N/A	70	N/A	70	N/A	64	49
	2.1.1.4	WMI and Schauenburg clarify the expected outcome of the adoption and system functionality	Y	80	N/A			90	N/A	70	N/A	95	N/A	90	N/A	80	N/A	60	N/A	70	N/A	79	
	Agreement of mutual acknowledgement on system functionality	Schauenburg clarify on the limitation of the MIMACS II system	Y	50	N/A			50	N/A	0	N/A	0		0	N/A	0	N/A	0	N/A	0	N/A	13	46

Overall compliance	58
Overall risk scale	Extreme (20)

Table-7

Blueprint contents			Checklist	Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		Average compliance of each activity
Main-task	Sub-task	Activities	Activities performed	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	Compliance (%)	Remarks	
2.1.2 Contracts drafting for the adoption	2.1.2.1 Drafting contracts	WMI develop project plan for both preparation and adoption work (e.g. project schedule and budget)	Y	80	N/A			70	N/A	70	N/A	50	N/A	50	N/A	90	N/A	70	N/A	50	N/A	66
		WMI Clarify pricing, payment and labor arrangement for the adoption (e.g. import tax)	Y	80	N/A			80	N/A	60	N/A	50	N/A	60	N/A	90	N/A	80	N/A	0	N/A	63
		Schauenburg develop the plan for overall system integration after adoption	Y	70	N/A			30	Not sure about this, but Schauenburg never gave this plan	70	N/A		N/A	50	N/A	0	N/A	0	N/A	0	N/A	31
		WMI and Schauenburg clarify deliverable outcome and achievable functionality after the adoption	Y	70	N/A			30	There was always a confusion, and non-clarity on this	60	N/A	100	N/A	60	N/A	90	N/A	70	N/A	50	N/A	66
		Schauenburg develop detailed plan for after-sales services required for maintaining the functionality of MIMACS system	Y	80	N/A			0	Not sure, but we struggled for a while to get Schauenburg back to us for maintenance	70	N/A	80	N/A	70	N/A	90	N/A	60	N/A	0	N/A	56

Overall compliance	57
Overall risk scale	Extreme (20)

Table-8

Blueprint contents			Checklist	Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		Average compliance of each avtivity
Main-task	Sub-task	Activities	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	
2.2.1 Documents required maintaining a functional system	2.2.1.1 System operation	Schauenburg develop System architecture with data flow	Y	50	N/A			90	N/A	80	N/A	100	N/A	100	N/A	80	N/A	60	N/A	80	N/A	80
		WMI ensure Schauenburg apply SOP (Standard Operation Procedures) for all the activities during adoption	Y	50	N/A			60	To some extent	60	N/A	0	N/A	0	N/A	90	N/A	0	N/A	90	N/A	44
		Schauenburg implement health and safety measurements	Y	80	N/A			0	Not sure	0	N/A	50	N/A	50	N/A	0	N/A	0	N/A	0	N/A	23
		Schauenburg produce a list of all possible sub-contractors	N	0	N/A			0	Not sure	50	N/A	0	N/A	0	N/A	50	N/A	40	N/A	50	N/A	24
	2.2.1.2 After-sales support	Schauenburg clarify system update & upgrade (include both hardware and software)	N	0	N/A			50	Only after our enquiry	60	N/A	90	N/A	70	N/A	90	N/A	50	N/A	90	N/A	63
		Schauenburg ensure system debug & system functionality recovery during system malfunction	N	0	N/A			50	It was a struggle on some days	50	N/A	50	N/A	0	N/A	90	N/A	50	N/A	90	N/A	48
		Schauenburg develop system maintenance plan and schedule	N	0	N/A			0	Not sure, but they did come for repairs when requested (sometimes after some	0	N/A	0	N/A	0	N/A	50	N/A	0	N/A	50	N/A	13
		WMI and Schauenburg create reporting system for better communications	N	0	N/A			20		50	N/A	45	N/A	0	N/A	50	N/A	50	N/A	50	N/A	33

43

39

Overall compliance	41
Overall risk scale	Extreme (20)

Table-9

Blueprint contents			Checklist	Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
Main-task	Sub-task	Activities	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Average compliance

2.2.2 Schauenburg prepare the System requirement documents for the installation (Cawood, 2017	2.2.2.1	Schauenburg provide system description to WMI	Y	90	N/A			60	N/A	80	N/A	100	N/A	100	N/A	80	N/A	60	N/A	50	N/A	78
		Schauenburg provide list of required system items to WMI	Y	50	N/A			60	To some extent	60	N/A	80	N/A	100	N/A	60	N/A	50	N/A	40	N/A	63
	Contents of key topics in each document	Schauenburg provide enabling elements required for installation to WMI (include both software and hardware)	Y	50	N/A			60	Not sure	0	N/A	90	N/A	100	N/A	70	N/A	60	N/A	70	N/A	63
		Schauenburg and WMI to meet to get clarity on everything and get feedbacks on the topics gathered above	Y	70	N/A			80	Not sure	50	N/A	100	N/A	100	N/A	50	N/A	70	N/A	50	N/A	71

Overall compliance	68
Overall risk scale	Extreme (20)

Table-10

Blueprint contents				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
				Checklist																		
Main-task	Sub-task	Activities	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Average compliance
2.2.1																						
2.2.3 Schauenburg provide requirement for infrastructure upgrade to WMI	2.2.3.1	WMI need to plan/execute in advance for civils work preparation (construction, logistics, etc.), as it is time consuming.	Y	100	Compliance from WMI was 100%			90	N/A	70	N/A	90	N/A	70	N/A	90	N/A	60	N/A	70	N/A	80
	WMI prepare civils work, hardware	WMI need to use holistic approach for the design of the civils work to avoid influence to other systems, (e.g. antenna signal interference)	Y	100	Compliance from WMI was 100%			90	N/A	60	N/A	80	N/A	80	N/A	90	Network infrastructure is managed by wits	0	N/A	60	N/A	70
	2.2.3.2 WMI prepare network, communication system, software and ICT system	WMI ensure sufficient network and I.T. system capability to support the installation (e.g. bandwidth, storage capacity, computing power and number of servers, etc.)	N	70	N/A			70	Except for the integration of the RFID with the university system	60	N/A	60	N/A	90	N/A	80	Network infrastructure is managed by wits CNS. The system operates with the provision by CNS	50	N/A	50	N/A	66

Overall compliance	72
Overall risk scale	Extreme (20)

Table-11

Blueprint contents				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
				Checklist																		
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Average compliance
2.3.1																						
	2.3.1.1 WMI appoint system champion to supervise the progress of the installation	WMI appoint system champion: People who oversee the entire the installation project	Y	100	N/A			80	N/A	60	N/A	80	N/A	90	N/A	90	N/A	80	N/A	50	N/A	79
		WMI system champion required to have general understanding of the technology system, and preferably to be involved from the initial stage of the identification/selection	Y	90	N/A			70	N/A	50	N/A	70	N/A	70	N/A	80	N/A	70	N/A	40	N/A	68
		WMI system champion responsible for communication/liaison with the vendors on behalf of the entity	Y	100	N/A			70	N/A	60	N/A	60	N/A	80	N/A	90	N/A	60	N/A	60	N/A	70
	2.3.1.2	WMI system champion ensure the implementation and execution of all legal documents	Y	100	N/A			80	N/A	60	N/A	0	N/A	70	N/A	0	N/A	0	N/A	0	N/A	39

72

WMI practice project management for Schauenburg MIMACS system installation	WMI system champion supervise the installation project	WMI system champion monitor the implementation/ execution of all the agreements and contracts in different phases	Y	100	N/A			80	N/A	50	N/A	0	N/A	70	N/A	0	N/A	0	N/A	0	N/A	38
		WMI system champion monitor the quality of implementation/ execution of the documenting and reporting	Y	100	N/A			75	N/A	60	N/A	50	N/A	80	N/A	60	N/A	50	N/A	60	N/A	67
		WMI system champion adhere to all the regulations, standards, COP during installation, such as wiring standards, emergency procedures and health and safety act, etc.	Y	80	N/A			60	N/A	70	N/A	40	N/A	80	N/A	85	N/A	60	N/A	50	N/A	66
		WMI system champion ensure the requirement of infrastructure upgrade is in place and is sufficient to accommodate the requirement of	Y	50	N/A			60	N/A	70	N/A	40	N/A	80	N/A	70	N/A	50	N/A	50	N/A	59
	2.3.1.3	Initiation and planning	Y	100	N/A			60	N/A	70	N/A	0	N/A	80	N/A	0	N/A	0	N/A	0	N/A	39
	WMI system champion apply actions to managing all the resources for each phase of the installation	Execution of the plan	Y	80	N/A			60	N/A	50	N/A	0	N/A	90	N/A	0	N/A	0	N/A	0	N/A	35
		Installation project monitoring and control	Y	100	N/A			60	N/A	60	N/A	70	N/A	80	N/A	80	N/A	70	N/A	60	N/A	73
		Installation project completion and closing	Y	80	N/A			60	N/A	70	N/A	60	N/A	80	N/A	70	N/A	60	N/A	70	N/A	69

54

54

Overall average	58
Overall risk scale	Extreme (20)

Table-12

Blueprint contents				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
				Checklist																		
Main-task to perfrom	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Average compliance
2.3.2 WMI's focusing areas for budget control during installation	2.3.2.1 Labour	WMI system champion ensure arrangement of labor during installation needs to follow the labor agreement drafted in 2.1.1.1	Y	0	Labour (either from Schauenburg or WMI) was arranged			0	N/A	0	N/A	0	N/A	0	N/A	20	N/A	20	N/A	0	N/A	5
									N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	2.3.2.2 Material	WMI system champion ensure purchase of material for installation should strictly follow the purchase agreement signed in 2.1.1.1	Y	0	N/A			0	N/A	30	N/A	0	N/A	0	N/A	0	N/A	0	N/A	30	N/A	8
									N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	2.3.2.3 Logistics	WMI system champion ensure requirement for logistics be done according to the guidance written by vendors in logistics agreement in 2.1.1.1	Y	0	N/A			0	N/A	0	N/A	0	N/A	0	N/A	30	N/A	0	N/A	0	N/A	4
									N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	2.3.2.4 Hardware and software	WMI system champion ensure hardware and software purchase: Strictly implement the purchase agreement in 2.1.1.3 and only approved items should be purchased	Y	0	N/A			20	N/A	0	N/A	0	N/A	40	N/A	0	N/A	20	N/A	30	N/A	14
		WMI system champion ensure hardware and software upgrade: based on the assessment of the existing hardware and software before go for upgrade	N	50	Upgrades came later on.			60	N/A	50	N/A	90	N/A	90	N/A	70	N/A	80	N/A	50	N/A	68

41

Overall average	20
Overall risk scale	Extreme (20)

Table-13

Blueprint contents				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
				Checklist																		
Main-task to perform	Sub-task to perform	Activities that need to be performed by the system champion/WMI	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Average compliance
2.3.3																						

WMI create communication mechanism between WMI and Schauenburg	2.3.3.1 Support & cooperation between WMI and Schauenburg	Multiple channels for efficient communication, documenting and reporting between WMI system champion and Schauenburg for the life of the MIMACS II system	Y	100	N/A			80	N/A	70	N/A	80	N/A	70	N/A	80	N/A	80	N/A	70	N/A	79
		WMI system champion and Schauenburg support/cooperate with each other during the installation	Y	100	N/A			90	N/A	60	N/A	70	N/A	80	N/A	70	N/A	70	N/A	80	N/A	78
		Sufficient communications between system champion and Schauenburg on progress and feedback during the installation	Y	100	N/A			100	N/A	70	N/A	60	N/A	60	N/A	60	N/A	60	N/A	60	N/A	71

Overall average	75
Overall risk scale	Extreme (20)

76

Table-14

Main-task	Sub-task	Activities that need to be performed by the system champion/WMI	Activities performed	Person A Compliance	Person A Remarks	Person B Compliance	Person B Remarks	Person C Compliance	Person C Remarks	Person D Compliance	Person D Remarks	Person E Compliance	Person E Remarks	Person F Compliance	Person F Remarks	Person G Compliance	Person G Remarks	Person H Compliance	Person H Remarks	Person I Compliance	Person I Remarks	Average compliance
3.1.1 System calibration after installation	3.1.1.1 System calibration	Schauenburg calibrate all the hardware such as sensors, equipment and devices to their required specifications, especially the sensors and measuring instruments	Y	60	Calibration was carried out late after the installation			70	N/A	70	N/A	25	N/A	60	N/A	40	N/A	0	N/A	0	N/A	41
		WMI system champion ensure the setting of all software matches the hardware and software and receive correct and sufficient data from the hardware	Y	90				50	N/A	65	N/A	55	N/A	50	N/A	15	N/A	30	N/A	50	N/A	51
	3.1.1.2 Certification of calibration	WMI system champion obtain calibration certificates for the overall system	Y	90	Late after the installation			40	N/A	45	N/A	50	N/A	70	N/A	20	N/A	40	N/A	60	N/A	52
		WMI system champion documenting all the record for calibration and update the certificates accordingly	Y	90				55	N/A	65	N/A	40	N/A	55	N/A	0	N/A	50	N/A	50	N/A	51

46

Overall average	48
Overall risk scale	Extreme (20)

51

Table-15

Main-task	Sub-task	Activities that need to be performed by the system champion/WMI	Activities performed	Person A Compliance	Person A Remarks	Person B Compliance	Person B Remarks	Person C Compliance	Person C Remarks	Person D Compliance	Person D Remarks	Person E Compliance	Person E Remarks	Person F Compliance	Person F Remarks	Person G Compliance	Person G Remarks	Person H Compliance	Person H Remarks	Person I Compliance	Person I Remarks	Average compliance
3.1.2 System testing after installation	3.1.2.1 System functionality testing	WMI and Schauenburg perform testing on individual and overall system functionality against the claimed functionality stated in the contract in main-task 2.1.2	Y	80	N/A			50	N/A	55	N/A	70	N/A	50	N/A	70	N/A	0	N/A	45	N/A	53
	3.1.2.2 System malfunction testing	WMI system champion recognize and record the system malfunction	Y	50	Malfunction is recognized but not formally recorded			70	N/A	70	N/A	65	N/A	60	N/A	60	N/A	70	N/A	0	N/A	56
		Schauenburg identify the major cause of system malfunction	Y	80	N/A			45	N/A	60	N/A	50	N/A	70	N/A	55	N/A	60	N/A	60	N/A	60
		Schauenburg identify any disruption to continuous functionality of the MIMACS II system during testing	Y	50	N/A			60	N/A	45	N/A	80	N/A	65	N/A	40	N/A	0	N/A	70	N/A	51
		Schauenburg debug and make corrections; WMI system champion documents all the findings	Not sure if it was formally written		N/A			55	N/A	75	N/A	75	N/A	70	N/A	0	N/A	50	N/A	30	N/A	51

53

Overall average	54
Overall risk scale	Extreme (20)

54

Table-16

Main-task	Sub-task	Activities that need to be performed by the system champion/WMI	Activities performed	Person A Compliance	Person A Remarks	Person B Compliance	Person B Remarks	Person C Compliance	Person C Remarks	Person D Compliance	Person D Remarks	Person E Compliance	Person E Remarks	Person F Compliance	Person F Remarks	Person G Compliance	Person G Remarks	Person H Compliance	Person H Remarks	Person I Compliance	Person I Remarks	Average compliance
3.1.3																						

Main-task	Sub-task	Activities that need to be performed by the system champion/WMI	Activities performed	Person A Compliance	Person A Remarks	Person B Compliance	Person B Remarks	Person C Compliance	Person C Remarks	Person D Compliance	Person D Remarks	Person E Compliance	Person E Remarks	Person F Compliance	Person F Remarks	Person G Compliance	Person G Remarks	Person H Compliance	Person H Remarks	Person I Compliance	Person I Remarks	Average compliance
System integration after installation	3.1.3.1	Schauenburg perform system compatibility test between newly installed technology system and the existing technology system installed at WMI	Y	0	N/A			50	N/A	30	N/A	0	N/A	0	N/A	10	N/A	30	N/A	50	N/A	21
	Apply appropriate integration method	WMI system champion identify and apply the appropriate integration method to integrate all the sub-systems in WMI according to their functionalities	Y	0	N/A			60	N/A	50	N/A	0	N/A	0	N/A	25	N/A	30	N/A	40	N/A	26

Overall average	23		
Overall risk scale		Extreme (20)	

Table-17

				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
Blueprint contents			Checklist																			
Main-task	Sub-task	Activities that need to be performed by the system champion/WMI	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Average compliance
3.2.1 Services required for continuous operation after installation	3.2.1.1 Activities required to maintain continuous system functionality	Schauenburg perform system maintenance & system debug	Y	70	N/A			50	N/A	30	N/A	60	N/A	70	N/A	60	N/A	0	N/A	0	N/A	43
		Schauenburg develop emergency procedures for system functionality recovery after system malfunction	Y	50	N/A			70	N/A	50	N/A	50	N/A	0	N/A	70	N/A	20	N/A	30	N/A	43
		WMI and Schauenburg perform regular system upgrade and update	Y	80	N/A			45	N/A	45	N/A	40	N/A	30	N/A	40	N/A	50	N/A	40	N/A	46
		WMI and Schauenburg create documenting & reporting system between entity and	N		N/A			55	N/A	50	N/A	30	N/A	40	N/A	50	N/A	40	N/A	50	N/A	45

Overall average	44
Overall risk scale	Extreme (20)

Table-18

				Person A		Person B		Person C		Person D		Person E		Person F		Person G		Person H		Person I		
Blueprint contents			Checklist																			
Main-task	Sub-task	Activities that need to be performed by the system champion/WMI	Activities performed	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Compliance	Remarks	Average compliance
3.2.2 Exit strategy	3.2.2.1 WMI conduct an assessment to review the performance of the technology system	Outcome of the assessment needs to answer following two questions:			N/A																	
		Did the performance of the technology system meet WMI's expectations?	Y	40				50	N/A	45	N/A	60	N/A	50	N/A	60	N/A	50	§	50	N/A	51
		Did the technology system address the problem faced?	Y	60	N/A			50	N/A	60	N/A	60	N/A	50	N/A	50	N/A	60	N/A	60	N/A	56
		Based on the personal experience and knowledge, System champion provide recommendations to WMI for the way forward: Either further the cooperation or terminate the contract	Y	99	N/A			50	N/A	50	N/A	70	N/A	30	N/A	50	N/A	50	N/A	80	N/A	60

Overall average	55
Overall risk scale	Extreme (20)