MANDELA MINING PRECINCT
MINDS FOR MINES

Modernisation:
Kolomela Case Study

science & innovation
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MINERALS COUNCIL
SOUTH AFRICA

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About the Mandela Mining Precinct

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The Mandela Mining Precinct is a Public-Private Partnership between the Department of Science and Innovation and the Minerals Council South Africa. The Precinct is jointly hosted by the Council for Scientific and Industrial Research and the Minerals Council. The Mandela Mining Precinct is an initiative aimed at revitalising mining research, development and Innovation in South Africa to ensure the sustainability of the industry. This is achieved through the South African Mining Extraction, Research, Development and Innovation (SAMERDI) strategy.

The strategy comprises six research programmes:

1. Longevity of Current Mining;
2. Mechanised Mining Systems;
3. Advanced Orebody Knowledge;
4. Real-Time Information Management Systems;
5. Successful Application of Technologies Centred Around People; and
6. Test Mine.

This guideline was developed under the Successful Application of Technologies Centred Around People (SATCAP) research programme. The programme is aimed at understanding how both specific and general challenges relating to people in the mining modernization process can be understood from all stakeholder perspectives.

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Executive Summary

The SAMERDI SATCAP project: *Modernisation Case Study at Kolomela Mine* develops a deeper understanding of the key people-related factors that affect the success or failure of modernisation initiatives. The project was conducted concurrently with the project Three Case Studies on Historical Modernisation Effects and Management Measures. These projects examined people- related and broader factors in modernisation from different perspectives.

An in-depth study of modernisation initiatives at a Kolomela mine was undertaken. In contrast to the aforementioned study, where the focus was on individual projects in different mining modernisation contexts, this in-depth analysis afforded the opportunity to interrogate a single company context within which modernisation takes place, and to focus on the people-related enablers and disablers in this context.

The work was conducted at an open cast iron ore mine, where both the iron ore subsidiary and the holding company have a clearly defined the modernisation focus and strategy. The study examined three modernisation projects of technology introduction in the mining and processing environments. The projects included autonomous drilling, advanced process control, and introduction of a mining information system (MIS). All projects were considered successful by the company; they were in progress for over three years and were nearing completion (that is; stable operations) at the time of the study.

This selection of projects provided a broad basis for the examination of the status of, and approach to, modernisation within this context. While project-level interviews were conducted with employees from the management, planning, implementation, and user perspectives, a significant focus was placed on the broader organisational context. Brief analyses of projects were conducted to develop an understanding of critical people-related factors, while discussions with managers facilitated interpretation of the organisational context and enhancement of the systems model and index of people-related factors.

Key factors that constitute a mine that is capable of successful modernisation were identified for enhancement of the systems model. These characteristics were derived from interviews across the case studies, and reflect the primary, secondary, and tertiary people-related factors of the systems model.

The systems model, as well as the people-related factors that comprise each of its dimensions, were derived through the work described in this document: (1) From an enterprise perspective, the strategy, structure, processes, and practice need to be conducive to modernisation; (2) From a people perspective,

education, skills, mindsets, experience and networks need to be appropriate to the demands of a modernised environment; and (3) The technology needs to be supported by appropriate R&D, maintenance, and supply chains. Similar requirements are defined at the various interfaces (overlaps) between people, technology, and enterprise. (4) Finally, to make the modernisation process work, consultation needs to be early and inclusive, and integrative design processes are required to ensure successful integration after the design period.

This report constitutes the final project deliverable. The document summarises the combined deliverables across the two SATCAP projects (namely; WP 2: *Three case studies on modernisation* and WP 2.7: *Modernisation case study at Kolomela mine*). These include a revised systems model of mining modernisation, a revised definition of modernisation from a resilience perspective, an updated index of people-related factors, proposed decision tools at the sector and company level to enhancemodernisation, and recommended next steps regarding a portfolio of research undertakings for people factors of mining modernisation.

The study has reflected a shift in focus from people-related factors as focusing on human-technology interaction towards a more holistic approach to modernisation. The implication being that the modernisation approach needs to consider enterprise, technology, and people-related perspectives, and the interfaces and integration thereof. Modernisation initiatives would be effective and sustainable if they form part of an overall holistic and strategic approach to modernisation (beyond change management), and that a long-term systemic focus is needed.

The results from this study offer valuable learnings which become important for modernisation in mining in the minerals sector. SAMERDI SATCAP 2019/2020 research work on the full modernisation impact assessment will use this study as a base, to further build onto these findings and validate them so as to be able to offer guidance in the approach to modernisation to the mining sector.

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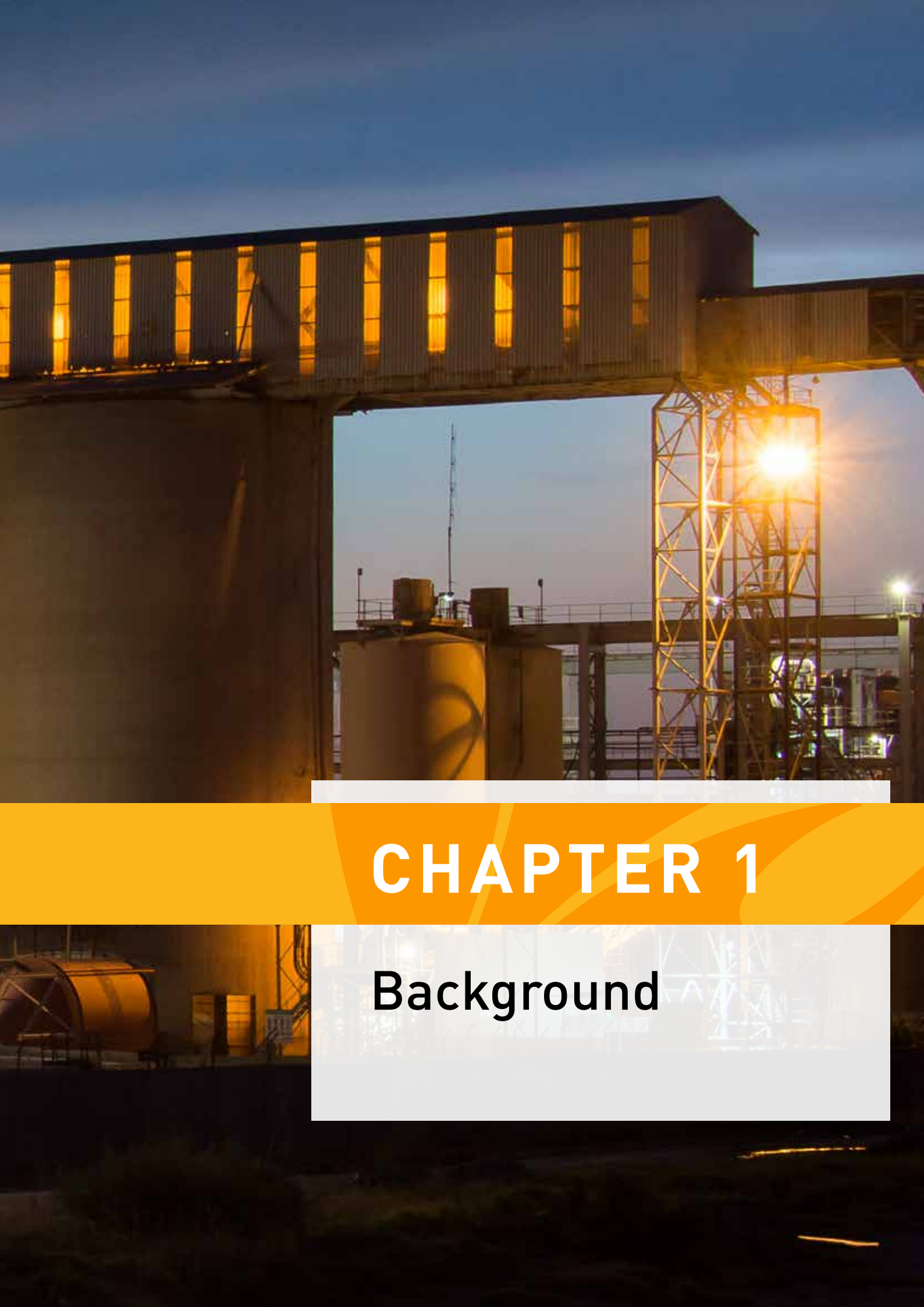
Definitions and Abbreviations

APC	Advanced Process Control
Decision framework	A structure that guides decision makers in focusing on appropriate aspects when making decisions.
Design science research	A study of the way in which objects or systems are designed and improved. Research results are often developed through multiple study iterations.
DMRE	Department of Mineral Resources and Energy
Mining modernisation framework	A structure that explains people-related factors in mining modernisation. It includes a decision framework and a systems model.
MIOC unit	Mining Information Operations Control unit
MIS	Mine Information System/ Management information System
MOSH	Mine Occupation Safety and Health
OEM	Original Equipment Manufacturer
Systems model (for mining modernisation)	A model that explains how key interactions in mining highlight the people factors that are relevant in mining modernisation.
Themes / sub-themes (dimensions)	A categorisation of the people-related factors that are important in mining modernisation. These themes and sub-themes (dimensions) form the decision framework.
WP 2.2	SAMERDI SATCAP Project: Three case studies on historical modernisation effects and management measures.
WP 2.7	SAMERDI SATCAP Project: In-depth case study of a recently implemented modernisation process at Kolomela mine (this project).



CHAPTER 1

Background

The SAMERDI SATCAP project: *Modernisation Case Study at Kolomela Mine* (WP 2.7) aims to:
"explore and identify people-related factors which affect the modernisation process, including community issues, skills development, technology adoption and organisational system design. The project aims to use the implementation of a fully digitised mine as a case study to identify the enabling and inhibiting human factors for modernisation" (SAMERDI, 2018).

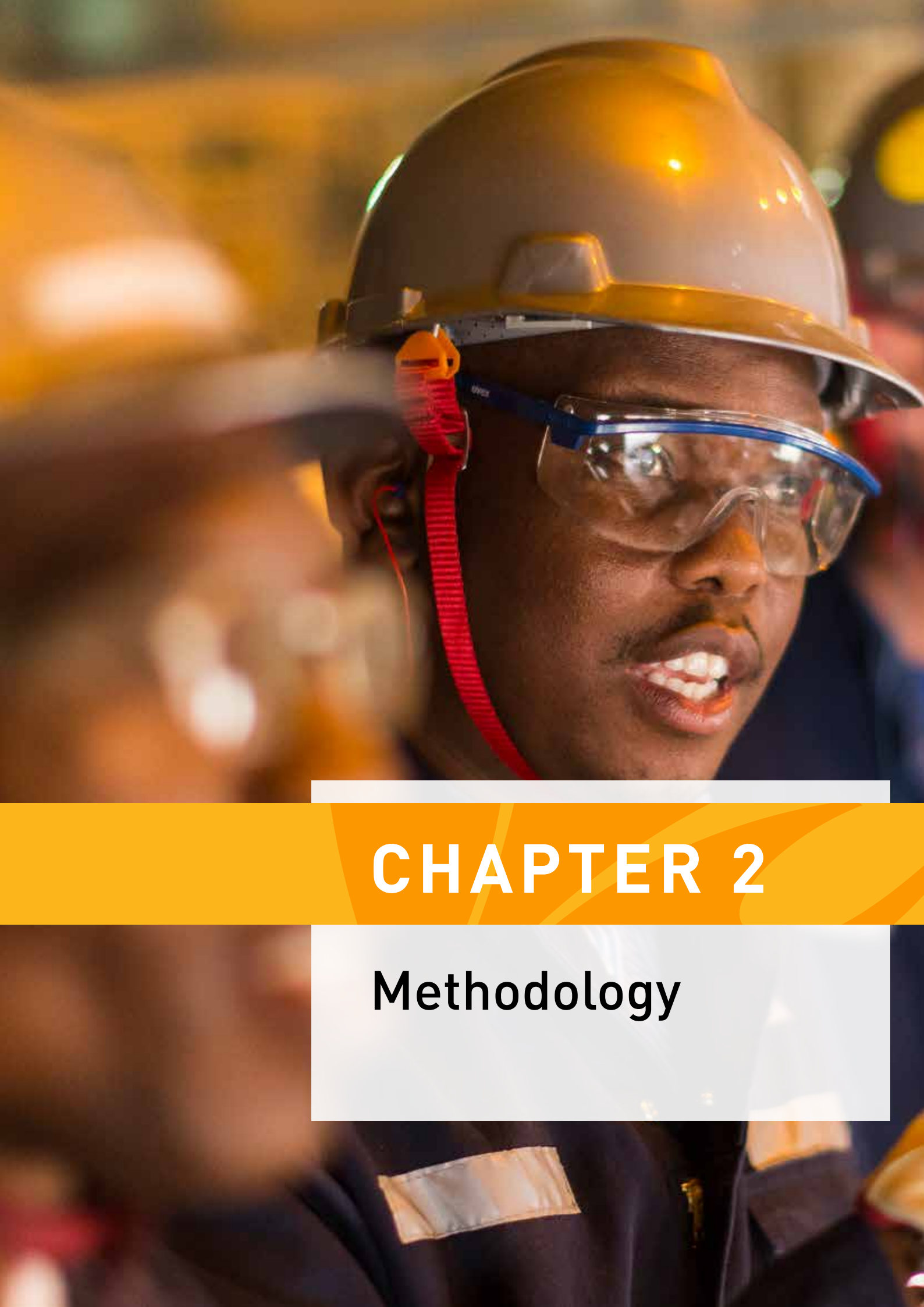
The project seeks to answer the following research question:
"understand how a technological and digital modernisation process can be successfully achieved in respect of the human factors associated with such change, including individual (personal) implications, organisational effects, and broader social implications" (SAMERDI, 2018).

Ultimately, the project aims to deliver *"the characterisation of the success and failure factors in the process of modernisation, in the case of a specific mine as a baseline on modernisation (processes, effects and management measures)"* (SAMERDI, 2018).

The WP 2.7 project *(Modernisation Case Study at Kolomela Mine) was conducted concurrently with the SAMERDI SATCAP project Three Case Studies on Historical Modernisation Effects and Management Measures* (WP 2.2). Collectively, these two work packages intended to deliver a decision framework for future modernisation processes, in addition to answering the research questions that were posed. The parallel execution of the two projects enabled sharing and integration of learning, prevented repetition of work and enabled the development of a more comprehensive research product.

The fieldwork of the three case studies project (WP 2.2) was undertaken first. This provided researchers with the opportunity to enhance the perspectives that were gained from an initial literature review in WP 2.7 *(Modernisation Case Study at Kolomela Mine)*, by obtaining a broad overview of people-related factors that affect mining modernisation in practice. The learning from the fieldwork served to inform the work done in WP 2.7 *(Modernisation Case Study at Kolomela Mine)*, which is described in this report.

This document provides an overview of the research methodology (Section 2). The concept of modernisation is briefly revisited and redefined based on learning from the cases (Section 3), after which the approach to modernisation at Kumba Iron Ore is described (Section 4). The three projects that were analysed as instances of modernisation at the Kolomela mine are outlined next (Sections 5), and findings are discussed in Section 6. Recommendations for future work are outlined in Section 7 and Section 8 concludes.



CHAPTER 2

Methodology

2.1 RESEARCH APPROACH

This research project adopted a Design Science1 research approach, as outlined in Figure 1. The approach facilitates iterative updates to the final decision framework, as more research activities are conducted.

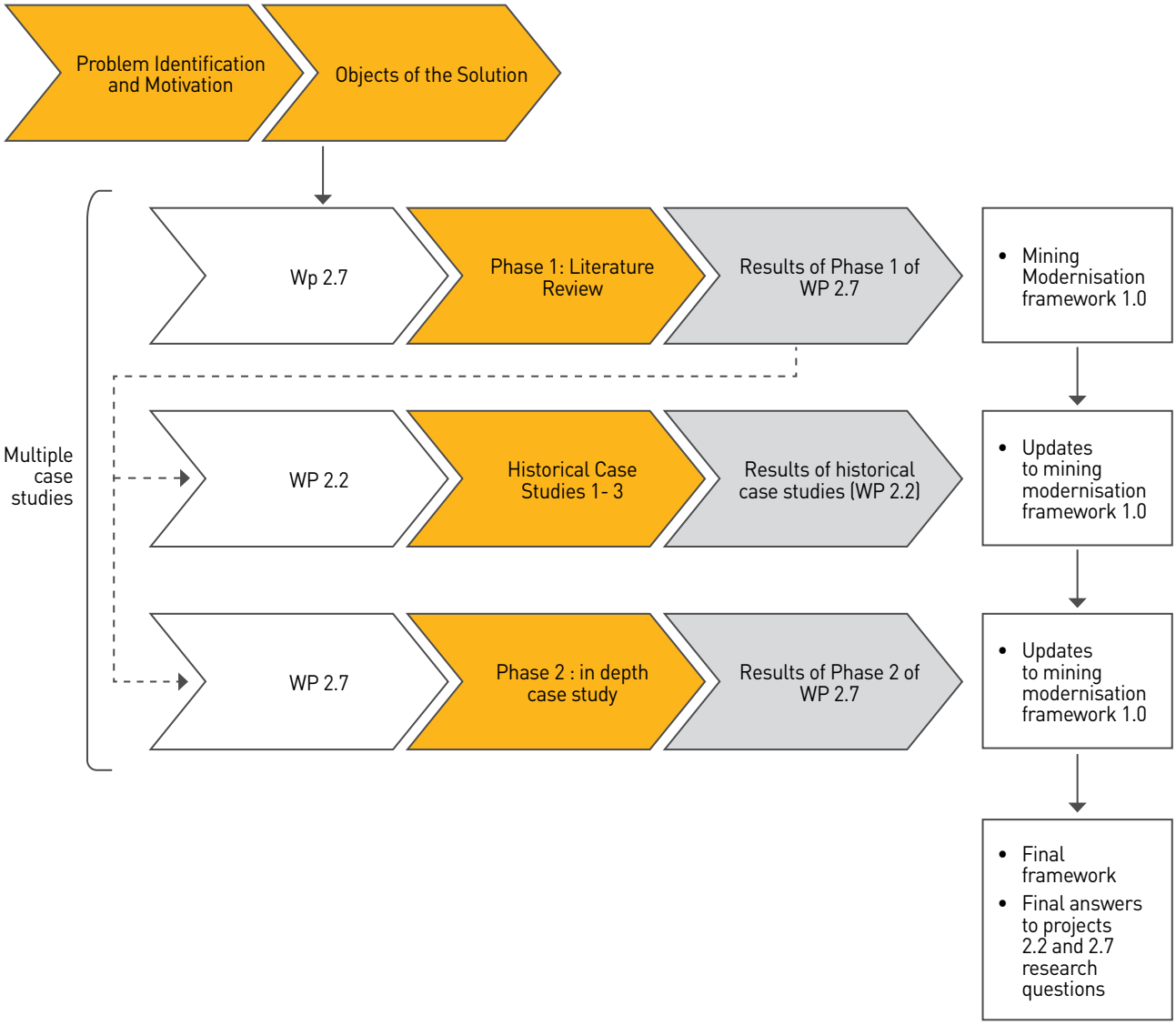


Figure 1: Research approach: modernisation framework development and case analyses

The work in WP 2.7 (*Modernisation Case Study at Kolomela Mine*) is based on an in-depth case analysis. For this study, a *qualitative research approach* was adopted and utilised a case analysis research method:

Table 1 Case analysis

TYPE OF ANALYSIS	OBJECTIVE AND ACTIVITIES	METHOD
Within-case analysis	• Identify and describe the context of the case. • Identify the objective of the intervention. • Define the modernisation context (stakeholders, constraints, influences). • Identify key themes that affect and inform modernisation.	• The researchers will analyse and interpret project documentation, and interviews will be conducted with key role players in each case. • Information will be interpreted against the research objectives and questions (see sections 5 to 7 in this report).
Interpretation	• Integrate the identified elements of modernisation to inform the revised framework, and to provide a comprehensive answer to the determined (i.e., does it constitute a new research questions.	• The relevance of the modernisation elements to the framework will be assessed, and its level of integration will be determined (i.e., does it constitute a new element, or a revision of an existing element). The framework will be adapted accordingly (Section 6.2).

Table 2 summarises the enquiry framework that was adopted for this in-depth case analysis, and the themes that were investigated:

Table 2 Themes in case analyses

THEME	DETAIL (INCLUDES THE FOLLOWING, NOT EXHAUSTIVE)	INFORMATION SOURCE
Modernisation strategy and approach	• Strategic context • Objectives of modernisation portfolio • Organisational enablers and disablers • Nature of modernisation in this context (technology introduction, process change, etc.) • Success of modernisation strategy	• Interviews
Modernisation context	• Social and labour baseline	• Literature • Interviews

[1] Design Science research refers to a study of the way in which objects or systems are designed and improved (Meyer, 2017). Research results are often developed through multiple study iterations.

Management of modernisation	• Change process • Management skill • Mind-set and culture • Enablers and disablers • Stakeholder definition and involvement	• Interviews • Project • documentation
Modernisation Project management	• Objective • Approach • Change process (what and why) → Progression over time → Current point in change process • Enablers and disablers • Perceptions of: success or failure, critical success and failure factors (human factor focus) • Skills requirements and skills development for modernisation • What changed, in terms of the following dimensions: → Technology adoption → Enterprise behaviour → Economic benefit	• Interviews with decision makers and planners involved with the modernisation process • Project documentation
Modernisation project participation	• Experience of modernisation projects • Perceptions of: success or failure, critical success and failure factors (human factor focus) • Skills development for modernisation	• Interviews with end-users

The data that was generated from the interviews were interpreted as per the case analysis method outlined in Table 1, and were used to answer the research questions and sub-questions. In addition, the data were reviewed to identify further people-related factors that play a role in mining modernisation. These factors were used to enhance and update the Mining Modernisation Framework.

2.2 PROJECT SCOPE AND FOCUS

For this in-depth case study, Kolomela's modernisation approach and strategy were reviewed, with specific reference to three modernisation projects within its technology application portfolio. The modernisation strategy spans across three Horizons, and the projects included in this study form part of the first and second horizons. The horizons differ in terms of the complexity of technology to be implemented and the outcomes to be achieved, and include the broad objectives or themes of *Best possible today* (Horizon 1), *Integrated autonomous operations* (Horizon 2), and *Smart mining* (Horizon 3). The three projects that were investigated are summarised in Table 3. The projects include modernisation of a specific activity in the mining process (i.e., autonomous drilling), modernisation of an entire function (i.e., automated plant control) in the mining value chain, and modernisation that was intended to include activities of the entire value chain (i.e., the mine/management information system). Kumba Iron Ore Ltd. proposed these specific projects to provide comprehensive insight into the extent of their current portfolio of modernisation activities.

Table 3 Summary of Cases

	PROJECTS	DESCRIPTION	SCOPE	STATUS
Horizon 1: Best possible today	**Advanced process control**	Control of plant-level process for improved output, quality, and consistency	Plant	Successful implementation and use
	Autonomous drilling	Development of a fleet of automated drilling machines that are operated from a control centre	Drilling	Successful implementation and use
	Management Information System	Implementation of an information system that provides a value chain perspective on mining operations	Value chain	Successful implementation and use (of part of the originally planned initiative)

The focus (and unit of analysis) of this investigation is the company-wide modernisation process, with projects reflecting examples of how modernisation is implemented. As such, the projects provide the opportunity to reflect on the instantiation of the intended modernisation process in practice, and hence the opportunity to contrast planning and intent with practice.

The investigation was conducted at the *organisation* level, where the organisation's drivers, approach, strategy, planning, and other aspects with respect to modernisation were investigated. Further, at the project level, the planning and implementation of modernisation initiatives were assessed, as well as the perceptions of participants, and any enabling and disabling people-related factors.

The project focus is outlined in Figure 2 as follows:

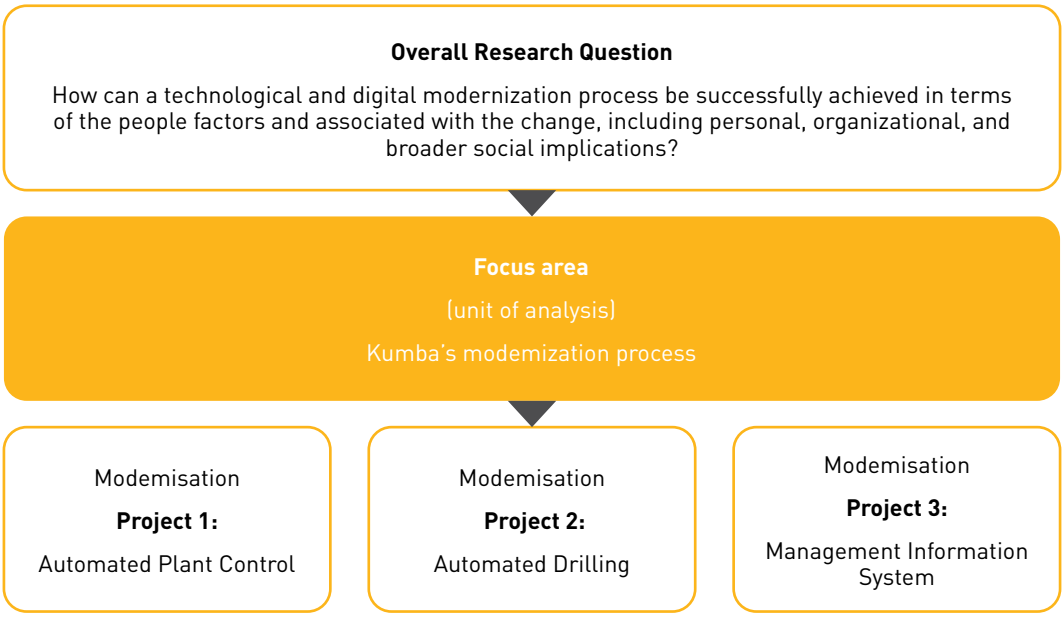


Figure 2 Project scope and focus

Jacobs and Webber-Youngman (2017) developed a technology mapping framework for mine modernisation, by indicating value drivers against the mining cycle and then mapping technologies against their role in the mining cycle (see Figure 3 for the conceptual framework).
This framework is used here to outline the scope of the cases that were investigated, and to identify areas of modernisation that are not addressed by these cases.

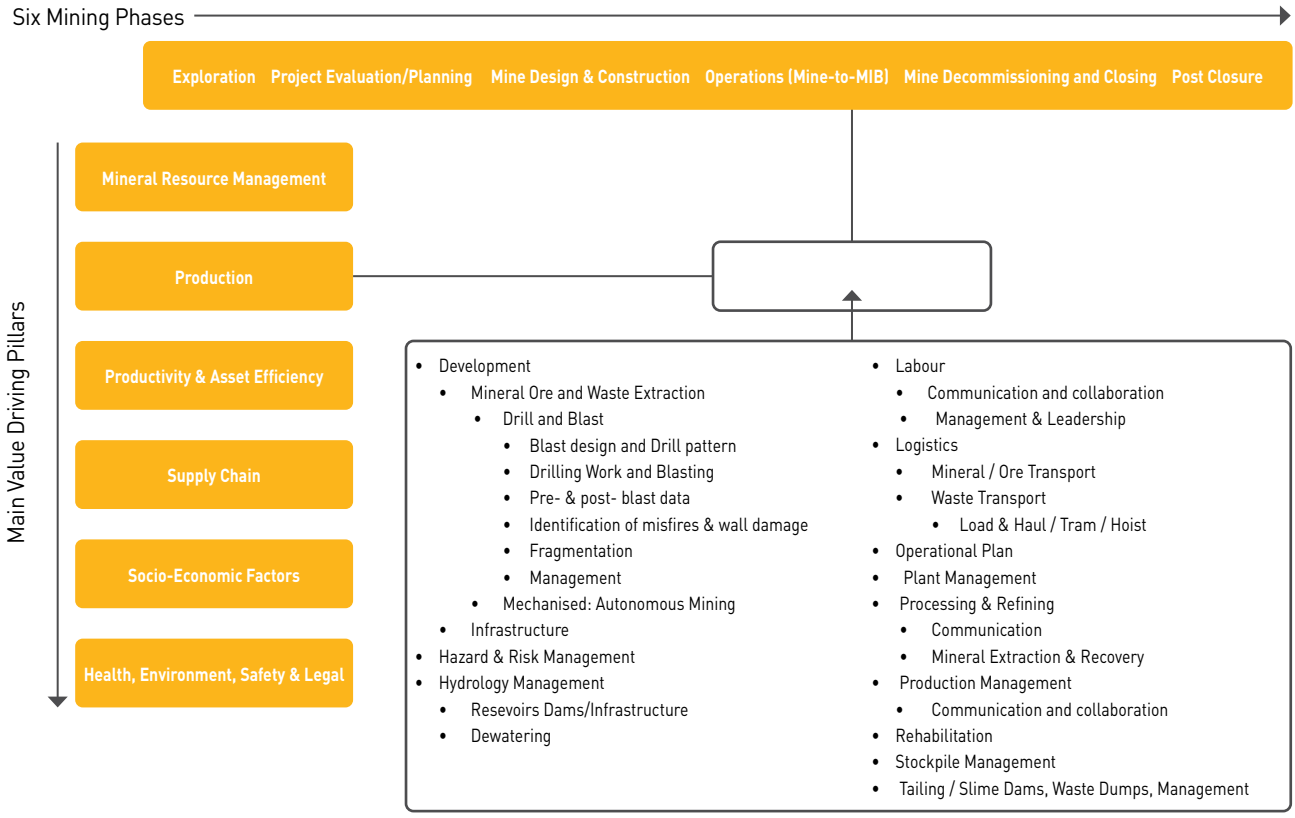


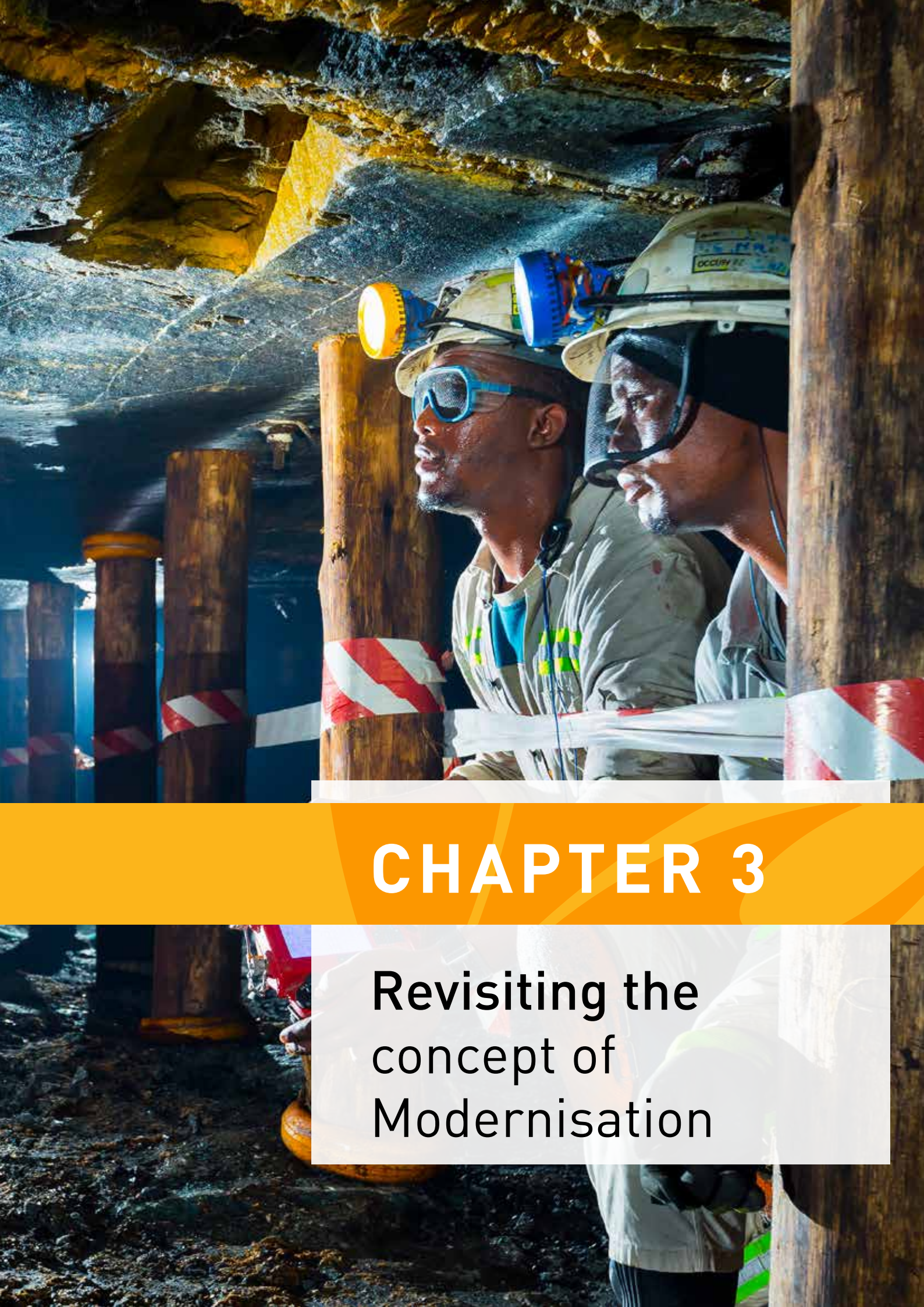
Figure 3 Mining cycle framework, with value drivers within a portion of the mining cycle (Jacobs and Webber- Youngman, 2017)

According to the Jacobs and Webber-Youngman (2017) framework, the selected cases reflect modernisation of the operations (mine to mill) of an open cast iron-ore mine, through examination of projects that address mechanisation and automation (autonomous drilling; automated plant control). It also includes modernisation that elicits a value chain-wide perspective through the introduction of information technology (MIS).

In terms of the value drivers identified by Jacobs and Webber-Youngman (2017), the drivers for the selected cases include production, productivity & asset efficiency, profitability and cost control, supply chain, and health, environment, safety, and legal.

This project complements and broadens the scope of modernisation that was covered in the SAMERDI project *Three Case Studies on Historical Modernisation Effects and Management Measures* (WP 2.2)[2], and addresses a broader spectrum of technologies. In combination, the cases that were investigated for the two projects cover a broader (although not complete) spectrum of modernisation.

[2] WP 2.2 was undertaken concurrently with the project described in this report (WP 2.7); the work contributed to the recommendations and final decision framework that are presented in this report.



CHAPTER 3

Revisiting the concept of Modernisation

Before proceeding with the case description and analysis, it is useful to reconsider what is intended when talking about modernisation. Modernisation as a general concept is often described in the context of a modernising society, relative to the associated progress, the changing relationships of society with technology, and the societal changes that happen as a result of the adoption of technology. While this broad description covers essential elements of modernisation at a macro level, the need exists to interpret modernisation in the context of a modernised mine and modernised mining sector and, for the purpose of this study, modernisation in relation to people factors.

It is clear from discussions with participants across cases and from the initial review of the literature that modernisation is not clearly defined, and that numerous terms are used interchangeably when talking about modernisation. Further, concepts such as mechanisation and modernisation is used interchangeably, without clear definition.

The definitions outlined below describe how *mining modernisation* has mostly been interpreted for this study, and how it differs from related concepts. Some elements that further contextualise modernisation are also outlined, including purpose, time frames, readiness, and others. Note that these definitions are mostly based on interpretation and learning from the cases, unless indicated differently.

3.1 **DEFINITIONS:** MODERNISATION AND RELATED CONCEPTS

The following concepts are differentiated:

- **MINING MODERNISATION (COMPANY LEVEL)**

Adoption or implementation of a "new way of doing" in the mining environment. This mostly (but not exclusively) involves the adoption and use of newer technology. It could also include a new way of work, the development or use of different processes, or the adoption of different practices. Examples of mining modernisation include the replacement of all technology in a processing plant with the latest versions thereof (i.e., mostly new technology adoption), or the implementation of trackless rather than tracked mining (which could include new technology, processes, practices, and new ways in which to structure and organise work).

- **MINING MODERNISATION (SECTOR LEVEL)**

Widespread modernisation of companies across different sub-sectors, which results in a need for different ways to support the sector. These could include the need to support the development of different skills, the facilitation of modernisation-focused research, enablement of new technology development, facilitation of different supply chain relationships, and others.

- **AUTOMATION/ MECHANISATION**

Introducing technology, machines, or automatic devices to enable a process or activity to be done with less or minimal human intervention or assistance. Automation/ mechanisation may or may not form part of modernisation.

- **DIGITISATION/ DIGITALISATION/ DIGITAL TRANSFORMATION**

Digitisation refers to the translation of information into its electronic form, while digitalisation refers (amongst others) to the use of digital technologies to improve business processes or move to a new business model. In contrast, digital transformation refers to "the customer-driven strategic business transformation that requires cross-cutting organisational change as well as the implementation of digital technologies." (Bloomberg, 2018: 1).

- **TECHNOLOGY DEVELOPMENT**

The development of new technology to facilitate improvement. New technology does not always form part of modernisation and, if it does, it does not necessarily have to be developed by the organisation that is modernising. A focus on technology development, automation, digitalisation and other improvement initiatives per se does not imply modernisation. Instead, modernisation relates to the successful adoption and use of new ways of work, which may or may not include these aspects.

- **PEOPLE-RELATED FACTORS IN MINING MODERNISATION**

The definition, for this study, is revised as follows, based on the case analyses:
People-related factors in mining modernisation refer to the primary, secondary, and tertiary factors that affect the interaction between people, technology, and enterprise in the process of mining modernisation.

This report further clarifies this definition by completing the identification of a directory of people- related factors in mining modernisation. Note that this definition moves beyond the ergonomics-focused definition of human-related factors, which is mostly concerned with man-machine interaction, by interpreting people-related factors from the perspectives of people, technology, and enterprise. Importantly, case analyses highlighted the fact that people-related factors should not focus on labour alone but should consider the ability of managers to successfully facilitate modernisation in a complex organisational context.

3.2 MODERNISATION IN CONTEXT

Modernisation is placed in context by considering a number of additional concepts:

- **PURPOSE: MODERNISE FOR RESILIENCE**

The purpose with which a company modernises is indicative of the scope and extent of effort that is required to succeed in its modernisation effort. Modernisation can in one extreme be viewed as a "game changer" and in the other as an incremental improvement of the way in which things are done.

Of the three cases that were explored in the related SAMERDI project Three Case Studies on Historical Modernisation Effects and Management Measures (WP 2.2)[3], two cases reflected incremental changes in the way in which things were done. Across all cases, modernisation was driven by a need to improve the mine's performance against the core parameters of reduced cost, improved efficiency, improved safety, and improved profitability.

[3] WP 2.2 was undertaken concurrently with the project described in this report (WP 2.7); the work contributed to the recommendations and final decision framework that are presented in this report.

This in-depth case provided the opportunity to interpret modernisation in the context of "resilience". This refers to modernisation that does not focus on incremental (and mostly short-term) improvements against the listed performance parameters, but the adoption of modernisation as a strategy and investment to buffer against short- and long-term fluctuations in performance, ore price, and the economy as a whole. Where modernisation is perceived as a strategy in support of resilience, the scope of modernisation would be broader and institutional changes for the long-term support of modernisation would be required.

- **MATURITY, READINESS, SCOPE: MODERNISE IN LINE WITH ABILITY**

Modernisation for its own sake, without clear purpose, could lead to significant investment without concomitant gain. Similarly, organisations that are not ready to modernise in line with their intended scope are likely to invest in vain. For example, the cases that were examined in the related project *"Three Case Studies on Historical Modernisation Effects and Management Measures"* indicated that an organisation that modernises without access to appropriate skills (e.g., conventional to mechanised mining) would not be able to generate appropriate benefit. Similarly, the introduction of new technology, without appropriate support of the supply chain to ensure availability of components, would result in unreliable availability of technology and therefore limited adoption.

In this context, maturity and readiness refers to the systemic readiness of the organisation and its supply chain to modernise. Specific aspects could include access to, and development of, appropriate skills; organisational capacity to define and incentivise new roles; the selection of technology that is "fit for modernisation" (i.e., enables rather than disables); the capacity of the supply chain to support new technology; and others. These aspects are explored and incorporated in the identification of people- related factors for modernisation throughout this document.

The concept of readiness also implies that mines of limited readiness and limited resources should consider a phased approach to modernisation within a larger strategy, so as to ensure that modernisation is aligned with the capacity to modernise, that benefit is maximised, and that risks are controlled.

CHAPTER 4

Modernisation Strategy at Kumba's Kolomela Mine

4.1 MINING AT KOLOMELA: A BRIEF REVIEW

Kolomela mine is one of four mines in the portfolio of Kumba Iron Ore Ltd. and is located near the town of Postmasburg in the Northern Cape province (Figure 4). The mine was commissioned in 2011. It produces high-grade direct shipping ore, and a dense media separation (DMS) modular plant was commissioned in 2017. The mine has a reserve life of 14 years (Kumba Iron Ore Limited, 2018a).

Figure 4 Location of Kolomela Mine (2b) (Kumba Iron Ore Ltd, 2018a)

Kumba Iron Ore follows a strategy of Transformation to Full Potential, called Tswelelopele (Kumba Iron Ore Limited, 2018a), that is phased over three horizons, as follows: Operating assets at full potential (Horizon One); Leveraging Endowment (Horizon Two); and Expanding the business into attractive adjacencies (Horizon Three). The strategic aim is to improve margins, extend the life of assets beyond 2035, attain a culture of zero harm, and maintain a high-performance culture of healthy, motivated employees (Kumba Iron Ore Limited, 2018a).

Kolomela's 2018 performance includes zero fatalities; a production of 13.9 Mt; a Lump to Fine ratio of 59:41; and a unit cash cost of R 249/tonne. The mine has 1382 permanent full-time employees and 1070 full-time contractors, and invested R 47.1 million in social and community projects in 2018 (Kumba Iron Ore Limited, 2018a).

4.2 ORGANISATIONAL CONTEXT

Anglo American has 76% ownership of Kumba Iron Ore Ltd., as indicated in Figure 5. This relationship influences Kumba's modernisation strategy and the implementation thereof, in particular with respect to technology initiatives.

Figure 5 Ownership of Kumba Iron Ore (Kumba Iron Ore Ltd, 2018)

4.3 MODERNISATION STRATEGY

Kumba Iron Ore Ltd.'s modernisation strategy is aligned with its overall organisational strategy of Tswelelopele (see Section 4.1). It supports the overall strategic focus of positioning for sustainability, while maintaining short-term viability within challenging global price environments. The modernisation strategy is expressed as a Technology Strategy, which is positioned as a potential game-changer for Kumba. The following goals are set:

> Through our technology strategy, we are looking to accelerate the adoption of appropriate technologies at our operations to improve safety to achieve our zero harm target, drive down costs by improving productivity and efficiencies, and maximise current and future resource utilisation through low-grade beneficiation technology (Kumba Iron Ore Ltd, 2018a).

The strategy evolved from a business that was under pressure in 2015, and in which technology was positioned as having a key role in facilitating the journey of recovery and growth (see Figure 6):

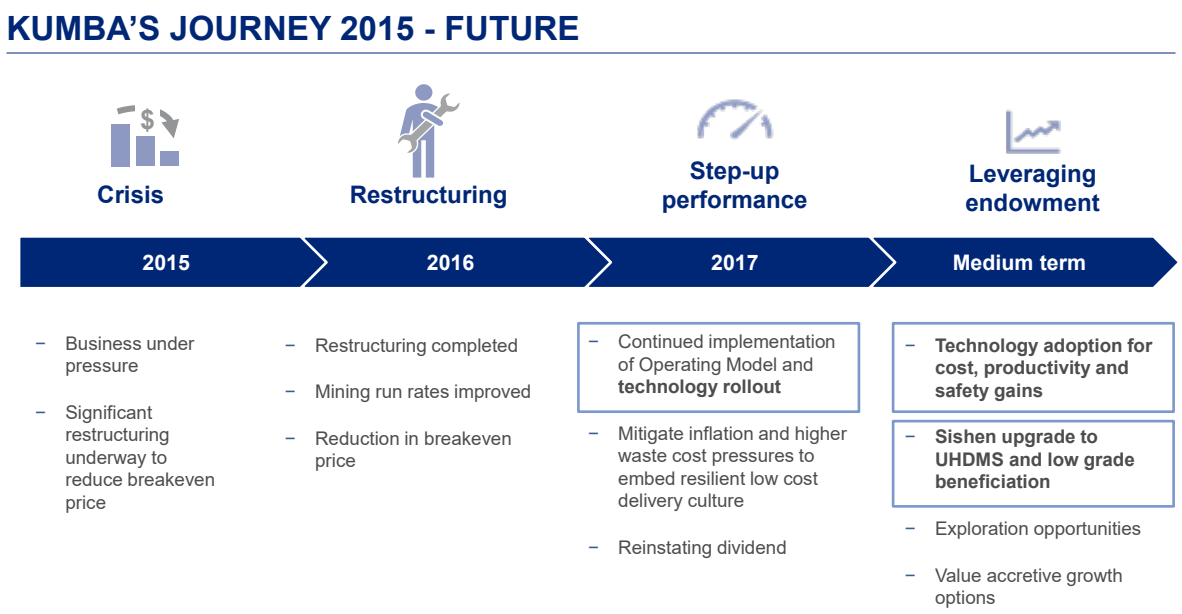


Figure 6 Kumba's technology portfolio as strategic enabler (Kumba Iron Ore Ltd., 2017).

Similar to the overall organisational strategy, the technology strategy consists of three different horizons, as depicted in Figure 7 (Kumba Iron Ore Limited, 2017):

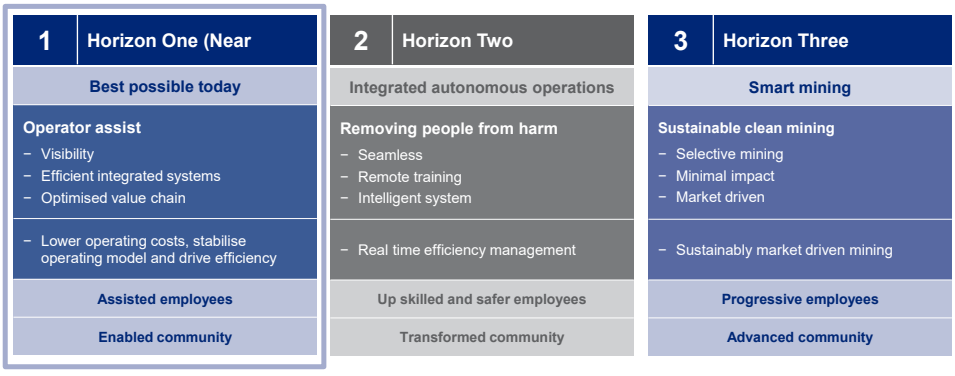


Figure 7 Kumba's technology strategy (Kumba Iron Ore Ltd., 2017).

The technology strategy is in support of a medium to long term initiative to leverage technology for improved performance. Horizon 1 is aimed at reducing costs, increasing production, and achieving better prices for a high-quality product; Horizon 2 focuses on extending the current life-of-mine beyond 13 years through exploration, and Horizon 3 aims to investigate potential value-adding opportunities that arise from diversification, beneficiation, and consolidation.

The strategy was updated in 2018, to reflect the following focus:

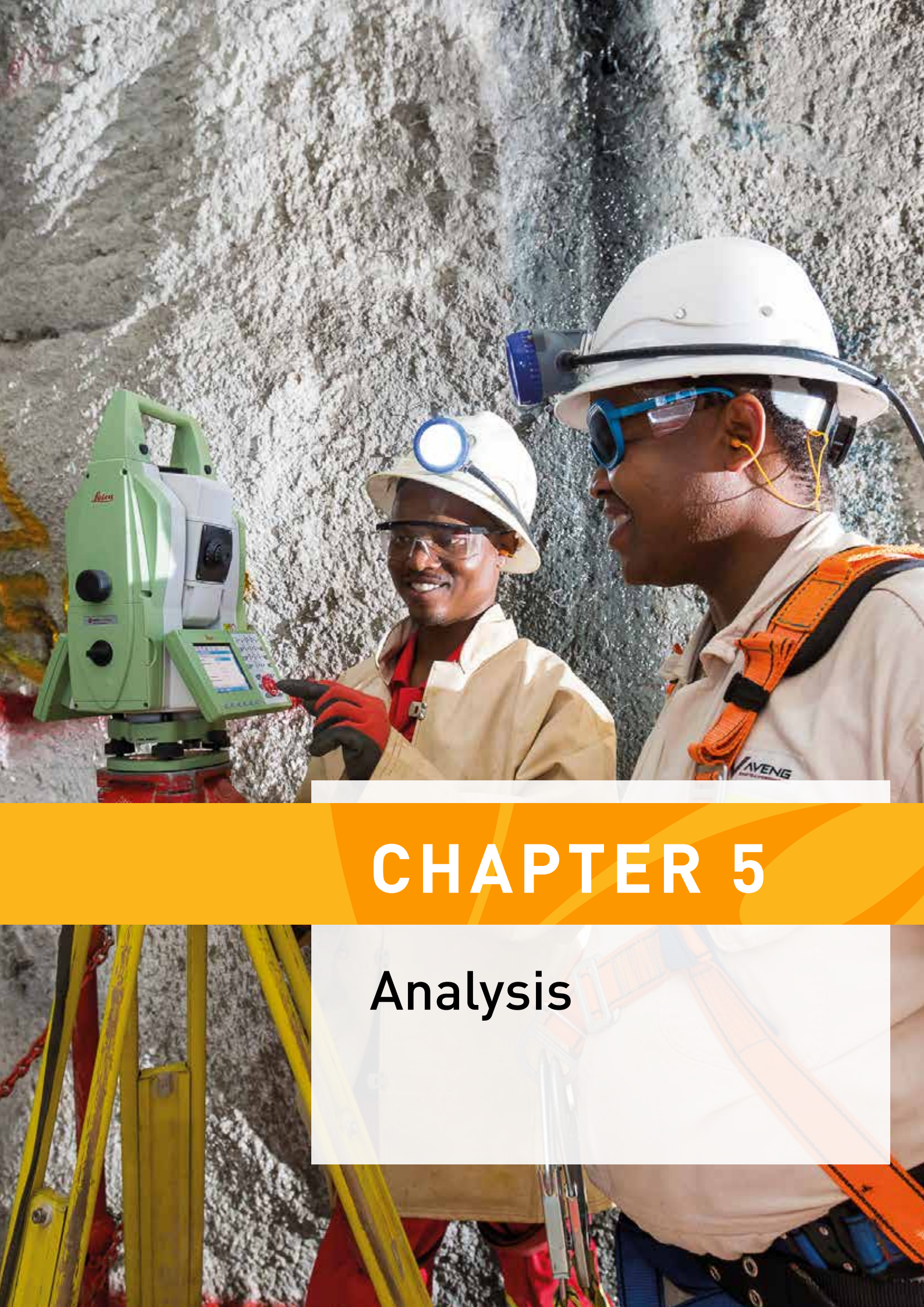
Table 4 Updated focus of technology strategy (Kumba Iron Ore Ltd., 2018a)

HORIZON	PERIOD	TECHNOLOGY FOCUS
Horizon One	2018-2022	Digital integrated solutions
Horizon Two	2023-2026	Seamless remote mining
Horizon Three	Beyond 2026	Smart mining technologies

This positioning of the technology portfolio has the following implications for modernisation at Kolomela:

- Modernisation is a strategic, long-term initiative, rather than short-term investment in short-term gain.
- Technology is the key driver of modernisation.
- Modernisation is phased across increasing levels of complexity (from known technology to unknown, untested technology). This allows for the possibility to develop the organisational readiness and maturity for modernisation over time.
- The organisation aims to develop resilience against a changing environment (depleting resources, unstable commodity prices, etc.). The direct objectives of the organisation, and of the technology portfolio, are to reduce cost, improve safety, and enhance productivity. This broader organisational search for resilience leaves the opportunity to define resilience itself as an objective of modernisation and technology introduction — that is, to move beyond the single-dimension objectives of cost, productivity, and safety gains, to develop an organisation over the long term that has the capacity (processes, structures, systems, practices, capability) to modernise in an ongoing manner for increased resilience.
- The role of technology is positioned as a game changer (Kumba Iron Ore Ltd, 2018a). This prompts the question as to whether the various organisational enablers are in place to facilitate modernisation as a game changer, in addition to enabling incremental improvements.

In the section that follows (Section 5), each project is narrated, the case is interpreted against key aspects of modernisation, and the implications in terms of the organisation's modernisation portfolio are outlined. The implications for the systemic understanding of modernisation, as well as the key people- related factors, are outlined. The interaction between community and modernisation is reflected on, and managers' strategic perspectives on Kumba's modernisation strategy and portfolio are summarised.



CHAPTER 5

Analysis

5.1 PROJECT 1: ADVANCED PROCESS CONTROL

5.1.1 PROJECT DESCRIPTION

5.1.1.1 BACKGROUND

The Advanced Process Control (APC) project at Kolomela aimed to maximise return on investment by ensuring improved plant utilisation and throughput, reduced cost, and consistent production of a higher-grade product that sells at a premium price. At the time of the study, APC has been in use at Kolomela for more than three years, and installation has been extended to the Sishen mine.

The following perspectives were represented in interviews:

Table 5 Interview participants: Advanced Process Control

PERSPECTIVE	INVOLVEMENT	ROLES INTERVIEWED
Project planning and management	Planning, coordination, management	Project manager (Technology implementation unit) Project coordinator (Site)
Mining operations	Implementation of technology in operations	Head of Mining
Plant operations	Supervision and use of system	Section supervisors

5.1.1.2 DESCRIPTION

The APC project comprised "the installation of conveyor belt cameras (particle size analysers) to actively monitor the crusher feed and product size distribution on the belts" (Mining Review Africa, 2016, p.1). This technology enables process control, including bin level control and crusher gap setting control. It manages the "fine" to "lump" ratio to ensure a consistently higher quality product (preference for "lump"), while maintaining constant throughput without manual stoppages (Mining Review Africa, 2016; SAIMM, 2018). Further, it assists in managing machine utilisation, so as to reduce the risk of breakdowns.

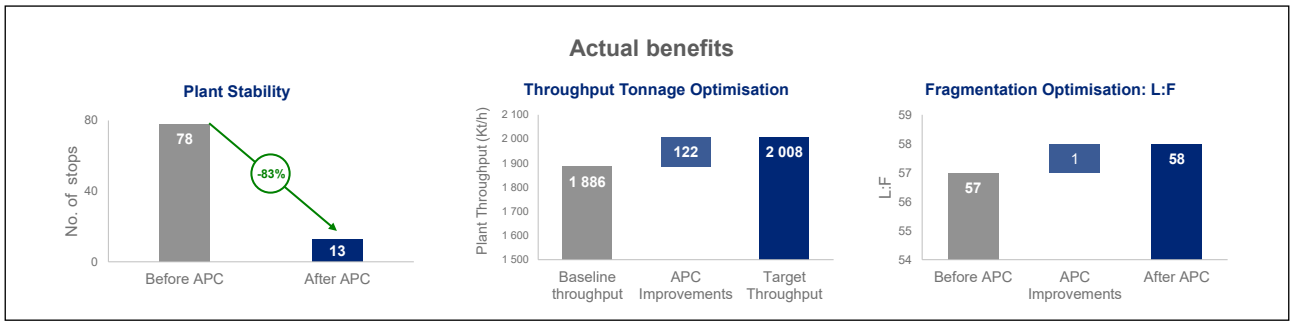


Figure 8 Plant performance before and after APC (Kumba Iron Ore Ltd., 2017)

The project has been successful in effecting a 2% increase in the lump to fine (L:F) ratio (AngloAmerican, 2017) and in reducing plant stoppages by 76%, thus increasing plant utilisation and throughput and reducing engineering and maintenance costs (Figure 8; Mining Review Africa, 2016).

5.1.1.3 CONTEXT AND OBJECTIVE

Advanced Process control was implemented as part of Horizon One (Best Possible Today) of Kumba's technology portfolio. As such, it supports the overall objective of lower operating costs, a stabilised operating model, and improved efficiency. Specifically, the drivers were to reduce process variation in the plant, to enhance throughput, and to deliver product of a higher and consistent quality.

5.1.1.4 PROCESS FOLLOWED

Sensors were sourced from vendors, who were engaged to enhance the technology for local conditions. This entailed the relocation and adaptation of sensors to cope with the extremely dusty local conditions. Software was sourced from inside Anglo American, and the vendors were contracted for ongoing support, so as to ensure availability and minimise the impact on production. A staged implementation process was followed in which operators were gradually introduced to the use of the software.

5.1.1.5 CONSTRAINTS

The system proved effective in its ability to optimise plant operations. However, operators retained the perspective that they were better able to manage plant operations (and produce the required tonnage) without the use of the APC. This resulted in the APC being bypassed and switched off. A further contributor to this behaviour was the requirement that the sensors are kept clean for efficient operation. The reluctance of operators was overcome through ongoing and persistent engagement and follow-up with the operators who exhibited this behaviour most often, and in demonstrating how the use of the software enhanced overall plant performance. Different scenarios were executed during training, for operators to compare their approach to the automated choices made by the plant control system. Specific attention was given to ensuring that operators bought into the concept of enhanced performance associated with the APC, as opposed to manual control, and in developing operators' trust in the system.

5.1.1.6 PROJECT IMPACT

The project succeeded in enhancing plant performance. The control system enabled performance that exceeded predetermined targets, and as such created "excess capacity". Investment in APC hence introduced resilience into plant operations, whereby capacity exists to buffer against unexpected future demands.

5.1.1.7 REFLECTIONS AND LESSONS LEARNT

Interviewees offered a number of insights when prompted to reflect on the lessons learnt during the implementation process.

The role of a "local champion" (plant controller) was emphasized, with specific reference to the technological skill and willingness of the champion to "go the extra mile" to assist process controllers in overcoming challenges. However, the dependency of projects on such champions in general was also challenged, by outlining the lack of continuity associated with such an approach.

The role of the Technology Unit, and specifically its position as geographically remote from the plant, was perceived as an advantage, since it gave them "more freedom to pursue technology options or solutions". Further, it was emphasized that technology should require the minimum human intervention, and that it should enhance rather than hinder the role of operators, so as to ensure adoption and use. This echoes a

sentiment that was put forward across all cases and prompts the question of what technology should look like that is "fit for modernisation."

Given the reduced role of the operator in the new system, in which preferred behaviour is for process controllers to interfere less rather than more in system operations, controllers were feeling "redundant". Scope exists to redefine the performance and KPIs of a successful operator, and to reward operators who enhance the overall system accordingly.

Finally, process controllers indicated that the use of the system developed a more systemic perspective in which controllers learnt to appreciate the impacts of their decisions on other parts of the system (specifically, on breakdowns and hence on maintenance requirements).

Specific recommendations by interviewees are summarised in Table 6 as follows:

Table 6 Recommendations by interviewees: Advanced Process Control

ASPECT	RECOMMENDATION
Learning by	Enable /incentivise management to do "cross-sector" learning as well as learning management within the Anglo group
Systems	People at all levels needed an enhanced ability to "see the bigger picture", that is,
Capability	an enhanced ability to "see and do" from an integrated systems perspective (this was also articulated as a value chain perspective)

5.1.2 INTERPRETATION

In this section, the project description is interpreted in terms of some of the research questions that are explored in this study.

5.1.2.1 KEY SUCCESS FACTORS

In spite of some issues with respect to adoption and use, the APC was implemented successfully and delivered significant improvements in performance. This is partially attributed to the management of the supply chain, which is facilitated by Anglo American's size and buying power. Vendors could be persuaded to adapt their technology for use in the local environment and to procure locally, where possible. Further, the automation enhanced a process that was already mature and well managed. This facilitated easier adoption of technology — automation of an inefficient process would render unsatisfactory results.

5.1.2.2 KEY FAILURE FACTORS

Adoption and use of technology are key factors to manage, so as to prevent failure of the initiative. The perception of diminished control over the process by operators needed to be countered with added training and skills development to ensure confidence and trust in the system.

5.1.2.3 HOW WERE HUMAN-CENTRED PERSPECTIVES CONSIDERED, IF AT ALL? (PLANNING IMPLEMENTATION)

The project manager ensured that an inclusive process was conducted, in which user perspectives (i.e., plant operator perspectives) were obtained at the outset and an extensive User Requirements Specification (URS) was developed. This facilitated buy-in and participation. Transfer from the project team to the team on site was facilitated through the development of Standard Operating Procedures, which were initiated by the project team and then "owned" and maintained by the team on site.

5.1.2.4 WHAT WERE THE PERSPECTIVES/PERCEPTIONS OF PEOPLE ACROSS ALL LEVELS ABOUT THE MODERNISATION PROCESS?

The perception across interviewees is that the APC implementation was successful, and that it was eventually adopted with positive results. Specific perspectives include the following:

- *"APC does what a good controller does but in a fraction of the time"*
- *"APC reduces the controller to an observer with spare time and capacity on hand"*
- *The "confidence and empowerment levels" of operators eventually enabled them to start "experimenting" with the new technology*
- *The new technology and the "lee-way" it created provided the organisation with an enhanced ability to "face tough times"*

5.1.2.5 STRATEGIC ALIGNMENT

As a Horizon 1 project, the APC was aligned with the organisational objectives of:

- Enhanced efficiency – that is, the ability to "produce more with less" (less time and input from operator in this case); and
- Enhanced profitability – facilitated in this case via increased product quality and consistency

Figure 9 positions the APC as modernisation initiative relative to the systems framework of modernisation. This (subjective) positioning illustrates the nature of this modernisation initiative in terms of the axes of the systems model of modernisation (see Section 6.2).

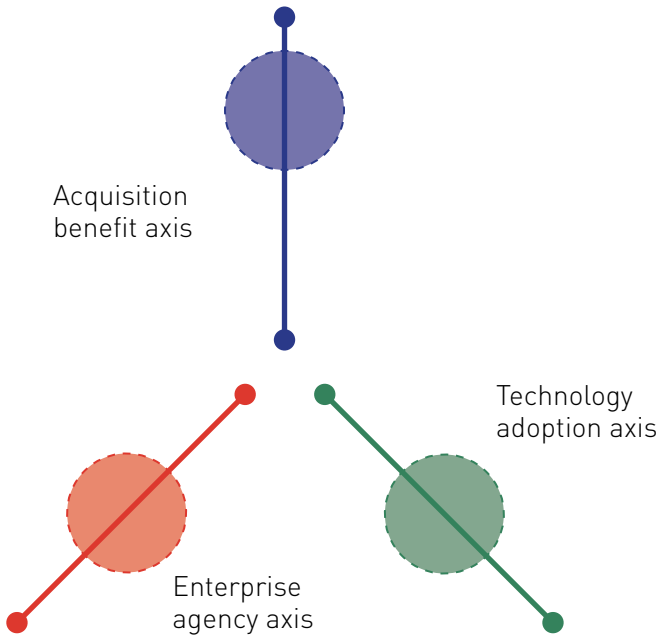


Figure 9 Characterisation of modernisation: APC

The axes are as follows:

- The *acquisition benefit* axis reflects the dimensions of the benefit that was realised from the implementation of the project (ranging from a single dimension such as profitability, to multiple dimensions that include, for example, profitability and resilience)
- The *technology adoption* axis ranges from prescribed use through experimentation to technological innovation; in the case of the APC, it was found that the operators started to experiment with the use of the technology; and
- The *enterprise agency* axis refers to the extent to which the people in the enterprise are empowered

towards engagement and action in the implementation of a modernisation initiative. It ranges from mere compliance with prescribed processes and procedures through strengthening of agency to facilitating enterprise innovation; in the case of APC, it reflects the fact that the level of empowerment of the operators led them to suggest improvements to the process.

In summary, the APC is positioned as a modernisation effort that realises gain in multiple dimensions (quality, productivity, resilience), that facilitates experimentation with new technology adoption, and that strengthens people's agency in the enterprise.

5.1.3 IMPLICATIONS

The unit of analysis of this study is Kumba's modernisation process. In this section, the implications of the APC project is interpreted in terms of the organisational environment for modernisation. Perceptions are summarised from different perspectives, after which the APC project is interpreted in terms of the enabling environment (i.e., the organisational context, change readiness, and change process). Thereafter, the key people-related factors that influenced the project are summarised.

5.1.3.1 PERSPECTIVES AND PERCEPTIONS

The following conflicting perspectives were deduced from the interviews:

- Process controllers, who mostly engage with individual components of the system, had an initial perspective of "loss of control"; and
- Management, who typically consider the performance of the plant as a system, had a perception of "enhanced control" and "enhanced performance".

These two differing perspectives had to be managed to ensure adoption and use of the system.

5.1.3.2 ORGANISATIONAL CONTEXT

The organisational context contributed to the modernisation process in a number of ways:

- Innovation: Innovation was achieved by persuading vendors to "localise" extensively and adjust the technology to local conditions. Further innovation was achieved by building on software solutions that were already available within Anglo American (Mokgalakwena Platinum mine).
- Alignment between solution and practice: The APC represents the automation of a process that was already in operation (as opposed to the introduction of an entirely new process). Alignment was further facilitated by the phased introduction of process controllers to the use of the system, and by ongoing training to influence behaviour.
- Integration across organisational functions: Good personal relationships between the project manager and the site champion facilitated good integration across organisational boundaries. This was further enhanced by the position of the Head of Mining, and his role in alleviating any concerns that occur at the mine/technology interface. The need to develop a value chain perspective for all role players across upstream and downstream aspects (ore grade information, mining, plant operations) that could influence performance in developing and adopting technology solutions was emphasised as an enabling factor to develop in modernisation initiatives.
- Stakeholder relationships and trust: The very close person-to-person relationship between the plant controller and project manager was a major "pillar of strength" in the project. Trust was gradually developed in the performance and reliability of the system, by mentoring and coaching.

5.1.3.3 CHANGE PROCESS

The change process focused on early involvement of all stakeholders and gradual introduction of process controllers to the system. This approach had positive effects. However, adoption had to be further facilitated through individual mentoring and coaching. This aspect was not foreseen at the outset.

5.1.3.4 READINESS FOR CHANGE

The positive outcome of the modernisation process is indicative of an environment that was ready for modernisation. However, the need to guide and influence adoption indicates that systemic interpretation and communication of benefit, trust in technology, and change process could be enhanced (e.g., by mentoring and coaching). Note that the process was structured in a manner that enabled non-adoption to be recognised and corrective measures to be taken. Change readiness can be considered as high.

By way of illustration, the APC is rated against key outcomes of a modernisation process that is aimed at generating trust and participation (Figure 10). Readiness is indicated on a robot- scale from red to green in a subjective interpretation of APC introduction. Note that the parameters that are used here were derived as part of the development of the systems model of mining modernisation (see Section 6.2 for an explanation of the outcomes and the organisational enablers thereof).

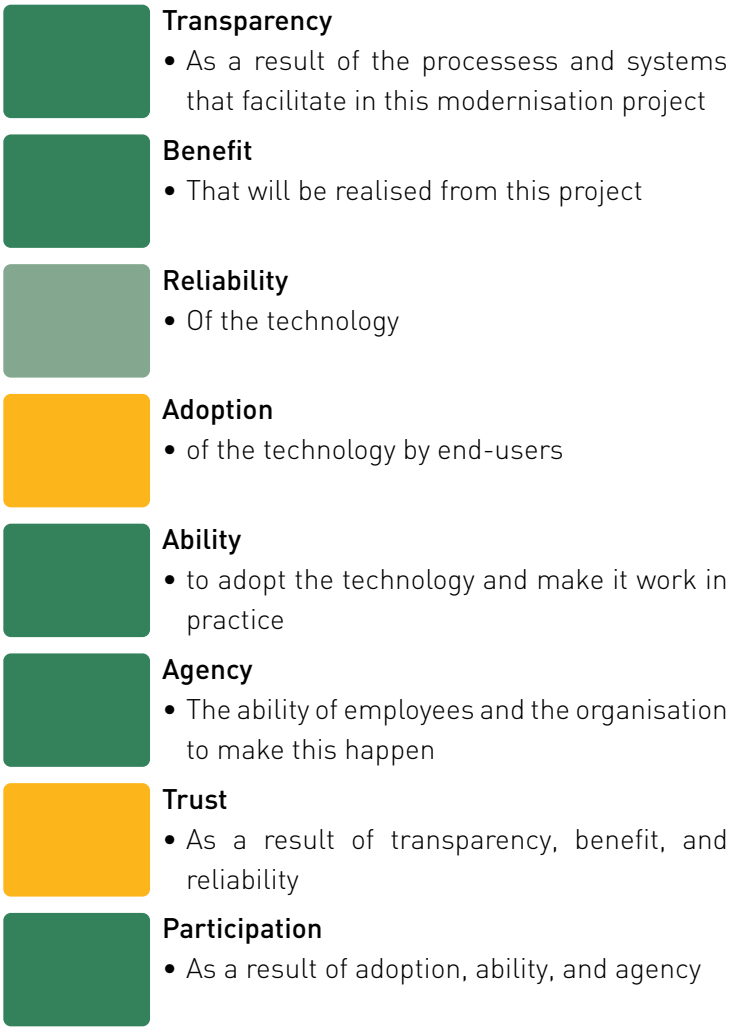


Figure 10 Subjective assessment of change readiness: APC

In this interpretation, the readiness of the organisation to produce positive modernisation outcomes is considered as positive on most parameters. It could be further enhanced by ensuring reliability of the technology (sensors that are suited to the environment). In addition, improved adoption could be facilitated by making benefits clear and by convincing users of the benefit along the entire value chain. In the systems model, both of these aspects enhance trust in technology and participation in the modernisation initiative.

5.1.3.5 KEY PEOPLE-RELATED FACTORS

The following people-related factors are derived from the above discussion. Factors are phrased as enablers:

Table 7 Case 1: People-related factors

FOCUS	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
People	Leadership	To facilitate buy-in and support by operational staff (here: local plant controller and/or project champion)
	Management excellence	To provide a sound basis for the introduction of new initiatives, and to reduce unexpected responses
	Experience	Previous engagement with similar technology and /or processes
Technology	Localisation	Ability to "push vendors" to do extensive localisation
Business	Cooperation across hierarchy	Excellent personal relationships across organisational boundaries to facilitate alignment, support, and buy-in
	Standard Operating Procedures (SOPs)	Clearly defined procedures provide a basis for transfer of the project from the development team to the site

5.2 PROJECT 2: AUTONOMOUS DRILLING

5.2.1 PROJECT DESCRIPTION

5.2.1.1 BACKGROUND

Autonomous drilling comprises the development of a fleet of autonomous drilling machines that are controlled from a central control room. The project has been successful in many dimensions, and is in the process of extended implementation at the Sishen mine.

The following perspectives were represented in interviews:

Table 8 Interview participants: Autonomous Drilling

PERSPECTIVE	INVOLVEMENT	ROLES INTERVIEWED
Project planning and management	Planning, coordination, management	Project manager
Project implementation in Mining	Part of team with the Head of Research to implement technology	Head of Mining
Operations	Supervision and use	• Mine Survey Head • Technologists (2) • Mine Information Operations Control (MIOC) Supervisor

5.2.1.2 DESCRIPTION

This modernisation initiative involves the use of a fleet of autonomous drilling machines that are controlled from a central control room (Figure 11). This is a cutting-edge project, with Kumba leading the industry together with BHP Billiton's Yandi mine as one of two users of autonomous drills globally (AngloAmerican, 2018).

Figure 11 Autonomous drill rig and mine control room at Kolomela (Kumba Iron Ore Ltd., 2017)

5.2.1.3 CONTEXT AND OBJECTIVE

This Horizon One (Best Possible Today) project aimed to:

- Enhance the safety and health of the workforce by removing the drill operator from an unhealthy (noise, dust, vibration) environment to a healthier office environment;
- Improve efficiency by enabling more precise and effective drilling; and
- Improve productivity by using fewer machines to drill more holes per time unit.

5.2.1.4 PROCESS FOLLOWED

Autonomous drilling was introduced in a phased manner, as follows:

- Stage 1: Move the drill operator from the "cab" to a "simulated cab" within line-of-sight of the drill; and
- Stage 2: Move the drill operator from the line-of-sight position to a remote control room (out of line-of-sight), with control over multiple drills.

Transfer of operations to the on-site team was facilitated by the development of very detailed new standard operating procedures (SOPs) to guide the new control process. The project manager kept a high visibility on site to develop trust and ensure progress. A participatory process was followed. All changes were introduced with the assistance of a human resources specialist, and concerns were addressed as they were raised by employees. The unions were involved throughout the process.

5.2.1.5 CONSTRAINTS

Resistance to the adoption of technology by operators included the following:

- Fear of job losses;
- Resistance due to a "loss of physical feel and touch", which led to a sense of decreased control;
- Fear of technology "taking the shine away from the operator"; and
- Fear of "not being in control of making my targets" (in terms of precision and metres drilled).

5.2.1.6 PROJECT IMPACT

The project succeeded in enhancing the work environment of operators, by removing them to a cleaner and healthier workspace, thus improving both health and safety. This enhanced work environment also provided a more gender-friendly context by, amongst others, enabling females to continue work until later in pregnancy. Reskilling of operators opened up new career opportunities, and more employees were interested in pursuing this option. Employees were eager to learn and progress beyond being operators, with some being interested to become technicians.

Further, the project realised productivity improvements of up to 20% by improving the operating hours per day through ongoing drilling during shift changes. The precision of the drilled holes improved, levelling time was reduced from 1.3 minutes to 0.4 minutes, and tramming time was improved from 2.4 to 0.9 minutes. Finally, fewer machines will be required over the life of the mine (Kumba Iron Ore Ltd, 2017; AngloAmerican, 2018).

5.2.1.7 REFLECTIONS AND LESSONS LEARNT

It was clear from the interviews that the role of the project manager in facilitating participation early on in the project was critical. Honest, people-focused engagements enabled resistance to be overcome and facilitated participation.

Drill operators had an increased sense of status that resulted from working in an office rather than in the pit environment, and had a generally improved experience of their work environments.

The following specific recommendations were made by interviewees when asked what they would do differently the next time round:

Table 9 Recommendations by interviewees: Autonomous Drilling

ASPECT	RECOMMENDATION
Managing expectations	A thorough job /skill description and evaluation of new jobs is necessary before implementation to prevent discontent about the new work conditions and new /different skills and mindsets that are required after modernisation
Integration into operations	Provide the operations team with an upfront goal of how many drills to upgrade; this would enable the entire team to be trained simultaneously, and will facilitate introduction over a shorter period.
Early involvement	Involve all stakeholders upfront. Technicians were only appointed later.

5.2.2 INTERPRETATION

In this section, the project description is interpreted in terms of some of the research questions that are explored in this study.

5.2.2.1 KEY SUCCESS FACTORS

Regardless of some initial resistance and uncertainty from operators, the project is successful and is contributing to improved people and improved enterprise factors. Success factors include the participatory

approach of the project manager, which generated trust and team cohesion. Further, the general level of education of operators is high, with at least 90% of operators having a senior secondary certificate. This facilitated easier adoption of technology.

5.2.2.2 KEY FAILURE FACTORS

The impact of the new role on workers – in terms of skills, mind-set, and compensation – is a key aspect that should be managed to prevent failure of the initiative. Engagement with operators at feasibility stage is required to ensure that the gap between advantages for the end-user advantage and advantages for the business is understood and accommodated.

Further, unexpected consequences (or inadequacies) of technology introduction had to be recognised. The excavator played a significant role in ensuring level surfaces before the introduction of autonomous drilling, and the technology had to be adapted to ensure that levelling remains accurate after removal of the excavator from the pit.

Role definitions had to be attended to, and change management was required pertaining to the impact of technology introduction on role definitions and role clarity. For example, the foreman had a key role in ensuring level surfaces, which had to be retained.

5.2.2.3 HOW WERE HUMAN-CENTRED PERSPECTIVES CONSIDERED, IF AT ALL? (PLANNING VS IMPLEMENTATION)

The project manager focused extensively on a participatory process, which succeeded in generating trust and ensuring engagement. The introduction took place in a phased manner, to enable operators to move gradually from one way of work to another. Standard Operating Procedures were employed as a mechanism by which transfer to the on-site team was simplified and error margins were reduced.

5.2.2.4 WHAT WERE THE PERSPECTIVES/PERCEPTIONS OF PEOPLE ACROSS ALL LEVELS ABOUT THE MODERNISATION PROCESS?

The project is considered a success that had benefits for employees and for the business. The following quotes reflect some perceptions about the project:

- *The PM "is always on site" and "in touch with what is happening on the ground"*
- *"Modernisation targets (e.g. 80% autonomous drilling) sometimes needs authoritative support by executives at site level"*
- *"We are now more clever and need better compensation"*
- *"Autonomous operations? I was not for it in the past, but I am now completely convinced. I was misinformed before. I had to adapt but the benefits are significant"*

5.2.2.5 STRATEGIC ALIGNMENT

As indicated earlier, the project was aligned with Kumba's Horizon One objectives of improved efficiency, safety, and production.

Figure 12 represents this modernisation initiative relative to its role in generating benefit, technology adoption, and enterprise agency.

In summary, autonomous drilling is positioned as a modernisation effort that resulted in benefit in multiple dimensions (productivity, safety), where technology adoption was limited to the prescribed use of equipment, and that contributed to enhanced human agency in the enterprise (suggestion of ways to "fix technical problems" by the operators and viewing themselves now as "managers" rather than just operators).

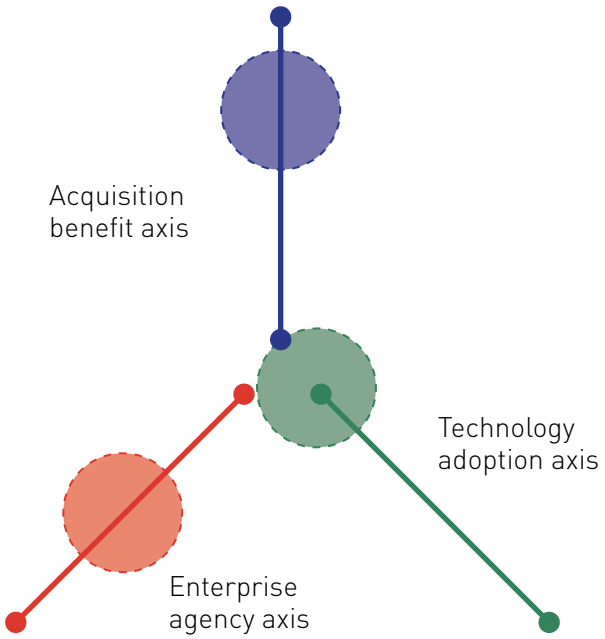


Figure 12 Characterisation of modernisation: Autonomous drilling

5.2.3 IMPLICATIONS

This section interprets autonomous drilling in terms of the organisational environment for modernisation. Perceptions are summarised from different perspectives, after which the case is interpreted in terms of the enabling environment for modernisation (i.e., the organisational context, change readiness, and change process). Thereafter, the key people-related factors that influenced this case are summarised.

5.2.3.1 PERSPECTIVES AND PERCEPTIONS

The following perceptions were deduced from the interviews, reflecting positive implications of the modernisation initiative:

- The project "levelled the playing field for the sexes" as it now enables easier participation in (and contention for) the job of a drill operator by women, as the negative health effects of the physical drill operation was overcome;
- People are "chasing records, there is a proudness in their work"; and
- Operators feel as if they now "operate on a higher level" and therefore need better compensation.

These perceptions reflect positive gains from modernisation, which are evidence in support of the benefits of this strategy.

The gain in terms of gender equality represents an important people-related benefit. The remuneration aspect is implicitly a gain from modernisation that the organisation wants to promote, especially in light of fears of job losses due to modernisation. However, realisation of this gain would require that the effect of the impact of technology on roles is anticipated, and that role definitions and benefits are restructured accordingly.

5.2.3.2 ORGANISATIONAL CONTEXT

The organisational context contributed as follows to this modernisation initiative:

- Innovation: Modernisation contributed here to levelling the playing field across genders, by using technology to remove barriers related to traditionally male-dominated jobs. While this may have been an unintended consequence, the innovative application of technology to resolve gender equality concerns can be explored in other areas.
- Alignment between solution and practice: The solution was phased in gradually, thus reducing the impact of change and facilitating improved adoption and appropriate use of the technology. Benefit was realised for operators, which facilitated acceptance and use of technology.
- Integration across organisational functions: Collaboration and mutual support for the technology by the Heads of Technology and Mining facilitated execution of the project.
- Stakeholder relationships and trust: visibility and presence of the project manager on the site contributed to good relationships with the users of technology, and with management.

5.2.3.3 CHANGE PROCESS

The change process is as follows:

- As for the APC project, the participatory manner in which the project was introduced, as well as the gradual introduction of technology, facilitated buy-in and adoption.
- Some consequences were not anticipated. These relate to role definitions, including: the roles of the operators and foremen in ensuring appropriate levelling, and the expectation of improved compensation by operators, given their changed roles. Role definitions were revised and jobs were upgraded to accommodate role changes. This facilitated distribution of benefit to the operator level, and enhanced adoption.

The latter aspect has been echoed in other cases, and is a key aspect to address in order to ensure successful technology adoption.

5.2.3.4 READINESS FOR CHANGE

By way of illustration, a subjective interpretation of how the autonomous drilling initiative rated in terms of the readiness to produce positive outcomes are summarised below. Readiness to generate successful outcomes is indicated in a robot-scale from red to green (Figure 13).

Figure 13 Subjective assessment of change readiness: autonomous drilling

As before, the key outcomes of the final decision framework are used for this description. Organisational contributors to these positive outcomes are outlined in Section 6.2.

The assessment indicates that agency could be enhanced through additional skilling /mentoring (job descriptions) that allows the operator to add further value to the enterprise by enhancing their roles, for example, through gathering and analysis of drill-related performance statistics. Further, even if adoption and trust was enabled well by the participatory approaches that were followed, this could further be enhanced by ensuring that user benefits are realised (e.g., by addressing compensation concerns).

5.2.3.5 KEY PEOPLE-RELATED FACTORS

The following people-related factors are derived from the above discussion. Factors are phrased as enablers:

Table 10 Case 2: People-related factors

FOCUS	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
People	Formal Leadership	Sometimes need to make an authoritative call to ensure compliance /participation in modernisation drives
	Task Leadership	A better, more comprehensive /systemic and assisted view of the task context provided enhances "agency"
	Education	Improved education relates to the improved potential to do more complex jobs
Technology	Terminology	"Automation" is a loaded and emotional term that lead to immediate fear of job losses. Appropriate communication is essential in addressing these fears, and facilitating participation
Business	Standard Operating Procedures (SOPs)	Clearly defined procedures provide a basis for transfer of the project from the development team to the site

5.3 PROJECT 3: MINE INFORMATION SYSTEM

5.3.1 PROJECT DESCRIPTION

5.3.1.1 BACKGROUND

The Mine Information System (MIS; also interchangeably referred to as Management Information System) aims to present a "single truth" across the value chain, by integrating information from diverse sources for enhanced decision making. The intent is to provide daily real-time information to inform mine planning and operations, based on accurate information (Mining Review Africa, 2016).

The following perspectives were gathered to inform the case analysis:

Table 11 Interview participants: Management Information System

PERSPECTIVE	INVOLVEMENT	ROLES INTERVIEWED
Project planning and management	Planning, coordination, management	Project manager
Technology management	Assist in development and implementation of technology strategy and an MIS expert	Principal Surveyor
Operations	Coordination with head office, implementation, use	MIS site champions Mining Information Operations Control (MIOC) supervisor

5.3.1.2 DESCRIPTION

The project intended to deliver a Mine Information System (MIS) that aims to "Enable the connected mine by providing central data warehousing, reporting and analytics tools to integrate all the data for use and value across operations, business units and the enterprise" (Kumba Iron Ore Ltd, 2017).

5.3.1.3 CONTEXT AND OBJECTIVE

This is another Horizon One (Best Possible Today) project, and is aimed at enhancing efficiency and productivity. However, instead of focusing on a single and localised operational improvement, it aims to share information for improved planning and decision making across the mine value chain.

The project is aimed at realising the following benefits:

- One source of the truth;
- Standardisation;
- Key Performance Indicator (KPI) variance dashboards;
- Elimination of data silos; and
- Movement towards integrated operations and big data analytics.

The focus is on enabling optimal decision making, as well as providing real-time support for operations, by facilitating visibility of information across the value chain.

5.3.1.4 PROCESS FOLLOWED

The development process entailed a 6-month period during which data collection and an "as-is" analysis was undertaken. A reliable representation of the status quo was developed, including a description of data sources, flows, and processes. The process included significant participation, as is reflected by the high number of recommendations (> 120) that were collected. Business architecture maps were produced, and a cost-benefit analysis was done, which considered safety as well as productivity impacts.

Supervisors are conducting regular "fearless discussions" with end-users in which problems with the technology can be discussed. This succeeded in getting users to accept, embrace, and contribute to the improvement of the technology. It also provides a mechanism for dealing with operator feedback, and as such reduces the workload on the supervisor.

5.3.1.5 CONSTRAINTS

The project was undertaken in an environment where entities at all organisational levels could influence the outcome. These included the Technical Solutions unit within Anglo American, Kumba's Technology unit, and Kumba's Business Improvement unit. The involvement of multiple organisational units makes it essential to align objectives, ensure that lines of authority are clear, and coordinate actions.

5.3.1.6 PROJECT IMPACT

The project succeeded in providing visibility across the value chain, and information from the system is used regularly to inform decision making — on site as well as at head office. The system succeeds in facilitating horizontal integration in the organisation, and is facilitating improved decision making.

5.3.1.7 REFLECTIONS AND LESSONS LEARNT

Interviewees shared the following insights when asked what they would do differently, if they had to undertake this modernisation initiative again, or what they can offer as learning for future initiatives based on their experience (Table 12).

Table 12 Recommendations by interviewees

ASPECT	RECOMMENDATION
Decision-making	Too many players in the project decision making process delays progress. In general, managers have to make a mind-shift to trust and delegate to those who are more knowledgeable.
Scale	Introduction of technology into smaller groups is easier to facilitate.
Participation	Technology deployment should start with end-users, as early as possible, to elicit their fears, understand their needs, and develop trust in the technology.
Focus	We must be careful not to roll out different technologies that give similar advantages; some solutions can work against each other.
Continuity	Some projects have failed because of hand-over between too many managers.

5.3.2 INTERPRETATION

In this section, the project description is interpreted in terms of some of the research questions that are explored in this study.

5.3.2.1 KEY SUCCESS FACTORS

Participants considered alignment between the problems that are experienced in practice and the solutions that are available in the market as key to success.

5.3.2.2 KEY FAILURE FACTORS

Multiple role players within and across Anglo American and Kumba Iron Ore Ltd. with respect to information management, technology, and business optimisation pose the challenge of mutual alignment with respect

to a joint vision and the clear definition of roles, responsibilities, accountability, and authority in terms of the implementation of a localised, site-specific solution. Local entities are necessarily closer to the problem environment and have more experience in terms of local requirements, culture, and constraints. Similarly, a balance is required between standardisation across the Anglo group and the local realities that may require non-standard solutions. A balance needs to be found between top- down design and hierarchical decision making for group benefit, and local decision making to make the most of local knowledge and opportunities.

5.3.2.3 HOW WERE HUMAN-CENTRED PERSPECTIVES CONSIDERED, IF AT ALL? (PLANNING VS IMPLEMENTATION)

The MIS implementation followed a change process that included significant consultation and early involvement of various role players, which facilitated buy-in.

However, systemic thinking across organisational boundaries (and the understanding of the systemic influence of own actions) is not well developed. This inhibits successful adoption and implementation. This aspect, as well as silo-based protection of boundaries, need to be managed to ensure successful implementation and value creation.

5.3.2.4 WHAT WERE THE PERSPECTIVES/PERCEPTIONS OF PEOPLE ACROSS ALL LEVELS ABOUT THE MODERNISATION PROCESS?

The role of the project in facilitating visibility and integration across silos is reflected by the following:

- "Previously the view would be whether the plant is reaching its targets; now, a plant and mining perspective is taken"
- "Huge improvement in terms of integrating the different departments"
- "The GM is speaking a lot in meetings about the reports that he is using

5.3.2.5 STRATEGIC ALIGNMENT

The Mine Information System is well aligned with the Horizon One goals of creating The Best Possible Today, but also lays the foundation for the Horizon Two goals of Integrated Autonomous Operations. As for the other cases, the role of the modernisation process is illustrated against the Acquisition benefit, Technology Adoption, and Enterprise Agency axes of the systems interpretation of modernisation (see Figure 14).

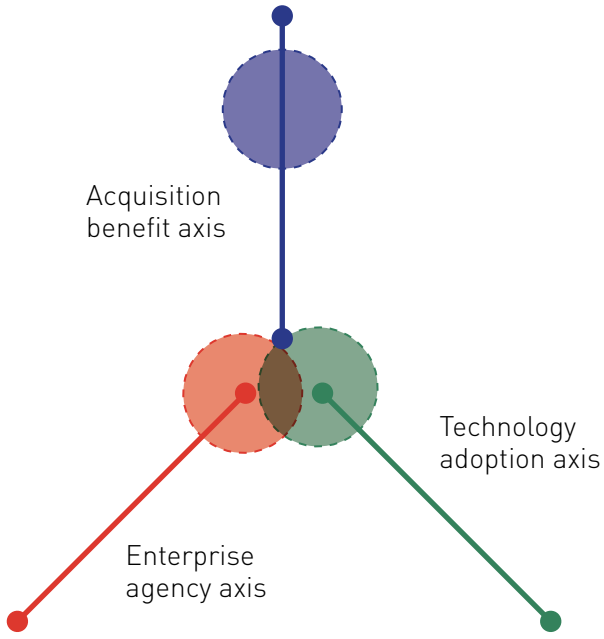


Figure 14 Characterisation of modernisation: Mine Information System

In summary, the Mine Information System is characterised as an initiative that facilitates benefit in more than one dimension (productivity, safety); that only achieved compliance with prescribed use of the technology; and that only achieved compliance to processes and procedures in terms of human agency in the enterprise.

5.3.3 IMPLICATIONS

As for the other projects, this case is interpreted in terms of the organisational environment within which it took place. Perceptions are summarised from different perspectives, after which the case is interpreted in terms of the enabling environment (i.e., the organisational context, change readiness, and change process). Thereafter, the key people-related factors that influenced this case are summarised.

5.3.3.1 PERSPECTIVES AND PERCEPTIONS

Perceptions were collected from a project management, operations management, and operations perspective, and these were in agreement that the project was successful, and provided visibility that enabled improved decision making and horizontal integration within the business. The MIS enhanced people's systemic view of their reality; as such, it facilitated an improved systems view of their total reality and facilitated improved decision making.

An important organisational perspective emerged with respect to the introduction of technology projects in general, namely, that the introduction of multiple projects could be counter-productive, for two reasons. First, duplication and/or contradiction in terms of benefit could realise and, second, operations could to some extent be overwhelmed by a large number of projects (leading to a loss of focus in terms of technology introduction).

To this end, a mine-level function was introduced in the Mining Information Operations Control (MIOC) unit, to facilitate coordination between the technology unit at head office and the mine. In terms of role definitions, users articulate the ideal balance between these two units as that the former is tasked with

identifying new technologies, seeking solutions, and developing the business case, while the latter should play a stronger role in coordinating the implementation of multiple projects across the operations.

This organisational arrangement points to another structure-related tension in technology projects, namely, the need to facilitate innovation at the most appropriate point in the organisational system. Interviewees were of the view that innovation needs to be localised at the mine level, to ensure a drive for continuous innovation, ownership of innovation initiatives, appropriateness of initiatives, and enhanced uptake and adoption. The MIOC unit has an important role in facilitating localised innovation, at least on the mining side, and in ensuring a balance between bottom-up "pull" and top-down "push" implementation of technology.

5.3.3.2 ORGANISATIONAL CONTEXT

The organisational context contributed as follows:

- Innovation and technology introduction: Technology is introduced in accordance with a top-down planning process, and implemented in a bottom-up manner, that allows for participation, user requirements specification, and context-specific design. This structured approach allows for user voices to be heard in the design of the system. Local requirements need to be balanced with the need for standardisation.
- Alignment between solution and practice: The solution was developed in consultation with end-- users.
- Integration across organisational functions: Horizontal integration across silos was facilitated by the relevant managers, and was easier to achieve than to integrate vertically across different levels of the hierarchy. An additional function was created in the MIOC to manage the introduction of multiple

technology projects, and to create a balance between technology introduction on a bottom- up, demand-driven (pull) or top-down (push) basis (see Section 5.3.3.1).

- Stakeholder relationships and trust: Different stakeholders seem to function in accordance with, and protect, their mandates, which counters the development of trust. This needs to be addressed at the organisational design level, through appropriate assignment of authority, accountability, incentives, and key performance parameters.

5.3.3.3 CHANGE PROCESS

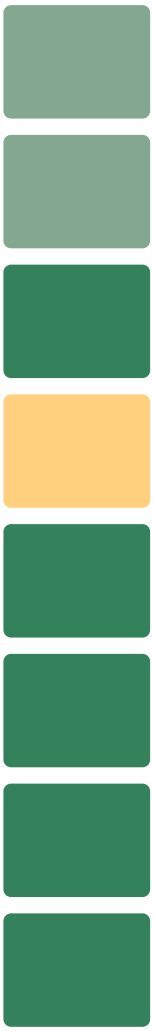
A well-structured conventional change process was followed, with significant upfront user involvement. The system was adopted well, and is used to improve decision making.

5.3.3.4 READINESS FOR CHANGE

By way of illustration, a subjective interpretation of how the MIS initiative rated in terms of the readiness to produce positive outcomes are summarised below. Readiness to generate successful outcomes is indicated in a robot-scale from red to green (Figure 15). As before, the key outcomes of the final decision framework are used for this description. Organisational contributors to these positive outcomes are outlined in Section 6.2.

The assessment indicates that the organisation was generally well positioned and ready to facilitate change related to this project appropriately, due to extensive experience that led to clarity of focus and a clear definition of benefit.

The readiness of Anglo American to engage at local (site) level can be further developed, with specific focus on a balance between a need for standardisation and the enablement of solutions for local uptake and impact.



Transparency
- As a result of the processess and systems that facilitate in this modernisation project

Benefit
- That will be realised from this project

Reliability
- Of the technology

Adoption
- of the technology by end-users

Ability
- to adopt the technology and make it work in practice

Agency
- The ability of employees and the organisation to make this happen

Trust
- As a result of transparency, benefit, and reliability

Participation
- As a result of adoption, ability, and agency

Figure 15 Subjective assessment of change readiness: autonomous drilling

Adoption could be enhanced by broader vertical integration between head office and the site, and of visibility of the vertical integration in decision making that is supported by the system (if any).

The development of a function to coordinate the introduction of multiple technology projects at site level is indicative of a further development to enhance the readiness for adoption of future projects. Some managers are involved in training programmes that include, amongst others, a reflection on the introduction of technology projects and the

development of a "playbook" that will address aspects related to the organisational aspects of technology introduction. Involvement in these initiatives is indicative of the ongoing improvement of readiness for technology introduction.

Elements of the originally planned system were not rolled out, and the implementation thereof could unlock further benefits. Similarly, wider use of the system could result in the realisation of more benefit. Integration between the Anglo American planning functions and local needs could be enhanced.

5.3.3.5 KEY PEOPLE-RELATED FACTORS

The following people-related factors are derived from the above discussion (Table 13). Factors are phrased as enablers as follows:

Table 13 Project 3: People-related factors

FOCUS	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
People	Networks	Used to drive change through focus groups and similar approaches and to combine different types of mining knowledge to develop the URS and to evaluate the proposed solutions.
	Formal leadership	Can derail a project if ill-informed or if aligned to a different agenda
	Power relations	Can derail well planned and intended processes due to human nature of self-interest and "turf protection" tendencies
Technology	R&D	The importance of ensuring good alignment between identified "pain-point" and available technology in the market
Business	Structure	A rigid and large hierarchical structure has the potential to derail (excellent) local initiatives without clear reasons
		Mechanisms to facilitate vertical (across levels of authority) as well as horizontal (across silos) collaboration is required to ensure implementation success

5.4 MODERNISATION AND COMMUNITIES

Kumba Iron Ore Ltd. has a number of initiatives in place to improve the life of the communities that are affected by its mining operations. This project includes a research objective to:
"Articulate the effects of the modernisation processes on communities"

The study focused on investigating within-mine modernisation processes. In addressing the above objective, it therefore articulates the potential tertiary effects of within-mine modernisation processes from a systems perspective. The sections that follow provide a brief overview of the socio-economic context

and Kumba's community initiatives, and then conceptualise community impacts in terms of outside-in and inside-out effects. Note that, based on the nature of the projects that were investigated, empirical evidence was mostly of indirect rather than direct community effects. However, parallel initiatives that were not investigated as part of the case projects do have potential direct benefits (for example: education initiatives).

5.4.1 SOCIO-ECONOMIC CONTEXT

5.4.1.2 EDUCATIONAL LEVEL

Education levels reflect a high percentage of below Grade 12 qualifications (including current learners), 19% of people with no schooling and low percentages of tertiary education.

Table 14 Education levels in and around Postmasburg (2011 data, Statistics South Africa)

LEVEL	PERCENTAGE
Less than Grade 12 (includes current learners)	59%
Grade 12	12.6%
NTC 1- 6	0.3%
Certificate and diplomas with less than Grade 12	0%
Diploma with Grade 12	0.1%
Bachelors, Honours	0.0%
Masters, PhD	0.03%
Other	0.1%
No schooling	19.3%
N/a	11.9%

5.4.1.1 HOUSEHOLD INCOME

The graphs in Figure 16 provide a brief overview of some of the socio-economic parameters of settlements in and near Postmasburg, based on 2011 data from Statistics South Africa.

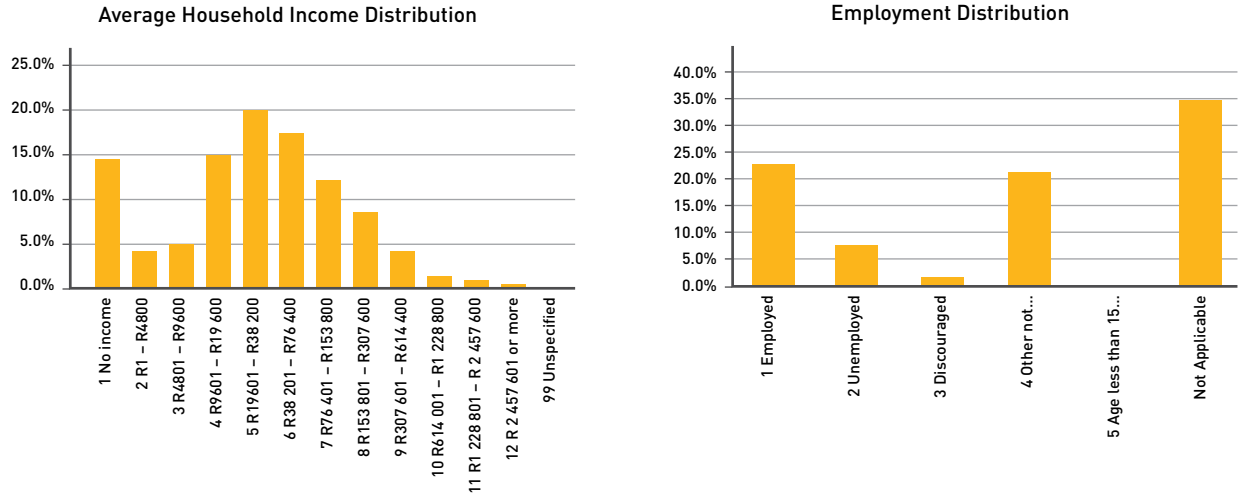


Figure 16 Household income and employment: Postmasburg and surrounds (Based on Statistics South Africa 2011 data)

The data reflect the following settlements in and around Postmasburg:
Tsantsabane, Goedgedacht, Groenwater, Postdene, Postmasburg, Boitshoko, New Town, and Marenteng.

The graphs indicate that the majority of households earn annual income between R 10 000 and R 153 000, with around 15% of households with no income. Just more than 25% of the population is employed.

5.4.2 SOCIO-ECONOMIC INFLUENCES: "OUTSIDE-IN"

We consider the influences of the community on the ability of the mine to modernise, and vice versa, are considered here from a systemic perspective.

Based on the interviews, it can be deduced that the influence of the community on modernisation is mainly determined by the level of education of workers and contractors who are employed by the mine. The ability to adapt easily to technology is further influenced by exposure to technology in the home environment. Given the fast pace of modernisation and rapid development of mining technologies, the education system is unlikely to produce appropriate skills for the future world of work. This places a burden on mines to provide appropriate training, and to reach out to communities to nurture skills and mindsets that are appropriate for modernisation.

5.4.3 SOCIO-ECONOMIC INFLUENCES: "INSIDE-OUT"

Mines have significant influences on communities; however, the nature of the impact is contested. While international development agencies see mines as a means to alleviating poverty and to developing communities, the economic and social benefits often fail to realise (Lamb et al, 2017).

Anglo American and Kumba Iron Ore Ltd. have clearly defined strategies for creating positive impacts on communities, including (Inside Mining, 2018):

- Creating five off-site jobs for every on-site job;
- Working with government to ensure that schools in the communities are among the top 20% state schools in the country;
- Reducing greenhouse gas emissions by 30%;
- Improving energy efficiency by 30%; and
- Reducing freshwater abstraction by 50% in water-scarce regions.

Figure 17 Impacts of current modernisation initiatives, as deduced from interviews

Accordingly, the interfaces between mine and community are primarily rooted in job creation, environment, and education.

Kumba's development initiatives in the region include environmental initiatives (rehabilitation, dust control, dewatering, improved resource use and efficiency); and socio-economic initiatives (artisan training, home ownership programmes, and local economic development projects). The latter focus on local enterprise development, education projects, skills development programmes for school leavers, health and welfare projects, and infrastructure development (Thulo, 2015).

Based on the interviews, the following links between modernisation and development could be identified:

Table 15 Community impacts of modernisation initiatives

PERSPECTIVE	INITIATIVE	DIRECT PEOPLE IMPACT	FUTURE / POTENTIAL IMPACT
Skills	Establishing a culture of continuous curiosity Community Education programmes	Increased skills Increased readiness to work in a high-technology environment	Access to modern career paths Increased income generating potential
	Autonomous drilling	Increased skills	New career paths Increased income generating potential
Health and wellbeing	Autonomous drilling	Removal of people from the unfavourable work environments	Improved health; reduced adverse health effects Less injuries and fatalities Better connectedness/ similarity with home environment due to office environments
	Technology in general	Improved safety	Less injuries and fatalities; longevity
Economic development	Infrastructure development: solar power, transport	Improved infrastructure; improved living environment	Economic development

In summary: based on current modernisation initiatives, the link between community health and wellbeing is indirect. The potential for "a better life" is established through a new way of work and doing and through exposure of employees, and potential future employees, through skills development. These empirical observations are in line with findings by Gumede (2018), who identified occupational health and safety, reskilling, and the resultant improved quality of life as some of the socio-economic benefits of modernisation.

Note that the indirect environmental impacts of modernised mining methods did not form part of this enquiry and are not reflected in this study.

5.5 STRATEGIC PERSPECTIVES ON MODERNISATION

The unit of analysis of this study is Kumba Iron Ore Ltd's implementation of modernisation initiatives at the Kolomela mine, and the projects that are discussed in the previous section serve as implementation examples. In this section, themes related to the portfolio of modernisation initiatives, rather than individual projects, are considered. Themes are identified and key success factors or disablers are listed within each theme, based on participant experience. Participants offered insights on strategy and practice; enablers and disablers of successful implementation; change management; skills development; and organisational alignment. Finally, the aspects that participants considered as "unknowns" in terms of modernisation are summarised.

5.5.1 STRATEGY AND PRACTICE

Participants raised the following aspects relating to strategy and practice:

Strategy, vision, purpose

- Kumba Iron Ore Ltd's technology (modernisation) strategy is aligned with its overall strategy and has clear objectives, aimed at maximising the following:
  → Safety;
  → Efficiency: a value chain focus is required to make this meaningful and impactful; and
  → Resource utilisation: the emphasis should be on operations that maximise ore body utilisation.
- Leadership is required to create a vision of how to deal with the realities of the decrease in both the grade and value of the natural resource.
- Modernisation can and should be seen as a means of creating resilience in the industry.
- The next level of modernisation will be driven by predictive analytics and the ability to integrate initiatives of different scopes of influence and at different "offices" in the organisation for overall improved performance.
- Managers should be supported to have adequate time and attention to explore new technologies and assess their appropriateness for deployment within the organisation.

Funding and resources

- For modernisation to be successful, significant investment is required. This requires a shift in mindsets, available budgets for modernisation, and executive commitment.
- Successful modernisation requires an exit strategy of the corporate initiative from the site at the appropriate time. This should be reflected in the budget, with corporate funding until hand-over, after which funding becomes part of the site's budget.
- A business case is compulsory, indicating (1) the value proposition as well as (2) the capex and opex implications. Importantly, the link between resources that are committed (input KPIs) and the expected gains (output KPIs) should be made clear.
- The business case should include consideration of the benefits, operationally and financially – if relevant, for the end-user.

5.5.2 IMPLEMENTATION: ENABLERS AND DISABLERS

The following enablers and disablers are seen as critical to the success of modernisation initiatives:

Design and buy-in

- Determine the real problem at the level of the user and of the direct management, and sell modernisation

at these "pain points".
- Target the appropriate "client" when promoting modernisation, that is, end-users and supervisors (direct management).
- The benefits of modernisation should be accounted for, benefits or lack thereof for the end-user should be made clear in the business case, and benefits or compensation should be equitably distributed to end-users to facilitate adoption and sustainability of the initiative. This should also translate into changed role definitions and KPIs, where appropriate.

Technology fit for modernisation
- Enabling the user to do the same – and more – with the same effort (or less) is the basic, fundamental driver of technology adoption /change.
- "Stand on the shoulders of technology suppliers" through the use and integration of newest technology without the need to have to develop it by yourself – but technology introduction is not necessarily modernisation, neither is automation /mechanisation.

Integration
- Integration at the systems level is difficult and should be managed carefully.

5.5.3 MANAGING CHANGE

- Change cycles should be adopted that are digestible to humans (e.g. Horizon 1, Horizon 2, etc.) to ensure success in a system where complexity is growing.
- Early consultation with unions is required to prevent derailment, but not necessarily as a means of determining the key problem (pain point) or user benefit.
- Modernisation can lead to a feeling of disempowerment due to a loss of direct control ("feel and touch") over machinery.
- Adequate attention and time should be allocated to modernisation initiatives, and modernisation or technology introduction should become a standard agenda point in meetings, similar to production and safety.
- Be cognisant thereof that modernisation is easier to implement with a young, ambitious workforce compared to a culture that wants to "do things the old way." At the same time, a younger workforce may not have the "wisdom" and experience to manage the organisational complexity that is associated with modernisation processes and the introduction of technology.

5.5.4 SKILLS DEVELOPMENT

Foster a different way of thinking
- Create a "culture of continuous curiosity" – internal to the mining context as well as in the feeder communities.

Community skills influence modernisation, and vice versa
- Systemic "outside in" as well as "inside out" interactions and inter-dependencies influence the skills in the community, and the skills available to the mine for modernisation.

Develop skills to integrate across organisational levels and boundaries
- Different mindsets, education, and world views are needed for employees to integrate top-down visions (of technologically advanced mining) and bottom-up people-related realities and constraints.

Manage Supply and demand

- The tension between required new skills and available skills should be managed, that is, real and potential job losses should be managed.

Develop relevant, appropriate skills

- The output from the education system and the skills needed for the next generation miner and manager are not aligned.
- Appropriate additional coaching and mentoring mechanisms are required to develop the new mindsets that are often required in a modernised workplace.

A broad scope of skills development is required

- Training is insufficient to provide the required modernisation skills. Training needs to be complemented with both coaching (for technical skills) and mentoring (for life skills).
- Training and education needs to develop new mindsets (world views).

5.5.5 ORGANISATIONAL ALIGNMENT

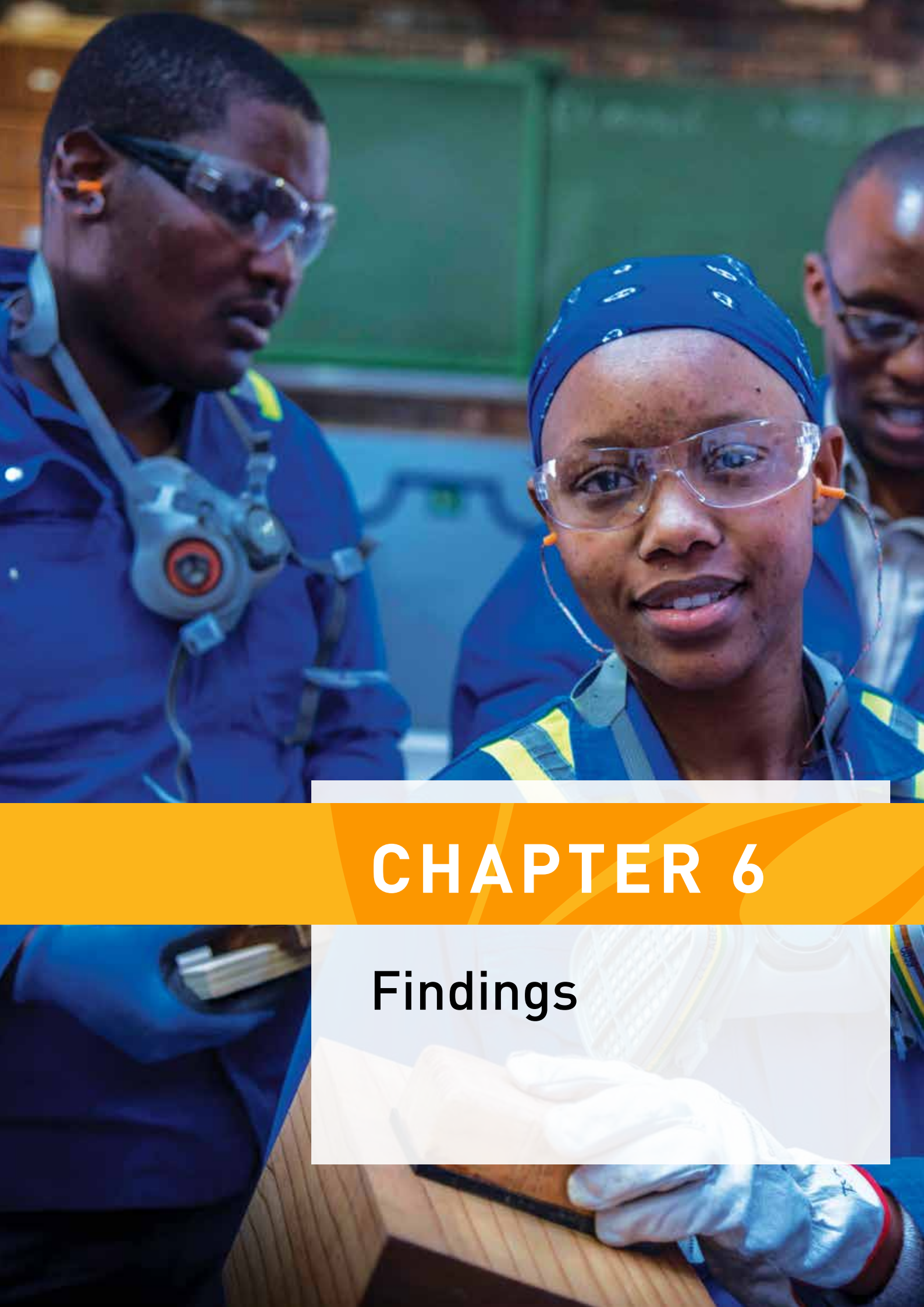
- The interactions between parties that are involved with a modernisation initiative — for example, mining (or technical services), the Technology Unit, and the Mine — needs to be contracted to ensure appropriate authority and accountability, and hence successful implementation.
- Interaction between multiple units with overlapping focus areas should actively be managed (e.g., Technology and Business Improvement unit).
- The mine designated a role in its Mine Information Operations Control (MIOC) unit to facilitate integration across technology projects (as related to the mining side of the business), and to retain control over the implementation thereof. This is indicative of a need to manage multiple concurrent, potentially overlapping or conflicting, technology implementations.
- The positioning of innovation within the organisational structure should be managed with an appropriate balance between technology that is based on demand by the mine, and technology that is sourced and pushed from the corporate environment.
- Membership of the larger Anglo family has brand utilisation advantages (e.g., procurement muscle as well as the ability to resist /filter technology push by vendors)
- The nature of the organisational structure (hierarchy) restricts modernisation progress. It prevents quantum leaps and reduces modernisation to playing catch-up. The Anglo American structure may be too big and demanding, and the game changers might come from some small and agile entity.
- Structural constraints dampen the appetite for risk taking and entrepreneurial behaviour /thinking in the (hierarchical) corporate structure. These qualities and activities are needed to innovate at the next level.

5.5.6 THE "UNKNOWNS"

Participants identified a number of unknowns that are to be resolved to ensure modernisation success. These are summarised in Table 16.

Table 16 What participants do not know about modernisation

THEME	DIMENSION	KEY QUESTION TO RESOLVE
People	Change management	Are conventional change management approaches sufficient to handle the demands for change management associated with modernisation?
	Skills and mindsets	How do we create mindsets that can accommodate a systems approach and complexity?
		What does the next generation miner and mine manager look like, and how do we develop these people?
	Culture	How does culture fit in with modernisation? Which underlying value systems should be created?
		How do we create an internal culture of learning, and entrepreneurial thinking and doing that will overcome the fear of failure, at operator and management levels?
	Variability	How do we deal with the "human factor" that brings variability into the system?
Technology	Emerging technologies	What is the "next big thing" that will enable us to move beyond incremental improvements?
Business	Readiness	How do we ensure readiness for modernisation, when complexity increases beyond simplification?
	Exploring and exploiting	How do organisations create and manage the ability to keep exploring (researching) new technologies, while at the same time exploiting (implementing) mature technologies?
	Modernisation	What is a comprehensive definition of modernisation that will ensure a systemic approach to modernisation?



CHAPTER 6

Findings

6.1 ANSWERING THE RESEARCH QUESTIONS AND OBJECTIVES

The project seeks to answer the following research question:

> *"understand how a technological and digital modernisation process can be successfully achieved in respect of the human factors associated with such change, including individual (personal) implications, organisational effects, and broader social implications".*

The selected projects were analysed in a manner similar to that used for the related SAMERDI project *Three Case Studies on Historical Modernisation Effects and Management Measures* (WP 2.2)[4], so as to ensure consistency. A number of common themes were addressed for each project, and strategic aspects of modernisation were summarised, irrespective of the project in which the case was addressed. This section summarises key people-related factors (Section 6.1.1), and summarises how the research objectives are addressed (Section 6.1.2).

6.2 SUMMARY OF PEOPLE-RELATED FACTORS

The key success and failure factors, as identified in the discussion of each case, are integrated and organised under themes (see Table 17). These factors are rooted in practice, and provide insight into people-related aspects that have been found to influence modernisation processes.

Table 17 Summary of people-related factors

FOCUS	DIMENSION	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
People	Formal leadership	Leadership for participation	To facilitate buy-in and support for the process by operational staff (here: local plant controller and/or project champion)
		Authority	Sometimes need to make an authoritative call to ensure compliance /participation in modernisation drives
		Authenticity	Can derail a project if ill-informed or if aligned to a different agenda
	Task Leadership	Contextual interpretation	A better, more comprehensive /systemic and assisted view of the task context provided enhances "agency"
		Power relations	Can derail well planned and intended processes due to human nature of self-interest and "turf protection" tendencies
		Education	Improved education relates to the improved potential to do more complex jobs
		Trust	High level of trust in project lead at all levels (management and workforce) ensured high levels of adoption
		Networks	Used to drive change through focus groups and similar approaches and to combine different types of mining knowledge to develop the URS and to evaluate the proposed solutions.

FOCUS	DIMENSION	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
Technology	Supply chain	Localisation	Ability to "push vendors" to do extensive localisation
	User benefit	Terminology	"Automation" is a loaded and emotional term that lead to immediate fear of job losses. Appropriate communication is essential in addressing these fears, and facilitating participation
	R&D	Alignment with needs	The importance of ensuring good alignment between identified "pain-point" and available technology in the market
Business	Structure	Cooperation across hierarchy	Excellent personal relationships across organisational boundaries to facilitate alignment, support, and buy-in
		Flexibility	A rigid and large hierarchical structure has the potential to derail (excellent) local initiatives without clear reasons
		Collaboration across silos	Mechanisms to facilitate vertical and horizontal collaboration is required to ensure implementation success
	Standards	Standard Operating Procedures (SOPs)	Clearly defined procedures provide a basis for transfer of the project from the development team to the site
	Process	Management excellence	To provide a sound basis for the introduction of new initiatives, and to reduce unexpected responses

This index is developed further in Section 6.2.3.

6.3 ADDRESSING THE RESEARCH OBJECTIVES

The parallel execution of WP 2.2 (Three Case Studies on Historical Modernisation Effects and Management Measures)[5] and 2.7 (Modernisation Case Study at Kolomela Mine) were intended to jointly address the research objectives across the two projects, as defined in the respective Requests for Proposal. The most important of these objectives is to identify people-related factors related to mining modernisation.

Table 18 summarises the combined objectives of WP 2.2 (Three Case Studies on Historical Modernisation Effects and Management Measures) and WP 2.7 (Modernisation Case Study at Kolomela Mine), and indicates how the objectives have been addressed across the two work packages.

[4] WP 2.2 was undertaken concurrently with the project described in this report (WP 2.7); the work contributed to the recommendations and final decision framework that are presented in this report.

[5] WP 2.2 was undertaken concurrently with the project described in this report (WP 2.7); the work contributed to the recommendations and final decision framework that are presented in this report.

Table 18 Summary response to research objectives

	OBJECTIVE	RESPONSE	REFERENCE
Success and failure factors	**WP 2.7** Obtain a clear understanding of success and hurdle factors of a modernised contemporary site, within the context of the Minerals Council South Africa "Mine 2030"	• Success and failure factors, as well as enablers and disablers, were identified within cases and from management's strategic perspective	This report: • Sections 5
	WP 2.2 Identify factors affecting adoption (including but not limited to physical, geographic, organisational, social, technological), and link these to specific conditions on each site and/or to general social and other factors	• Addressed in the discussion of each case • Addressed in the identification of general factors across cases, and the summary of people-related factors	WP 2.2 report: • Sections 4–6 • Sections 7.1 and 7.2
	WP 2.2 Identify commonalities in success and failure	• Discussion of generalisable factors	WP 2.2 report: • Section 7.1
Change process	**WP 2.7** Provide practical insight into change processes utilised	• The nature of the change process was discussed for each case, and management reflections on change were incorporated with strategic perspectives	This report: • Sections 5
	WP 2.2 Improve the development of a change protocol, including inputs to and from the MOSH process Results will feed into the change protocol, as well as training requirements	• The change process that was followed in each of the cases was discussed. • Critical success factors and considerations for training were identified, and aspects to explore in WP 2.7 were determined	WP 2.2 report: • Sections 4–6
Skills	**WP 2.7** Understand skills changes and opportunities related to specific technologies implemented	• Specific observations related to skills requirements were made from a management perspective, and various skills dimensions were included as a specific factor in the index of people-related factors	This report: • Sections 5 and 6.2.3

	OBJECTIVE	RESPONSE	REFERENCE
Communities	**WP 2.7** Articulate the effects of the modernisation processes on communities	• "Outside-in" and "inside-out" influences, as identified from interviews, are summarised	This report: • Section 5.4
Stakeholders	**WP 2.7** Identify practical factors to inform government and union stakeholder engagement	• The most pertinent practical factor across case studies is early involvement of unions, for facilitating participation and to avoid disruption (not to define user needs – this needs to be done separately). • The perceptions of job losses need to be countered in practice. • Finally, role definitions need to be adjusted in accordance with changes that result from modernisation, and benefits should be realised for employees.	This report: • Sections 5 WP 2.2 report: • Case analyses
Shifts	**WP 2.7** Provide initial insight into shift-change requirements (if any)	• Shift changes did not emerge as a key aspect associated with the modernisation cases that were assessed. Autonomous drilling enabled drilling not to be interrupted by shift changes, thus resulting in improved productivity	This report: • Section 5.2
People	**WP 2.7** Contribute insight to practical technological implementation options for people-management in a modernised mine.	• The concept of "technology fit for modernisation" was defined, to indicate that technology should enable rather than disrupt, and that it should be supported by well- managed supply chains, for reliability and availability. The detailed people-related technology aspects are defined in the people and people/ technology dimensions of the Index and model	This report: • Section 6.2.3
Pilot interventions	**WP 2.2** Recommend pilot intervention processes for common and technology- specific people-aspects.	• Possible pilot interventions were identified, for further exploration in the in-depth case • Decision tools and areas of future research were defined	WP 2.2 report: • Sections 4–6 • Sections 7.1 and 7.2 This report: • Section 6.2 and 7

6.4 A FRAMEWORK FOR PEOPLE-RELATED FACTORS IN MINING MODERNISATION

6.4.1 POSITIONING THE RESEARCH CONTRIBUTION

This research applied a Design Science research approach to deliver a decision framework, which would serve as a basis for the definition of decision tools or processes that could be used to support future modernisation initiatives, at the company and industry level. The framework consists of two elements:

- A systems representation of people-related factors (conceptual model); and
- A list (index) of key people-related factors in mining modernisation.

It is proposed that the systems representation be used as a theoretical basis from which people-related factors in mining modernisation can be considered in future work. In conceptualises modernisation as the integration between people, technology, and enterprise, and as such ensures that modernisation is considered in its broadest sense.

While every new technology, process improvement, or other advancement in mining, since the earliest mining operations, could be considered as modernisation, the confluence of a number of factors — rapid technology development, the advent of the fourth industrial revolution, the need for efficient as well as sustainable resource exploitation, and others — define the current wave of modernisation as a new "problem" or opportunity, for which solutions are largely immature. As such, the knowledge contribution of the Design Science research that was undertaken in these two projects can be positioned as follows (Gregor and Hevner, 2013):

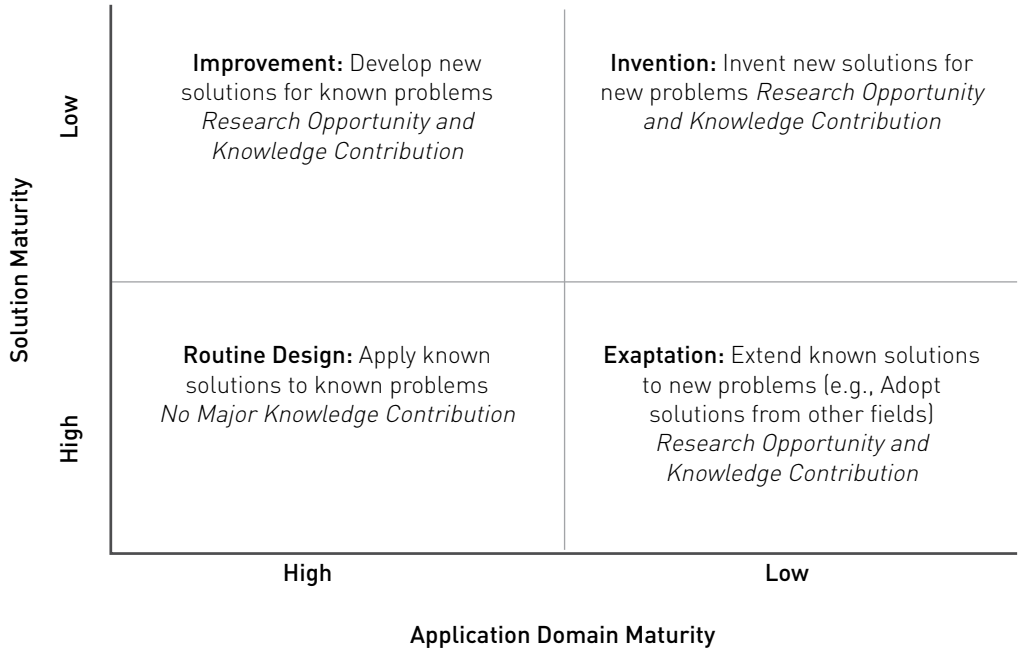


Figure 18 Design Science Research Knowledge Contribution Framework (Gregor and Hevner, 2013:345)

In this framework, the research is considered as invention, that is, the development of new solutions for new problems. The implication of this positioning is, amongst others, that solutions need to develop and mature within their areas of application.

For the research to be applicable and useful, it is essential that the theoretical grounding (systems model) be translated into tools that can be applied in practice. For this project, it is proposed that this translation from theory to practice comprises the following (Figure 19).

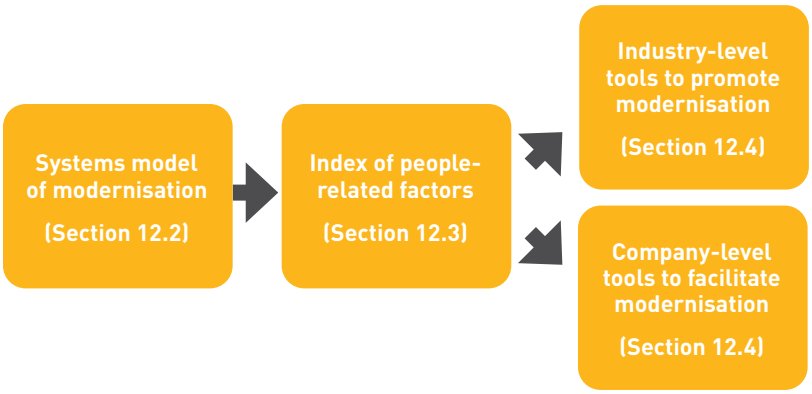


Figure 19 From theory to decision tools

The remainder of this section outlines the final versions of each of these elements, as indicated in the diagram.

6.4.2 A SYSTEMS REPRESENTATION OF PEOPLE-RELATED FACTORS

The systems representation serves as baseline for the conceptualisation of the Index of People-related factors, and for the definition of decision tools. It considers modernisation from three perspectives, namely, enterprise, people, and technology. Modernisation is conceptualised as happening at the confluence of these three areas. Modernisation is influenced by dimensions or factors within each of these areas and, conversely, the state or maturity of dimensions or factors within each of these perspectives determine the extent to which modernisation can take place in a company or sector. The current systems representation, based on (a) the conceptualisation and literature review of WP 2.7 and (b) the final report from WP 2.2 (Three Case Studies on Historical Modernisation Effects and Management Measures)[6], reflects the interactions between business, technology, people, and the context within which they operate (Figures 20 and 21).

[6] WP 2.2 was undertaken concurrently with the project described in this report (WP 2.7); the work contributed to the recommendations and final decision framework that are presented in this report.

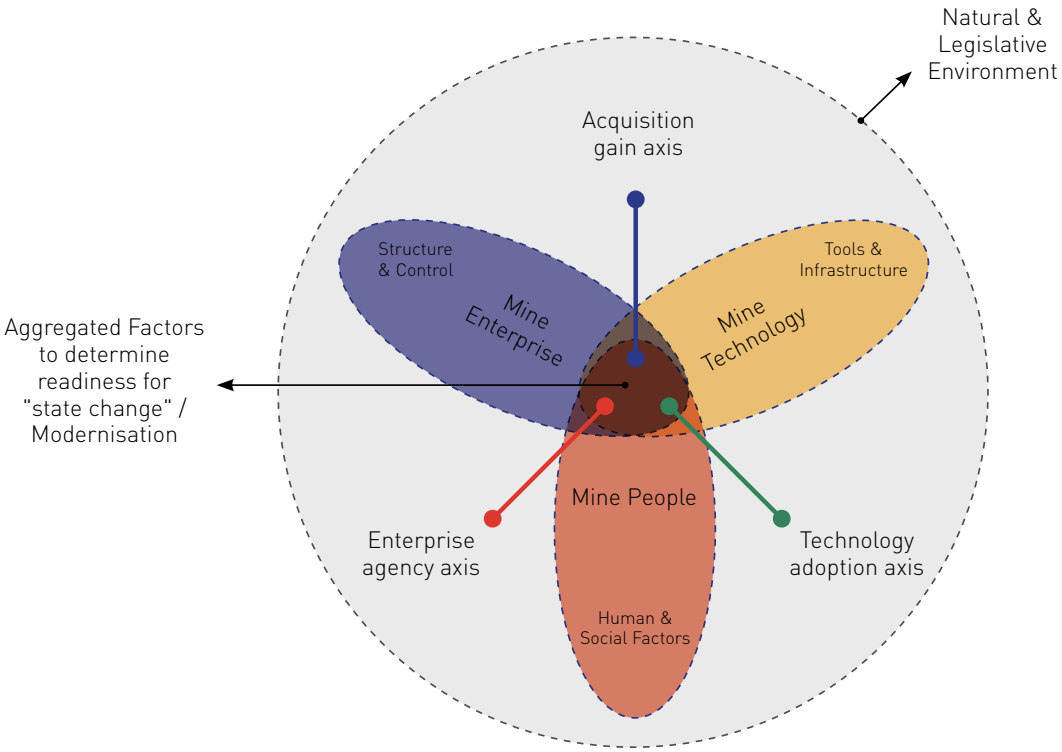


Figure 20 Systems representation: key elements

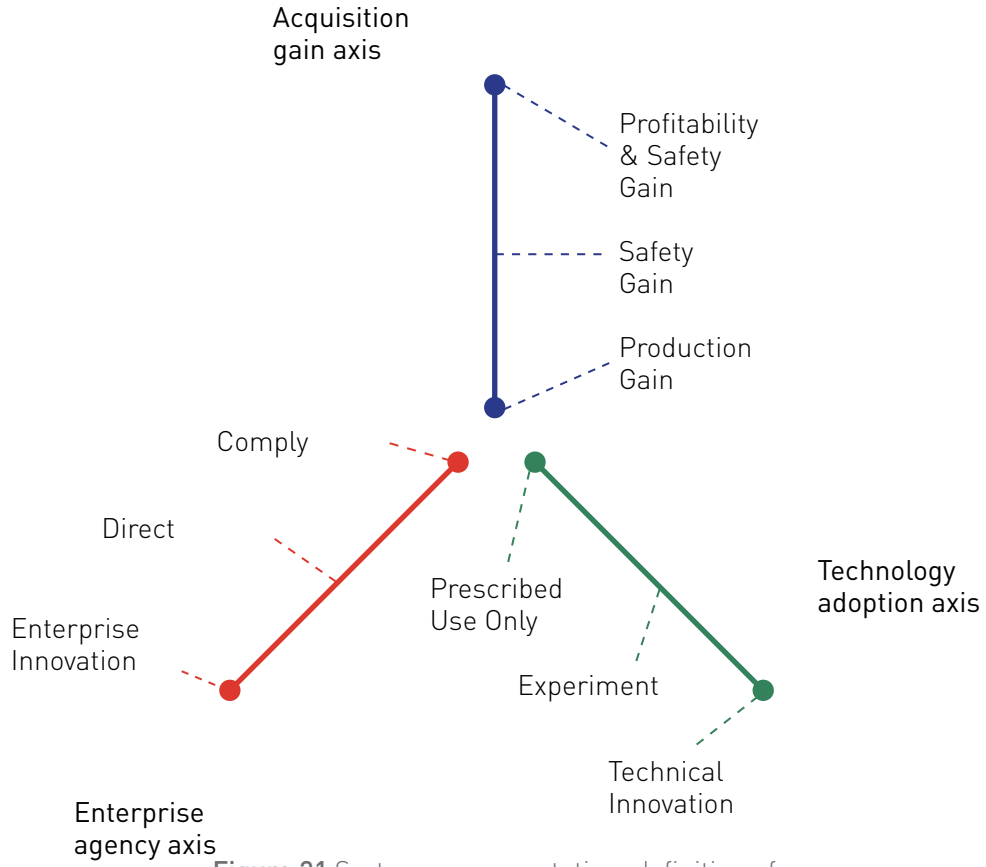


Figure 21 Systems representation: definition of axes

The representation in Figures 20 and 21 describes the different perspectives, and outlines the axes upon which the dimensions that affect modernisation can be described. The axes could also serve as an ideal

positioning towards which an organisation or sector could strive in the process of modernisation. For example, in terms of Technology adoption, the enterprise could be satisfied with the use of technology as described; it could encourage employees to experiment with technology to encourage adoption; or it could foster technological innovation. Similarly, the Acquisition axis could reflect gain for the enterprise from modernisation in terms of increased production, improved safety, or a combination of both.

Following the work done for the in-depth case study of WP 2.7 (Modernisation Case Study at Kolomela Mine), these concepts were enhanced, both in terms of the description of the perspectives and in terms of the definition of the axes. The enhancements are as follows:

- The mining system, with its people, technology, and enterprise sub-systems (and "overlaps"), is positioned within the broader context of the societal, technology, and economic landscapes. This provides an improved view of the interplay ("outside in" and "inside out") between the internal (mine only) and external (mine within context) systems elements; and
- The names and definitions of the major areas of interaction between the four system elements are refined.

The main interaction areas, including descriptions, are indicated in Table 19:

Table 19 Revised systems model definitions

INTERACTION	WP 2.2 DESCRIPTION	REVISED DESCRIPTION
People and technology	Technology adoption	Technology adoption
Technology and enterprise	Acquisition gain	Acquisition benefit
People and enterprise	Enterprise agency	Enterprise agency
People, technology, and enterprise	Successful modernisation	Aggregated factors to drive "state change" /modernisation

The interplay between the internal and external contexts of the identified sub-systems (i.e. people, technology and the enterprise — which is the focus of this project) can now be depicted as follows:

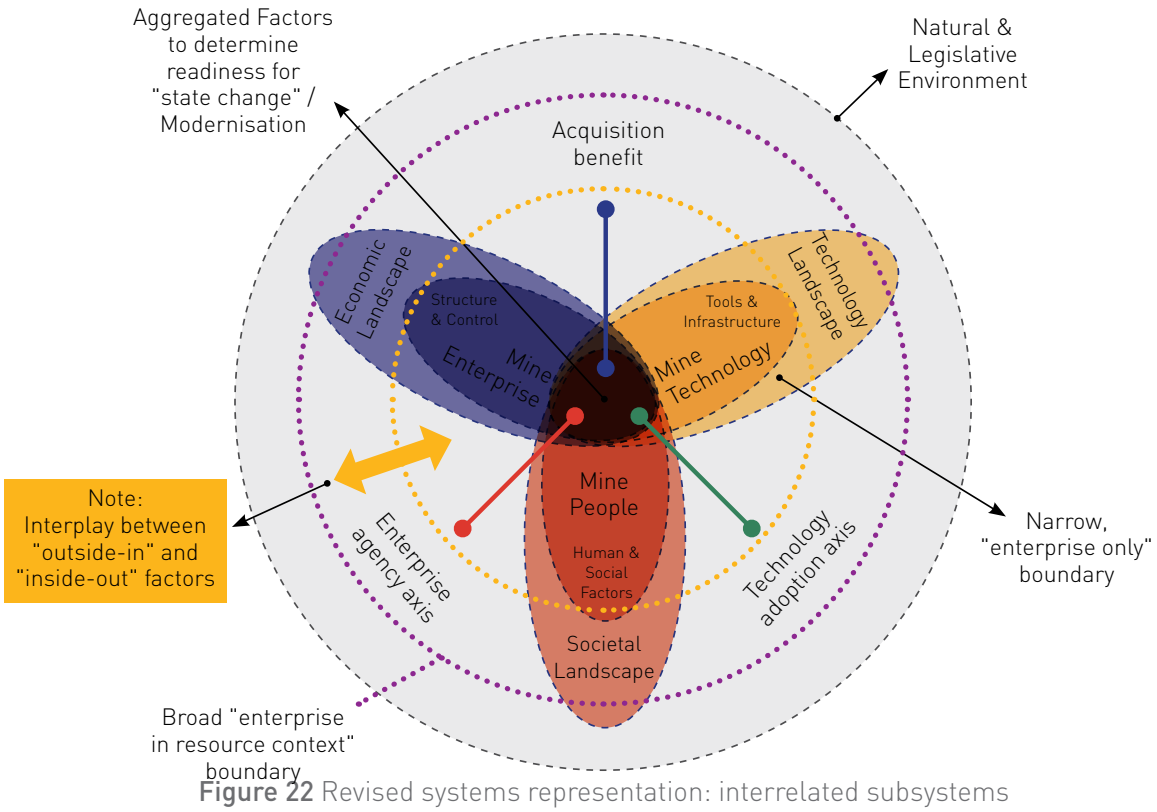


Figure 22 Revised systems representation: interrelated subsystems

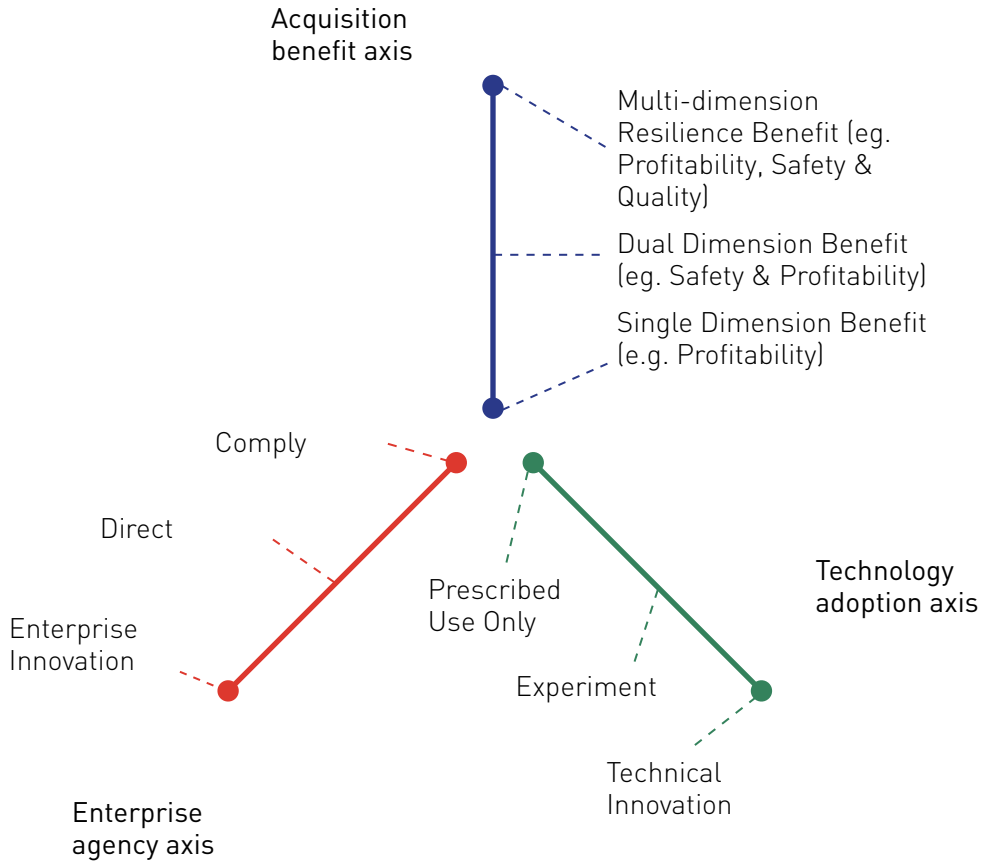


Figure 23 Revised systems representation: definition of axes

The range of possible outcomes on the different axes of interaction between the sub-systems (people,

technology and the enterprise) has been re-labelled.

As presented here, the model guides the positioning of the various "interaction" elements that form part of a modernisation process, when viewed from the perspective of the enterprise, people, or technology.

These representations are at the sub-system level. To enable the translation from sub-systems to a more detailed grouping of the factors that influence modernisation from within each of these perspectives, the model was refined further.

This refined version of the model identified the following dimensions within each sub-system (see Table 20 below).

Table 20 Sub-systems and dimensions of final decision framework

SUB-SYSTEM	DIMENSIONS (PRIMARY FACTORS)	OUTCOME (SECONDARY FACTORS)	CONTRIBUTING TO (TERTIARY FACTORS)
Enterprise	Strategy	**Transparency** (Clarity with regards to the current status of the strategy, structure, standards and processes of the enterprise)	**Trust**
	Structure		
	Standards		
	Process		
Enterprise and Technology	Innovation / Modernisation Structure	**Benefit** (The nature of the gain achieved through the acquisition of the technology)	
Technology	Business Case	**Reliability** (The ability of the technology to consistently perform according to design and expectations)	
	R&D		
	Supply Chain		
	Maintenance		

SUB-SYSTEM	DIMENSIONS (PRIMARY FACTORS)	OUTCOME (SECONDARY FACTORS)	CONTRIBUTING TO (TERTIARY FACTORS)
Technology and People	User Benefit	**Adoption** (The extent to which people are making the technology their "own")	**Participation**
	User Empowerment		
People	Education	**Ability** (The end result of education, skills development, a workable view of the world and the social networks of people)	
	Skills		
	Experience		
	Mindsets		
	Networks		
People and Enterprise	Structural (Formal) Leadership	**Agency** (The degree to which an individual can influence the system within which he /she operates)	
	Task (Informal) Leadership		

The model implies that the presence of these primary and secondary factors within a mining system contributes significantly to the generation of "trust" and "participation", which seem to be the bedrock of positive outcomes of modernisation initiatives.

These elements were used to guide the revised structuring of the index of people-related factors in the next section.

6.4.3 AN INDEX OF PEOPLE-RELATED FACTORS IN MINING MODERNISATION

This research set out to develop a systems model of mining modernisation, as a basis for an index of people-related factors in mining modernisation. An initial literature review served to familiarise the researchers with modernisation and the people-related factors that are cited in popular and academic literature, and to assess the scope and extent to which people-related factors are studied.

Following on the literature reviews, the interviews across case studies were used to empirically identify people-related factors that affect modernisation initiatives in practice. These were themed and grouped in a bottom-up manner. At the same time, a systems model was developed with the aim of identifying subsystems and potential relationships between groupings (dimensions) of people-related factors (see Sections 6.1.1 and 6.2).

This section uses the dimensions that were identified in the systems model, as well as the people-related factors that were identified in empirical work across WP 2.2 *(Three Case Studies on Historical Modernisation Effects and Management Measures)* and WP 2.7 *(Modernisation Case Study at Kolomela Mine)*, to present a final index of people-related factors.

Table 21 Index of people-related factors

FOCUS	DIMENSION	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
Enterprise	**Strategy**		
	Structure	**Empowerment**	Empower the right roles to facilitate availability of components and functioning of system
		Flexibility	A rigid and large hierarchical structure has the potential to derail (excellent) local initiatives without clear reasons
		Cooperation across hierarchy	Excellent personal relationships across organisational boundaries to facilitate alignment, support, and buy-in
		Collaboration across silos	Mechanisms to facilitate vertical and horizontal collaboration is required to ensure implementation success
	Standards	**Compliance**	Since the use and importance of standards is well established in the industry, effort should be made to develop best-practice standards for modernisation, and to ensure compliance with these standards.
		Standard Operating Procedures (SOPs)	Clearly defined procedures provide a basis for transfer of the project from the development team to the site
	Process	**Integration**	Ability to anticipate effects from an integrative perspective Ability to integrate an initiative into the organisation across different functions and silos
		Inclusiveness	Inclusive, early participation Testing of new initiative in practice — to prevent unintended consequences
		Communication	Early and comprehensive communication Communicate to elicit inputs into solution acquisition as well (not only communication of solution)

FOCUS	DIMENSION	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
Enterprise And Technology	Innovation / modernisation structure	Local innovation	Allow for local innovation, so as to facilitate modernisation
		Systemic innovation	Adopt a systemic approach to innovation and the introduction of technology, to allow for a comprehensive, well-researched solution that addresses multiple organisational factors (supplier reliability, in-practice testing, implications on end- users, assessment of readiness, leadership, skills transfer)
	Business case		
Technology	Research and development	Adoption	Technology that is tested and proven in real-life conditions
		Intuitive use	Technology that enables rather than disables
		Trust in technology (reliability)	To ensure that benefits are sustained Define specifications that are appropriate for a harsh environment Ensure availability
		Appropriate complexity	Too many new systems, or systems that are too complex, distract from core business and hinder adoption
		Fit for modernisation	Technology that is designed to compensate for human factors (e.g., errors, age, adherence, culture)
		Alignment with needs	The importance of ensuring good alignment between identified "pain-point" and available technology in the market
	Supply chain	Localisation	Ability to "push vendors" to do extensive localisation
		Supplier management	Too much dependency on external suppliers prevents the early recognition of problems internally
	Maintenance		
Technology And People	User benefit	Terminology	"Automation" is a loaded and emotional term that lead to immediate fear of job losses. Appropriate communication is essential in addressing these fears, and facilitating participation
	User empowerment		

FOCUS	DIMENSION	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
People	**Education**	**Level**	Improved education relates to the improved potential to do more complex jobs
	Skills	**Skills development**	Appropriate training and skills transfer to ensure sustained benefit and local knowledge Development of a "new breed of miner" that is technology savvy and able to adapt to ongoing technological change
		Experience	Previous engagement with similar technology and /or processes
	Mindsets	**Buy-in**	Develop an understanding among affected employees of purpose, impact on people, and reason for roll-out, to facilitate adoption
		Participation	To ensure appropriateness of solution to practice
		Self interest	Modernisation that makes the job easier will be welcomed, adopted, and will not need to be circumvented
		Incentivisation	Appropriate incentives to facilitate adoption; balance between production and safety incentives.
		Accountability	To ensure that developments aimed at safety improvements are not bypassed
		Culture and behavioural change	Address elements that counter adoption of modernisation (here: risk appetite)
		Role fulfilment	Individuals should identify with, and adopt the changes to, their roles after modernisation
		Trust	High level of trust in project lead at all levels (management and workforce) ensured high levels of adoption
	Networks	**Empowerment**	Feedback from one's network can either enhance or counter modernisation
		Enabler of change	Networks can facilitate change through focus groups and similar approaches, and to combine different types of mining knowledge in solution development

FOCUS	DIMENSION	PEOPLE-RELATED FACTOR	ROLE IN MODERNISATION SUCCESS
People And Enterprise	**Structural (formal) leadership**	**Leadership for integration**	Leaders that provide holistic direction and integration across organisational functions
		Authority	Sometimes need to make an authoritative call to ensure compliance / participation in modernisation drives
		Authenticity	Can derail a project if ill-informed or if aligned to a different agenda
	Task (informal) leadership	**Leadership for participation and adoption**	Leaders that are able to facilitate participation and promote adoption
			To facilitate buy-in and support for the process by operational staff (here: local plant controller and/or project champion)
		Contextual interpretation	A better, more comprehensive /systemic and assisted view of the task context provided enhances "agency"
		Power relationships	Can derail well planned and intended processes due to human nature of self-interest and "turf protection" tendencies
			Power relationships that are balanced and negotiated to facilitate inclusiveness, participation, and collaborative decision making, so as to ensure modernisation success in a complex environment.
	Management excellence	**Baseline for operations**	To provide a sound basis for the introduction of new initiatives, and to reduce unexpected responses

6.4.4 PROPOSED DECISION TOOLS

A portfolio of decision support tools is proposed as a further step in aiding the translation from the theory (systems model) to practice. It is assumed that modernisation can be influenced by developing tools for use at the sector level as well as tools for use at the company level.

At the sector level, tools are aimed at aiding modernisation across companies, and at addressing aspects that individual companies would not necessarily focus on, either for a lack of resources, or because of the risk associated with failed implementations. At the company level, the focus is on aiding companies towards clarity in terms of panning for modernisation. In both cases, the focus is on people-related factors in modernisation.

Proposed tools or interventions are summarised in Table 22, and briefly explained thereafter. The tools reflect requirements that were expressed during interviews across cases. Tools are described at the

concept level, as proposals for future development. Note that "tool" is used here in the broadest sense, and could refer to a method, roadmap, process, guidelines, or any other appropriate means of supporting progress towards modernisation.

Table 22 Proposed decision tools

	FOCUS	OBJECTIVE	ACTION	PROPOSED TOOL
Sector	Strategic	Influence sector towards adoption of a systemic perspective on people factors in modernisation	Translate the future into today	People-centred technology road-mapping
			Develop modernisation capabilities	People-centred technology road-mapping
			Observe, report, track	'State of modernisation' report
Company	Strategic	Provide a guide towards a systemic strategy for modernisation	Guide companies towards modernisation	People-centred modernisation roadmap (including readiness assessment; strategic focus assessment)
	Strategic		Translate strategic intent into organisational design	Guidelines for systemic organisational design to facilitate modernisation in the local context (structure, incentives, leadership, culture, etc.)
	Tactical	Provide guidelines for modernisation portfolio design, to include human factors	Facilitate people-focused portfolio planning	Modernisation portfolio planning guide
			Facilitate people-focused project planning	Modernisation project planning guide
	Operational	Provide guidelines for assessment of modernisation-related behavioural changes	Influence adoption	Guide for translation of new skills into a value-adding role

6.4.5 SECTOR-LEVEL TOOLS

6.4.5.1 TRANSLATE THE FUTURE INTO TODAY: PEOPLE-CENTRED TECHNOLOGY ROADMAP

It is clear across the in-depth case as well as the historical case studies that mines need to make sense of a vast spectrum of available technologies, to match to their requirements. Vendors play a key role in promoting technology solutions, with the result that progress is vendor-driven. Where a strategic approach is followed to modernisation and technology introduction, organisations need to divide their focus between identifying, adopting, and implementing solutions, while at the same time being aware

of future developments. A roadmap that provides insight into the spectrum of technologies (current and emerging), and the human-resource requirements (both in terms of technology use and the management of modernisation initiatives) could facilitate more effective progress.

6.4.5.2 DEVELOP MODERNISATION CAPABILITIES: THE "NEW BREED OF MINER"

A key theme across cases is the need to understand the skills requirements of a "new breed of miner", who is capable of rapid adoption of new ways of work and new technologies, is comfortable with continuous uncertainty, understands the implications of work in a modernised environment, and can think systemically about the consequences of actions. Importantly, this includes a view on a "new breed of manager", who knows how to facilitate modernisation and create space for employees to innovate for long-term resilience. Industry-level initiatives should define such characteristics and facilitate the establishment of training protocols for skills development.

6.4.5.3 OBSERVE, REPORT, TRACK

A "state of modernisation" report could reflect annually or bi-annually on progress in the industry with respect to people and modernisation. Focus areas include leading practice, common challenges, and new horizons, with emphasis on topics such as leadership for modernisation, capability development, and others. It could identify the potential for modernisation, the current adoption, readiness of companies across the sector, and the status of skills development for modernisation. It could reflect on the effectiveness, or lack of, sectoral strategies in support of modernisation.

The purpose is to provide a mirror against which the sector as a whole and individual companies could measure their approaches to people and modernisation, so as to promote improved practice.

6.4.6 COMPANY-LEVEL TOOLS

6.4.6.1 GUIDE COMPANIES TOWARDS MODERNISATION: PEOPLE-CENTRED MODERNISATION ROADMAP

Companies differ in their interpretation of, and readiness for, modernisation, and in terms of the skills and capability (including processes, systems, etc.) for modernisation. Modernisation processes such as technology adoption fail for reasons that include inadequate skills, inadequate management capability (including supply chain management), unexpected people-related consequences, and failure to revise roles and incentives in line with the demands of a modernised environment. Further, companies are often not clear as to their objective for modernisation or engage in modernisation activities without an overarching strategy. A guide for modernisation would include company-level readiness assessment (structure, incentives, leadership, culture, etc.) for modernisation, capability assessment (people and management capacity), as well as a guide in terms of strategy development for modernisation (with a focus on people-related factors).

6.4.6.2 TRANSLATE STRATEGIC INTENT INTO ORGANISATIONAL DESIGN

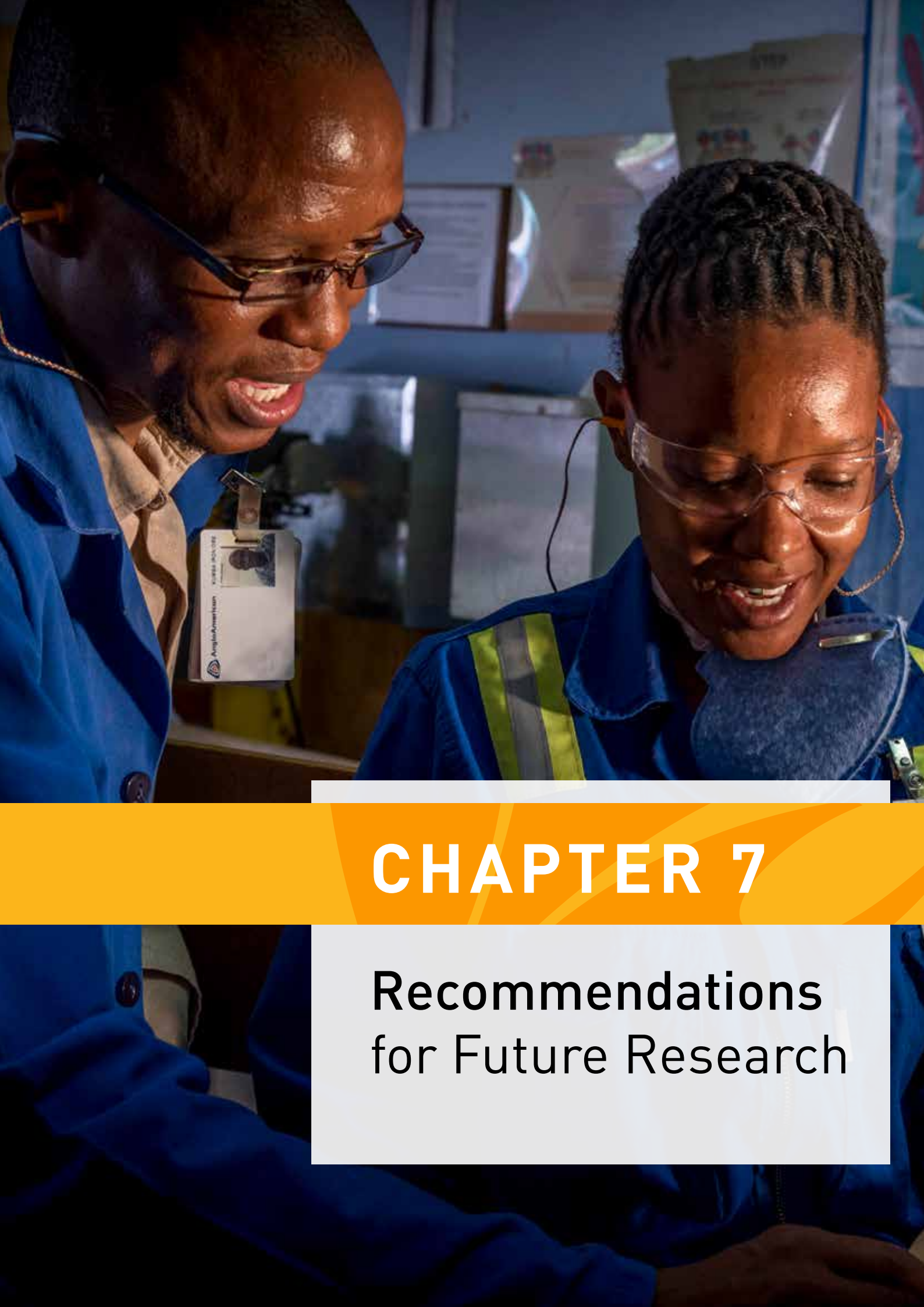
The people-related modernisation strategy needs to live in an enabling organisational design. This guide would facilitate the matching of strategic intent with organisational design, by identifying enablers and disablers. The focus would be on incentives, role definitions, KPIs, structure, and the appropriate positioning of units that drive modernisation. Related aspects such as enablement of entrepreneurial culture would be relevant.

6.4.6.3 FACILITATE PEOPLE-FOCUSED PORTFOLIO AND PROJECT PLANNING

This study identified a number of people-related factors that are essential to the successful outcome of modernisation initiatives. This decision tool would comprise a guide at portfolio and project level to guide companies towards accommodating people-related factors at the portfolio and project level.

6.4.6.4 INFLUENCE ADOPTION

Modernisation initiatives bring about behavioural change, which needs to be unlocked for successful organisational gain. This tool would influence organisations to assess behavioural change, and determine changes to the organisational environment that would facilitate adoption and ensure sustained benefit.



CHAPTER 7

Recommendations for Future Research

This research conceptualised mining modernisation from a systems perspective, and developed a model and an index of people-related factors that are important to address during mining modernisation initiatives. Based on this learning, a number of decision tools were proposed, that could be developed to promote modernisation at a sector level, and to facilitate modernisation at the company level. The intent is to put mechanisms in place that will allow the sector to exploit modernisation for long-term gain.

Interviews with various role players across four case studies] indicated that the concept of modernisation is ambiguous, and that no clear definition exists. A comparison of people-related factors as identified from empirical work with those identified from the literature highlights that a number of concepts are assumed with respect to modernisation that may not be as relevant in practice. The researcher is left with the sense that, in many instances, modernisation is used as a popular concept, but that the strategic intent and implications thereof is poorly understood. This research attempted to address this gap by putting forward and differentiating concepts related to modernisation. This was done by proposing a definition for modernisation as well as for people-related factors in modernisation, and by defining a systems model, index of people-related factors, and decision tools in support of modernisation.

However, the research also highlighted a number of questions that remain unanswered. Some of these could be examined when developing decision tools, while others would require new research initiatives. Based on these unresolved questions (Section 5.5.6) and the proposed decision tools (Section 6.2.4), the following themes for future research for people-related factors in mining modernisation are proposed:

Table 23 Proposed research themes

THEME	DESCRIPTION
Sector-level tools	Prioritise and develop sector-level tools to facilitate modernisation
Company-level tools	Prioritise and develop company-level tools to facilitate modernisation
	Enterprise agency
Change management	Develop change management approaches (not only processes) that are suited to modernisation (i.e., fast-changing, highly uncertain environments)
Management for modernisation	How to develop mindsets and facilitate behaviour that can accommodate a systems approach and complexity?
	How to manage the variability that is introduced by human engagement with technology in modernising and modernised environments?
Culture	Develop models and theory in support of culture and value systems that are appropriate to a modernising and modernised environment

Questions that are not directly or not only related to people-related factors have been incorporated in the definition of tools for modernisation, for example, how to ensure readiness for complex environments, and how to identify and respond to emerging technologies (how to manage exploitation and exploration simultaneously, to ensure that ongoing benefit is created from modernisation).

CONCLUSION

This document summarises work done in two projects (WP 2.2: *Three Case Studies on Historical Modernisation Effects and Management Measures and WP 2.7: Modernisation Case Study at Kolomela Mine)*[7] of the SAMERDI SATCAP programme. It consolidates learning across four case studies into people-related factors in mining modernisation. This exploratory empirical work informed the following concepts:

- A resilience-based definition of mining modernisation;
- A definition of people-related factors in mining modernisation, expressed in terms of primary, secondary, and tertiary factors;
- A systems model for people-related factors in mining modernisation (theory base);
- An index of people-related factors in mining modernisation (bridge between theory and practice);
- Proposed tools to inform strategic, tactical, and operational decision making and action for promoting modernisation, at the company and sector level; and
- Proposed directions for future research, for people-related factors in mining modernisation.

This work elicited preliminary factors and relationships between them, based on empirical work in four case studies in underground and open cast mining from the platinum and iron ore sectors in South African mining.

The research products and proposed directions of future research were based on repetitive observations across cases, and as such forms a valid basis to inform further exploration. However, it is acknowledged that more work in different subsectors could elicit additional factors or different perspectives.

The study reflected a shift in focus from people-related factors as focusing on human-technology interaction towards a more holistic approach to modernisation. The implication being that the modernisation approach needs to consider enterprise, technology, and people-related perspectives, and the interfaces and integration thereof. Modernisation initiatives would be effective and sustainable if they form part of an overall holistic and strategic approach to modernisation (beyond change management), and that a long-term systemic focus is needed.

The results from this study offer valuable learnings which become important for modernisation in mining in the minerals sector. SATCAP 2019/2020 research work on the full modernisation impact assessment will use this study as a base, to further build onto these findings and validate them so as to be able to offer guidance in the approach to modernisation to the mining sector.

[7] WP 2.2 was undertaken concurrently with the project described in this report (WP 2.7); the work contributed to the recommendations and final decision framework that are presented in this report.

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APPENDIX

APPENDIX A: FINAL SYSTEMS MODEL

The extended, final version of the systems model reflects the primary and secondary factors (not limited to people-related factors) within the various sub-systems, as well as in the "overlap" areas of the sub-systems and their (primary and secondary factors') contribution to the "trust" (of) and "participation" (in) modernisation. These extensions to the model are based on the interviews that were conducted for the WP 2.7 case study (Modernisation Case Study at Kolomela Mine).

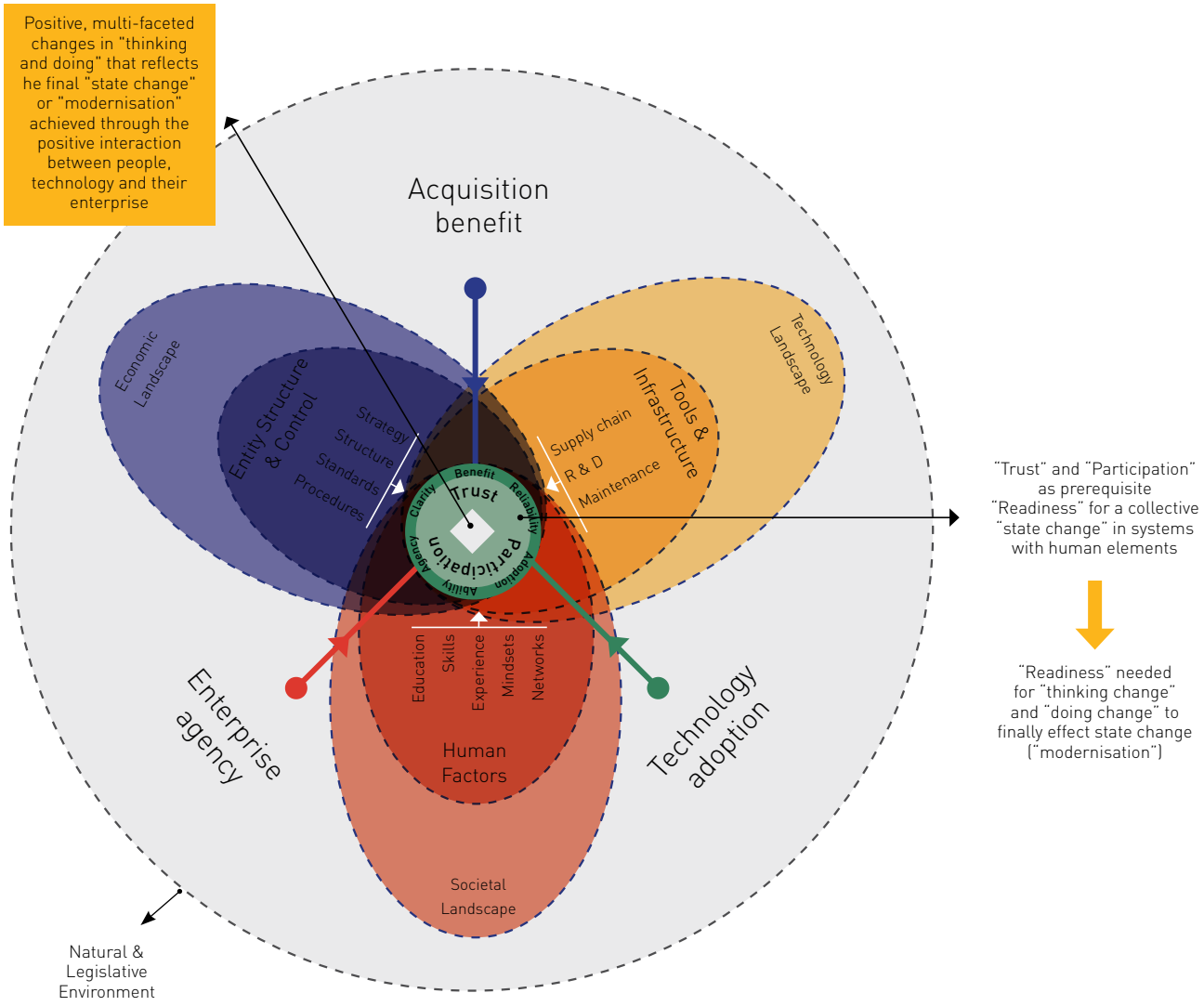

Figure 24 Final systems model

Table 24 provides an initial view of each sub-system (i.e., each perspective) and the overlapping sub-systems, in terms of the elements that comprise these subsystems. For each element, the outcome is defined if the element is positively present in the system.

The outcomes were considered as successful contributors to modernisation success (as established during the interviews). The aspects that these outcomes will contribute to, in terms of readiness of the mining system for modernisation, are also indicated.

Table 24 Sub-systems and dimensions of final decision model

SUB-SYSTEM	DIMENSIONS (PRIMARY FACTORS)	OUTCOME (SECONDARY FACTORS)	CONTRIBUTING TO (TERTIARY FACTORS)
Enterprise	Strategy	**Transparency** (Clarity with regards to the current status of the strategy, structure, standards and processes of the enterprise)	**Trust**
	Structure		
	Standards		
	Process		
Enterprise and Technology	Innovation / Modernisation Structure	**Benefit** (The nature of the gain achieved through the acquisition of the technology)	
	Business Case		
Technology	R&D	**Reliability** (The ability of the technology to consistently perform according to design and expectations)	
	Supply Chain		
	Maintenance		
Technology and People	User Benefit	**Adoption** (The extent to which people are making the technology their "own")	**Participation**
	User Empowerment		
People	Education	**Ability** (The end result of education, skills development, a workable view of the world and the social networks of people)	
	Skills		
	Experience		
	Mindsets		
	Networks		
People and Enterprise	Structural (Formal) Leadership	**Agency** (The degree to which an individual can influence the system within which he /she operates)	
	Task (Informal) Leadership		