ENGINEERING PRINCIPLES FOR THE DESIGN OF A NEW / EXISTING MINE'S PERSONNEL TRANSPORTATION SYSTEM

(Case study Bafokeng Rasimone Platinum Mine)

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Presented as partial fulfilment for the degree

M.Eng (Mining Engineering)

IN THE FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

DEPARTMENT OF MINING ENGINEERING

UNIVERSITY OF PRETORIA

Date: July 2014

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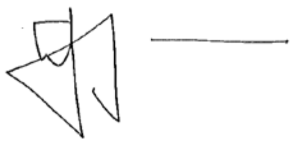

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ACKNOWLEDGEMENTS

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- Christo Joubert – Mine Planner
- Paul Ferreira – Shaft Planner
- Stephan Roestorff – Mine Design and Scheduler

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To Anglo American Platinum for allowing me in submitting this treatise.

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ABSTRACT

ENGINEERING PRINCIPLES FOR THE DESIGN OF A NEW / EXISTING MINE'S PERSONNEL TRANSPORTATION SYSTEM

(Case study Bafokeng Rasimone Platinum Mine)

Supervisor: Prof. R.C.W. Webber-Youngman

Department: Mining Engineering

University: University of Pretoria

Degree: M.Eng (Mining Engineering)

This document describes the re-engineering principles applied in the design of a personnel transportation system for a platinum mine in the Rustenburg area of South Africa. It incorporates conveyor belt travelling, chairlift operation and also includes consideration of proposed changes / modifications to existing conveyor belt infrastructure.

The purpose of the project was to identify the appropriate option and / or combination of transportation options through a process of evaluation that would be safe in terms of personnel transportation and cost effectiveness. If alternative measures could be found to transport personnel (in other words not using belt riding as a means of transport), it would have a significant positive spin-off increasing the availability of the belt, to increase production. This document therefore explores the feasibility of new interventions investigated.

The design in consideration at the Bafokeng Rasimone Platinum Mine consisted of two shaft systems, namely the North Shaft and South Shaft. Each shaft system comprises of twin decline shafts. One of which is equipped with a conveyor belt for rock and personnel transportation and the other with a winder for track bound material transport. From the date of commissioning of the shafts, the conveyor belt was used for personnel transportation. The conveyor belt is equipped with platforms for getting off and on the belt and a number of safety devices designed to ensure the safety of personnel travelling on the conveyor belt. Intensive training in the practical aspects of belt riding was given to each and every person and unsupervised riding on the belt was only undertaken once belt riding competence was demonstrated. Despite this, the safety results were poor, having experienced 106 injuries between 2006 and May 2013. No fatalities were reported during this period.

It was therefore needed to investigate alternative means for personnel transportation or through engineered solutions to the current conveyor belt infrastructure in the safest, most

effective and most economical way. There was a major risk of safety related stoppages being imposed following another belt accident / incident. This would prevent the mine from transporting personnel underground by belt and subsequently result in major production losses. From the commissioning of the Phase 2 shaft deepening project on both shafts, the decision was to install dedicated chairlifts for personnel transportation opposed to the man riding conveyor belt installed in the Phase 1 area. The chairlift installations were in operation since 2004 and no chairlift related incidents were recorded thus far. According to safety statistics it was clear that the chairlift installation is the safer method for the transportation of people in the shaft.

To fulfil the objectives / scope of this investigation / study, it was recommended that both primary (new chairlift decline with infrastructure) and secondary options (modifications to the current conveyor belt infrastructure) be considered for implementation on both North Shaft and South Shaft to reduce / eliminate accidents / incidents as a result of belt transportation. The associated CAPEX would be approximately ZAR 200 million. Considering the future impact on the business as a whole, this would definitely be CAPEX well spent!

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LIST OF SYMBOLS / ABBREVIATIONS

°	Degrees
°C	Degrees centigrade (Degrees Celsius)
%	Percentage
ADT	Anglo American Technical Division
BP	Business Planning
BRPM	Bafokeng Rasimone Platinum Mine
CAPEX	Capital expenditure
CDS	Anglo American Platinum's Capital Development Services
COP	Code of Practice
DMR	Department of Minerals and Resources
etc.	Etcetera
FOG	Fall of Ground
FW	Footwall
g/oz	Grams per ounce
g/t	Grams per ton
IC	Investment Centre
i.e.	In example
JV	Joint Venture
kg/m	Kilogram per metre
kN	Kilo Newton
kV	Kilo Volt
kVA	Kilo Volt Ampere
kW	Kilo Watt
LOM	Life of mine
LTP	Long Term Plan
m	Metres
m/month	Metres per month
m^2	Square metres
m^3	Cubic metres
m/s	Metres per second
m/s^2	Metres per second squared (Acceleration)

MES	Mine Extraction Strategy
MR	Merensky reef
MHSA	Mine Health and Safety Act
MPa	Mega Pascal
MRC	Murray and Roberts Cementation
N#	North Shaft
OPEX	Operational expenditure
oz	Ounce
Pa	Pascal
P&G's	Preliminaries and Generals
PGM's	Platinum Group Metals
RAW	Return air way
R/m^3	Rand per cubic metre
RBH	Royal Bafokeng Holdings
RBR	Royal Bafokeng Resources
RPM	Rustenburg Platinum Mines
S#	South Shaft
Sareco	South African Ropeways Engineering Company
SANS	South African National Standards
SET	Simulation Engineering Technologies
t	Tons
TBM	Tunnel Bore Machine
tpm	Tons per month
V	Volt
VSD	Variable Speed Drive
UG2	Upper Group 2
ZAR	Rand (South African currency)

CHAPTER 1

MOTIVATION FOR THIS STUDY

1. INTRODUCTION

This chapter contains the background and some general information. It also discuss, by means of examples, the impact of incorrect decision making by not installing a proper, effective and safe personnel transportation in the current hardrock environment. Specific reference is made to the Bafokeng Rasimone Platinum Mine (BRPM) and its challenges. It contains the project statement, objectives and methodology followed.

1.1. Background and General Information

In any mining operation, labour is one of the most valuable resources. In order to ensure that the personnel get to the workplace, safe and in time, it is important to plan and design a transportation system that could also meet the required production output of the mine. The extent of the system will be determined by a number of factors. These are the mining layout, the size of the ore body, the mining method, the subsequent amount of people that will have to be transported at any given time. This also relates to the travelling time and the actual time spent in the workplace.

During the last decade and a half, numerous declines were developed to either access deeper reserves that were inaccessible from the existing vertical infrastructure, or new declines from surface to access sub-outcrop material that were left in the past. With the change in the economic environment and the increase in demand, it became imperative to mine the available resources.

Several of these declines were planned and designed without considering the future impact of not installing a proper, effective and safe personnel transportation system. Therefore wrong decisions and design were made upfront. The Khuseleka 1 Shaft of Anglo American Platinum (AAP) is a good example of this statement. When the decline was developed (September 1991), 1.1 km away from the current vertical shaft infrastructure, the decision was that the employees would either walk the horizontal distance, or be transported by means of track bound personnel carriages. The last option mentioned was found not to be a viable option due to the number of employees that would be required to be transported at the start and end of the shift and the limitations to the track bound personnel carriages. The horizontal chairlift was installed to transport employees the distance. This chairlift was installed and commissioned in July 2013 (Personal experience, 2012).

In some cases the existing personnel transportation system had to be altered or redesigned as it was jeopardizing the existence of the mine due to the poor safety and health statistics and risks associated with the personnel transportation system. BRPM as discussed in this document is a good example of this statement (Personal experience, 2008).

In some instances, a proper personnel transportation system was not even considered at all. With the deepening of the operations, the travelling distances increase and actual face time are negatively impacting the productivity of the employees. Alternatives are investigated to try and minimize damage caused already. The Bathopele Mine of AAP is a good example of this statement.

When the two declines were developed in 1999, no provision was made for personnel transportation. This was not a concern during the early stages of the operation and employees easily walked in and out the shaft. When the vertical distances of the workplaces increased beyond 150 m, the mine had to provide alternative means of transport. Personnel carriers were purchased in 2006 for each section with additional for spare during maintenance cycles. Light diesel vehicles (LDV's) were also provided for supervision and original equipment manufacturers (OEM's) maintaining the mechanized equipment (Personal experience, 2011).

Several design principles have to be considered when a personnel transportation system for a mine is considered, especially more so if a current transportation system is already in place. The design considerations applicable in such a case has to concurrently consider several other factors that will have a short, medium and long term impact on production. Other critical parameters such as safety, health and environmental impacts also need to be considered. This needs to be done in the most economical way possible. The design principles considered in a re-engineering of transportation systems was done through a case study at BRPM.

1.2. Bafokeng Rasimone Platinum Mine

At the time of the study (January 2008 to October 2009), BRPM was an unincorporated 50:50 joint venture (JV) between Royal Bafokeng Holdings (RBH - held through a wholly owned subsidiary, RBR - Royal Bafokeng Resources) and AAP's wholly-owned subsidiary, Rustenburg Platinum Mines (RPM) Limited. Each partner had a 50 % participation interest and equal powers, duties, rights and obligations in relation to management, although the mine was operated in terms of a service agreement by AAP. AAP was the world's largest platinum producer with its primary operations, RPM Limited and Amandelbult, located on the western limb of the Bushveld Igneous Complex (Anglo American Platinum Annual Report, 2009).

BRPM was established to exploit Platinum Group Metals (PGM's) in the Merensky (MR) and Upper Group Two (UG2) reefs on the Boschkoppie, Frischgewaagd and Styldrift farms in the Rustenburg area. BRPM is close to Boshoek and Sun City in the North West province of South Africa. Figure 1.2 shows the location of BRPM. BRPM produced its first platinum concentrate from the Boschkoppie property in February 1999, initially from only exploiting the MR reef. The operation will produce in the excess of 500,000 refined ounces of platinum per annum when the Styldrift project reaches steady state levels as per Mine Extraction Strategy (MES) during 2015, which will be from exploiting both MR and the UG2 reefs (BRPM MES, 2008). Capital funding for the JV is apportioned equally between the parties. RBR has concluded an off-take agreement with Rustenburg Refineries for the disposal of its concentrate.

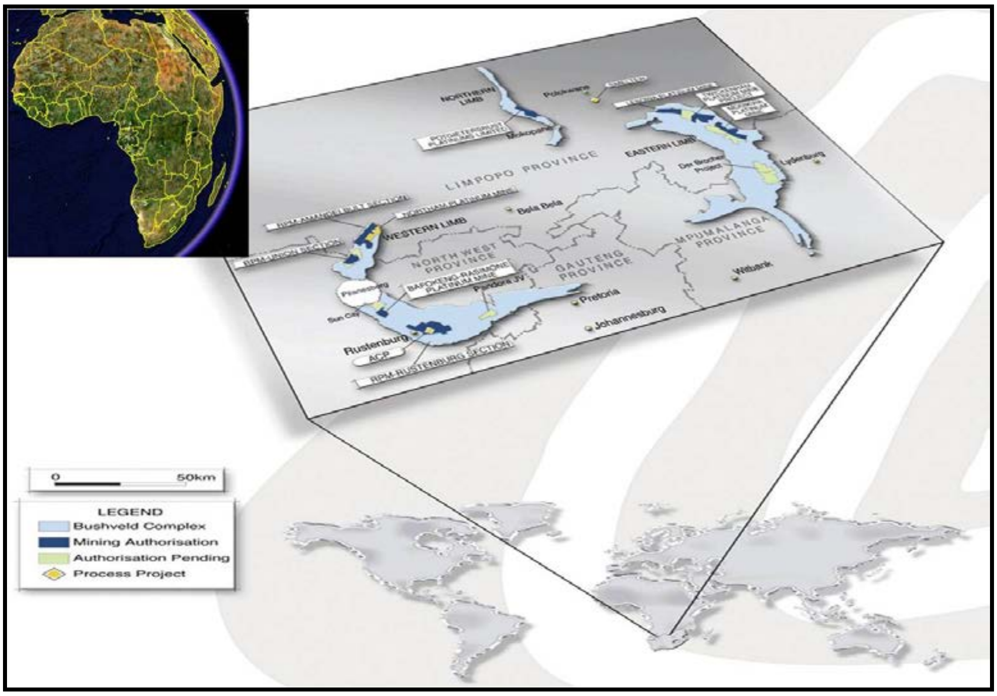

Figure 1.2: BRPM location map
(Anglo American Platinum Annual Report, 2009)

1.3. Mine Layout and Personnel Transportation at BRPM to be Re-designed

BRPM consists of two shaft systems namely the North Shaft and South Shaft. Figure 1.3 and 1.3a show the two shaft systems. Each shaft system comprises of twin decline shafts. One of which is equipped with a conveyor belt for rock **and** personnel transportation and the other with a winder for track bound material transport.

The shafts are divided into Investment Centres (IC). Each IC comprises of a couple of levels. The two shafts are divided as followed on the different reef horizons:

- **North Shaft**
  - Phase 1 Merensky – Levels 1 to 5
  - Phase 2 Merensky – Levels 6 to 10
  - Phase 3 Merensky – Levels 11 to 13
  - Phase 1 UG2 – Levels 1 to 5
  - Phase 2 UG2 – Levels 6 to 13
- **South Shaft**
  - Phase 1 Merensky – Levels 1 to 5
  - Phase 2 Merensky – Levels 6 to 10
  - Phase 1 UG2 – Levels 1 to 5
  - Phase 2 UG2 – Levels 6 to 10

From the date of commissioning the conveyor belt was used for personnel transport. The conveyor belt is equipped with platforms for getting off and on the belt and a number of safety devices, designed to ensure the safety of personnel travelling on the conveyor belt. Despite all the approved engineering solutions, the mine continued to experience poor safety results. The decision was taken by mine management that from the commissioning of the Phase 2 shaft deepening project on both shafts, dedicated chairlifts for personnel transportation will be installed, as shown in Figure 1.3b, opposed to the man riding conveyor belt installed in the Phase 1 area. At North Shaft the Phase 1 area extends up to / including level 5 and at South Shaft up to / including level 6.

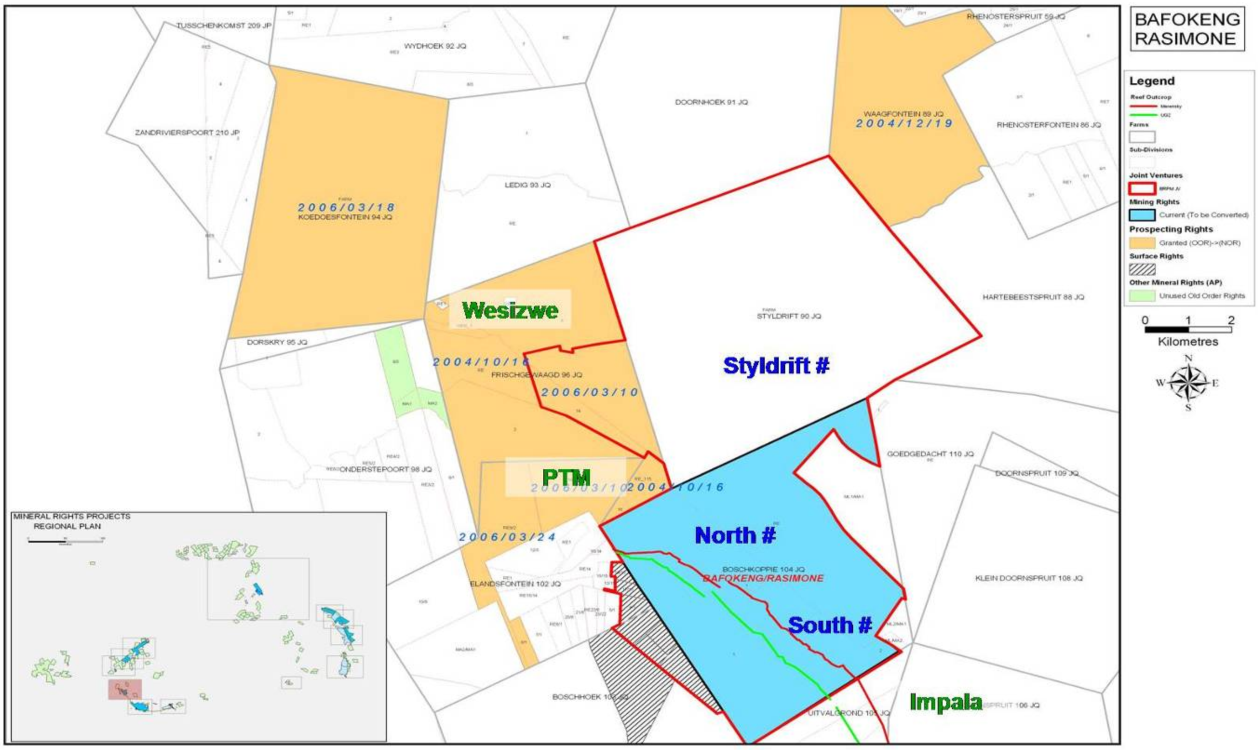

Figure 1.3: Map showing the BRPM lease area and the locations of the shaft systems (BRPM, 2008)

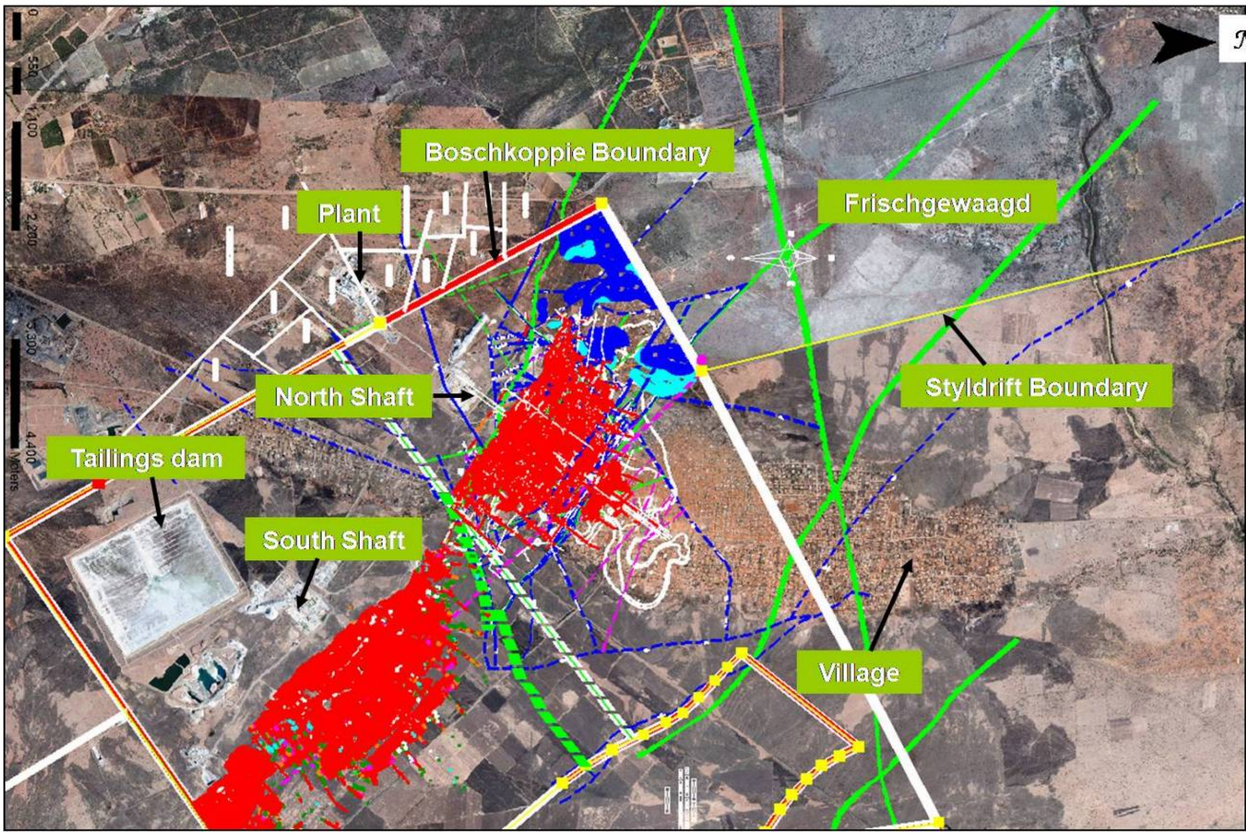

Figure 1.3a: Areal photo showing the location of the shaft systems and other infrastructure (BRPM, 2008)

Figure 1.3b: Chairlift installations in the Phase 2 areas of both shafts at BRPM
(BRPM, 2008)

1.4. Belt Transport System Problems Identified

It was important to identify specific challenges related to the belt transportation system so as to be able to get to feasible solutions in a new design, such as the MES, safety statistics as a result of conveyor belt riding, challenges experienced with conveyor belt riding, especially getting off from the belt when going down the mine and getting off from the belt when going out the mine. Finally, the challenges associated with conveyor belt training at BRPM were identified.

1.4.1. Mine Extraction Strategy (MES)

When considering the MES, it is evident that if a solution to the current method of personnel transportation is not found, the risk of injuries / incidents on the belt could persist for many years to come. BRPM was only mining the MR reef on the farm Boschkoppie from North Shaft and South Shaft at the time of the study. Mining the UG2 reef will play an important role in achieving the Long Term Plan (LTP) production profiles as prescribed in the MES. The LTP production profiles of the MES illustrates the duration that the proposed chairlifts will be in operation as shown in Figures 1.4.1 to 1.4.1c. North Shaft will be in operation beyond 2060 and South Shaft up to 2050. At the time of the study the focus was only the Boschkoppie area, where the current two shafts were in operation (BRPM MES, 2008).

On both North and South Shafts the MR reef is depleted on 1 and 2 levels (Phase 1). At North Shaft UG2 mining in the Phase 1 area will commence in 2020 and it will continue beyond 2060. At South Shaft the UG2 mining in the Phase 1 area will commence in 2013 and it will continue until approximately 2050.

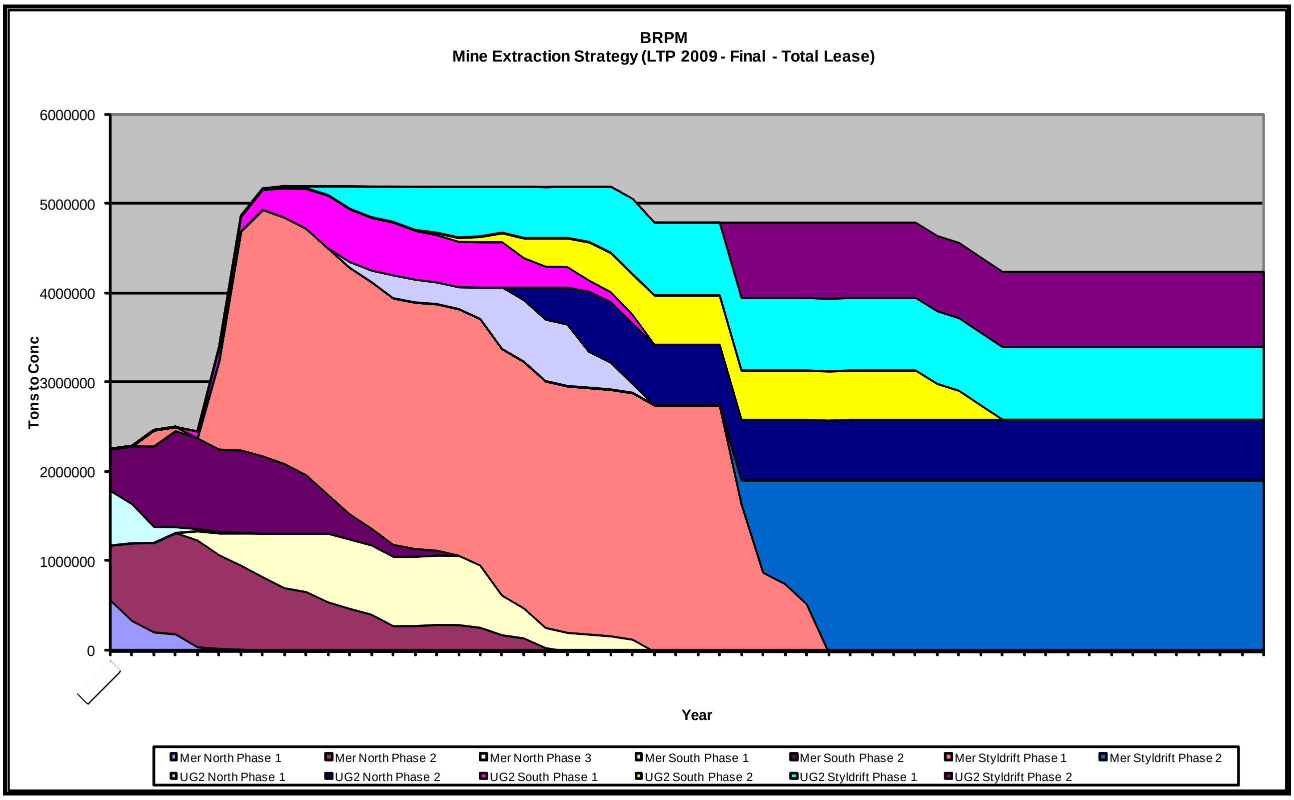

Figure 1.4.1: The LTP profile for the entire BRPM lease area both MR and UG2 reefs
(BRPM MES, 2008)

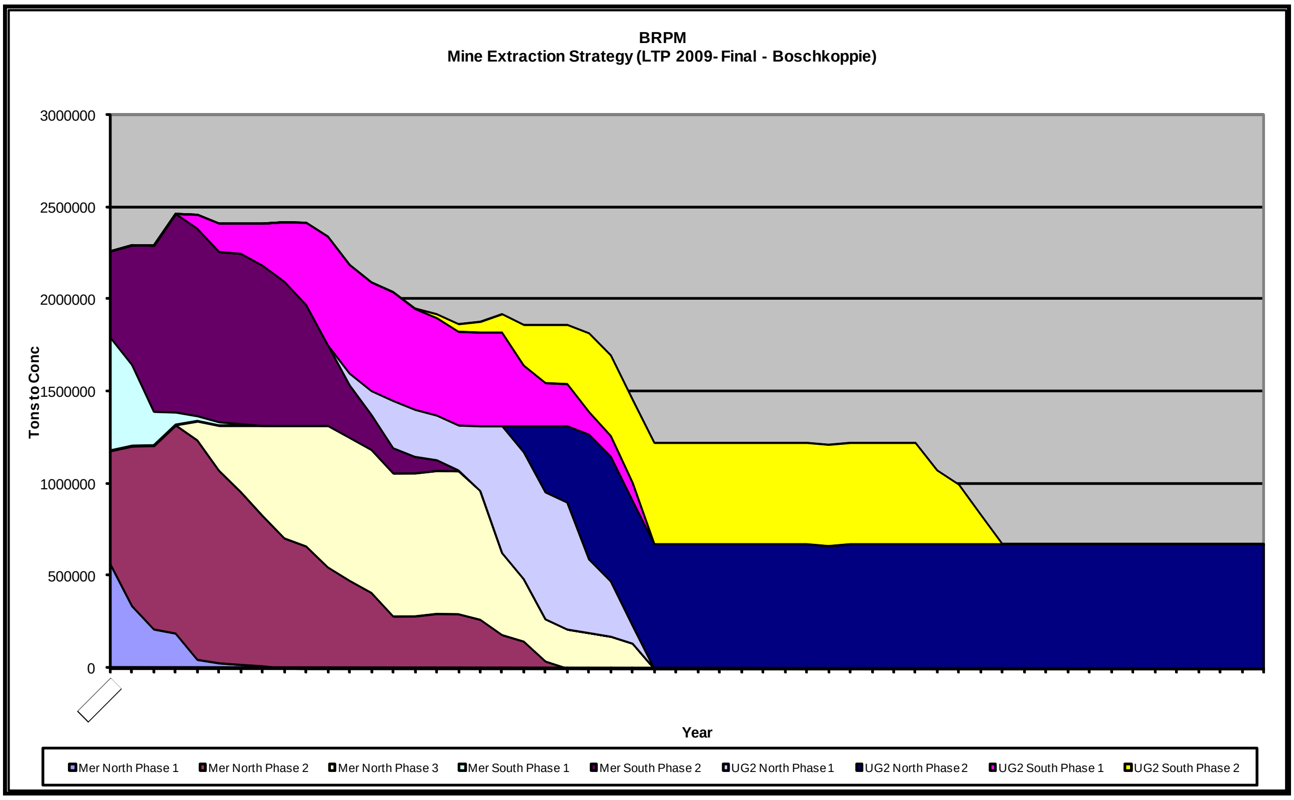

Figure 1.4.1a: The LTP profile for the Boschkoppie area both MR and UG2 reefs
(BRPM MES, 2008)

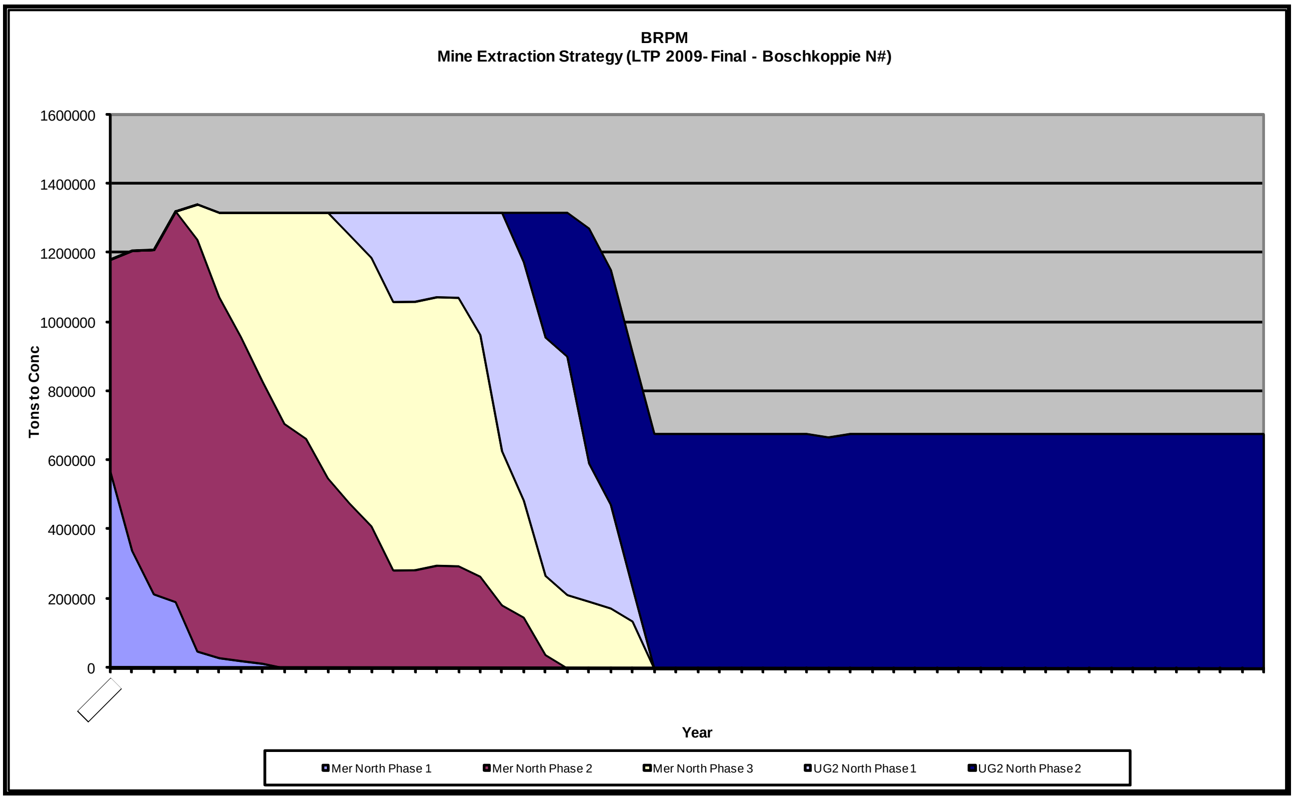

Figure 1.4.1b: The LTP profile for North Shaft both MR and UG2 reefs
(BRPM MES, 2008)

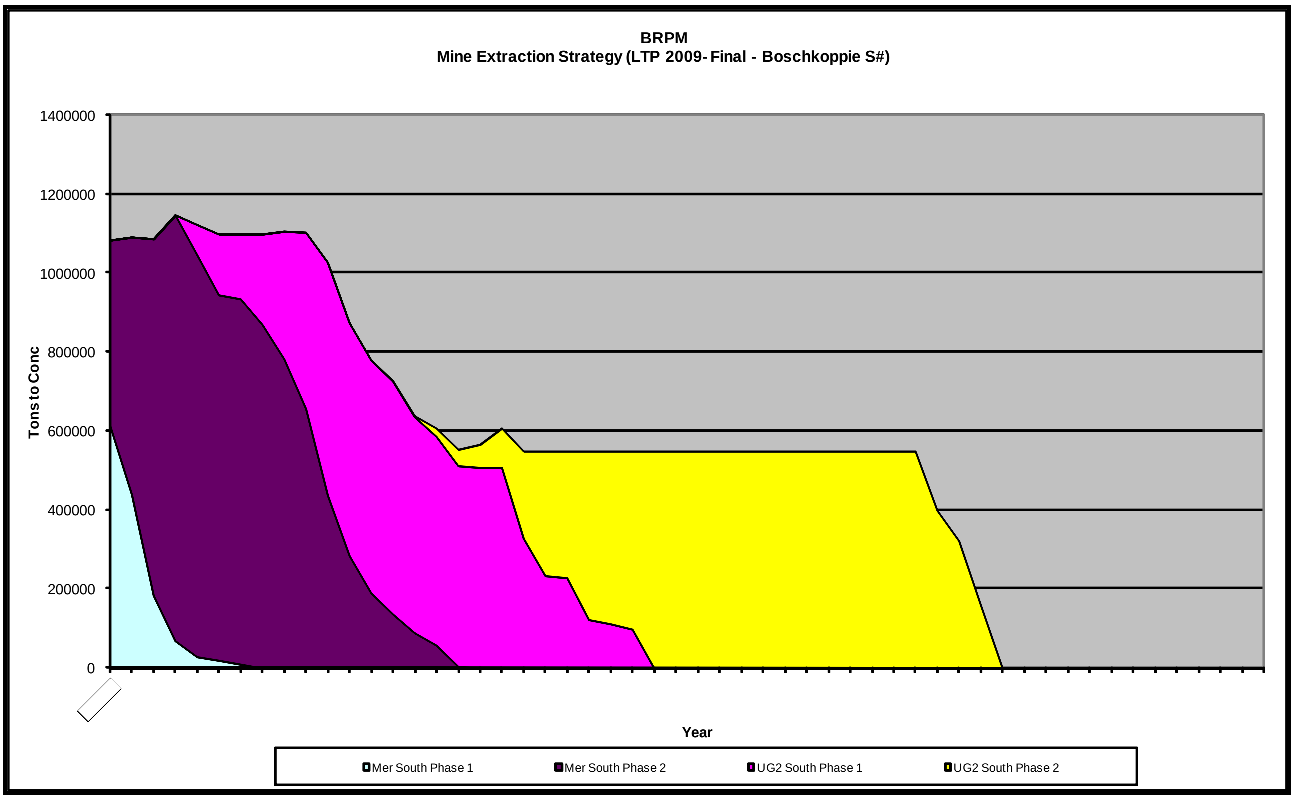

Figure 1.4.1c: The LTP profile for South Shaft both MR and UG2 reefs
(BRPM MES, 2008)

1.4.2. Safety Statistics as a Result of Conveyor Belt Riding

BRPM experienced bad safety results pertaining to conveyor belt transportation of personnel having experienced 106 injuries between 2006 and 2013 (May 2013). Figure 1.4.2 highlights the class of injuries and the number of injuries per class. During this period, 70 % of the injuries were medical treatment cases (MTC - no shift / day lost), 20 % were lost time injuries (LTI – less than 14 days lost) and 10 % were serious injuries (SI – more than 14 days lost). Serious injuries are also referred to as reportable injuries for which reporting is required by the Mine Health and Safety Act (MHSA) to the local DMR office within three days after becoming a serious injury. Of these 106 injuries 98 (92.5 %) were injuries whilst going down and coming up from underground, with the remaining 8 (7.5 %) taking place during training. The training includes both practical training on the surface conveyor belt facility at North Shaft as well as applying the knowledge acquired on the actual underground conveyor belt (BRPM Safety Department, 2013).

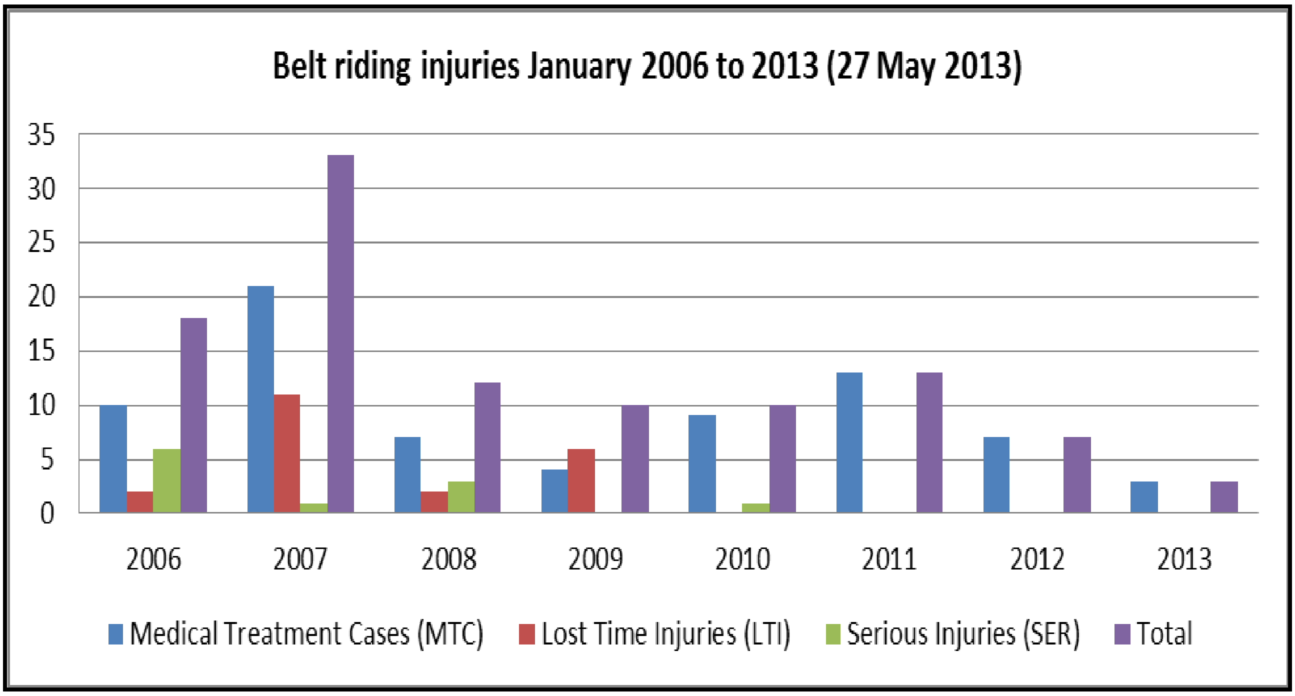

Figure 1.4.2: Class of injuries and number of injuries per class
(BRPM Safety Department, 2013)

Challenges Experienced with Conveyor Belt Riding

Seventy one of the injuries that were reported happened when the personnel travelled down the mine (or 72.5 %) This is significant as the average person travelling down the mine will only once get on and off the belt on the downward trip (at this time there is no rock being transported on the belt). On the contrary, the same person may repeat this process up to five times on the way out of the mine due to the level ore passes and chute infrastructure configuration. This means that a person will have to get off the belt several times (rock now being transported out of the mine and personnel have to get off the belt for rock to be tipped onto the belt at different levels). The personnel then walk around the chute and then get back onto the belt. This is at the end of the shift with personnel struggling with fatigue (risk of making mistakes). It is also a risk due to the fact that the personnel have to get on and off the belt whilst broken rock is conveyed.

Getting off the belt (going down the mine)

Of the 71 injuries recorded, 55 (77 %) occurred whilst getting off the belt going down the mine. Sixty five percent of the injuries sustained related to injuries to the knees (27 %), ankles (27 %), feet (4 %) and abdomen (7 %). A breakdown of the injuries recorded is shown in Figure 1.4.2a. This is definitely the most physically taxing of the tasks carried out and is due to the fact that the legs are forced to absorb the combined force imparted by the belt moving at 2.5 m/s combined with the natural acceleration caused by gravity which, at -9° amounts to 1.7 m/s^2. This combination requires a person to decelerate at the equivalent of 2.95 m/s^2 in order to stop in the required distance and is illustrated in Figure 1.4.2b.

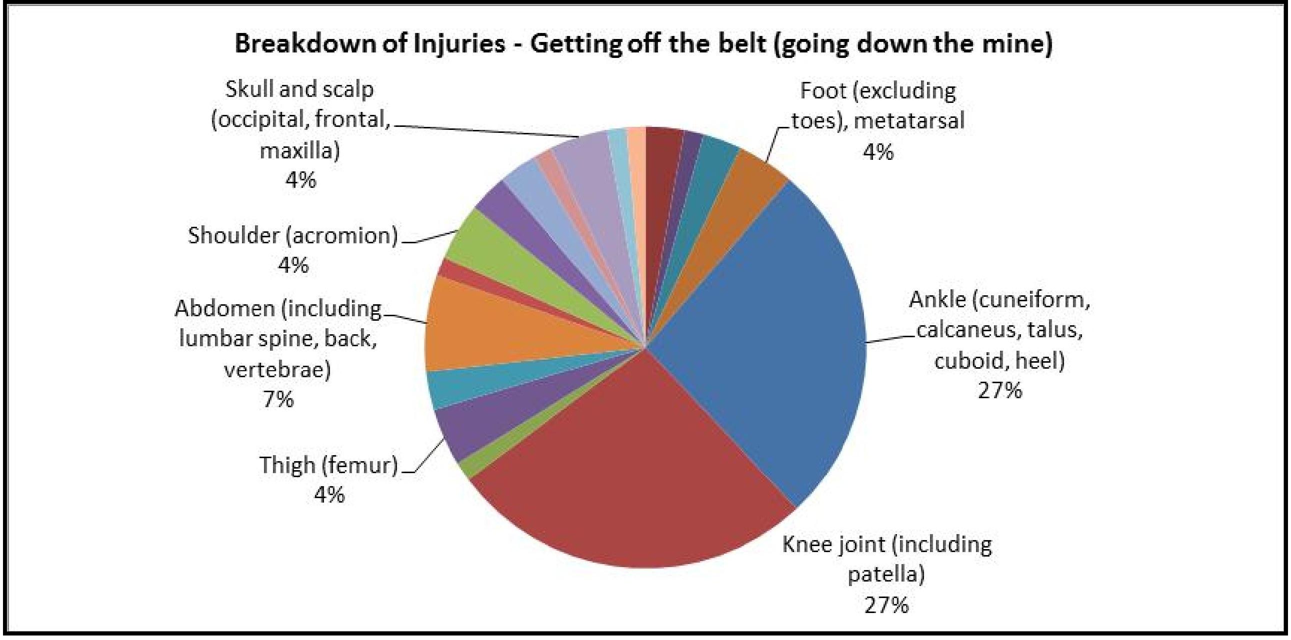

Figure 1.4.2a: Breakdown of injuries – Getting off the belt (going down the mine)
(BRPM Safety Department, 2013)

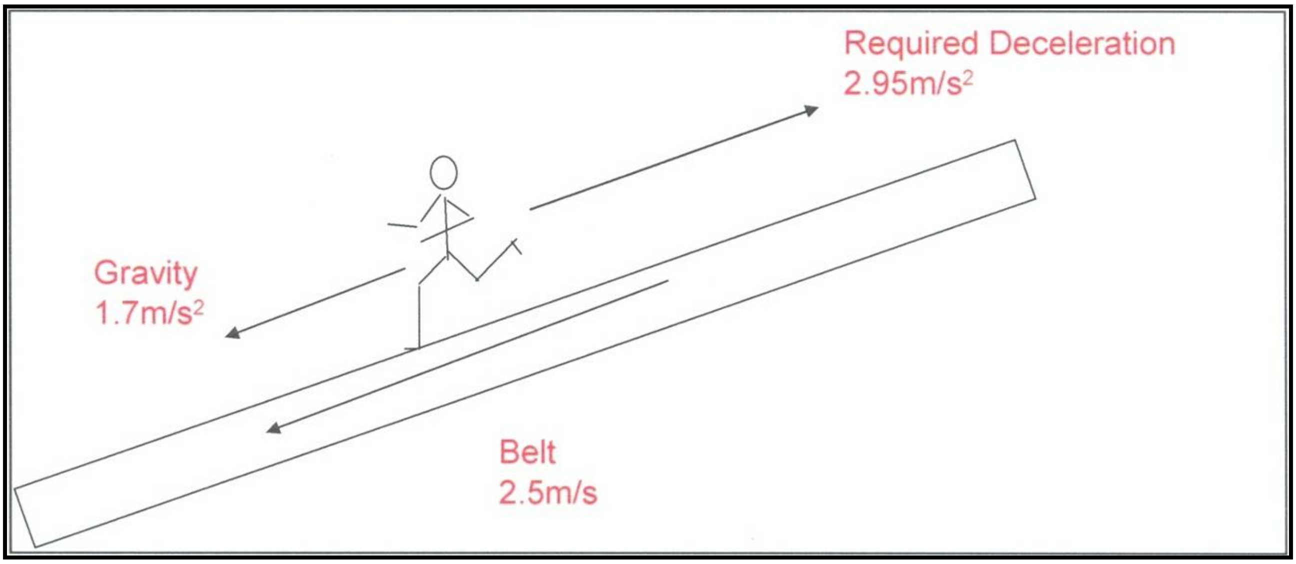

Figure 1.4.2b: Schematic representation getting off the belt (going down the mine)
(Van Heerden, 2008)

Getting off the belt (going out the mine)

Of the 27 injuries recorded, 15 (56 %) occurred whilst getting off the belt going out the mine. An analysis of injuries recorded indicated different types of injuries compared with getting off the belt going down the mine. The injuries were classified as follows, head (19 %) and facial (including jaw, nose, eye and ear – 22 %) which equated to 11 of the 27 (41 %), followed by fingers (15 %), hands (7 %) and elbow (7 %), 8 of the 27 (30 %), and the knees, ankles and feet, 3 of the 27 (12 %). From this it was obvious that injuries occur when people fall over when getting off the belt. A breakdown of these injuries is presented in Figure 1.4.2c.

Getting off the belt is very physically taxing as the naturally high friction coefficient between a rubber boot and rubber conveyor is reduced by the presence of small rock particles which makes it very difficult to secure footing when launching off the belt. Getting on the belt is risky for the same reasons as outlined above. The presence of rock on the conveyor forces one to abandon the lessons learned at the training centre and, instead of boarding in a fluid manner with the hands first followed by the feet one is forced to adopt a form of sideways leap in order to secure footing on the conveyor either side of the rock.

When considering the number of injuries recorded going down the mine versus going out the mine it is evident that the latter contains less risk due to natural deceleration imparted by gravity which has the effect of stopping one almost as one hits the platform, requiring almost no effort at all.

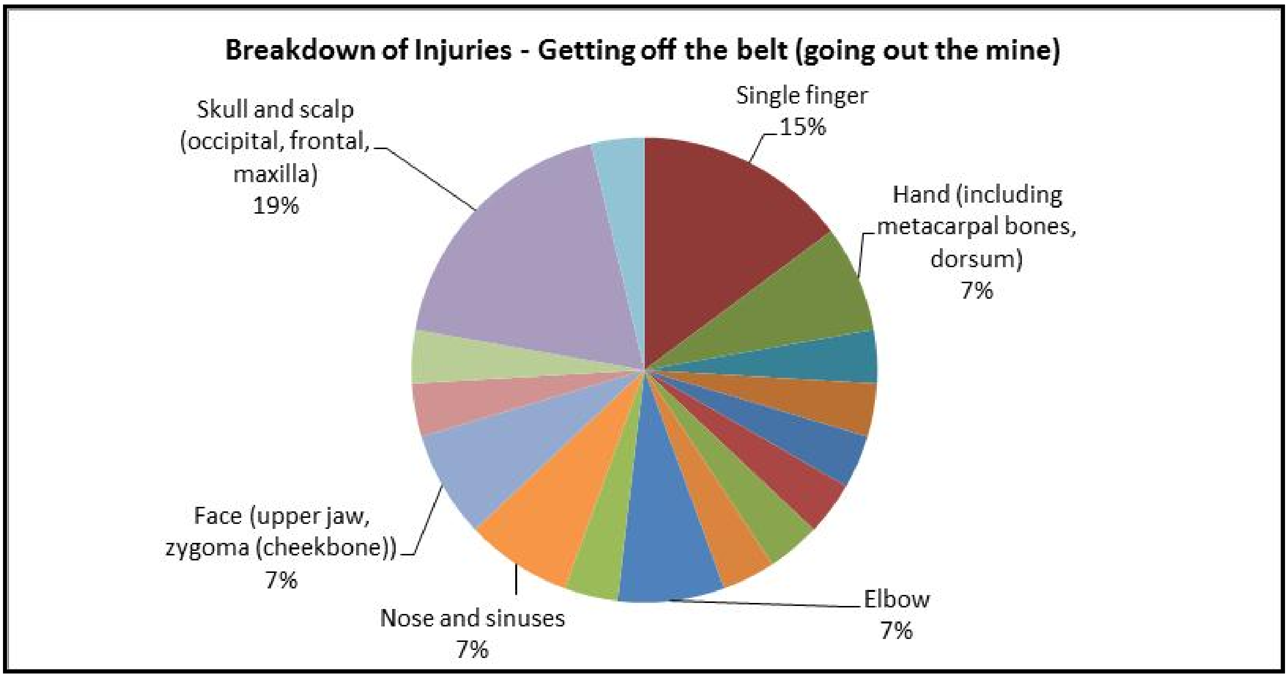

Figure 1.4.2c: Breakdown of injuries – Getting off the belt (going out the mine)
(BRPM Safety Department, 2013)

1.4.3. Conveyor Belt Training at BRPM

There is a specific conveyor belt training facility build at North Shaft. Once the personnel completed their medical examination and are proven fit for underground work (including induction and work related training modules), belt training is done. Intensive training with regards all the practical aspects of belt riding is given to all personnel. Unsupervised riding on the belt is only undertaken once competence is demonstrated. The demonstration of competency is done both on the surface training belt (Figure 1.4.3) and then applying it on the actual underground belt at North Shaft (Figure 1.4.3a).

The importance of this practical training is for the personnel to experience the actual getting on the belt and travelling on the top belt whilst broken rock is being conveyed out the mine. All personnel are certified competent after completing the belt training. This belt training is not only required for mine employees working underground, but to all visitors going underground. If any staff member or visitor fails the belt training, they will not be allowed to go or work underground. Therefore no person employed to work underground, will be allowed to go underground if they are not certified competent in belt riding.

In the event of belt stoppages due to accidents and / or maintenance procedures no further travelling on the belt will be possible. This clearly indicates the vulnerability of the system in terms of personnel transportation for which the conveyor belt is the only way of going down or getting out from underground. This will have a major production impact on the mine because the conveyor belt is the only way of transporting personnel underground effectively. Furthermore, the MHSA also gives specific guidance with regards exceeding the allowable vertical distance for unaided travelling.

Accordingly, and in line with BRPM's safety strategy, investigations were undertaken to identify safer engineering solutions to the current transportation system and / or identify alternative means of personnel transportation which could be implemented to reduce or eliminate belt riding related incidents / injuries.

Figure 1.4.3: Surface conveyor belt training at North Shaft
(BRPM, 2008)

Figure 1.4.3a: Underground conveyor belt personnel transportation
(BRPM, 2008)

1.5. Problem Statement
Considering various engineering principles for the design of a new / existing mine's personnel transportation system.

1.6. Objectives (Critical items to be considered in the re-engineering investigation)
At the commencement of the study, the following objectives were set:
- Clearly define what the ***motivation*** for this particular study is.
- Conduct a comprehensive ***literature study*** on personnel transportation for hardrock decline shaft systems employed in the past.
- Discuss the ***results*** obtained during the study.
- ***Analyse and evaluate the results*** obtained during the study.
- Make ***conclusions*** after completion of the study.
- Make ***recommendations*** after completion of the study.
- Provide ***suggestions for future work***.

1.7. Methodology
In order to satisfy the defined objectives, the following methodology was followed:
a. Motivation for this study:
- Discussed the background and general information, with examples, where incorrect decision making lead to ineffective and unsafe personnel transportation.

- BRPM was discussed with specific reference to the following:
    - Background and general information
    - Mine layout and personnel transportation to be re-designed
    - Belt transport systems problem identified, with detailed discussion regarding the MES, Safety statistics as a result of conveyor belt riding, challenges experienced with conveyor belt riding (getting off the belt whilst going down and out the mine) and conveyor belt training.

b. Literature Study:

- Conducted a comprehensive literature study on personnel transportation for hardrock decline shaft systems employed at other mines in the past. This included various transport systems employed successfully throughout the mining industry in the past. For each type of conveyance, conclusions were made in terms of the significance of the available information and whether or not the system would be applicable for further investigation. During the literature study neighbouring mines were also visited to investigate alternative means of personnel transportation and the collection of data.

c. Results:

- In this chapter, the option selection and decision analysis process was discussed.
- The identification of the appropriate option and / or combination of transportation options through a process of evaluation that would be safe and cost effective was discussed.
- Both primary and secondary options were discussed and selected for both North and South Shafts.
- The following were considered:
    - Capital expenditure (CAPEX) estimation (capital development, civil engineering works, piping, electrical, mechanical, structural, instrumentation, 10 % contingency and chairlift installation).
    - Practicality in terms of implementation.
    - Timing in terms of life of mine (LOM) profile, in line with the MES.
    - Accessibility from current infrastructure available or through consideration of local communities surrounding the mine, as well as access control on surface and access to different levels.
    - Detail design, scheduling, supply, delivery, construction and commissioning of a chairlift system from surface to level 5 at North Shaft and level 6 at South Shaft.
    - Strength, Weakness, Opportunity and Threat (SWOT) analysis for each of the options.
    - Project duration from start of development to commissioning, and its fit into the LOM profile.
    - Utilising the current MR infrastructure.
    - Start developing the chairlift decline from different positions simultaneously (various attack points).
    - Access to both MR (current operation) and UG2 (future prospect) mining.
    - Increased future ventilation flow to the UG2 horizon.
    - Risk analysis (from an engineering, rock engineering, geology, planning and ventilation perspective).
    - Benchmarked the proposed design criterion against actual achievements, in terms of production, construction and costs. This included actual development in progress on the chairlift decline, the actual installation and the associated costs in the Phase 2 area of both North Shaft and South Shaft.
    - Compared different development / sinking methodologies i.e. Conventional, mechanised, raise bore, etc.

- Obtained quotes and had sessions with current contractors and proposed new contractors.
- Did a simulation on the trade-off between belt riding and chairlift transportation.
- Discussed the engineering philosophy adopted for the study.

d. *Analysis and evaluation of results:*

- This chapter summarised the option identification processes for both North and South Shafts including the final primary options and secondary options selected for both shafts.
- For the final primary options, the following were discussed:
  - Surface access and position.
  - Geology and rock engineering factors considered.
  - Ventilation factors considered.
  - Development and construction schedule.
  - Estimated CAPEX.
- For the final secondary options, the following were discussed:
  - Platform modifications.
  - Addition of an intermediate conveyor belt.
  - Addition of overhead endless ropeway.
- Finally the chapter summarised the total estimated CAPEX for both North and South Shafts including the primary and secondary options.

e. *Conclusions:*

- Conclusions were made after completion of the study on personnel transportation.

f. *Recommendations:*

- Recommendations were made after completion of the study on personnel transportation.

g. *Suggestions for future work:*

- Suggestions for future work were made after completion of the study on personnel transportation.

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CHAPTER 2

LITERATURE STUDY

2. RESULTS FROM LITERATURE STUDY

This chapter contains the literature study that was conducted prior to commencing the study on personnel transportation for hardrock decline shaft systems employed at other mines in the past.

2.1. Introduction

BRPM currently use conveyor belts for transporting personnel down and out of North and South Shafts with the same conveyor belt being used for personnel and broken rock (reef and waste). The decision was taken by mine management to review the method used for transporting personnel due to increasing numbers of injuries / incidents occurring as a result of conveyor belt riding.

The proposal is to either install chairlifts dedicated to personnel transport or investigate alternative options for personnel transportation or modifications to the current conveyor belt and belt infrastructure and use the conveyors entirely for broken rock transportation. This arrangement will help to alleviate the increasing number of injuries / incidents and provide potential for increased tonnage output.

2.2. Walking

The initial option to evaluate when considering personnel transportation systems is definitely walking. The average walking pace of an employee wearing mine boots and walking on an uneven surface such as footwall is approximately 1 m/s on the level. This will reduce by approximately 33 % on an incline up to 10˚ and by approximately 50 % for climbing stairs (Frankland, 1984). The risk of walking to and from the workplace as well as up and down the declines has a safety and health (related lung diseases including colds and flu) impact. The number of slip and fall incidents / injuries increased dramatically over the last decade. There is also the risk of employees taking chances (conscious decision) in riding on unauthorised conveyor belts instead of walking. There could also be employees taking the chance in riding on an unlicensed skip or scotch cars, or even loco, hoppers or material cars rather than walking. There is also specific guidance with regards exceeding the allowable vertical distance (150 m) for unaided travelling (MHSA, 1996).

Significance of the available information

In the case of BRPM, due to the configuration of the shafts and the specific requirements, walking is not the preferred option. Walking, however would be required when the proposed transportation system have a breakdown or during planned maintenance.

2.3. Underground Conveyor Belt Personnel Transportation

The concept were originated as an optimised option for both rock and personnel transportation. Instead of having two separate systems as well as two separate excavations, the plan was combined to manage both the requirements of ore and waste transportation from underground as well as personnel transportation to and from the different levels in operation. This application resulted in huge saving in capital expenditure. Training and competency levels of employees are very important as the risks associated with belt transportation are very high.

There are a couple of important factors / actions to take into consideration when conveyor belt transportation is considered. The actions involved are listed below in order of difficulty:

- Getting off the belt (going down the mine).
- Getting off the belt (going out the mine).
- Getting on the belt (going out the mine).
- Getting on the belt (going down the mine).

When considering underground conveyor belt personnel transportation, two underground mines were considered during the Literature Study, namely BRPM (as discussed elsewhere in this document) and the Target Gold Mine as discussed in the paragraphs to follow.

2.3.1. Underground Conveyor Belt Personnel Transportation – Target Mine

Harmony Gold Mining Co Ltd (Target Mine) conducts gold mining operations at various sites. The Target Mine is situated in the magisterial district of Welkom, in the Free State province. The mine has two operational shafts: Target 1 and Target 3 shafts as well as a processing plant. The Target ore bodies, which lie at depths of between 2,200 m and 2,500 m below surface, have been accessed by declines sunk from the existing underground infrastructure at Loraine, where production ended in mid-1999. This has substantially reduced the cost of bringing Target into production.

The declines are equipped with roof-slung Walter-Becker monorails for transporting materials from the Loraine shaft to the Target production areas. The declines also handle crushed ore from the main underground primary crushers to the hoisting skips in Loraine's No.1 shaft, using a conveyor belt system that are also used for transporting personnel (Target Gold Mine – Mining Technology, 2013).

From the establishment of the mine in the mid 90's, the mine used a conveyer belt system which runs down an incline shaft (Target 1 Shaft) to transport employees to and from their places of work. The shaft was designed and conceptualized on the conveyor belt riding system philosophy from the start. The design of the shaft precludes the use of any other mode of transport given the number of employees, the physical dimensions of the shaft and the distance to be travelled. The conveyer belts system spans a distance of approximately 6 km. Only employees who work in Target 1 Shaft utilize the belt riding system as a means of transport to get to their places of work.

Target 3 Shaft employees do not use the belt riding system. Target 1 Shaft was designed in such a way that employees will first descend down a vertical shaft and then move to their work stations *via* a decline shaft which runs from 50 level for approximately 6 km at an angle of nine degrees to the horizontal. The belt riding system is made up of six independently operated sections, each of which is separately powered. There are platforms for getting on and off the belt at the beginning and the end of each section. Should one section of the conveyor belt become inoperative the remaining five will still be able to operate. Employees will then have to walk the distance of the inoperative belt section.

At Target Mine it is a condition of employment that employees use belt riding as a form of transportation. Should new employees not fulfill the conditions, in other words, if the employee does not pass the heat tolerance screening and belt riding test or does not obtain a certificate of fitness, the employee will not be able to work in Target 1 Shaft. All employees are required to undergo an assessment at a training centre on surface when they are assigned to Target 1 Shaft. This assessment consists of a practical and a theoretical assessment. Each employee is also required to go through the assessment annually when he / she return from annual leave. It is implicit from the declaration made by each employee that, by signing the assessment declaration, he / she accepts that the belt riding system is a term and condition of his / her employment.

In 2011 there were several disputes from organised labour with reference to belt riding as a mode of transport. The disputes were never safety related but rather instances of intermitted stoppages of the conveyor belt that requires employees to walk the 6 km between the two shafts. Several alternatives were considered during a proper investigation, including underground bus transport between Target 1 and Target 3 shafts. From the investigation it was concluded that there is no practical alternative to the conveyor belt system for transporting employees to and from their place of work. Preliminary findings were that the bus system, which has to meet stringent regulations for underground trackless mobile machinery, would not meet the operational requirements to transport employees effectively to their workplace. In brief, an 18 seater bus will take approximately 2 hours to do a return trip and because the decline shaft accommodates one-way traffic transporting only, transporting approximately 700 workers per shift, will result in a turnaround of 17 hours. There are also no 50-seat vehicles available which comply with the necessary standards and exigencies of the underground environment. Utility vehicles (UV's) can furthermore only carry 6 - 7 persons safely and is therefore also not a viable option.

Between 2011 and 2012 there have only been six incidents associated with the belt riding system. Of the six incidents, only two necessitated sick leave. Furthermore, of these six incidents five incidents were caused by the employee failing to follow the correct procedures in utilising the belt riding system. It appears from these six incidents that none of the employees lost a limb or was incapacitated. It is further estimated that should 1,000 employees make two trips daily this would equate to 600,000 trips per year or 1,200,000 over two years (assuming that every employee work 300 days per year). Given the six incidents over the aforementioned period, the safety record therefore amounts to one incident per 200,000 trips or **99,9995 %** none of which resulted in a serious injury.

Target Mine has a Code of Practice (COP) in place as required by section 9 of the MHSA. This Code sets out safety procedures that must be followed by employees using belt riding as a mode of transport (Harmony Gold Mining Co Ltd v National Union of Mineworkers and Others, 2012).

Significance of the available information

There are a lot of similarities between Target 1 Shaft and BRPM. It could be summarized as follows:

- Belt riding is used as a mode of transport.
- It is a condition of employment that employees use belt riding as a form of transportation.
- Both personnel and broken rock are transported via the conveyor belt.
- Belt infrastructure installed in decline at an angle of nine degrees to the horizontal.
- Both mines produce similar tonnage per month.

Differences between Target 1 Shaft and BRPM could be summarized as followed:

- Target is highly mechanized compared to BRPM that utilize conventional mining methods.
- Much less employees utilized at Target compared to BRPM due to mining methods selected (700 employees at Target per shift and a maximum of 2600 during morning shift per shaft at BRPM).
- Belt speed at BRPM is 2.5 m/s compared to 1.5 m/s at Target 1 Shaft.
- At Target 1 Shaft, the belt riding system is made up of six independently operated sections, each of which is separately powered. This is not the case at BRPM.
- BRPM recorded a much worse safety record (106 injuries between 2006 and May 2013) compared to Target 1 Shaft (6 injuries between 2011 and 2012) mainly as a result of the much higher belt speed at BRPM (2.5 m/s vs. 1.5 m/s).
- The nature of the injuries recorded at BRPM was more serious compared to Target 1 Shaft.
- Both Mines were forced to investigate alternative means of personnel transport, however it was for different reasons. At BRPM it was purely due to safety reasons compared to Target where they had to deal with disputes from organised labour.

2.4. Chairlift Personnel Transportation

When considering underground personnel transportation, except for walking, chairlift installation has been widely, successfully applied in underground mines as a mode of transport. The main objective for the installation is to increase working time at the face area, to eliminate fatigue in travelling to the workplace and to increase production by achieving the latter (Brophy, 1984).

Chairlifts have been introduced to the South African mining industry since the early 1970's. It was based on the European ski lift design and was adapted for local underground conditions. Today, chairlifts are being used in various commodity mines in South Africa on an ever increasing scale. The angle of installation varies from horizontal to a maximum of 45°. The length of the installation varies, depending on the specific requirement. The longest known installation is in a South African gold mine on a single level of 3 km. There are two different types of chairlifts available, namely the fixed grip and the detachable types. These two types will be discussed below (Frankland, 1984):

Fixed grip chair type

The chair is permanently attached to the rope by a grip or clamping device that is able to negotiate the drive and return sheaves at the extreme ends of the system. Refer to Figure 2.4. For the purpose of personnel transportation, the chair has to be mounted and dismounted while the system is in motion in a similar manner to riding a bicycle. This system is usually installed on either horizontal or inclined planes. The angle of installation could go up to a maximum of 45°, but it is more commonly installed where the inclination varies between 15 and 35°.

The speed of this system could increase up to 1.5 m/s depending on the specific requirements. Undulations could be negotiated by fitting brow and heel sets where required. Bends in the system cannot be tolerated. Intermediate stations can also be designed into the system at various points along the length depending on the requirement and mine layout. The system could also be split into smaller units, especially when the distance becomes too long. This could allow for routine servicing, breakdowns and maintenance on smaller units without affecting the entire system. This will allow for transportation to continue as normal, except for the portion that is unavailable. This will increase the system's overall availability.

The drive is usually from an electric motor, via a fluid coupling and gearbox to a ring gear and pinion and onto the main drive sheave. This main sheave is also fitted with a friction lining to impart a non-slip grip between the rope and sheave. For capacities of less than 750 employees per hour, rope centres (diameter) of 1.1 m are usually selected. For more than 750 employees per hour, rope centres of 1.5 m are used. The difference in centres is to give a longer rope life in service.

Figure 2.4: Fixed Grip Chair Type
(Leitner Ropeways, 2014)

Detachable chair type

This system is usually used on horizontal or slightly inclined planes. This system is usually much longer compared to the fixed grip types. The speed of this system could increase up to 3.0 m/s depending on the specific requirements. With this system, the chair rests on the rope and is held in position by a friction lining in the chair boxhead. Refer to Figure 2.4a. This system allows for change in direction. Ropes could be deflected around bends by means of deflection sheaves. The chairs usually run on station rails that are graded to prevent chair-swing due to centrifugal force. The station rails are graded to decelerate the chair into the bend, negotiate the bend and to accelerate to match the speed of the rope when the chair and the rope meet. Incorrect application could result in a great deal of wear between the rope and the friction insert.

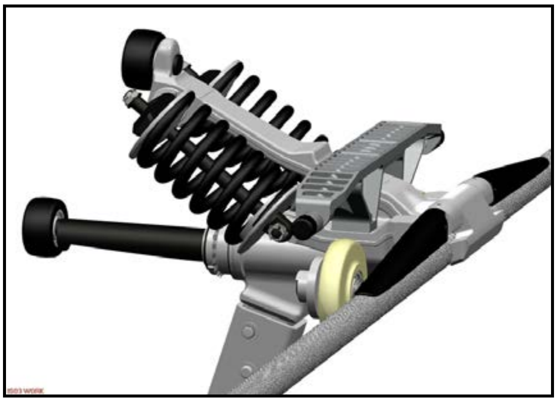

Figure 2.4a: Detachable Chair Type
(Leitner Ropeways, 2014)

Stations could be arranged anywhere along the length of the system, similar to the fixed grip system, as long as a deceleration ramp was installed to reduce the chair speed to approximately 1.25 m/s. The rider could dismount and either lifts the chair off the rope or gives it a push and sent it empty to the tension station. In comparison with the fixed grip system where only one chairlift operator is required, it is recommended that one operator is required for each angle station or boarding station on the detachable system. The operator is required in case the system is stopped while a chair is on the station and has not got the impetus to travel round with its own velocity or if it became derailed and cause a collision with the following chair. To obtain the correct chair spacing, a timer could be fitted that prevents the chairs from entering the system until the correct spacing has been achieved.

The application of this system is more favourable in the horizontal mode with slight undulations, however haulage inclinations of up to 8 to 10° could be traversed for short distances. The biggest risk is if a chair starts sliding down an incline. The lining will soon wear out and a metal contact will be made between the boxhead and the rope which could cause dangerous sparks. There will not be anything to stop the chair once it starts to slide and a very dangerous situation could arise for the rider.

Due to the longer lengths of these systems, larger diameter of rope is usually used and therefore 1.5 m rope centres are used. The drive is a remotely situated hydraulic system using a closed loop principle consisting of two main units, a hydraulic motor and an electrically controlled variable volume piston pump. To select the required drive speed and electrical input signal is given to the pump controller which in turn strokes the pump to give the required flow.

When deciding to install a chairlift, it must be borne in mind that certain personnel problems may arise, both physical and mental. Certain people have a definite fear of riding on a chairlift and the steeper the slope, the greater their fear. If the speed is reduced when the angle is increased, it makes it easier.

The minimum cross-sectional dimensions to fit in a chairlift installation is 2.1 m high and 2.1 m wide, depending on the dip and the number of line stands fitted to reduce rope sag. Line stands are usually spaced at about 20 m centres (chair spacing – 6 m), less for higher capacity systems and more for lower capacity systems (number of chairs per span – 3). Line spans could either be supported from the hangingwall or from the footwall. If supported from the hangingwall it could be necessary to change the position due to ground conditions. These changes should be within certain limitations. A change of up to 1m in either way can usually be accommodated. If greater changes are desired, it should be referred to the suppliers so that the rope sag can be re-calculated to ensure that it is within the regulation footwall clearance. The industry norm at this stage for cross-sectional dimensions to fit in a chairlift installation is between 2.5 m and 3.0 m.

The design payload per chair should be a minimum of 70 kg. Each mine should look specifically at its own requirements and particular design because mass affects the rope sag and the footwall clearance to a large extent, therefore, if it is necessary to carry heavier persons, then it would be wise to specify this. Chairlifts are designed to carry employees, but it is possible to carry small items of plant, machinery or equipment also, but care must be taken when traversing round the main drive and return sheaves. Stretcher carriers have also been made up to fit the chairlift. The system must be stopped when uploading, travelling round the drive and return sheaves and offloading.

In order to ensure safe transportation of personnel, it is essential that the chairlift system has certain safety features. The following safety features are most common in recent chairlift system installations:

- The main control panel on the fixed grip system is fitted with a reverse phase delay to prevent the system from going in the wrong direction and the gearbox is fitted with a sprag hold-back device.
- When the start button is depressed, a warning siren sounds a time delay that prevents the system from starting up immediately to warn personnel in the shaft of impending start.
- Rope dislodge switches are fitted to each brow and heel set to stop the system in the unlikely event of a rope coming of the sheaves.
- Limit switches are also fitted to the tension weight and tension carriages to close down the system in an event of a loss of rope tension.
- Trip switches and a pull wire over the full length of the system are used should one of the personnel want to stop the system in the event of an emergency.
- There are also two brakes fitted at the driving end, one of which is a fast brake, spring applied, thrusters released, the other a thruster-released, gravity-applied brake operating on the driving sheave.
- The detachable system is also fitted with 2 brakes, one electric and the other hydraulic. There is an emergency stop and an over speed trip fitted.

Significance of the available information

This option of utilising a chairlift in the Phase 1 areas of both North and South Shafts for the purpose of personnel transport was considered during the Option Selection and Decision Analysis process. This option was evaluated against the current available system where employees are making use of conveyor belt infrastructure to be transported to and from their respective work places.

2.5. Chairlift Regulations

The MHSA contains numerous sections with regards to chairlifts. The entire abstract of the regulation is available in Appendix A of this document. The regulations stated here are the minimum requirements from the DMR. It is the mine's responsibility to have their own COP and relevant standards to ensure the compliance as well as safety of all personnel using the chairlifts as a means of transportation down and out the mine. The following should all be considered and addressed in the COP (MHSA, 1996):

- Application for use
- Use of chairlifts
- Suitability of rope or chain
- Carrying-hauling rope
- Carrier
- Passage of the carriers
- Driving motor
- Brakes
- Emergency stopping device
- Boarding and landing site for passengers
- Warning system
- Emergency ladderway
- Chairlift attendants
- Handrail
- Transport of goods and persons
- Inspection.

2.6. Applicable Standards, Regulations and Codes of Practice (COP)

The following standards, regulations and COP's were considered during the study at BRPM (BRPM, 2008; AAP, 2008):

Compliance with the latest amendments of the following South African National Standards (SANS) codes and standards shall be considered a minimum requirement:

- SANS 1461 Hot Dip Galvanising
- SANS 273: 2007 Edition 1

Obligatory Standards and Regulations

- MHSA (Act 29 of 1996)
- Occupational Health and Safety Act (Act 85 of 1993)
- Minerals Act and Regulations (Act 50 of 1991).

AAP Standards. The following AAP Specification Standards will apply:

- AAP Mechanical Standards AGS 016-02 - Mechanical Standard
- AAP Mechanical Standards AMN 006-00 - New Chairlift
- AGS 024-01 – Ultra & Electromagnetic Test and inspection (NDT)
- AGS 029-02 – Vendor Quality Assurance.

International and Other Standards

The latest applicable editions of the following international specifications, standards and codes should be used in design, construction and testing of equipment. They should be used as a guide only and not as a complete list:

- Technical Recommendations of the International Standards Organisation for Transport by Rope

- APT Propriety Equipment – AMS 012-03.

The following COPs and standards are also applicable during the design and construction of steel infrastructure:

- SANS 10162-1: The structural use of steel, Part 1: Limit state design of hot-rolled steelwork
- SANS 10100-1: The structural use of concrete, Part 1: Design
- SANS 10160-1: The general procedures and loadings to be adopted in design of buildings
- AAP Specification AA 114001 issue 11: Design of steel structures
- AAP Specification AA 114010 issue 2: Design of concrete structures
- AAP Specification AA 114005 issue 4: Open grid grating for floors and stairways.

Significance of the available information

Compliance to the MHSA is confirmed through the issuing of a licence to operate the Chairlift by an Inspector of Machinery from the DMR. It is therefore important to comply with the standards and procedures laid down by the MHSA and the company / mine in order to ensure successful installation and usage of the personnel transportation system.

2.7. Monorail Transportation System

Monorails are in operation worldwide, and in 1996 the first electric monorail system was implemented in a South African Platinum mine (Impala Platinum). This operation has proven the advantages of monorails for South African hard rock mines. Over 600 units have been built and installed worldwide and it has proven its reliability under arduous conditions. The life cycle of the monorail under normal operating conditions, applying the suppliers maintenance plan, is in excess of 12 years. There is the option between Diesel and Electric driven units. The track bound monorail is easy to control and safe against derailment compared to a free-steered vehicle. It has a hoist on board and one driver can do the loading and unloading procedure without additional assistance. The safety records of monorail systems are phenomenal. The on-board safety brake system will stop the train immediately when the system or human faults lead to an uncontrolled movement of the train on the rail. Low operational cost compared to LDV’s and UV’s (Solutions for Mining Transport by Scharf, 2010).

Monorail systems have the advantages of:

- Being able to negotiate steep gradients and sharp horizontal curves and changing gradients.
- Most efficient at gradient of 10° (max 18° without further train adjustments).
- Could accommodate a maximum turning radius of 30°.
- Having a small cross-sectional area - minimal excavation.
- Include its own load pick up system.
- No special floor preparation is required.
- Being able to transport both personnel and material (Refer to Figures 2.7. to 2.7b to view the monorail transportation system infrastructure)
- Efficient delivery of personnel and material (able to move at speeds of 2 m/s).
- Diesel driven - no electrical cable or connection issues.
- A standard train can carry 15 tons material.
- The mechanical controls and functions withstand humid and dusty conditions. The small cross sectional dimensions (800 mm width) enables the train to access low and tight roadways and support the mining operations right at the face. The modular built-up allows the Mine to choose the configuration which fits into their conditions.

- The monorail system has a good fuel consumption, (average 9.5 litres per operation hour), spare and wear parts are readily available at low cost. Its robust design has been approved in coal and hard rock mines around the world.

Monorail systems have the disadvantages of:

- In a conventional mining environment, not the solution for personnel transportation:
  - Capacity of 60 persons per trip.
  - Time to travel 1.5 km is approximately 25 minutes.
  - Time to embark from monorail is approximately 5 minutes.
  - Thus a round trip of 3.0 km will take approximately 1 hour.
- Environment should remain dry at all times. The monorail tends to slip where fissure water or other water sources wet the rails.
- The monorail system is expensive (Initial Capital Cost):
  - Cost per unit is approximately ZAR 6.4 million, 2014 money terms (AAP Union Section Mine, 2008).
  - Cost for infrastructure and installation is approximately ZAR 8.9 million.

A site visit was arranged to the AAP's Union Section Mine close to Northam in the Limpopo province. The monorail transportation system was investigated as a possible option for replacing the current belt riding situation at BRPM. The following conclusions were made during the visit (Personal visit, 2008):

- The monorail travel at a speed of 2 m/s and it has a capacity of 75 persons per trip.
- Thus a round trip of 3.0 km will take approximately 1 hour. Thus it could be calculated that the actual transportation efficiency is 75 persons per hour.
- Thus to transport 2,600 people will take approximately 35 hours.

Significance of the available information

This option was considered during the Option Selection and Decision Analysis process. There is however limitations with regards to the transportation of large amount of personnel to their respective workplaces within the available time period. The main objective is to increase working time at the face area resulting in improved productivity.

Figure 2.7: Monorail Transportation System Infrastructure
(AAP Union Section Mine, 2008)

Figure 2.7a: Monorail Transportation System Infrastructure
(AAP Union Section Mine, 2008)

Figure 2.7b: Monorail Transportation System Infrastructure (Material cassettes)
(AAP Union Section Mine, 2008)

2.8. Chairlift Installation in Raise Bore Shaft

A site visit was arranged to the Anglo Gold Ashanti's Kopanong Mine near Klerksdorp in the North West province. This chairlift system utilising a 2.4 m diameter raise bore shaft was investigated as a possible option or to be used in conjunction with other layout options to solve the current conveyor belt riding situation at BRPM. The following observations were made during the visit as per Table 2.8 (Personal visit, 2008):

Table 2.8: Chairlift Technical Specifications

Upper level	62 level		
Lower level	64 level		
Mining area	D/West Area		
Name of manufacturer	Walter Becker SA (Pty) Ltd		
Dimensions		**Units**	**Symbol**
Length of installation	287.381	m	L
Vertical lift	86.536	m	H
Angle of inclination	28	deg	°
Rope centre distance	1.5	m	
Carrying Specifications		**Units**	**Symbol**
Capacity of chairlift	900	Persons/hour	
Rope speed	1.5	m/s	
Number of chairs	96		N
Payload per chair	70	kg	
Mass of chair	17	kg	Mc
Chair spacing	6	m	
Rope Specifications		**Units**	**Symbol**
Rope construction	6x19(9/9/1)/F		
Rope diameter	26	mm	
Rope finish	Galvanized		
Mass of rope	2.462	kg/m	MR
Breaking force	413.40	kN	F
Rope of lay	Right hand lay		
Pulley diameter	150	mm	
Total rope length	579.474	m	
Static factor of safety	1.2		
Rope material MPa	1,800	MPa	
Drive and Tension Units		**Units**	**Symbol**
Position of drive unit	Top of incline		
Position of tension unit	Bottom of incline		
Power requirements	21.837	kW	
Power installed	37	kW	
Type of tension unit	Gravity tower		
Static tension	2,727	kg	
Drive wheel diameter	1,500	mm	
Return wheel diameter	1,500	mm	

(Kopanong Mine, 2008)

Figures 2.8 and 2.8a will illustrate the chairlift in operation at Kopanong Mine as well as some of the infrastructure required.

Figure 2.8: Chairlift installation in the raise bore shaft at Kopanong Mine
(Kopanong Mine, 2008)

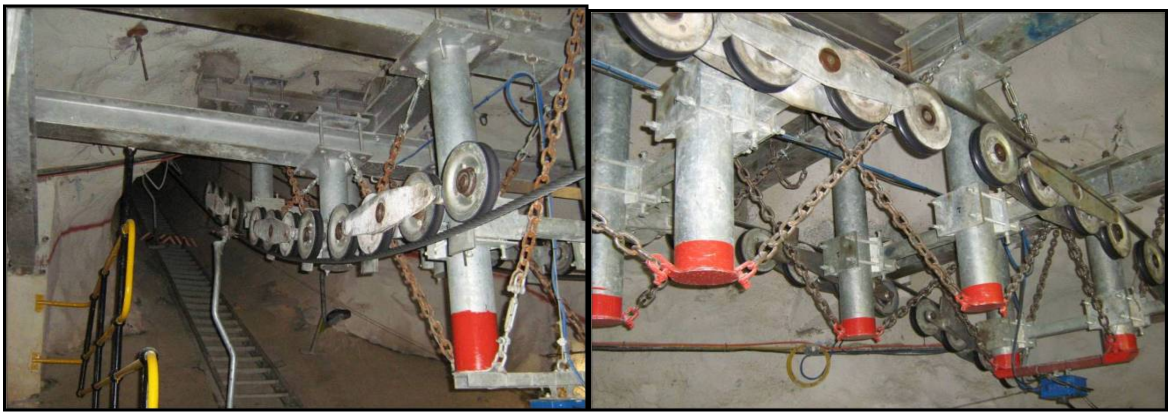

Figure 2.8a: Chairlift infrastructure in the raise bore shaft at Kopanong Mine
(Kopanong Mine, 2008)

The following conclusions were made during the visit:

- The use of a raise bore shaft should definitely be investigated during the personnel transportation study at BRPM.
- The minimum angle of inclination is 28°, this is the minimum angle required to ensure that self-cleaning occur during the drilling of the raise bore shaft.
- The maintenance (preventative and routine) on the infrastructure is much higher compared to a normal chairlift installation as a result of the acute angles it has to operate in.
- The diameter of raise bore shaft should be clearly defined and calculated in terms of required clearance from the side walls (including footwall). Special permission should be granted by the DMR for application of similar type of arrangement.
- There should be compliance with MHSA regarding walking up and down the inclined shaft when chairlift is standing. This could be during normal maintenance or during breakdowns.

Significance of the available information

This option of utilising a raise bore shaft for the purpose of a chairlift installation or any part thereof (individually as a chairlift leg on its own or in combination with the rest of the system) was considered during the Option Selection and Decision Analysis process.

2.9. UK Patent for Personnel Riding Equipment Assisting Transfer to or from Conveyor Belt

This pending patent application discusses various modifications to the conveyor belt and belt infrastructure that could assist personnel during the process of getting on or off the conveyor belt. This document is available in Appendix B of this document (Gurr *et al*., 2008).

Significance of the available information

The application was used during the design of proposed changes to the current BRPM system as a secondary option to have an immediate impact and to reduce the risk of incidents / injuries whilst using the conveyor belt for personnel transportation.

2.10. Material and Personnel Transport by Endless Rope Haulage

This document was written by G.L. du Plessis in 2001 for the 6th International Symposium on Mine Mechanisation and Automation held by the South African Institute of Mining and Metallurgy (SAIMM). This document describes the design, installation and operation of an endless rope haulage system build and commissioned at Evander Gold Mines in the Mpumalanga province of South Africa. It include the factors which lead to the decision analysis and option selection of the specific system as well as the advantages gained over more commonly used winding systems. This document is available in Appendix C of this document.

Significance of the available information

This option was considered during the Option Selection and Decision Analysis process. The objective was to review the option of obtaining a licence to use the material winder for the purpose of personnel transportation. During the process, consideration was given to the fact that the material winder is already under strain due to the configuration of the mine as well as operational requirements in terms of the material supply schedule.

2.11. LDV's and Personnel carriers / carriages

Due to the nature of the operation, utilizing a conventional mining method with large number of personnel, mechanised LDV's and / or personnel carriers were not considered as a possible option to replace / alter the current personnel transportation system at BRPM. Conventional track bound carriages were also not considered as this option could not be applied going down / up the mine, except in conjunction with an available winding system under strict conditions as discussed in previous paragraph. This option is however applicable and very successful in horizontal transport of personnel from the level station to their respective workplaces and back at the end of the shift.

2.12. Literature Study Conclusion – Significance of the available information

During the Literature Study, various alternative means of personnel transportation or through applying engineered solution to the current conveyor belt infrastructure were investigated. This allowed for consideration of proposed new personnel transport arrangements changes as well as proposed changes / modifications to the existing conveyor belt infrastructure in the safest, most effective and most economical way. All of these proposed options were considered during the Option Selection and Decision Analysis process. Table 2.12 contains the literature study summary that was conducted prior to commencing the study on personnel transportation for hard rock decline shaft systems employed in the past.

Table 2.12: Literature Study Summary

Type of Conveyance	Description	Significance	Applicability
Walking	The risks of walking are slip and fall incidents / injuries and unauthorized riding of unapproved conveyances or cars (Frankland, 1984). 150 m is the allowable vertical distance for unaided travelling (MHSA, 1996).	In the case of BRPM, due to the configuration of the shafts and the specific requirements, walking is not the preferred option.	**Not applicable for further investigation**
Underground Conveyor Belt Personnel Transportation	The concept were originated as an optimised option for both rock and personnel transportation. Instead of having two separate systems as well as two separate excavations, the plan was combined to manage both the requirements of ore and waste transportation from underground as well as personnel transportation to and from the different levels in operation. This application resulted in huge savings in capital expenditure. Training and competency levels of employees are very important as the risks associated with belt transportation are very high (BRPM and Target Gold Mine, 2008 - 2013).	The risk of continuous usage of the conveyor belt infrastructure for personnel transportation with regards the safety and health of employees. BRPM recorded a much worse safety record (106 injuries between 2006 and May 2013) compared to Target Gold Mine (6 injuries between 2011 and 2012). The nature of the injuries recorded at BRPM was more serious compared to Target. The effect on production associated with belt safety stoppages. Belt riding is used as the only mode of transport. It is a condition of employment that employees use belt riding as a form of transportation. Both personnel and broken rock are transported via the conveyor belt. Both BRPM and Target were forced to investigate alternative means of personnel transportation. At BRPM it was purely due to safety reasons compared to Target where they had to deal with disputes from organised labour (BRPM, 2008 - 2013), (Harmony Gold Mining Co Ltd v NUM and Others, 2012).	**Not applicable for further investigation:** This mode of transport was not considered as an option on its own, however it was included during the consideration of proposed changes / modifications to existing conveyor belt infrastructure
Chairlift Personnel Transportation	Chairlift installation has been widely, successfully applied in underground mines as a mode of transport. (Brophy, 1984). The angle of installation varies from horizontal to a maximum of 45°. The length of the installation varies, depending on the specific requirement. There are two different types of chairlifts available, namely the fixed grip and the detachable types. (Frankland, 1984).	The main objective for the installation is to increase working time at the face area, to eliminate fatigue in travelling to the workplace and to increase production by achieving the latter (Brophy, 1984). From the commissioning of the Phase 2 shaft deepening project at BRPM, the decision was to install dedicated chairlifts opposed to the man riding conveyor belt installed in the Phase 1 area. This iinstallations were in operation since 2004 and no chairlift related incidents were recorded thus far. According to safety statistics it was clear that the chairlift installation is the safer method for the transportation of people in the shaft (BRPM, 2008 - 2013). The MHSA contains numerous sections with regards to chairlifts. The regulations stated here are the minimum requirements from the DMR. It is the mine's responsibility to have their own COP and relevant standards to ensure the compliance as well as safety of all personnel using the chairlifts as a means of transportation in and out the mine (MHSA, 1996). This is confirmed through the issuing of a license to operate by an Inspector of Machinery from the DMR.	**Applicable for further investigation**
Chairlift Installation in Raise Bore Shaft	The chairlift system utilising a raise bore shaft was investigated as a possible option or to be used in conjunction with other layout options (individually as a chairlift leg on its own or in combination with the rest of the system).	The minimum angle of inclination is 28°, this is the minimum angle required to ensure that self-cleaning occur during the drilling of the raise bore shaft. The maintenance (preventative and routine) on the infrastructure is much higher compared to a normal chairlift installation as a result of the acute angles it has to operate in. The diameter of raise bore shaft should be clearly defined and calculated in terms of required clearance from the side walls (including footwall). Special permission should be granted by the DMR for application of similar type of arrangement. There should be compliance with MHSA regarding walking up and down the inclined shaft when chairlift is standing. This could be during normal maintenance or during breakdowns (Personal visit, 2008).	**Applicable for further investigation**
Monorail Transportation System	Monorails have proven its reliability under arduous conditions. There is the option between diesel and electric driven units. The track bound monorail is easy to control and safe against derailment compared to a free-steered vehicle. It has a hoist on board and one driver can do the loading and unloading without assistance. The safety records of monorail systems are phenomenal.	Being able to negotiate steep gradients and sharp horizontal curves and changing gradients. Having a small cross-sectional area - minimal excavation. Include its own load pick up system. Being able to transport both personnel and material. Efficient delivery of men (between 60 and 75) and material (up to 15 tons) at 2 m/s. Diesel driven (good fuel consumption - no electrical cable or connection). The mechanical controls and functions withstand humid and dusty conditions. Small cross sectional dimensions (800 mm width) enables the train to	**Applicable for further investigation**

	The on-board safety brake system will stop the train immediately when the system or human faults lead to an uncontrolled movement of the train on the rail. Low OPEX compared to LDV's and UV's (SMT by Scharf, 2010).	access low and tight roadways and support the mining operations right at the face. High initial CAPEX (Personal visit, 2008).	
UK Patent for Personnel Riding Equipment Assisting Transfer to or from Conveyor Belt	This pending patent application discusses various modifications to the conveyor belt and belt infrastructure that could assist personnel during the process of getting on or off the conveyor belt (Gurr *et al.*, 2008).	The application was used during the design of proposed changes to the BRPM system as a secondary option to have an immediate impact and to reduce the risk of incidents / injuries whilst using the conveyor belt for personnel transportation.	**Applicable for further investigation**
Material and Personnel Transport by Endless Rope Haulage	This includes the design, installation and operation of an endless rope haulage system. It includes the factors which lead to the Option Selection and Decision Analysis of the specific system as well as the advantages gained over more commonly used winding systems (Du Plessis, 2001).	This option was considered during the Option Selection and Decision Analysis process. The objective was to review the option of obtaining a license to use the material winder for the purpose of personnel transportation.	**Applicable for further investigation**
LDV's and Personnel carriers / carriages	This included mechanized LDV's and / or personnel carriers, as well as conventional track bound carriages (Personal experience).	Not considered: Utilizing a conventional mining method with large number of personnel, mechanized LDV's and / or personnel carriers were not practical. Not considered: Conventional track bound carriages (Personal experience).	**Not applicable for further investigation:** Conventional track bound carriages are applicable and very successful in horizontal transport (Personal experience).

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CHAPTER 3

RESULTS

3. RESULTS

This chapter contains the results of the study that were conducted on the personnel transportation systems at BRPM.

3.1. Introduction

Initially seventeen different options were identified during P1 ***(Process 1)***. After following a process of elimination, the decision was taken by the BRPM Risk Assessment Team to further investigate six options at North Shaft and nine options at South Shaft during P2 ***(Process 2)***. Finally only three options (one being a total new decline with infrastructure [***primary options***] and two being modifications to the current conveyor belt and belt infrastructure [***secondary options***]) at North Shaft and five options (three being a total new declines with infrastructure and two being modifications to the current conveyor belt and belt infrastructure) at South Shaft were selected to be further investigated during P3 ***(Process 3)*** with detailed design and scheduling. At the end of P3, there was only one primary (Option 3) and one secondary option (Option 10 - with alterations) feasible for each of the shafts (refer to Table 3.2 for different options).

For each of the options, the following were considered:

- Detail design, scheduling, supply, delivery, construction and commissioning of a chairlift system from Surface to level 5 at North Shaft and level 6 at South Shaft.
- SWOT analysis for each of the options.
- Project duration from start of development to commissioning, and how it fits into the LOM profile.
- Utilising the current MR infrastructure.
- Start developing the chairlift decline from different positions simultaneously (various attack points).
- Access to both MR (current operation) and UG2 (future prospect) mining.
- Increased ventilation flow to UG2 horizon in future.

Other factors considered during the selection process:

- Computer Aided Draughting Software for Mining (CADSMine) was utilised to design and schedule the primary options for both shafts.
- CAPEX estimation (capital development [mining], civil engineering works, piping, electrical, mechanical, structural, electrical, instrumentation, 10% contingency and chairlift installation).
- Benchmark the proposed design criterion against actual achievements, in terms of production, construction and costs. This included actual development in progress on the chairlift decline, the actual installation and the associated costs in the Phase 2 area of both North Shaft and South Shaft of BRPM.
- Financial evaluation and trade-off against major risks (safety stoppages and variable speed drive (VSD)).
- Risk analysis (critical technical factors involved to be considered – engineering, rock engineering, geology and ventilation).
- Timing in terms of the LTP and lay-out designs.
- Accessibility from current infrastructure available or through consideration of local communities surrounding the mine.
- Access control on surface (surface transportation from lamp room to chairlift).
- Access to different levels.
- Safety on levels when moving from one chairlift to another.
- Obtaining quotes and had sessions with current contractors and proposed new contractors.

- Do a simulation on the trade-off between belt riding and chairlift transportation.

Other critical issues considered:

- Development end sizes of chairlift decline.
- Lengths of different legs required and the drive stations required accommodating the layout.
- Sliping of zero raise (width and depth – need 3.2 m height and 3.0 m width).
- Alternative travelling route for personnel when chairlift is not running due to maintenance or as a result of a breakdown.
- Access control at landings on different levels.
- Comparison between different development / sinking methodologies i.e. Conventional, mechanised, raise bore, etc.
- Collected belt transportation related safety data from the mine.
- The production and financial impact of installing the VSD at both 1.5 m/s and 2.0 m/s.

3.2. P1 – Option Identification Phase

Risk Assessment workshops were held at BRPM involving all stakeholders (refer to team members below) where a number of possible solutions to the belt riding problem were identified and brainstormed. These are listed in Table 3.2. The following legends are applicable:

- N # - North Shaft
- S # - South Shaft
- ✘ - Not applicable for further investigation
- √ - Applicable for further investigation

The Risk Assessment team members of BRPM included the following stakeholders:

- Glenn Harris – General Manager
- Clive Ackhurst – Mine Technical Services Manager
- Devan Moodley – Engineering Manager
- Gawie van Heerden – Chief Mine Planner
- Christo Joubert – Mine Planner
- Paul Ferreira – Shaft Planner
- Philip Coetzer – S&SD Manager
- John Jeffry – Production Manager South Shaft
- Leka Monama – Production Manager North Shaft
- Tienie Roux – Shaft Ventilation Engineer
- Brian Baker – Shaft Ventilation Engineer
- Dan Ngakane – Resident Engineer North Shaft
- Danie Vos – Resident Engineer South Shaft
- Udo Sachse – Senior Mining Engineer (Coordinator / Corporate)
- Debby Raby – Shaft Rock Engineer
- Jaco Vermeulen – Chief Geologist

Table 3.2: Different options for consideration identified during P1

Option	Description	N #	S #	Comment
1	Chairlift in current belt decline	✘	✘	Sliping required – damage to belt
2a	Chairlift in zero raise – decline from surface	✘	√	N# zero raise line not straight and continuous. S# applicable for further investigation
2b	Chairlift in zero raise – vertical shaft to surface	✘	✘	Surface infrastructure / communities
3	New chairlift decline – new infrastructure	√	√	High CAPEX
4	Vertical shaft from surface to level 3	✘	✘	Still need transport / travelling through workings to upper levels
5	Multiple chairlifts in ventilation bypass areas	✘	✘	Extensive infrastructure required with additional development
6	Slower personnel – riding speed	√	√	Applicable for further investigation
7	Single chairlift at South 40 position for both shafts	✘	✘	Logistical and infrastructure constraints (single access between shafts)
8	One way chairlift down belt decline, up zero raise (continuous loop)	√	√	Need connection to surface, engineering challenges when considering infrastructure installation in loop configuration
9	Licence material winder for personnel transportation	✘	✘	Impact on already tight material supply schedule
10	Safer platforms for getting off the belt	√	√	Applicable for further investigation
11	1st Leg chairlift in belt decline then in zero raise	✘	✘	Sliping required – damage to conveyor belt and belt infrastructure
12a	Chairlift in zero raise – incline under opencast	✘	√	N# zero raise line not straight and continuous. S# applicable for further investigation
12b	Chairlift in zero raise – portal in opencast highwall	✘	√	N# zero raise line not straight and continuous. S# applicable for further investigation
13	Vertical shaft from surface to level 5 at N# and level 6 at S#	✘	✘	Still need transport / travelling through workings to upper levels
14	Monorail system	√	√	Applicable for further investigation
15	New decline on UG2 horizon	✘	✘	Much higher CAPEX compared to MR horizon options
16	Additional belt riding conveyor in belt decline	√	√	Applicable for further investigation
17	Hector pipe	✘	✘	No personnel transport to surface, only down the mine

In the following paragraphs, detailed commentary is provided for the seventeen options identified and brainstormed during P1. During this stage of the project, no option was deemed impossible or discarded based on capital requirements, practicality, timing in terms of LOM profile, accessibility, safety or impact on surface infrastructure / as a result of surface infrastructure (communities).

3.2.1. Option 1 – Install Chairlift in Current Belt Decline

The existing belt decline at both shafts was developed to dimensions of 4.2 m wide x 4.0 m high. In order to obtain the necessary clearance for a chairlift installation, sidewall sliping of about 1.5 m along the route would be required. Blasting operations carried out in this area have a high likelihood of inflicting serious damage to current infrastructure with the consequent production losses. This option was considered to be high risk and consequently not feasible. No further investigations were carried out.

3.2.2. Option 2 – Chairlift System in Zero Raise

The zero raise was a 1.8 m x 1.5 m excavation originally developed as an airway concurrently with shaft sinking operations, beginning at level 1. It was initially reported that the excavations on both shafts are still in good condition and there was the possibility of utilising it as a potential option for personnel transportation. A connection to surface would be required at both shafts which could be either via a decline, raise bore shaft or vertical shaft system. Initial investigations into this option indicated the following:

- **South Shaft** – zero raise was in a good condition and was developed in a straight line. Whilst sliping would be necessary to get the zero raise to the required dimensions, this was definitely achievable. This option was rated as possible but required further investigation during the next phase to determine its viability.
- **North Shaft** – zero raise would require considerable work as it was not straight and not continuous. Considerable sliping would be required to obtain the required dimensions. This was rated as probable and possible to implement, but required further investigation during the next phase to determine its viability.

3.2.3. Option 3 – Chairlift Decline System on Belt Decline Elevation

This option would involve developing a new decline parallel to and on the same elevation as the existing belt decline. While this option would be time consuming and expensive, it was definitely possible and was considered applicable for further investigation during the next phase to determine its viability.

3.2.4. Option 4 – Vertical Shaft from Surface to Level 3 Position at Both Shafts

While this option would facilitate the transport of people into the workings of the mine, it would not solve the problem of transporting them from level 3 to or level 1 or level 5, which would necessitate either travelling on the belt to these areas or installing a chairlift. This option was not considered feasible and no further investigation was carried out. Access via a vertical shaft system was discounted as an option for the following reasons:

- Time constraints with transporting 2,600 people down a small lift shaft.
- Location of current surface infrastructure which would be approximately 600 m from the shaft position.
- Access from the vertical shaft to the existing shaft infrastructure would also be problematic as discussed above.
- The positioning of the shaft would also be influenced by the local communities which are in close vicinity of the two shafts.

3.2.5. Option 5 – Multiple Chairlifts in Old Ventilation Bypass Areas

This option was a possibility, but it would involve considerable infrastructural development and several chairlift systems. This option could also have an impact on the return air should the control systems not be in place or fail for whatever reason. This will result in leakage of return air in old worked out areas in an uncontrolled manner resulting in a negative air pressure which will jeopardise the entire shafts ventilation system. There was also the risk of having personnel in the old worked out areas of the mine. Consequently this option was not considered to be feasible and no further investigation was carried out.

3.2.6. Option 6 – Reduce Belt Speed to Facilitate Personnel Transportation

While definitely possible, the impact of reduced belt speed with the installation of VSD's on production levels needed to be quantified. This option was applicable for further investigation during the next phase to determine its viability.

3.2.7. Option 7 – A Single Chairlift System for Both Shafts

This option would entail developing a single chairlift decline at a point midway between both shafts in order to transport the entire workforce for both shafts. Several concerns were identified regarding this option, namely:

- A significant infrastructure would be required in order to facilitate the transport of all 5,200 personnel down and out the mine.
- The infrastructure would be situated away from the current shafts with resulting transport problems.
- The additional travelling time to the new chairlift shaft on surface and to the workings underground, particularly for those working on the Northern and Southern extremities of the mine's boundaries, would decrease available face time.
- Arrangements would need to be made to transport personnel to the current chairlift on level 5 at North Shaft and level 6 at South Shaft in order to access the lower levels of the mine.
- The new shaft would be situated very close to the community with resultant environmental and social problems.

Consequently this option was deemed not feasible and no further investigations carried out.

3.2.8. Option 8 – Single Chairlift System in Belt Decline Returning up Zero Raise

The zero raise was developed concurrently with the other declines. This development took place on the reef horizon. The objectives of the zero raise or alternatively called, the smoke box was to act as a return airway during multi-blast conditions in the sinking section. The zero raise was connected to the up-cast ventilation shaft on level 1.

This option would involve installing a one way chairlift running down the existing belt decline, through a connecting rope raise to the current zero raise position and then returning up zero raise. Thus, the chairlift will form a one directional continuous loop. Whilst this option would still require developing of a holing from zero raise to surface, it would negate the need for sliping in the belt decline in specific identified areas. This option was considered possible and applicable for further investigation during the next phase to determine its viability.

3.2.9. Option 9 – License Material Winder for Personnel Transportation

This option would require special permission from the DMR. There will also have to be a lot of mine specific standards and COP's to ensure the safety of personnel whilst making use of this transportation means. Whilst possible, this option would put additional pressure on an already strained material transport system due to additional maintenance on all the prerequisite safety devices that would be required. From an engineering and safety perspective, this option was considered not feasible and no further investigation carried out.

3.2.10. Option 10 – Implement Safer Platforms for getting on and off the Belt

This option involved reviewing the design of the current platforms for getting on and off the belt configuration with a view to improving the ergonomics and safety of personnel travelling on the conveyor belt. Points of consideration were:

- Flatten the angle of the belt at the landing stations.

- Install additional belts that run parallel to the current belt, at a reduced speed.
- Look at softer landing stations with less steel work to reduce severity of injuries.
- Investigate the option of installing an endless rope arrangement for assisting personnel getting off from the conveyor belt.

These were considered possible and applicable for further investigation during the next phase to determine its viability.

3.2.11. Option 11 – Chairlift in Zero Raise, Access via Belt Decline
It would be possible to install a chairlift system in the current belt decline from surface to level 1 on both shafts. From there, personnel could be transferred to the zero raise position with an additional chairlift that goes down to level 5 at North Shaft and level 6 at South Shaft.

This option requires sliping from surface to level 1 to accommodate the chairlift. This could have a possible impact on production as well as damage to the current belt infrastructure. Therefore, this was rated not feasible and no further investigations were carried out.

3.2.12. Option 12 – Chairlift in Zero Raise – Surface Accesses
The following two options revolve around potential surface access from zero raise:

- **Option 12a – Portal at Shaft Infrastructure**
  Develop a decline at shallow dip from level 1 to go beneath the opencast workings and establish a portal at the current shaft position. This was rated as possible and most likely to implement and applicable for further investigation during the next phase to determine its viability.
- **Option 12b – Portal in Old Opencast Highwall**
  Extend the zero raise to daylight in the old opencast position. Establish a portal that connects to the current shaft infrastructure. This was also rated as possible and most likely to implement, and applicable for further investigation during the next phase to determine its viability.

3.2.13. Option 13 – Vertical Shaft from Surface to Level 5 at North Shaft and Level 6 at South Shaft
This option was evaluated, but discounted as a possible solution for the same reasons as given in Option 4.

3.2.14. Option 14 – Monorail System in Belt Decline
This option would most likely require sliping in the decline and a huge CAPEX requirement as discussed in paragraph 2.7 of the Literature Study (Chapter 2). Timing to get 2,600 people down the mine would be a definite constraint. Cognisance should be taken of the fact that the installation of a similar unit at AAP's Union Section has been largely unsuccessful. This option was however still applicable for further investigation during the next phase to determine its viability.

3.2.15. Option 15 – Chairlift Decline on the UG2 Horizon
The possibility of establishing a new decline from surface on the UG2 horizon was considered. The amount of development required whilst utilising the current MR infrastructure would be much less compared to that on the UG2 horizon. There was also much more attack points on the MR horizon as a result of the already established levels on all the required levels for both shafts as per project scope, compared to on the UG2 horizon where there would be only a single attack point. This would have a tremendous impact on the project duration. This option was discounted due to the time constraints to establish the new decline, the high CAPEX requirements and the potential for sterilising UG2 ore reserves.

3.2.16. Option 16 – Additional Belt Riding Conveyor in Belt Decline

This would be a separate, dedicated personnel riding conveyor belt installed alongside the existing conveyor belt and belt infrastructure. This conveyor belt will be running at much lower speed compared to the existing conveyor belt. The existing conveyor belt will then be dedicated for transporting broken rock only. In certain areas, as identified in the current belt decline, sliping would be required to accommodate the installation of the personnel riding conveyor belt. This option was considered possible and applicable for further investigation during the next phase to determine its viability.

3.2.17. Option 17 – Install a Hector Pipe to Transport Personnel down the Shafts

This option could be successful in transporting personnel into the workings, but there is no way of transporting them out of the mine. Therefore, this option was rated not feasible and no further investigation was carried out.

3.2.18. Summary – P1 – Elimination Phase

At this stage the first round of eliminations took place. The options listed in Table 3.2.18 were selected for further investigation during P2 of the study:

Table 3.2.18: Different options selected for further investigation during P2

Option	Description	N #	S #	Comment
2a	Chairlift in zero raise – decline from surface	✘	√	N# zero raise line not straight and continuous. S# applicable for further investigation
12a	Chairlift in zero raise – incline under opencast	✘	√	N# zero raise line not straight and continuous. S# applicable for further investigation
12b	Chairlift in zero raise – portal in opencast highwall	✘	√	N# zero raise line not straight and continuous S# applicable for further investigation
3	New chairlift decline – new infrastructure	√	√	High CAPEX. Applicable for further investigation
6	Slower personnel – riding speed	√	√	Actual effects of VSD applicable for further investigation
8	One way chairlift down belt decline, up zero raise (continuous loop)	√	√	Need connection to surface, engineering challenges when considering infrastructure installation in loop configuration. Applicable for further investigation
10	Safer platforms for getting off the belt	√	√	Applicable for further investigation
14	Monorail system	√	√	Applicable for further investigation
16	Additional belt riding conveyor in belt decline	√	√	Applicable for further investigation

3.3. P2 – Elimination Phase

The options as summarised in Table 3.2.18 were further investigated during P2 where more options were eliminated based on safety, practicality, effectiveness and costs. The primary options could be illustrated by using a decision tree analysis process. The decision trees for both North and South Shafts are shown in Figure 3.3 and 3.3a. The secondary options were considered to be all modifications to the current conveyor belt and belt infrastructure, VSD, monorail and additional belt specifically for belt riding in parallel to existing belt. These secondary options were not included in the decision tree illustrations.

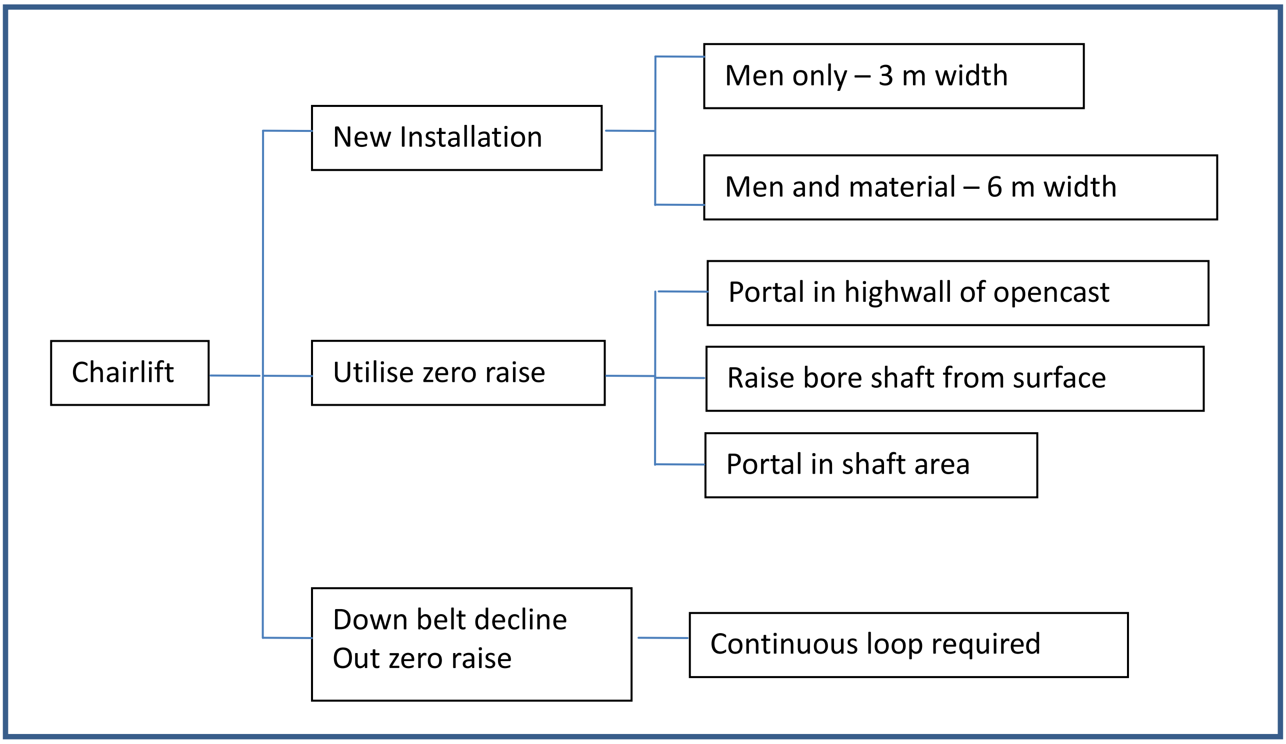

Figure 3.3: South Shaft Decision Tree for various options
(Van Heerden, 2008)

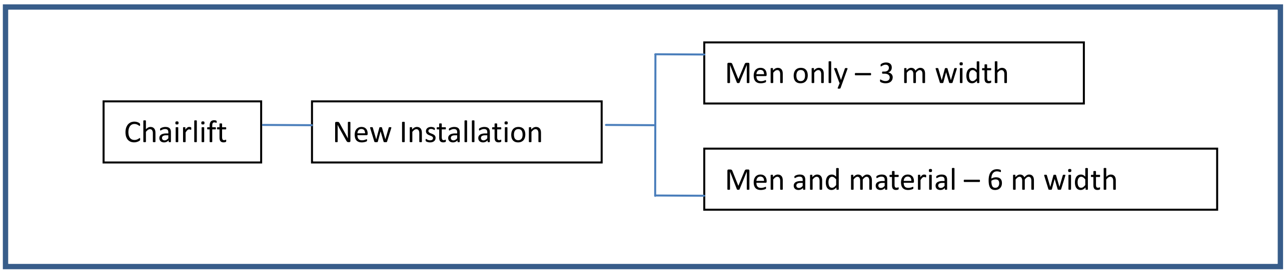

Figure 3.3a: North Shaft Decision Tree for various options
(Van Heerden, 2008)

3.3.1. Options 2 and 12 – Chairlift System at Zero Raise Position at Both Shafts

Options 2 and 12 were combined into one investigation as they deal with the installation of a chairlift in zero raise while considering various potential access routes to connect the raise to surface, namely to incline to daylight in the old opencast workings or develop underneath the opencast to daylight in the shaft complex. Other possibilities such as the drilling of a raise bore hole were also considered.

South Shaft

The zero raise was definitely considered as a viable option as the raise is relatively straight and levels 3 and 4 are close to the station cross cuts. Sliping would however still be required to obtain the minimum dimensions required for chairlift installation. This was considered as a definite option at South Shaft, although it would have to be evaluated in considerably more detail. Much thought would need to be devoted to resolve the issue of connecting the raise to surface, possible solutions to be considered were:

- Incline below old opencast workings to daylight in shaft area (Figure 3.3.1).
- Portal in opencast highwall (Figure 3.3.1a).

➢ Raise bore shaft from surface (Figure 3.3.1b).

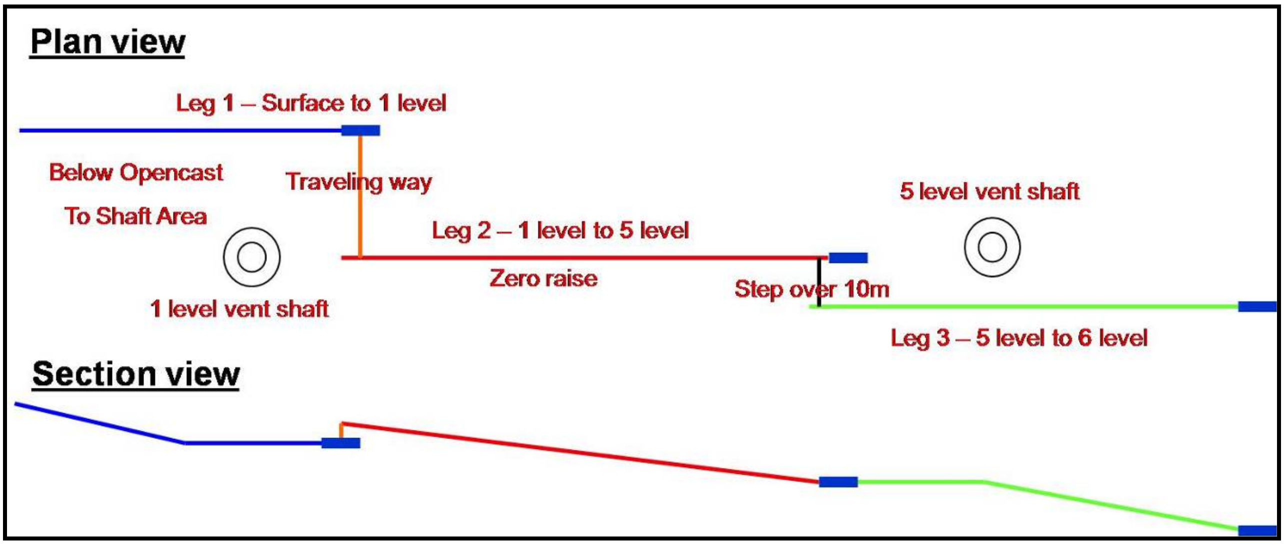

Figure 3.3.1: Installation of a Chairlift System in the Zero Raise – below old opencast workings
(Van Heerden, 2008)

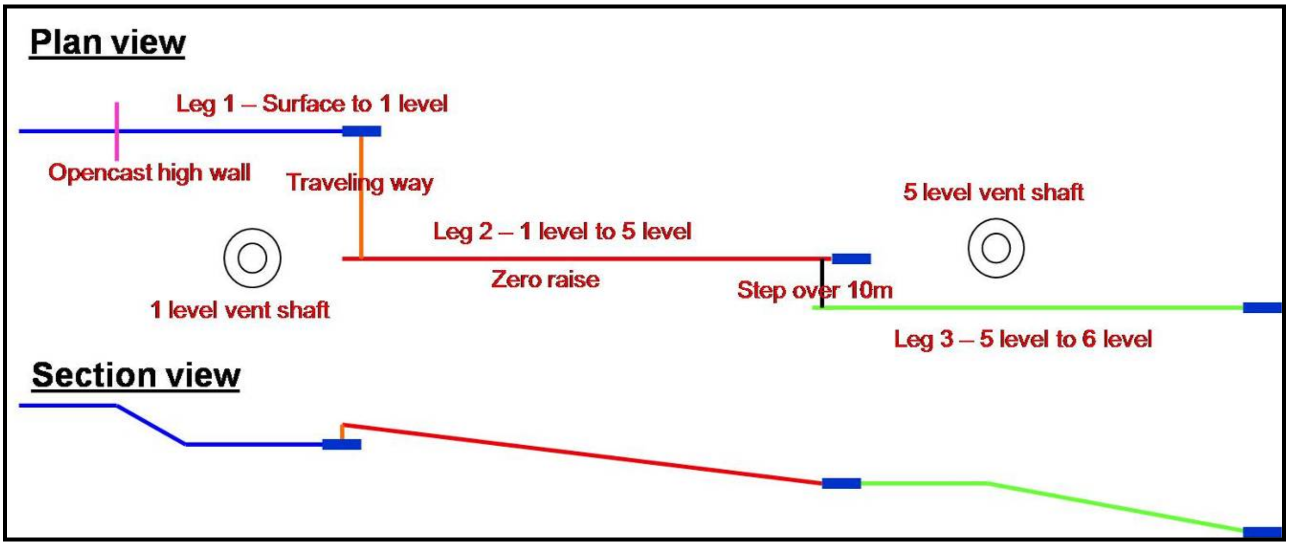

Figure 3.3.1a: Installation of a Chairlift System in the Zero Raise – in opencast highwall
(Van Heerden, 2008)

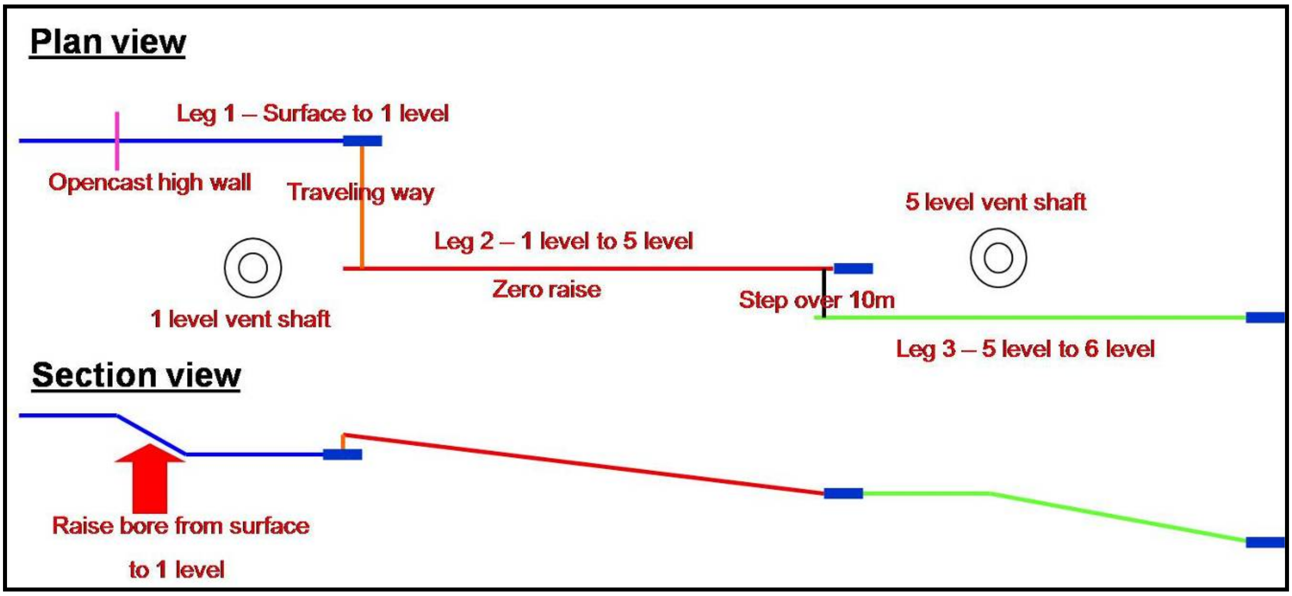

Figure 3.3.1b: Installation of a Chairlift System in the Zero Raise – raise bore shaft from surface
(Van Heerden, 2008)

North Shaft
Due to the nature of the North Shaft zero raise, this option was eliminated for the following reasons:

- There would be three line changes before getting to level 5.
- The area between levels 3 and 5 was developed using a Tunnel Bore Machine (TBM) and was drilled to a diameter of 2.1 m which would entail massive sliping to obtain chairlift dimensions.
- The remaining raise is not straight which would entail further sliping.
- There are currently training centre activities between levels 1 and 2.
- The ground conditions between levels 4 and 5 are very poor.
- Making use of the zero raise would have an effect on the ventilation removing 10.0 m^2 from the return air system.

3.3.2. Option 3 – New Chairlift Decline from Surface to level 5 at North Shaft and level 6 at South Shaft
This option considered the possibility of developing a new decline from surface to level 5 at North Shaft and level 6 at South Shaft. Existing cross cuts close to proposed stations could be used to develop the decline from a number of attacking points. This new decline would be capable of servicing both the current MR and future UG2 mining.

South Shaft
This option was considered as a definite possibility at South Shaft, although zero raise was considered the favoured option at this stage. Trade-off studies were conducted to identify the best option. This option was thoroughly investigated during P3 of this study. Figure 3.3.2 provides a schematic representation of this new chairlift decline in plan and section views.

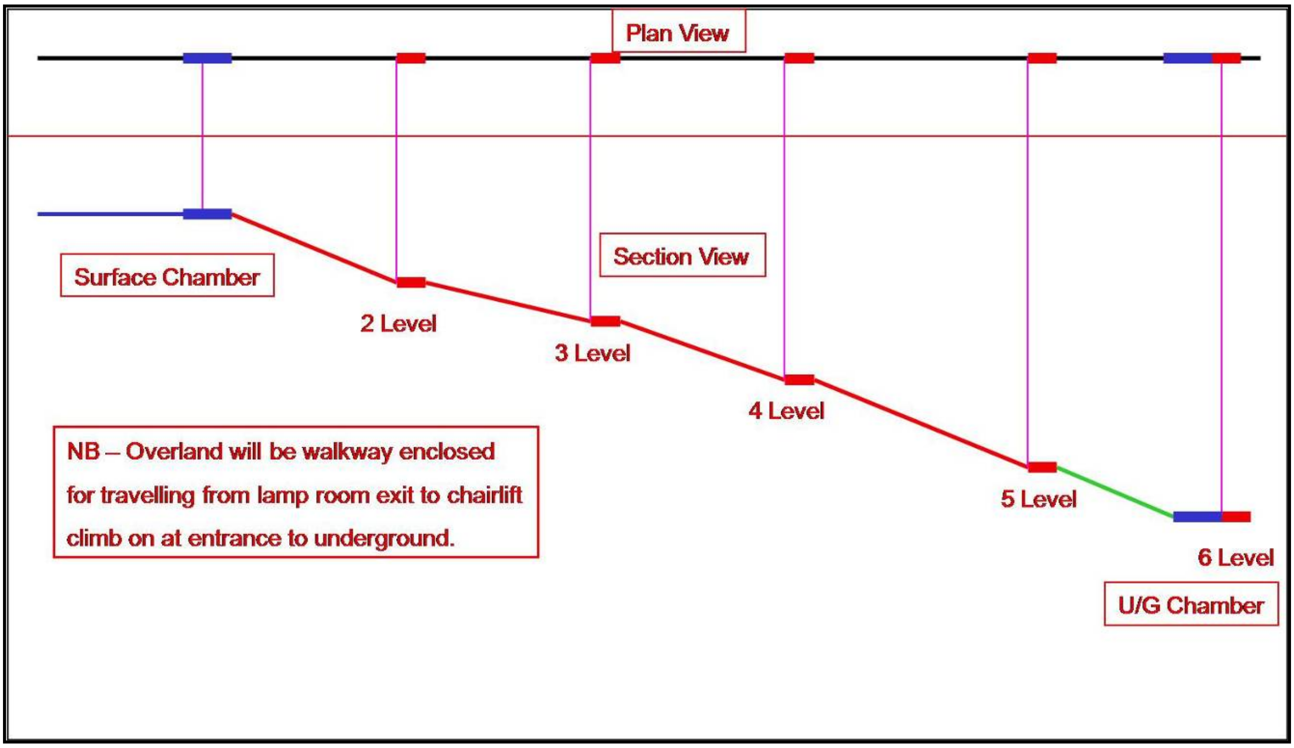

Figure 3.3.2: Installation of a new Chairlift Decline from surface at South Shaft
(Van Heerden, 2008)

North Shaft
This was considered as the favoured option at North Shaft with serious consideration being given to the location and stratigraphic position of the shaft. The new chairlift decline will be accessed from existing infrastructure via access cross cuts. It was suggested to move the proposed chairlift decline closer to the current UG2 breakaways, thus to the northern side of the cluster.

The projected line to surface is much more practical due to the current shaft position, as well as taking the opencast into consideration. This access to surface could also assist with ventilating the UG2 in future when required. This option will allow for six different attack points, one from surface and then one each from levels 1 to 5. Figure 3.3.2a provides a schematic representation of this new chairlift decline in plan and section views.

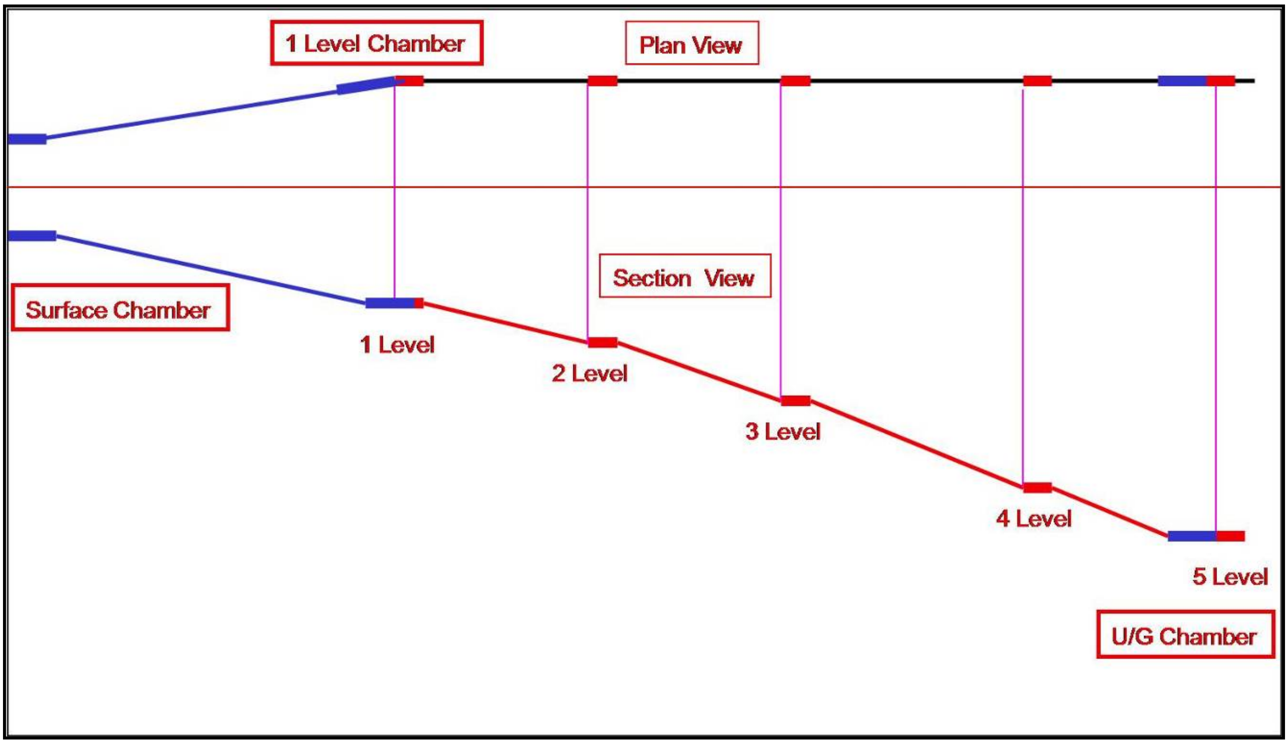

Figure 3.3.2a: Installation of a new Chairlift Decline from surface at North Shaft
(Van Heerden, 2008)

3.3.3. Option 8 – Install a One-Way Chairlift System in the Current Belt Decline

South Shaft

Utilising zero raise is definitely an option at South Shaft. There is sufficient clearance next to the current belt infrastructure to install a one way chairlift. Both levels 3 and 4 are close to the station cross cuts, however minimal sliping would be required. It was envisaged that the chairlift installation will be as follows:

- Start with installation on surface at exit from lamp room.
- Access to the underground workings would be via the existing belt decline with a single line chairlift. The single line installation will be next to the current belt infrastructure.
- A 50 m long rope raise would be developed at an inclination of 72° in order to connect the belt decline to zero raise through which the chairlift would be fed.
- The zero raise will be used to go out from underground.
- Just before the ventilation shaft on level 1 it will be required to develop a connection around the ventilation shaft.
- From this connection, a raise would be developed from the top of zero raise, below the open cast workings and below reef horizon, to the bank area. Return for the chairlift would be via this route.
- A continuous loop is required.

Table 3.3.3 illustrates the SWOT analysis that was conducted by the Risk Assessment team for Option 8 at South Shaft during the evaluation process.

Table 3.3.3: SWOT analysis for Option 8 at South Shaft

Strengths	**Weaknesses**
▪ Access to underground working from surface ▪ Eliminate belt riding ▪ Gives access to both MR and UG2 reef horizons ▪ Single line installation in zero raise – less sliping due to smaller required width (3.3 x 1.5 m) ▪ Low CAPEX	▪ Elevation difference between belt decline and zero raise (50 m at 72º) ▪ Maintenance on 2 ends, cost and time ▪ Installation of chairlift drive / return will be at an angle – promotes wear and tear ▪ Stop for maintenance – stop shaft ▪ Restricted vent flow due to additional infrastructure in belt decline ▪ Engineering challenges
Opportunities	**Threats**
▪ None	▪ Breakdown reporting ▪ Single person in end – cannot report injuries ▪ Breakdown – takes long to discover

This layout is illustrated conceptually in Figure 3.3.3.

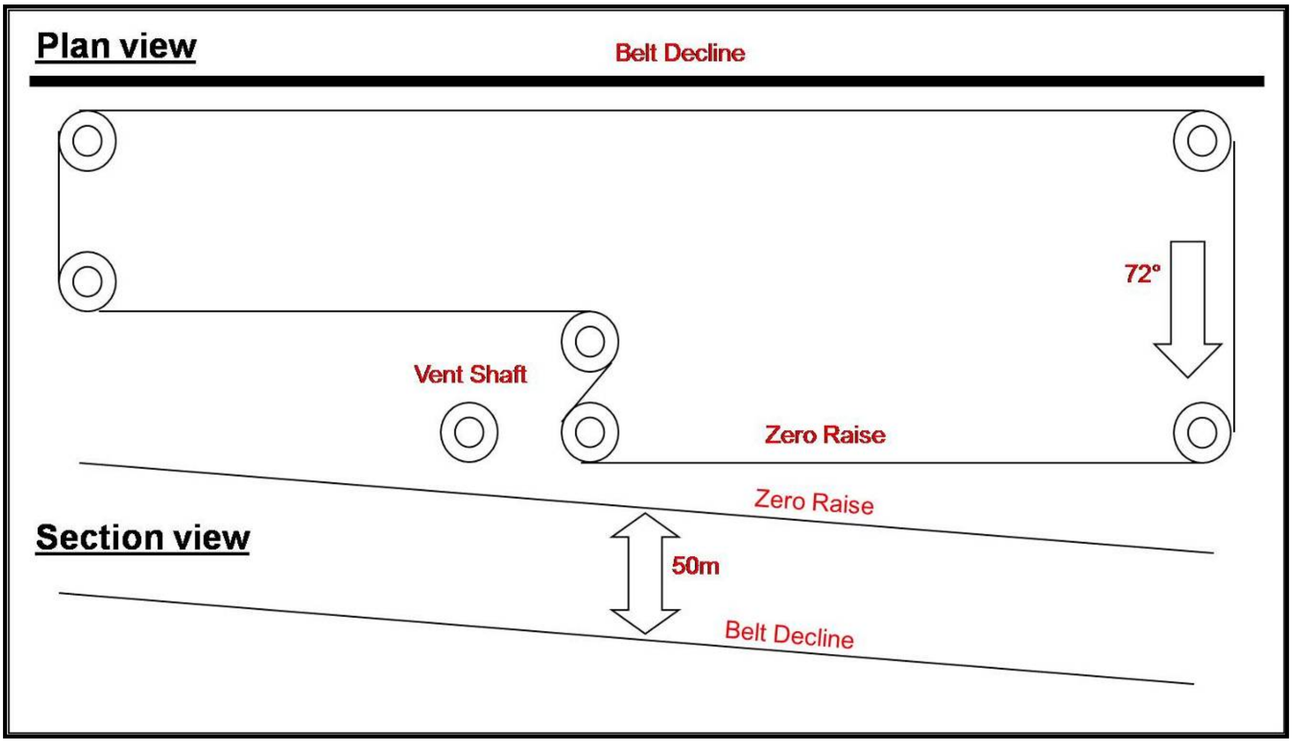

Figure 3.3.3: Installation of a One-Way Chairlift System in the Current Belt Decline
(Van Heerden, 2008)

While this would appear to offer a cost effective solution, in terms of lowest estimated capital expenditure, to the problem, the engineering challenges and complexity involved with installing a chairlift system capable of negotiating so many turns and changes in inclination are extensive. Eventually this option was rejected as it was not possible to install a reliable system in this way.

North Shaft
This option was rejected as a solution for North Shaft for the same reasons as mentioned in Section 3.3.1.

3.3.4. Options 6 and 10 – Improvements to Current Belt Safety

As part of the secondary options was to reduce the speed of the current conveyor belt and investigate the implementation of safer landing stations to reduce the safety risk and severity of injuries / incidents.

At this stage installation of a VSD at both shafts was approved with the cost of implementation at both shafts estimated at ZAR 7.8 million (2008 money terms). Commissioning of these drives was planned for the end of 2008. While the intention was to reduce the belt speed to 1.5 m/s during shift time, Anglo American Technical Division (ATD) was tasked to run a simulation on the impact of reducing belt speed on the shafts capacity to deliver on production targets.

The potential to introduce safer platforms would be applicable for further investigation. This report is attached in Appendix D and indicates the reduction in the shafts' ability to meet production targets.

The following scenarios were simulated:
- Scenario 1: Belt speed at 2.5 m/s with personnel riding on broken rock (current situation - Base).
- Scenario 2: 2.5 hour delay at the start of the shift to allow for personnel transportation separate from broken rock.
- Scenario 3: Belt speed at 2.5 m/s with personnel riding separately from broken rock.
- Scenario 4: Belt speed at 2.5 m/s when conveying on broken rock, belt speed reduced to 1.5 m/s when transporting personnel only by means of the VSD.

Table 3.3.4 illustrate the results of the simulation. Allowing 2.5 hours at the beginning of each shift resulted in a 16 % drop in daily tonnage. Holding back the broken rock until all personnel were transported resulted in a 15 % drop. The biggest impact (47 %) was when the personnel travelled separately from the broken rock at a reduced belt speed of 1.5 m/s (Jele, 2008).

Table 3.3.4: Simulation model results

Scenario	Total daily tonnage (t) – reef and waste	Change to base (%)
Scenario 1	7,409	0
Scenario 2	6,385	-16
Scenario 3	6,426	-15
Scenario 4	5,056	-47

(Anglo American Conveyor Simulation Report, 2008)

The following calculations were done to illustrate the impact of reducing the belt speed with the introduction of the VSD at 1.5 m/s and at 2.0 m/s when personnel are travelling on the conveyor belt.

Reducing the belt speed to 1.5 m/s *(from 2.5 m/s, 60% of capacity)*
- Introduction of VSD during shift times only
- Effective introduction = 2 hours per shift or 6 hours per day
- Daily reef call = 4,500 t / shaft **(9,000 tons – BRPM)**

- Reduction = 40 % of 1,125 = 450 t possible loss / day **(900 tons – BRPM)**
- Loss of 450 t/day x 24 tramming shifts = 450 t x 24 = 10,800 t **(21,600 tons – BRPM)**
- Belt grade = 4.40 g/t **(Average LE07** (Latest Estimate Seventh month completed)**)** (BRPM, 2008)
- Ounce conversation = 31.10458 g/oz
- Basket price = ZAR 17,126 / Pt oz **(Average LE07)** (BRPM, 2008)
- = 10,800 x 4.4 / 31.10458 x 17,126 = ZAR 26.2 million per month **(ZAR 52.4 million – BRPM, 2008 prices)**

Reducing the belt speed to 2.0 m/s *(from 2.5 m/s, 80% of capacity)*
- Introduction of VSD during shift times only
- Effective introduction = 2 hours per shift or 6 hours per day
- Daily reef call = 4,500 t / shaft **(9,000 tons – BRPM)**
- Reduction = 20% of 1,125 = 225 t possible loss / day **(450 tons – BRPM)**
- Loss of 225 t/day x 24 tramming shifts = 225 t x 24 = 5,400 t **(10,800 tons – BRPM)**
- Belt grade = 4.40 g/t **(Average LE07)** (BRPM, 2008)
- Ounce conversation = 31.10458 g/oz
- Basket price = ZAR 17,126 / Pt oz **(Average LE07)** (BRPM, 2008)
- = 5,400 x 4.4 / 31.10458 x 17,126 = ZAR 13.1 million per month **(ZAR 26.2 million – BRPM, 2008 prices)**

Thus, from the simulation done by ATD as well as the calculation it is evident that the introduction of the VSD's would not be the preferred solution for the current situation at BRPM. Other options or combination of options will have to be considered to ensure that BRPM maintain its planned production targets.

3.3.5. Option 14 – Monorail Installation

This option would also require sliping in the belt decline. This option would come at a total cost of ZAR 8.9 million for a 1.5 km installation of monorail per shaft (year price 2012). This cost includes the cost for the unit and the required infrastructure. Calculations showed that a round-trip would take 1 hour, transporting 75 people. Thus, to take down 2,600 people would take 35 hours. While this could be mitigated by installing a loop system with a number of trains, experience gained from the installation of a similar system at the AAP's Union Mine did not indicate this as a viable solution. The reason for this being the train slipping considerably when the rails are exposed to water resulting in the maximum speeds achieved similar to a fast walking pace. As a result, further investigations in this regards were abandoned. Refer to paragraph 2.7 of the Literature Study (Chapter 2).

3.3.6. Option 16 – Dedicated Man-riding Conveyor Belt in Belt Decline

While this would be a possible solution, the existing dimensions of the belt declines would not cater for this. Sliping would be required over the full length of the current system. The risk of damaging the current conveyor belt infrastructure is too high. This was considered not feasible and investigations discontinued.

3.3.7. Summary – P2 – Elimination Phase

At the end of this Process phase there were five suitable options available at South Shaft and three at North Shaft. These are summarised in Table 3.3.7 and 3.3.7a:

Table 3.3.7: South Shaft – different options selected for further investigation during P3

Option	Description	South Shaft	Comment
12a	Chairlift in zero raise – incline under opencast	√	Applicable for further investigation
12b	Chairlift in zero raise – portal in opencast highwall	√	Applicable for further investigation
3	New chairlift decline – new infrastructure	√	High CAPEX. Applicable for further investigation
6	Slower personnel – riding speed	√	VSD installed. Effects of VSD to be investigated
10	Safer platforms for getting off the belt	√	Applicable for further investigation

Table 3.3.7a: North Shaft – different options selected for further investigation during P3

Option	Description	North Shaft	Comment
3	New chairlift decline – new infrastructure	√	High CAPEX. Applicable for further investigation
6	Slower personnel – riding speed	√	VSD installed. Effects of VSD to be investigated
10	Safer platforms for getting off the belt	√	Applicable for further investigation

3.4. P3 – Elimination Phase

The options as summarised in Table 3.3.7 and 3.3.7a was investigated further during P3 whereby more options were eliminated based on safety, practicality, effectiveness and costs.

3.4.1. North Shaft

As there was only one primary option (Option 3), apart from the modifications to the current conveyor belt and belt infrastructure (secondary options), available at North Shaft, considerable effort was focussed on this option. There is one other alteration to this option, and that is to develop a 6 m wide chairlift decline instead of the standard 3 m decline. The objective of this 6 m wide decline would be to equip it with both a chairlift and a winder for material transportation to the future UG2 operations. The decision was taken by mine management that this option should not be considered at this stage together with the personnel transportation study but rather as an alternative when conducting the UG2 studies.

3.4.1.1 Layout – North Shaft

Surface Access

Only one primary option proved feasible for further investigation namely:

A portal could be created within the shaft area. From surface a new chairlift decline would be developed down to level 5. This was considered the most logical approach as the infrastructure to support this is in place and there are no additional issues involved.

Positioning

Assessment of a number of potential positions for the decline indicated that the best position would be between the UG2 and MR horizons, as this would be in competent ground and provide easy access to both the existing MR haulages and future UG2 workings. The middling between the two horizons at North Shaft is approximately 70 m which gives adequate space to develop the decline without impacting on the workings. Figure 3.4.1.1 shows a plan view of the chairlift decline with a schematic section representation of the system in Figure 3.4.1.1a.

Essentially the chairlift installation will begin at the exit from the existing lamp room with the first leg running to level 1. From there the chairlift decline will turn approximately 30° to the north and proceed directly to level 5. Landings will be provided at each level through which access to the workings (current MR and future UG2) will be achieved. Figure 3.4.1.1b shows a section and isometric view of the planned station landing layouts. Figure 3.4.1.1c shows a section view of the chairlift decline in relation to the two reef horizons.

Table 3.4.1.1 illustrates the SWOT analysis that was conducted by the Risk Assessment team for this primary option (Option 3) at North Shaft during the evaluation process.

Table 3.4.1.1: SWOT analysis for Option 3 at North Shaft

Strengths ▪ Access to underground workings from surface ▪ Gives access to both MR and UG2 reef horizons ▪ New development can be secured for LOM – more stable ground conditions ▪ Straight line – less wear and tear on moving parts ▪ 6 attack points for quicker development	**Weaknesses** ▪ Cost – CAPEX and maintenance ▪ Maintenance time – if only 1 leg (between levels 2 and 5) ▪ Breakdown time – No alternative to get to surface / workplace but to walk – shift down late and blast late ▪ Cannot take material down on chairlift
Opportunities ▪ Existing haulages to UG2 already in place ▪ Install 2 / 3 legs to prevent total stop for maintenance / breakdown ▪ Additional ventilation to UG2	**Threats** ▪ Long travelling distance in event of failure / stoppage ▪ Maintenance time ▪ Workforce become negative if not running for a couple of days

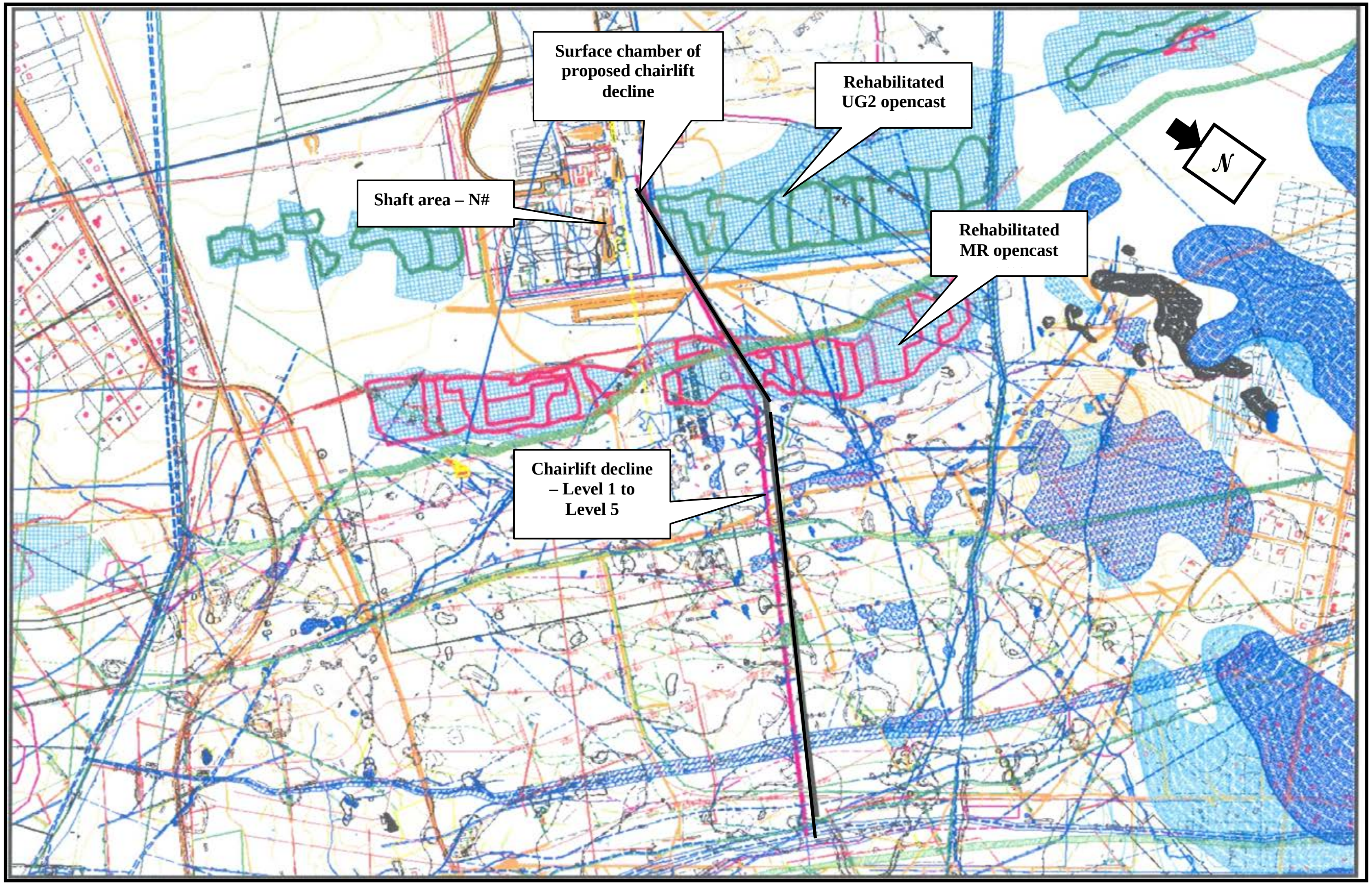

Figure 3.4.1.1: Plan View of Proposed Decline Position and Associated Surface Infrastructure
(BRPM, 2008)

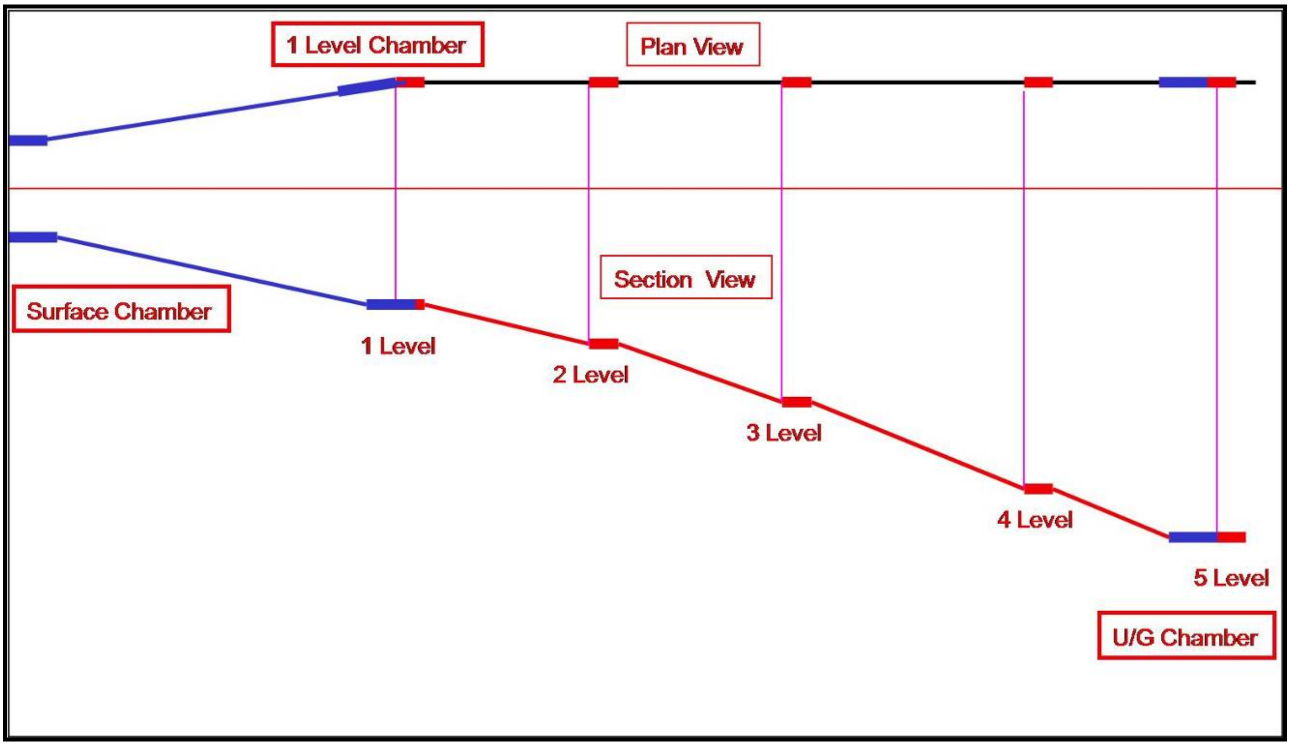

Figure 3.4.1.1a: Schematic Representation of Decline System
(Van Heerden, 2008)

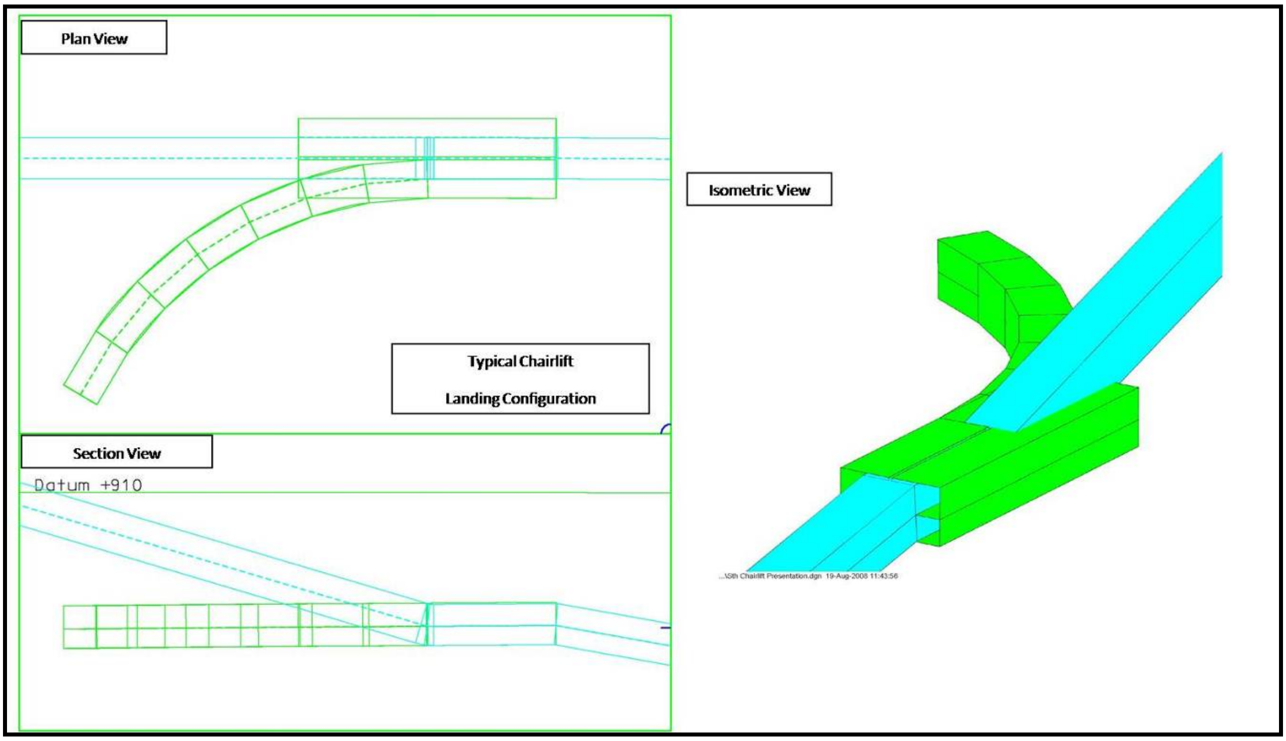

Figure 3.4.1.1b: Plan, Section and Isometric View of Chairlift Decline Stations (Landings)
(Van Heerden, 2008)

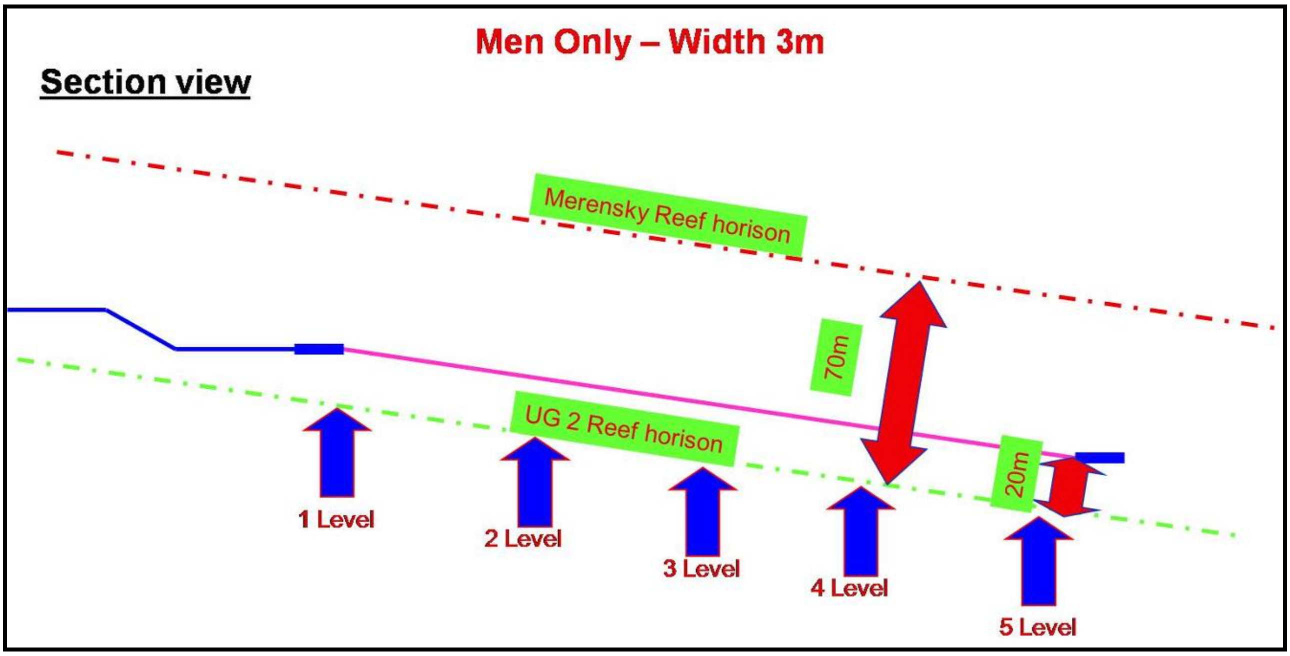

Figure 3.4.1.1c: Section View of Chairlift Decline in Relation to the two Reef Horizons
(Van Heerden, 2008)

3.4.1.2 Geology and Rock Engineering – North Shaft

Introduction and general Geology

The rock engineering department was requested to comment on possible geological features that could be expected during the sinking of the chairlift decline based on Option 3 (a new chairlift decline from surface down to level 5 at North Shaft). The decline system and some footwall development mined successfully through the features / geological structures as mentioned below. Specific rock engineering support recommendations need to be adhered too to ensure the success of mining through these features / geological structures. Reduced mining rates are planned when features / geological structures are encountered benchmarked from historical information.

Major Geological Structures

- Weathered zone up to a vertical depth of 30.0 m.
- Water bearing shear within the first 10.0 m of sinking (observed at both North and South Shafts).
- There is a fault intersection with a 4.7 m throw and dip of 80º.
- Randal's Dyke.
- Strike Dyke.
- North Shaft UG2 Fault.

Additional Geological Structures

- Major faults with associated shear zones.
- Sills (flat dipping dykes), dolerite or lamprophyre.
- Lamprophyre dykes are usually always very weak.
- Dolerite dykes can be very competent, but when associated with faulting, sheared ground contacts can be weak.
- Iron replacement zones also vary from competent to very weak.
- Potholes which result in excavations having to pass through incompetent layers.
- Pothole edges can also be sheared.
- Weak rock types: e.g. Leuconorite and Mottled Anorthosite.

Joint Orientations

In addition to the above geological features, jointing can also be expected to be encountered. The attached Rosette plot of Joint mapping (as shown in Figure 3.4.1.2) conducted at North Shaft indicates that four major joint sets are present with two minor sets. Additional random sets could be expected.

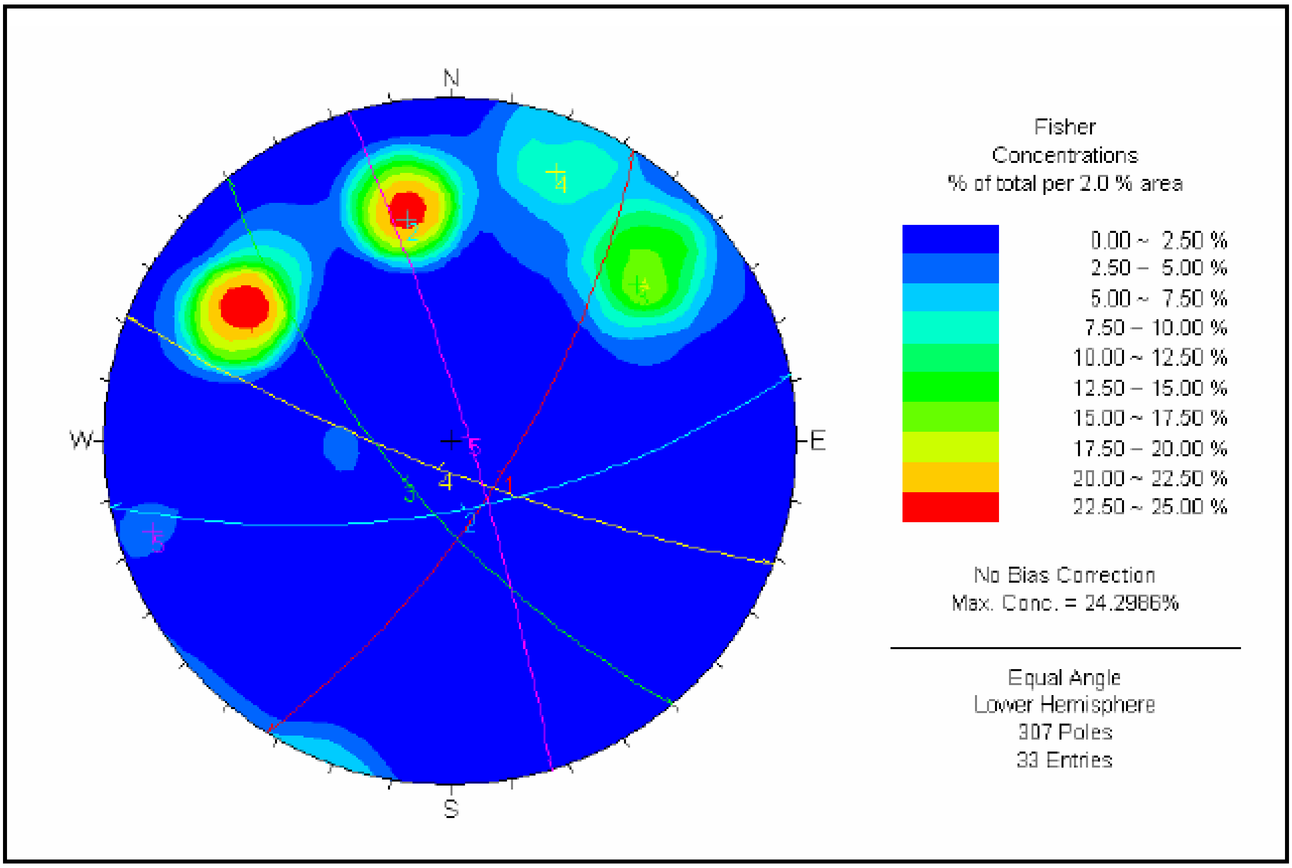

Figure 3.4.1.2: Rosette Plot of Joint Mapping at North Shaft
(BRPM, 2008)

Table 3.4.1.2 indicates the details of these joint sets and display some variation at the various sites where they were mapped. This provides a clear understanding of the expected ground conditions in the vicinity of the proposed chairlift decline.

Table 3.4.1.2: Details of Joint Sets

Set	Strike N=0°	Dip	Dip Direction	% of Sample	Main Joints/10/m	Intra-joints per 10 m	Remarks
1	32°	67°SE	122°	30	16	40	Major joint set
2	140°	71°SW	230°	24	12	15	Major joint set
3	79°	70°S	169°	24	20	10	Major joint set
4	111°	80°SW	201°	15	8	5	Major joint set
5	345°	80°NE	75°	4	2	0	Minor joint set
6	356°	35°E	86°	2	1	0	Minor joint set
7				7			Random joints

This information provides a representative summary of the overall joint regime that could be expected in the excavation. Mitigating the risk is similar to mining through the geological features mentioned above.

Additional Concerns

- The proximity of the new proposed portal and the current belt decline portal high walls is in very close proximity to each other.
- The change from leg 1 to leg 2 of the chairlift decline where larger excavations will be required to accommodate for drive units will be in a disturbed and faulted block of ground.
- The depth of the chairlift decline excavation with relation to the UG2 reef could result in the sterilisation of UG2 ore reserves.

The following support standard, as shown in Figure 3.4.1.2a, should be followed during the development of the chairlift decline.

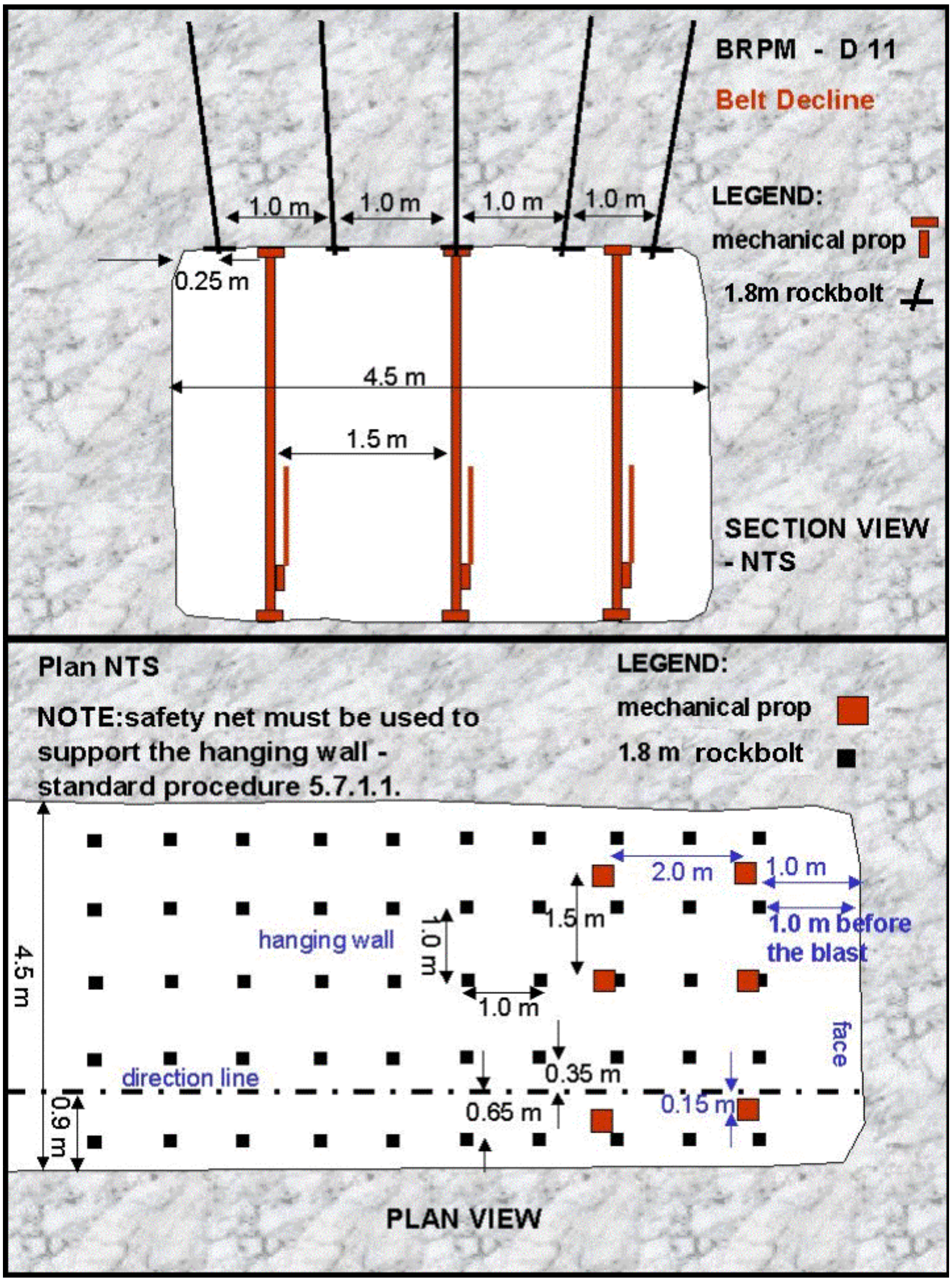

Figure 3.4.1.2a: Support Standards for Decline Development – North Shaft
(BRPM, 2008)

(BRPM Geology Department, 2008; BRPM Rock Engineering Department, 2008)

3.4.1.3 Ventilation – North Shaft

Due consideration by the Ventilation Department was taken towards the effect on the ventilation during the planning and design of the proposed chairlift decline (Option 3).

With the addition of a chairlift from surface to level 5 to replace belt-riding, the following points were considered:

- Since there will be no holing into the reef-planes on levels 1 to 3 UG2 excavations short-circuiting of fresh air into the up-cast shaft will be prevented.

- Ventilation controls in haulages should be correctly placed to eliminate possible short circuiting of fresh air into worked-out areas.
- Distances to the station cross cuts should not be excessive as this would be the new route for the Material decline - and conveyor belt decline workers to travel between levels.

Weaknesses (Disadvantages)

- The chairlift decline excavation has not been designed large enough to replace the current conveyor belt decline excavation as an intake airway and hence reduce the risk of an intake air conveyor belt fire.
- Ventilation controls will be required in the conveyor belt decline to reduce airflow in the decline and cater for the newly developed chairlift decline.

Strengths (Advantages)

- Reduction in the shaft's total air resistance leading to reduced power consumption of the main surface fans due to the additional intake chairlift decline available to increase the overall shaft's air intake. The additional intake could result in the velocities of the belt decline being reduced.
- Reduced air velocities in conveyor belt decline excavation leading to less dust generation and hence reducing the probability of getting foreign bodies into people's eyes. The current OEL standard is 3.0 mg/m^3. From actual measurements taken, the exposure ranges from 0.3 to 1.0 mg/m^3. Thus, reducing the air velocities will further reduce the exposure to dust.
- Fire telemetry cable could be routed through the proposed chairlift decline in parallel enabling the system to continue working during a conveyor belt fire.

In general the additional airway will be a major advantage from a ventilation perspective (BRPM Ventilation Engineering Department, 2008).

3.4.1.4 Development and Construction Schedule – North Shaft

Owing to the configuration of the chairlift decline and the fact that it will be developed through an existing mining infrastructure, it is possible to begin development from six attacking points and the schedule has been compiled as such. Refer to Figure 3.4.1.4 to view the various attack points from surface and underground from the different operational levels. CADSMine Design and Scheduling software were used during the process. Development of the chairlift decline and associated landings and cross cuts has been scheduled at a rate of 32 m/month. This rate has also been applied during the 2009 Business Planning (BP) Process for ends with similar dimensions and inclination. The resultant schedule in months is shown in Table 3.4.1.4.

Thus, from the scheduling it was concluded that the total duration to complete the development was 12 months. The total metres that needed to develop were 1,934 m. It was also assumed that the installation of the infrastructure will be continuous as the different legs between levels become available. There will be a bottleneck during the completion of the leg from surface to level 1. This will take an additional 2 months. The total project duration would be 14 months.

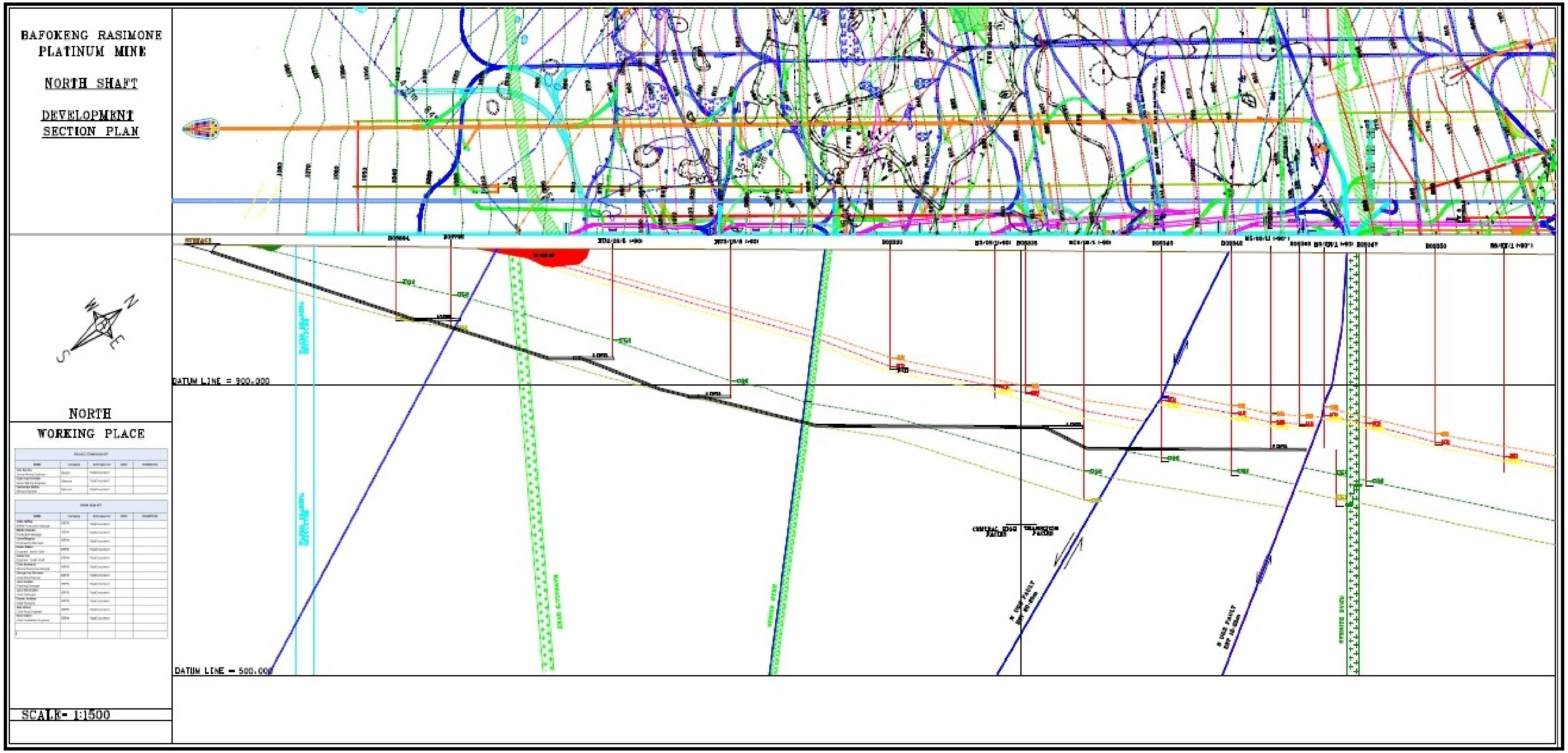

Figure 3.4.1.4: Plan and Section View of the North Shaft Chairlift Decline System (design)
(BRPM, 2013)

Table 3.4.1.4: Development Schedule in Months – North Shaft

Half level	Standard name	1	2	3	4	5	6	7	8	9	10	11	12	Total (m)
N 01LN	Cross cut	32	30											**62**
N 01LN	Chairlift decl / incl	32	34	64	64	64	64	64	64	64	64	64	10	**652**
N 02LN	Cross cut	32	27											**59**
N 02LN	Chairlift decl / incl		5	32	32	32	32	32	20					**185**
N 03LN	Cross cut	32	17											**49**
N 03LN	Chairlift decl / incl	11	15	32	32	32	32	32	32	32	32	21		**292**
N 04LN	Cross cut	53	43	64	64	64	38							**284**
N 04LN	Chairlift decl / incl	32	21											**74**
N 05LN	Cross cut		7											**39**
N 05LN	Chairlift decl / incl		25	32	32	32	34	45	32	6				**238**
	Cross cut	181	101											**282**
Total Development		**224**	**224**	**224**	**224**	**224**	**200**	**173**	**148**	**102**	**96**	**85**	**10**	**1,934**

3.4.1.5 Estimated CAPEX – North Shaft

Compilation of the estimated CAPEX in respect of the mining costs involved was based on the numbers mentioned above. It was also assumed that the development would be conducted by making use of AAP's Capital Development Services (CDS) which were developing the Phase 2 declines on both shafts. The development cost used is as per agreed rate per cubic metre with CDS. The chairlift costs (infrastructure and installation) were obtained from Sareco, who was installing the Phase 2 chairlifts on both shafts. Table 3.4.1.5 quantifies the costs as estimated (2014 money terms). A 10% allowance has been made on the time related Preliminaries and Generals (P&G's) to allow for reduced performance on the development rates.

Costs were estimated on the following basis:

- Chairlift costs were factored using the cost of current installations as a base.
- Electrical supply costs were estimated from first principles (Appendix E).

Table 3.4.1.5: Estimated CAPEX – North Shaft

Item	Description	Unit	Quantity	Rate (ZAR)	Total Amount (ZAR)
1	Fixed P&G	Allow	1	8,678,714	8,678,714
2	Time related P&G	Allow	16	1,717,701	27,483,221
3	Chairlift Decline Development	m	1,934		40,554,061
4	Chairlift Installation				14,307,228
5	Electrical Supply				2,532,345
	Total for Fixed P&G				**93,555,572**
	Cubic metres	24,754			
	ZAR/m^3	3,099			

- **Men and Material Decline**

The future planning for North Shaft indicates that the shaft will be developed to level 13 with production from the UG2 stopes in the upper levels of the mine taking place concurrently with MR stoping in the lower levels. Although total output from the shaft will remain constant the geographic diversity of the operations is likely to put additional strain on the materials handling system. For this reason a proposal was made to develop a decline of sufficient width (6 m) to accommodate both a chairlift and a winder system for materials transport. This would have the effect of almost doubling the cost of the decline and raise several safety issues with regard to transporting men and material in the same excavation.

It was suggested that a detailed simulation of the logistics be carried out in order to ascertain the risk to production before making a decision in this regard. The decision was then taken by mine management that this option should not be considered at this stage together with the personnel transportation study, but rather as an alternative when conducting the UG2 studies.

3.4.2. South Shaft

As there were two primary options (Option 12a and Option 3) after P2, apart from the modifications to the current conveyor belt and belt infrastructure (secondary options), available at South Shaft, considerable effort was focussed on these options. As at North Shaft, there is one other alteration to Option 3, and that is to develop a 6 m wide decline instead of the standard 3 m decline. The objective of this 6 m wide decline would be to equip it with both a chairlift and a winder for material transportation to the future UG2 operations. The decision was then taken by mine management that this option should not be considered at this stage together with the personnel transportation study, but rather as an alternative when conducting the UG2 studies.

After thorough investigation by the ventilation, rock engineering and geology departments into Option 12a (installing chairlift in zero raise), the following concerns were raised:

Ventilation

- The zero raise also serve as a return air way (RAW) for the sinking section as well as the lower levels were multi-blast conditions exist. Thus there is the risk that personnel travelling on the chairlifts could be exposed to blasting fumes. There is no specific blasting schedule in the multi-blast areas. A schedule to accommodate the chairlift will certainly have an impact on production. On the other hand, if the chairlift have to be abandoned every time blasting in the multi-blast areas take place, personnel will not spend sufficient time in the workplace. There is thus a very high risk that this option could sacrifice production efficiency.
- The RAW will have to stay intact. Thus there is a very high risk in making use of the reef horizon. When the chairlift is installed in the reef horizon, there is always the risk that ventilation seals could be damaged. This will result in subsequent loss of ventilation on the remaining working faces. With the increase in cable theft experienced over the last couple of years, damage to seals is evident in order to get access to old worked out areas. There is also the risk and possibility of gas traps and heat generation.

Rock Engineering

- It cannot be guaranteed that the zero raise will remain open and intact for the remaining LOM (40 years).
- The zero raise will have to be sliped in certain areas. There are no services available.
- The entire zero raise will have to be re-supported. Additional support would also be required in areas that were stoped out and where there are large excavations or spans. This will have an impact on the support cost.
- There is the risk of possible closure in the zero raise.
- A large number of falls of ground (FOG) occurred in the upper levels, specifically where the chairlift is planned.

Geology

- The shear zone and UG2 fault could also cause bad ground conditions. The proximity of these features to each other in the chosen route could exacerbate poor ground conditions

After the concerns by the relevant specific responsible departments were presented, the decision was taken not to expose the mine and management to unnecessary risks. Installing the chairlift in the zero raise could have detrimental results leading to loss in live and damage to infrastructure. Based on this, the decision was taken to eliminate Option 12a from the options available. The final primary option that was considered for further investigation was developing a new chairlift decline (Option 3).

3.4.2.1 Layout – South Shaft

Surface Access

Three options for this were investigated namely:

- Access will be gained through a portal starting at the highwall of the opencast section. This option was discarded as not feasible as the opencast workings have been rehabilitated and filled with broken rock. In the event of severe rainfall, this will act as a sponge and direct drainage water to the nearest escape point. The risk of flooding the workings of the mine is too high. For this reason, this alternative to Option 3 was not applicable for further investigation / study work.

- Drilling of a 28° raise bore hole from surface to intersect the workings at level 1. The amount quoted was ZAR 7.8 million (excluding VAT – June 2008) for a 206 m x 3.1 m diameter raise bore shaft (pilot and ream) at 28°. The quotation from Murray & Roberts Cementation (MRC) is available in Appendix F of this document. A very long horizontal access cross cut will also have to be developed to ensure the raise bore shaft is at least 28°. This resulted in the total development actually being much more compared to the option of starting on surface and developing down to level 2 at a constant angle of 9°. While this would be a quicker option, the logistics of handling the raise bore chips from underground pose a threat to the current operation and this alternative was abandoned.
- A portal could be created within the shaft area. This was considered the most logical approach as the infrastructure to support this is in place and there are no additional issues involved. The remaining study work will only focus on this primary option at South Shaft.

Positioning

The portal will be situated some 350 m from the current infrastructure. Access to the portal will be via an overland walkway traversing the main road and rehabilitated opencast workings. The CAPEX for this overland walkway could be viewed in Appendix G (BRPM, 2008). The preliminary engineering drawings for this proposed walkway could be viewed in Appendix H (BRPM, 2008).

Assessment of a number of potential positions for the decline indicated that the best position would be between the UG2 and MR horizons, as this would be in competent ground and provide easy access to both the existing MR haulages and future UG2 workings. The middling between the two horizons at South Shaft is approximately 70 m which gives adequate space to develop the decline without impacting on the workings. Figure 3.4.2.1 shows a plan view of the decline with a schematic section representation of the system in Figure 3.4.2.1a.

Essentially the chairlift installation will begin at the exit from the existing lamp room with the overland walkway to the entrance of the chairlift decline. This walkway will be constructed over the existing road to South D mine as well as over the rehabilitated opencast. The entire walkway will be 353 m in length. From there the chairlift decline will be developed in a straight line directly to level 6. Landings will be provided at each level through which access to the workings (current MR and future UG2) will be achieved. Figure 3.4.2.1b shows a section and isometric view of the planned station landing layouts (similar to North Shaft). Figure 3.4.2.1c shows a section view of the chairlift decline in relation to the two reef horizons (similar to North Shaft).

Mining from level 2 to the tail of the chairlift at level 6 could start from 5 different attacking points. Mining from surface to level 2 could only be done from underground due to surface infrastructure limitations (no connection from level 1 is required). From the scheduling done it was found that the installation from level 2 to the tail will be completed before the development from level 2 to surface is completed. Thus, this is definitely the bottleneck of the South Shaft chairlift installation. This installation will take another two months once the development is completed. This development methodology resulted in the South Shaft chairlift decline taking in total 3 months longer to complete compared to the North Shaft chairlift decline. However the North Shaft decline has approximately 200 m more development to be done compared to South Shaft.

Table 3.4.2.1 illustrates the SWOT analysis that was conducted by the Risk Assessment team for this primary option (Option 3) at South Shaft during the evaluation process.

Table 3.4.2.1: SWOT analysis for Option 3 at South Shaft

Strengths ▪ Access to underground workings from surface ▪ Gives access to both MR and UG2 reef horizons ▪ New development can be secured for LOM – more stable ground conditions ▪ Straight line – less wear and tear on moving parts ▪ **5 attack points for quicker development**	**Weaknesses** ▪ Cost – CAPEX and maintenance much more compared to alternative options ▪ **Maintenance time – if only 1 leg (from surface to 6 level)** ▪ Breakdown time – No alternative to get to surface / workplace but to walk – shift down late and blast late ▪ Cannot take material down chairlift decline ▪ **Will have to make use of a very long surface overland walkway – 353 m**
Opportunities ▪ Existing haulages to UG2 already in place ▪ Install 2 / 3 legs to prevent total stop for maintenance / breakdown ▪ Additional ventilation to UG2 ▪ **Could install an overland chairlift as an alternative to the overland walkway**	**Threats** ▪ Long travelling distance in event of failure / stoppage ▪ Maintenance time ▪ Workforce become negative if not running for a couple of days

(Highlighted bullets indicate differences between Option 3 for North and South Shafts)

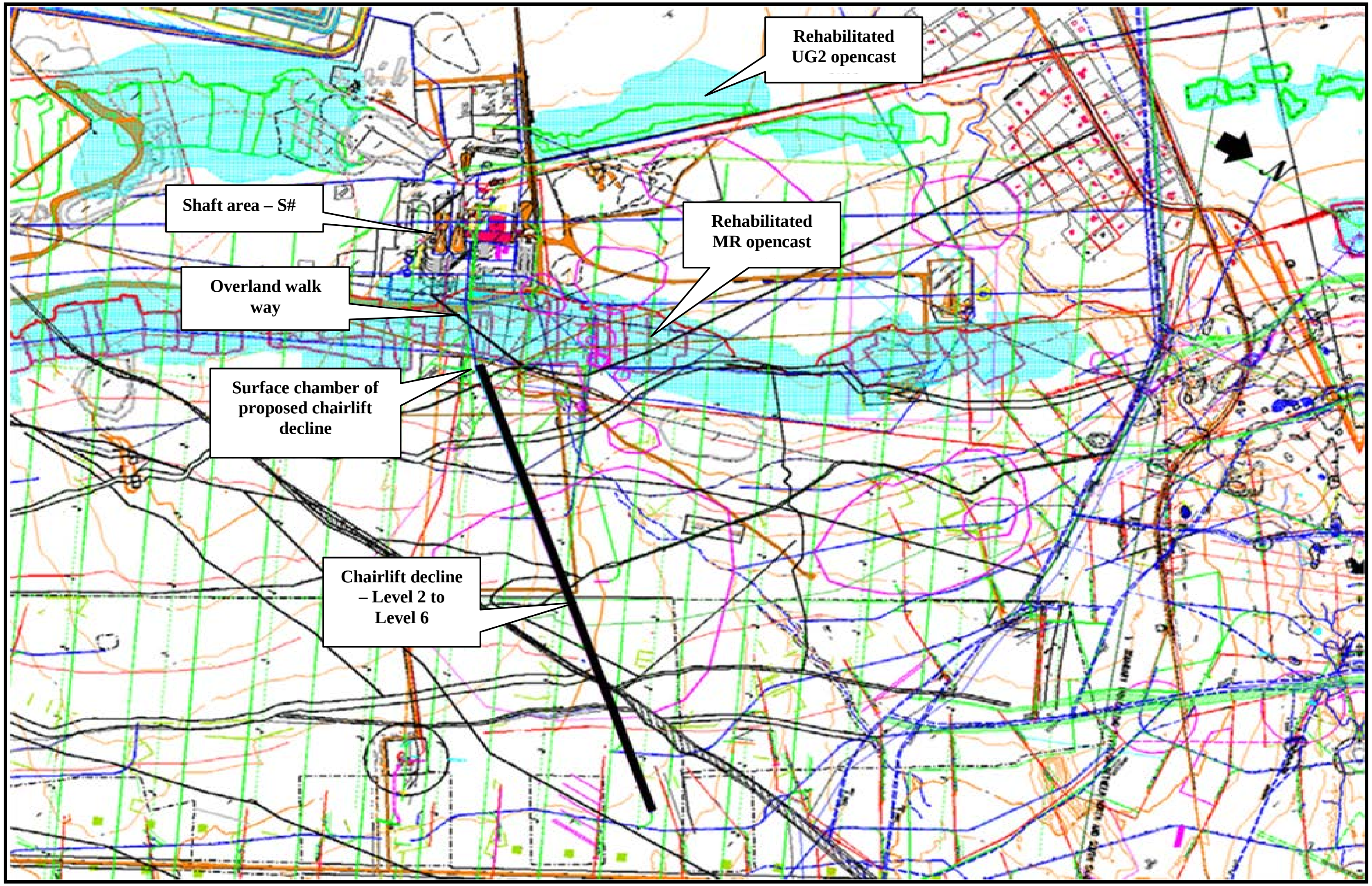

Figure 3.4.2.1: Plan View of Proposed Decline Position and Associated Surface Infrastructure
(BRPM, 2008)

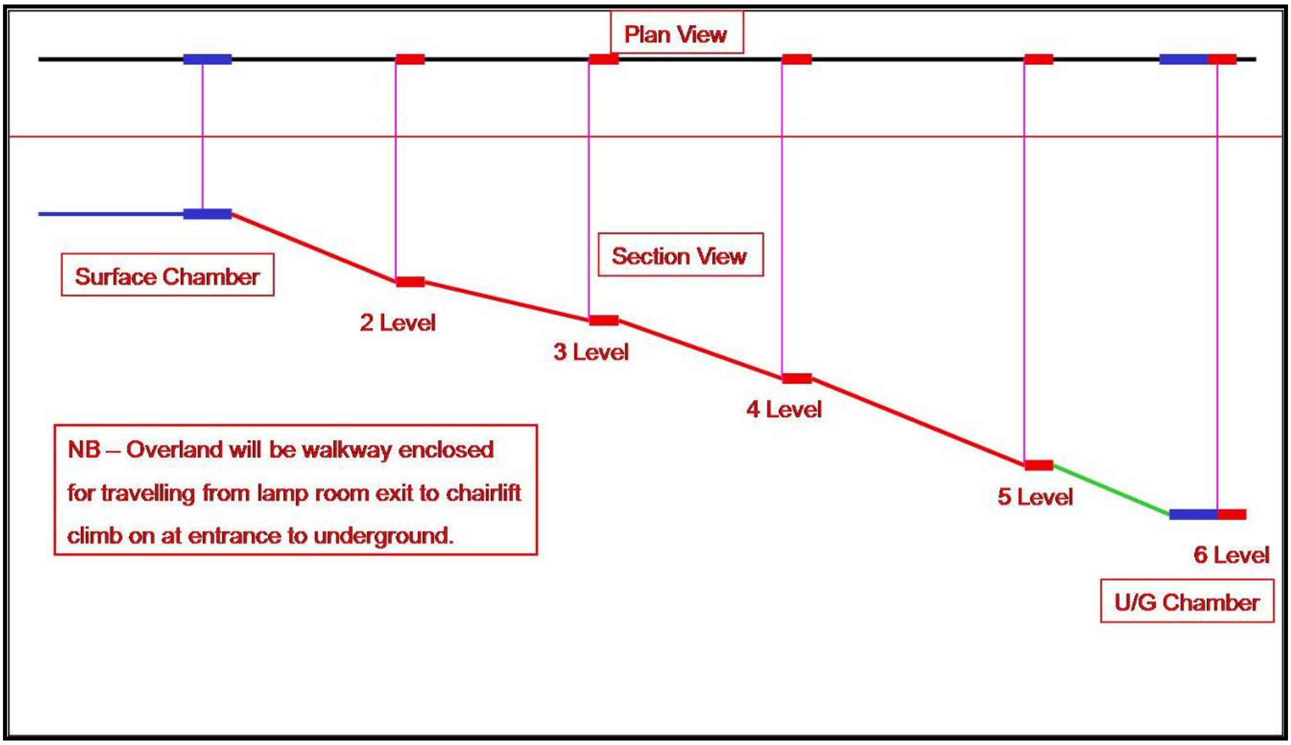

Figure 3.4.2.1a: Schematic Representation of Decline System
(Van Heerden, 2008)

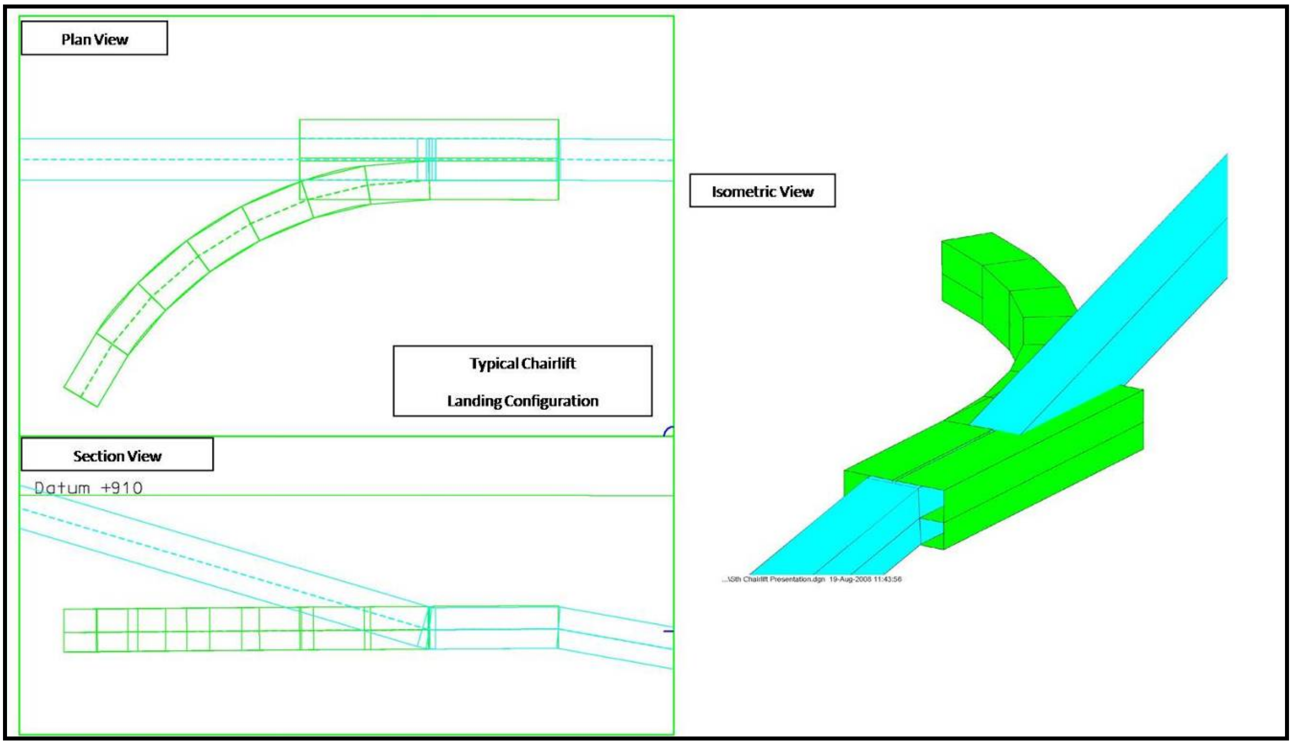

Figure 3.4.2.1b: Plan, Section and Isometric View of Chairlift Decline Stations (Landings)
(Van Heerden, 2008)

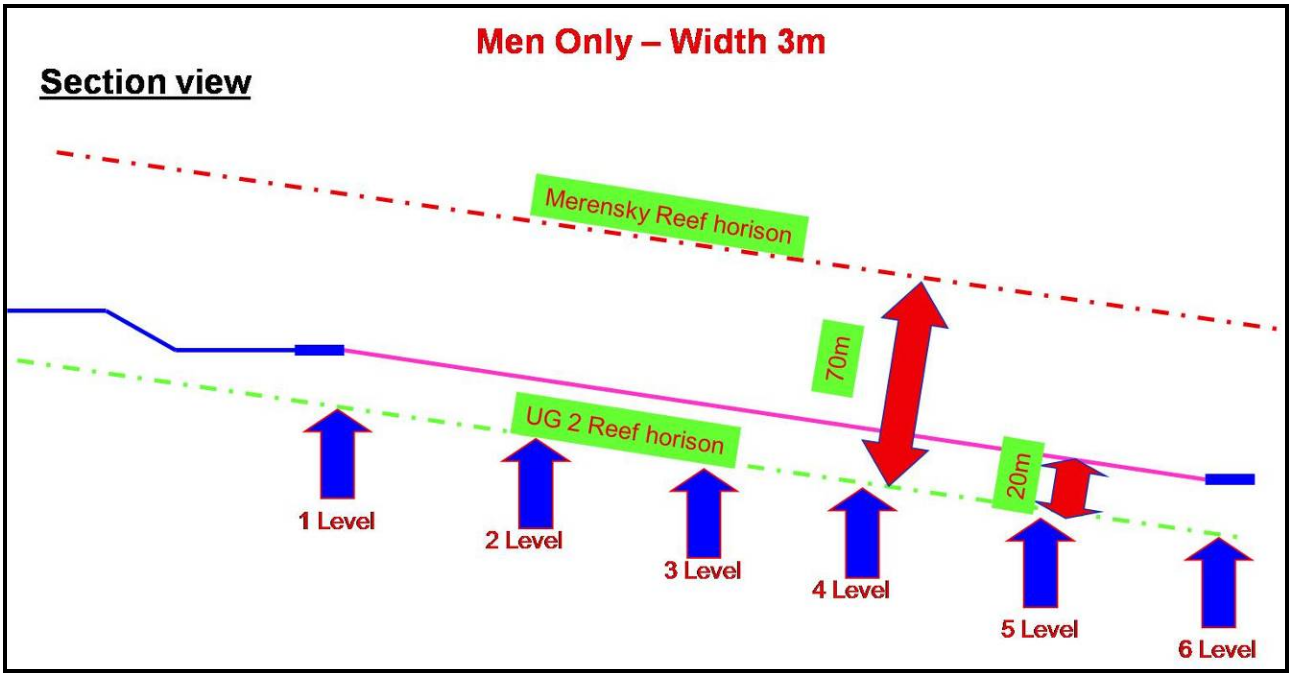

Figure 3.4.2.1c: Section View of Chairlift Decline in Relation to the two Reef Horizons
(Van Heerden, 2008)

3.4.2.2 Geology and Rock Engineering – South Shaft
Introduction and general Geology

The chairlift decline excavation is planned to be developed in the footwall of the MR reef for its entire length. It must start at surface 350 m from the current shaft infrastructure. The chairlift decline will dip in a northerly direction to level 6 between the North 2 and North 3 cross cuts. There will be development provided to access the chairlift decline from each level (except levels 1 and 5a). This will be developed either east or west from the current MR haulages.

The chosen path of the proposed chairlift decline is largely overstoped on the MR reef horizon and the geology is therefore well known. Stratigraphically it will lie almost entirely in FW7 (Footwall 7) - characteristically a very competent horizon of Norites and Anorthositic Norites. It is impossible to traverse the mine from surface to level 6 without crossing all four features / geological structures that contribute to the major known geological losses. These features / geological structures have traditionally been used to divide the mine into Structural Zones. These features / geological structures are:

- ***Randall's Dyke***. It is on average 23 m wide, very competent, usually with tight contacts, steeply dipping at 85°.
- ***The Nyala Dyke***. It could be compared to the Randall's Dyke but it is narrower – approximately 12 to 15 m.
- ***The UG2 Fault***. It has a 32 m throw. It is a normal fault always associated with a dolerite dyke and lamprophyre dykes on either or both sides. It dips 66° towards the outcrop (West).
- ***The Shear Zone***. Lateral (dextral) throw of up to 150 m with a variable up throw of up to 6 m on the outcrop side. Rock is sheared and pulverized into a sticky clay made up of Sericitic material that can provide surprisingly stable ground. The Shear Zone can be quite narrow (5 m) but balloons to tens of metres in width when traversed by exacerbating features such as faults or dykes.

Level by Level Geology

- ***Surface to level 2*** *(level 1 has no access to the chairlift decline)***:** The collar is in FW7. Mining below the opencast. Many minor features occur such as lamprophyre dykes, jointing and small faults. These are all weakened by the proximity to surface and concomitant weathering. This portion of the chairlift decline excavation will traverse the Randall's Dyke.
- ***Level 2 to 3*****:** Chairlift decline passes below both levels requiring cross cuts west for access. All in FW7 with no major geological features anticipated.
- ***Level 3 to 4*****:** Chairlift decline passes above level 4 haulage requiring a cross cut east for access. All in FW7 with no major geological features anticipated except a catastrophic pothole in the vicinity of the haulage. Catastrophic rocks are considered to be very competent and the negative connotation refers to their effect on the reef.
- ***Level 4 to 5*** *(including level 5a)***:** Chairlift decline passes far above level 5 haulage and below level 5a requiring a cross cut west for access. This area is where the chairlift decline traverses all the major features except the Randall's Dyke mentioned above. The anticipated order of events assuming a winze to be developed from level 4 is as follows:
    - The first feature is expected to be the Shear Zone. Projections show that this is the gap area where the Nyala Dyke traverses the Shear Zone. This may be advantageous as the dyke can provide competent ground.
    - Approximately 100 m down dip through potholed ground (which probably will not affect the chairlift decline) is the always troublesome UG2 Fault. Competent FW7 is anticipated from the fault to level 5.
- ***Level 5 to 6*****:** Chairlift decline ends to the west of level 6. All in FW7 with no major geological features anticipated

Geology Conclusion and Recommendations

A majority of the chairlift decline is planned in geologically competent ground. The unavoidable structural knot between levels 4 and 5a will require special attention. Double diamond drilling cover is recommended and provision should be made to drill this area well before the development. Attention must also be given to the middling at the crossover positions of the chairlift decline and all the haulages. Specific rock engineering support recommendations need to be adhered too to ensure the success of mining through these features. Reduced mining rates are planned when features are encountered benchmarked from historical information to mitigate the risk (BRPM Geology Department, 2008).

Introduction to Rock Engineering

The rock engineering department was requested to comment on possible geological features that could be expected during the sinking of the chairlift decline based on Option 3 (a new chairlift decline from surface down to level 6 at South Shaft). Mitigating the risk is similar as mentioned above in the geology section.

The structures that are envisaged to affect the planned chairlift decline according to the current design are as follows:

- ***Weathered Zone*****:** The surface area consists of soils and then weathered rock, both of which require robust, specially designed support. Information on the depth of soils and weathering is needed for proper portal design. Development is normally slow in these areas as installation of specialised support is time consuming.
- ***Randall's and Nyala Dykes*****:** These dykes are relatively competent and generally not problematic as long as normal precautions are taken.

- ***Shear Zone***: The Shear Zone is generally problematic and requires additional support. The conditions in the zone vary considerably but it is expected that there will be delays in development in the Shear Zone area and robust secondary support will be needed.
- ***UG2 Fault***: The UG2 fault is a large zone of jointing and can present difficulties during development. The size of excavations in the UG2 Fault should be minimized and important excavations should not be sited in the faulted area.
- ***General***: In addition to the above, there are several minor faults, dykes and sills. The sills will definitely need some secondary support. At level 4, one of the dykes intersects the station which will also need secondary support. Some other factors to consider include the following:
  - The size of the excavations should be kept to a minimum.
  - Intersecting excavations can result in large spans which can be unstable, so appropriate spacing need to be maintained.
  - Avoid sterilising the UG2 ore reserves. If the chairlift decline is too close to the UG2 horizon then large pillars will have to be left underneath it.
  - Avoid intersecting the MR horizon. Not only is the reef plane more unstable than the Norites but the influence of pillars can be minimised with a sufficient middling. There are quite a few areas where pillars have been left over the planned chairlift decline.

The following support standard, as shown in Figure 3.4.2.2, should be followed during the development of the chairlift decline.

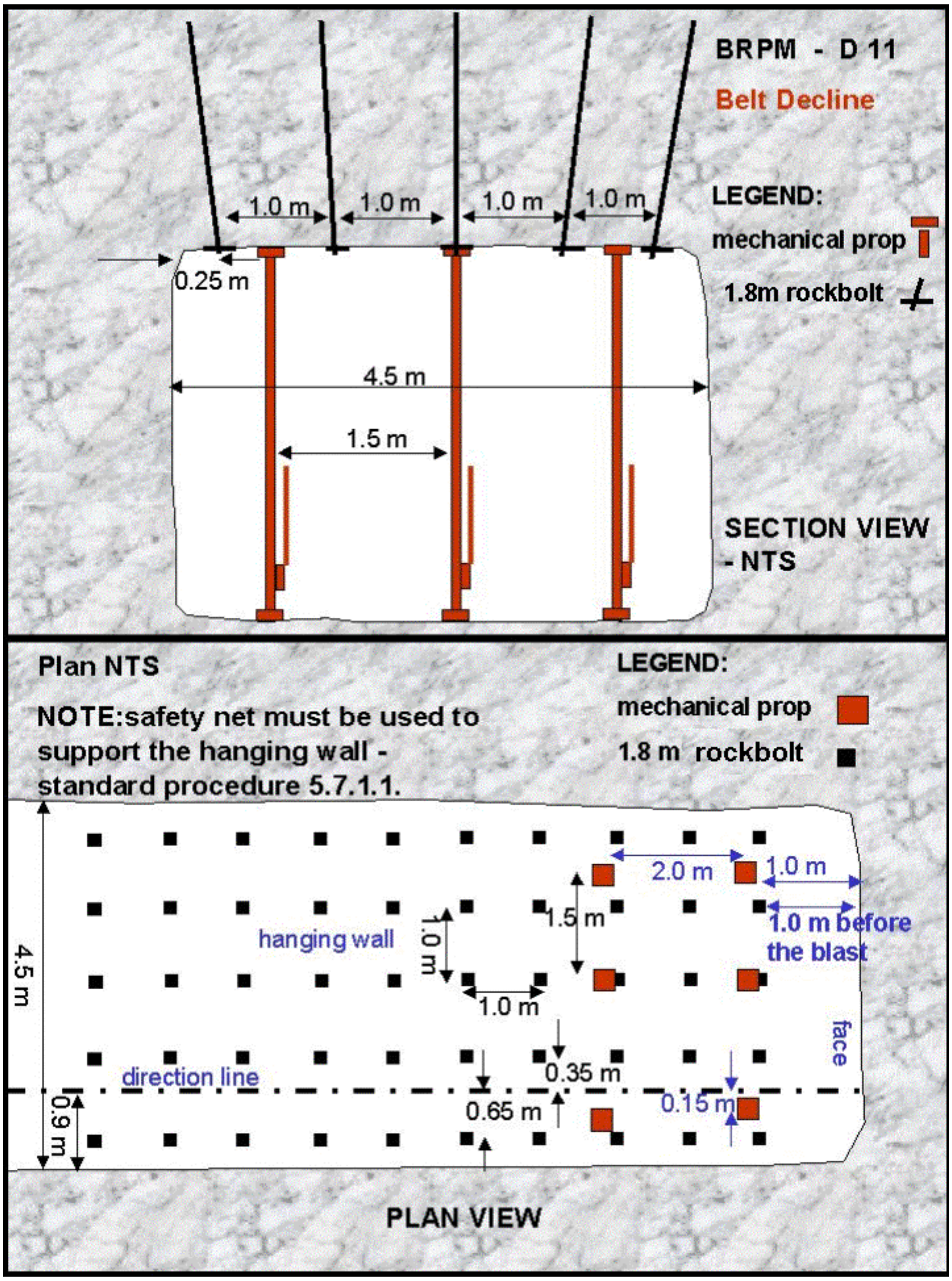

Figure 3.4.2.2: Support Standards for Decline Development – South Shaft
(BRPM, 2008)

(BRPM Rock Engineering Department, 2008)

3.4.2.3 Ventilation – South Shaft

Due consideration by the Ventilation Department was taken towards the effect on the ventilation during the planning and design of the proposed chairlift decline (Option 3).

With the addition of a chairlift from surface to level 6 to replace belt-riding, the following points were considered:

- No holing into the reef-planes or level 1 UG2 RAW was to be allowed as this would result into loss of fresh air, circulating directly to the up-cast shaft. This in turn would require intensive sealing in areas difficult to maintain the effectiveness of the seals.
- Ventilation controls in haulages should be correctly placed to eliminate possible short circuiting of fresh air into worked-out areas.
- Distances to the station crosscuts should not be excessive as this would be the new route for the Material decline - and conveyor belt decline workers to travel between levels.

Weaknesses (Disadvantages)

- The chairlift decline excavation has not been planned large enough to replace the existing belt decline excavation as an intake airway. The risk remains where possible conveyor belt fires could be worsen due to continuous high volume intake air.
- There is an increased travelling distance to material landings, beltways and main sub-stations.

Strengths (Advantages)

- Reduction in the shaft's total air resistance leading to reduced power consumption of the main surface fans due to the additional intake chairlift decline available to increase the overall shaft's air intake. The additional intake available could result in the velocities of the belt decline being reduced.
- Reduced air velocities in the conveyor belt decline excavation will lead to less dust generation and hence reducing the probability of getting foreign bodies into people's eyes. The current OEL standard is 3.0 mg/m^3. From actual measurements taken, the exposure ranges from 0.3 to 1.0 mg/m^3. Thus, reducing the air velocities will further reduce the exposure to dust.
- Fire telemetry cable could be routed through the proposed chairlift decline in parallel enabling the system to continue working during a belt fire.

In general the additional airway will be a major advantage from a ventilation perspective (BRPM Ventilation Engineering Department, 2008).

3.4.2.4 Development and Construction Schedule – South Shaft

Owing to the configuration of the chairlift decline and the fact that it will be developed through an existing mining infrastructure, it is possible to begin development from six attacking points and the schedule has been compiled as such. Refer to Figure 3.4.2.4 to view the various attack points from surface and underground from the different operational levels. CADSMine Design and Scheduling software were used during the process. Development of the chairlift decline and associated landings and cross cuts has been scheduled at a rate of 32 m/month. This rate has also been applied during the 2009 BP Process for ends with similar dimensions and inclination. The resultant schedule in months is shown in Table 3.4.2.4:

Thus, from the scheduling it was concluded that the total duration to complete the development was 15 months. The total metres that needed to develop were 1,727 m. It was also assumed that the installation of the infrastructure will be continuous as the different legs between levels become available. There will be a bottleneck during the completion of the leg from surface to level 2. This will take an additional 2 months. The total project duration would be 17 months.

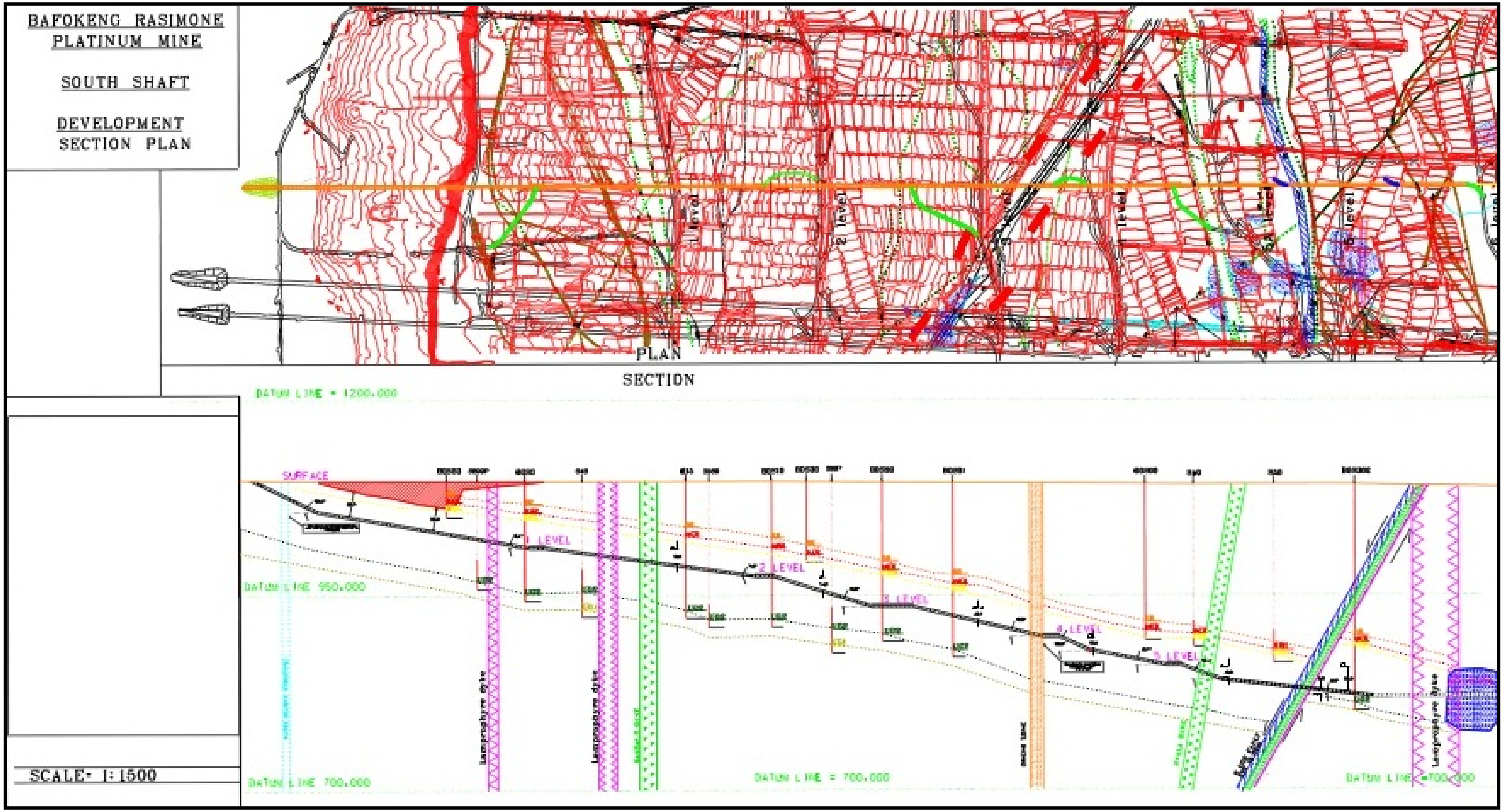

Figure 3.4.2.4: Plan and section view of the South Shaft chairlift decline system (design)
(BRPM, 2013)

Table 3.4.2.4: Development Schedule in Months – South Shaft

Half level	Standard name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total (m)
S 02LN	Cross cut	31	31	31	14												**107**
S 02LN	Chairlift decl / incl				16	31	31	31	31	31	31	31	31	31	31	31	**357**
S 03LN	Cross cut	22															**22**
S 03LN	Chairlift decl / incl	8	31	31	31	31	31	31	31	31	31	31	31	22			**371**
S 04LN	Cross cut	31	31	2													**64**
S 04LN	Chairlift decl / incl			28	31	31	31	17									**138**
S 05LN	Chairlift decl / incl					24	31	31	31	31	31	31	21				**231**
S 06LN	Cross cut	61	61	32	31	7											**192**
S 06LN	Chairlift decl / incl				20	31	31	31	31	31	31	14					**220**
S 06LN	Chamber			29	11												**40**
	Cross cut	145	122	65	45	7											**384**
Total Development		**153**	**153**	**153**	**153**	**153**	**153**	**139**	**122**	**122**	**122**	**106**	**83**	**53**	**31**	**31**	**1,727**

3.4.2.5 Estimated CAPEX – South Shaft

Compilation of the estimated CAPEX in respect of the mining costs involved was based on the numbers mentioned in the earlier section. It was also assumed that the development would be conducted by making use of AAP's Capital Development Services (CDS) which were developing the Phase 2 declines on both shafts. The development cost used is as per agreed rate per cubic metre with CDS. The chairlift costs (infrastructure and installation) were obtained from Sareco, who were installing the Phase 2 chairlifts on both shafts. The walkway cost was also included in the South Shaft CAPEX. Table 3.4.2.5 quantifies the costs as estimated (2014 money terms). A 10% allowance has been made on the time related P&Gs to allow for reduced performance on the development rates.

Costs were estimated on the following basis:

- Chairlift costs were factored using the cost of current installations as a base.
- Electrical supply costs were estimated from first principles (Appendix E).
- Walkway costs were estimated from first principles (Appendix G)

Table 3.4.2.5: Estimated CAPEX – South Shaft

Item	Description	Unit	Quantity	Rate (ZAR)	Total Amount (ZAR)
1	Fixed P&G	Allow	1	8,678,714	8,678,714
2	Time related P&G	Allow	19	1,717,701	32,636,325
3	Chairlift Decline Development	m	1,727		37,109,906
4	Chairlift Installation				14,307,228
5	Surface walkway				5,613,086
6	Electrical Supply				2,532,345
	Total for Fixed P&G				**100,877,607**
	Cubic metres	22,720			
	ZAR/m^3	3,452			

3.4.3. Summary – P3 – Elimination Phase

At the end of this process phase there were two suitable options available at South Shaft and two at North Shaft. These are summarised in Table 3.4.3 and 3.4.3a:

Table 3.4.3: South Shaft – Final Options Selected

Option	Description	South Shaft	Comment
3	New chairlift decline – new infrastructure	√	High CAPEX. R100.9 million
10	Safer platforms for getting off the belt	√	To continue with investigation

Table 3.4.3a: North Shaft – Final Options Selected

Option	Description	North Shaft	Comment
3	New chairlift decline – new infrastructure	√	High CAPEX. R93.6 million
10	Safer platforms for getting off the belt	√	To continue with investigation

3.5. Engineering

3.5.1. Introduction

The engineering design philosophy adopted for the study was to provide a functional system required for personnel transportation (primary options) and to review the current system with a view to improving and making the system safer (secondary options). AAP standards and SANS were incorporated in the engineering design, with the emphasis on safety.

3.5.2. General Arrangements, Layouts and Design Criteria

Conceptual general arrangements for the chairlift and covered walkways have been developed and this drawing of the proposed walkway is contained within Appendix H (BRPM, 2008).

3.5.2.1 Infrastructure

The surface infrastructure required for personnel to access the chairlift decline at South Shaft consists of a covered walkway from the exit of the lamp room to the chairlift decline. No dedicated walkway would be required at North Shaft due to the close proximity of the proposed chairlift decline portal. The underground infrastructure for both North and South Shafts for transporting personnel to the required levels consists of a chairlift with platforms at each station.

3.5.2.2 Surface Covered Walkway

The covered walkway at South Shaft is designed to direct traffic from the exit of the lamp room to the chairlift decline portal and from the chairlift decline portal to the entrance of the lamp room using two distinct areas. The walkway roof is covered with IBR sheeting and has screens on both sides and a central screen to divide the area in two for controlling traffic in both directions. A bridge will be provided over the South D mine road that will be accessed using stairs. Turnstiles are provided at the lamp room to control the access into the walkways that lead to the decline chairlift. This walkway is required only at South Shaft. North Shaft will have only a turnstile at the chairlift entry point.

This design criteria was intended to describe the loads that will be applied in the design of the new structural steel walkway reinforced concrete slab and foundations connecting the lamp room at South Shaft to the chairlift decline. It included the following:

Design Parameters

The walkway must be designed to transfer the personnel requirements as listed below:

- Morning shift 2,600
- Afternoon shift 500
- Night shift 500

Loading

The walkways, staircase and landing platforms and all beams will be designed for the following loads:

- Self-weight of the beams, concrete slab, screening, hand railing, sheeting, purlins and other permanent fixtures will be assessed.
- Imposed load of 5 kPa or a point load of 10 kN at the position that causes the most detrimental effect on the beam being designed.
- Imposed load of 0.5 kPa on the rafters and purlins.
- Any imposed loading that is anticipated on these floors.
- Wind load using the following:
    - Terrain category wind speed of 40 m/s.

- Altitude above sea level 1,000 m.

Load Factors and Combinations
Load combinations as per SANS 10162:1 will be applied.

Construction Materials
Structural Steel
All steel will be designed assuming grade 350 WC steel for universal beams, columns and channels. All steel will be designed assuming grade 350 WC steel for angles and plates.

Corrosion Protection
All floor beams, portal frame and screens will be hot-dipped galvanised.

3.5.2.3 Chairlift
The chairlift is designed to cater for 900 persons per hour with a 4 second (6 m) interval between chairs (AAP, 2008). Components are common with the chairlifts currently under construction to service levels 5 to 10 at North Shaft and levels 6 to 10 at South Shaft. Drive units are the standardized AAP 55 / 75 kW with high friction insert 1.8 m diameter sheave wheel as supplied currently by Sareco to give a rope speed of 1.5 m/s. The tensioning assembly is of the gravity take-up type with a 1.8 m diameter sheave wheel lined with low friction inserts. A VSD would be used instead of the soft starter usually installed, as it is known that for brake testing purposes a soft starter does not allow the motor to develop full rated torque at start-up meaning that the brakes are not fully tested before the chairlift is started. A 26 mm rope will be supplied with standard torque tightened rope grips on the chairs. Line stands are envisaged to be attached to the footwall pending an investigation into the competency of the hanging wall for the use of hanging line stands.

In the paragraphs to follow are the detailed discipline specific design criteria for the installation of a new chairlift infrastructure at both North and South Shafts. It included the following:

Description of Mine and Production Parameters
Approximate personnel numbers per shaft for both North and South Shaft that will make use of chairlift personnel transportation down and out the mine is as followed:
- Morning shift 2,600
- Afternoon shift 500
- Night shift 500

Chairlift Requirements
Table 3.5.2.3 shows the chairlift requirements for both North and South Shafts.

Table 3.5.2.3: Chairlift Requirements

	North Shaft	South Shaft
Personnel capacity	900 per hour	900 per hour
Chairlift decline average inclination	10.0º	17.9º
Chairlift decline maximum inclination	17.6º	19.0º
Chairlift decline minimum inclination (excluding the landing areas which are flat)	8.5º	10.0º
Length of decline	1,934 m	1,727 m
Rope speed	1.5 m/s	1.5 m/s
Deceleration limits (as per SANS 273)	$1.5\ m/s^2 – 0.375\ m/s^2$	$1.5\ m/s^2 – 0.375\ m/s^2$

Design Life
The chairlift system is to be designed for a useful life beyond 20 years. The LOM requires between 40 and 50 years for South and North Shaft respectively.

Protective Coating
All structural components and items that do not have machined parts are hot dip galvanised. The remaining mechanical components will be sandblasted to SA 2.5 and receive a 3-part epoxy polyamide finish. The chair frames and saddles will be hot dip galvanised inside and out. The rope grips, line sheave components and all fasteners will all be electro-galvanised.

Equipment Specifications
- **Drive End**

Drive Sheave
The drive sheave shall be 1,800 mm rope PCD fitted with Becorit D920 high friction lining. The friction lining blocks shall be easily replaceable by using a wedge type design.
Ratings
All bearings shall be rated for 100,000 hours life according to the ISO basic rating life L10 bearing equation.
Electrical Drive
A VSD must be used. The VSD must be suitable for the following operating conditions:
- The motor nominal rating should be at least 25 % greater than the calculated absorbed power of the chair lift load.
- The drive must be equipped with dynamic braking resistors or similar energy recovery equipment to handle continuously the full regenerative energy due to a fully loaded down going shift with a temperature rise of not more than 300 °C rise. The resistors or regenerative equipment should be designed in value to handle the peak torque developed by the drive.
- The drive / motor package should be a full vector control system that utilises an encoder for feedback.
- The VSD should be rated such that controllable torques of 200 % of nominal motor rating is achievable, and that a variable level of torque is possible for brake testing.

The electrical supply is to include the chairlift controller with the following additional features in addition to those identified in SANS 273:
- A control to stop the chairlift if the hydraulic pressure drops below a predetermined minimum.
- A control to stop the system if the hydraulic oil temperature exceeds a predetermined maximum.
- Circuitry to allow the start-up warning sirens to be utilised for safety line switch.
- Testing of system functionality.
- Dual safety circuit trip relays / contactors.
- Brake self-test operation during start-up.

Primary Memorised Safety Devices
The following primary, latched, safety devices which could only be reset by the appointed person are to be incorporated and memorised under power failure condition:
- Over-speed
- Under-speed / rope slip
- Motor overloads
- Rope de-rail switches
- Over / under tension switches

- Motor controller fault
- Brake system failure
- Phase reversal.

Secondary Latched Safety Devices

The following secondary memorised safety devices which can be reset by the operator will be provided:

- Trip wire pull-switches; the position of a tripped safety line switch is to be shown on a coded numerical LED display in conjunction with a chart. Both the "operator reset" and the "artisan reset" safety line circuits are to have its own fault finder system.
- Vigilance circuit
- Passenger over-run
- Local stop
- Remote stop.

Non-Latched Safety Devices

The following safety devices should be incorporated and indicated but will not be memorised:

- Brakes off
- Brake adjustment required
- Rope derail switches are to be allowed on every third line support and at each change in vertical angle.

➢ **Tensioning End**

Return Sheave

The return sheave shall be 1,800 mm rope PCD fitted with Becorit D530S low friction lining. The friction lining blocks shall be easily replaceable by using a wedge type design.

Brow and Heel Curves

The brow and heel curves will be made up of multiples of 4, 6 and 8 sheave units depending on the break angle of the rope and the total rope loading to be carried. Derailment switches will be incorporated to interrupt power to the drive motor and automatically apply the brakes in the event of a derailment. To counter rope spin, generated at the brow and heel curves due to lateral flexibility, the design will be "stiff" with bolted hollow axles at the beam joints and slide guides between the beam faces. All pivot joints will be fitted with dry running bushes fitted with greasing facilities.

Line Support

The line support will allow for the rope height to be adjusted as well as centre alignment. The line supports will feature as standard, individually adjustable wheel bogies to allow the sheaves to be brought perfectly in line with the rope and virtually eliminate tyre wear. The line supports can be footwall or hanging mounted.

Line Sheaves

The line sheave which, is utilised throughout the system on the guide sheaves, brow and heel curves and line support units must be of the split design which allows the tyres to be replaced. The sheave must be assembled from pressed steel side plates, sealed for life bearings mounted in a bearing hub and a specially compounded rubber tyre. The sheave must have side flanges which prevent rope derailment and allows up to 10 mm depth of tyre wear.

Roof and Floor Anchor Bolts, Holes and Resins

The roof and floor anchor bolts, nuts and resins will be supplied and installed by the mine.

Rope Grips
The rope grip must be of the "conventional" type whereby the clamping force is directly applied to the rope by a moving jaw. Correct clamping force will be specified in terms of a torque applied to the adjusting bolt.

Chairs
The chairs will be of the straddle type fitted with either a pressed steel or non-flammable plastic saddle. The chair will be designed to maintain its balance even when it is empty.

Level Landings
Entering and exiting each level landing will take place via an overpass platform with three sets of stairs. Two of the stairs will be inside the landing area, to allow access for embarking and disembarking. There will be a minimum 800 mm clearance between each stair and the rope. The third stair will be on the level entrance side of the landing and will be screened off from the inside of the landing to enforce the use of the overpass platform. The landing will be divided along the full length with safety screens down the centre, between the line supports to prevent people from crossing between the embarking and disembarking sides of the landing. The landing floor will be concreted, allowing for drainage, with clearly demarcated embarking and disembarking areas (BRPM Engineering Department, 2008).

3.6. Basis of Electrical Requirements

Capex
The following assumptions were made:

- An 11 kV supply point is 100 m from the chairlift and allowance has only been made for 11 kV XLPE cables to the chairlift. This excludes any cable feeder breakers or isolators at the supply point. This should be supplied by the mine.
- 550 V underground gully supply points are available in the vicinity of the chairlift landings for the decline haulage lighting.

The estimate allowed for the following:

- The supply and installation of an 11 kV XPLE cable from the 11 kV supply point to a 630 kVA mini-sub at the chairlift drive motor. A 600 / 1000 kV cable will be installed from the mini-sub to each chairlift control panel.
- The supply and installation of lighting transformers, cables and light fittings for the walkway lighting and the chairlift decline lighting (BRPM Engineering Department, 2008).

3.7. Safety Enhancements to Current Conveyor Belt and Belt Infrastructure (secondary options)

3.7.1. Introduction

In order to have a clear understanding of the rigours involved with belt riding, a training session was arranged at the training facility at North Shaft. This involved a three hour practical session on the mine's surface training belt, learning the art of getting off and on the belt in various configurations and culminated in a trip on the North Shaft conveyor belt to level 5 and back to surface. The actions involved are listed below in order of difficulty and will be discussed further in the following sections:

- Getting off the belt (going down the mine).
- Getting off the belt (going out the mine) on broken rock.
- Getting on the belt (going out the mine) on broken rock.
- Getting on the belt (going down the mine).

➢ Getting on the belt (going out the mine).

Getting off the belt (going down the mine)
This is definitely the most physically taxing of the tasks carried out and is due to the fact that the legs are forced to absorb the combined force imparted by the belt moving at 2.5 m/s combined with the natural acceleration caused by gravity which, at -9° amounts to 1.7 m/s^2. This combination requires a person to decelerate at the equivalent of 2.95 m/s^2 in order to stop in the required distance and is illustrated in Figure 3.7.1.

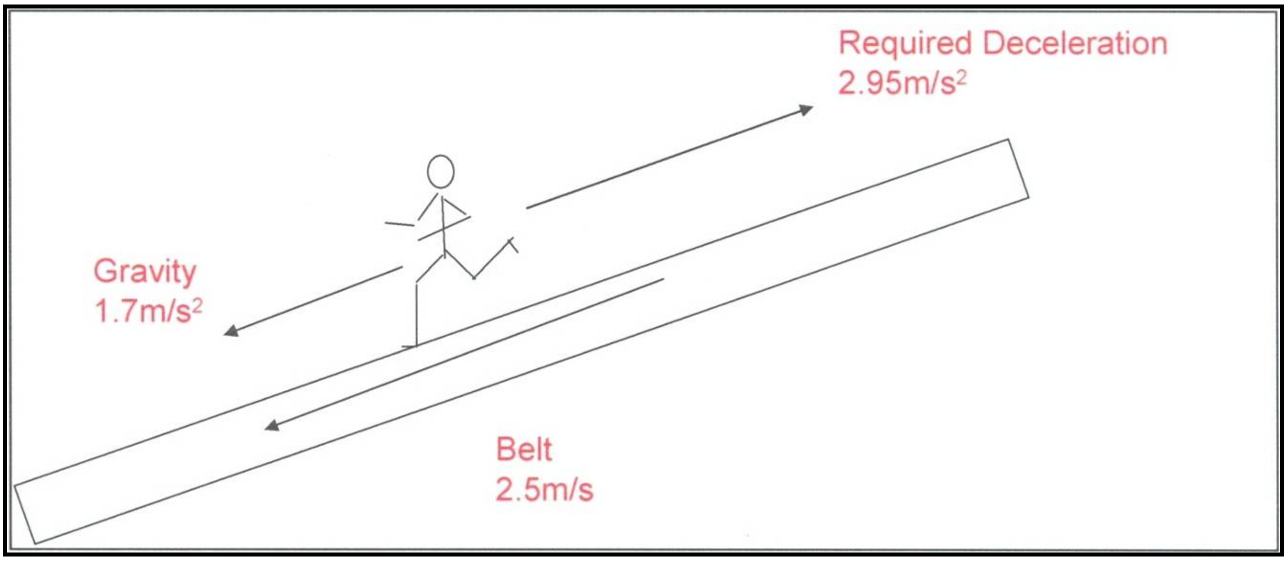

Figure 3.7.1: Schematic Representation Getting off the Belt (going down the mine)
(Van Heerden, 2008)

Getting off the belt (going out the mine) on broken rock
This is also very physically taxing as the naturally high friction coefficient between a rubber boot and rubber conveyor is reduced by the presence of small rock particles which makes it very difficult to gain the necessary purchase when launching off the belt. It appears to be good practice to spend the time sitting on the belt to clean a section for your feet before getting off the belt, but even this is of only minor assistance.

Getting on the belt (going out the mine) on broken rock
This is risky for the same reasons as outlined above. The presence of rock on the conveyor forces one to abandon the lessons learned at the training centre and, instead of getting on the belt in a fluid manner with the hands first followed by the feet one is forced to adopt a form of sideways leap in order to gain purchase on the conveyor either side of the rock.

Getting on the belt (going down the mine)
The only problem here is the trough of the conveyor belt which, together with the fact that the conveyor belt is dipping away from the rider, makes it quite a drop from the platform to the belt.

Getting on the belt (going out the mine)
This is comparatively a pleasure for the opposite reason as what makes getting off down such a challenge. The natural deceleration imparted by gravity has the effect of stopping one almost as one hits the platform, requiring almost no effort at all.

3.7.2. Platform Modifications

Having analysed the configuration, particularly of the platforms for getting off the belt, some relatively minor modifications could be made which will greatly assist with the alighting process. Figure 3.7.2 shows that the lower conveyor belt is very deeply troughed which, together with the fact that the platform itself is elevated above the level of the conveyor belt, means that the rider has to take a step up of approximately 400 mm to launch off the conveyor belt. The platform is also broad, being 1,200 mm from the side of the conveyor belt to the grab rail. This means that the grab rail currently installed, for all practical purposes, of no assistance at all when getting onto or off the belt.

Figure 3.7.2: Platform Modifications
(Van Heerden, 2008)

Getting off the belt whilst going down the mine

This is the most challenging action to perform when considering the past safety performance at BRPM. This platform requires the most attention. Figure 3.7.2a shows a section of the existing configuration of the platform.

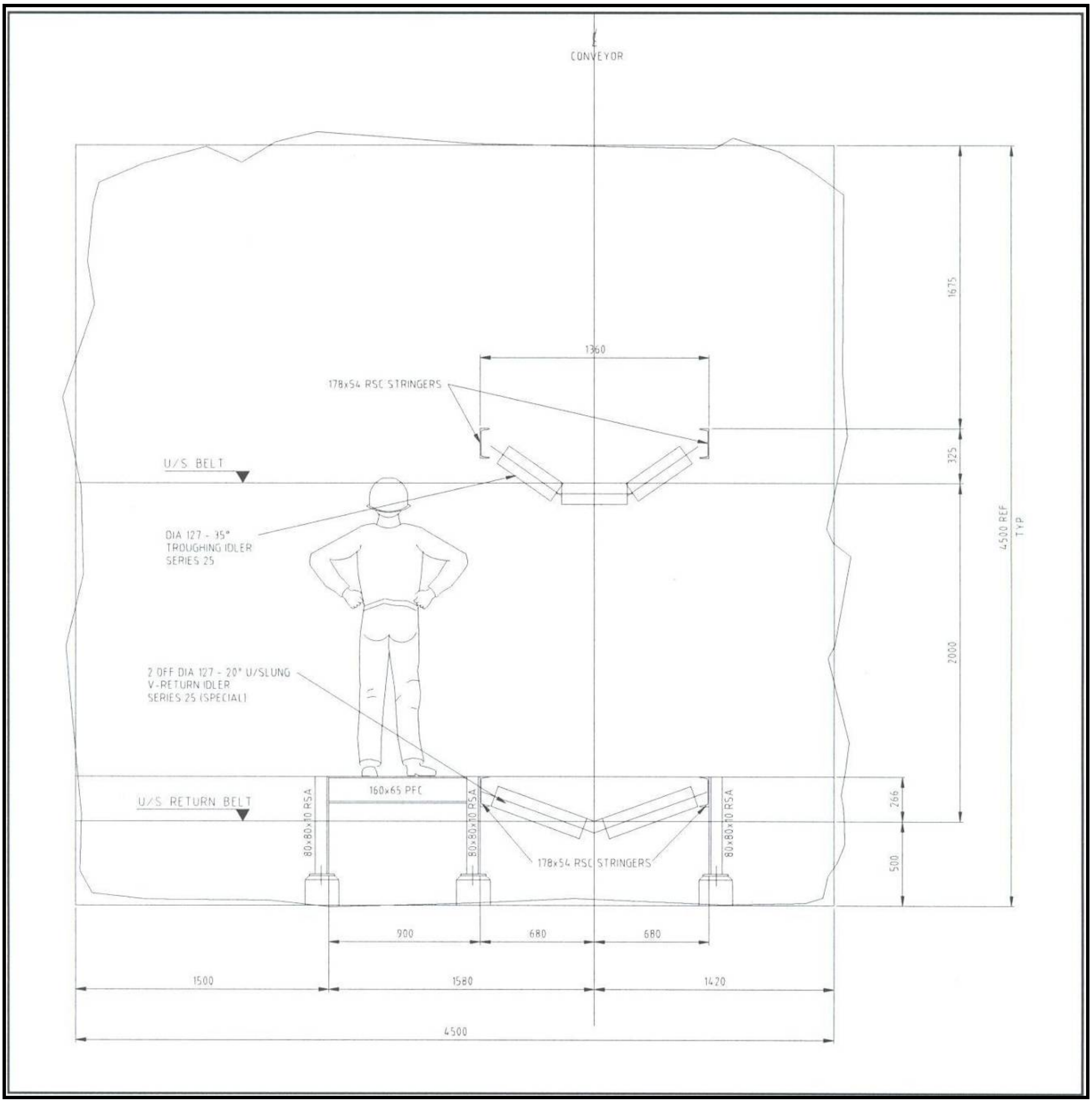

Figure 3.7.2a: Getting off the Belt (going down the mine) – Section through Platform (Bottom Belt – Existing)
(BRPM, 2008)

One of the options proposed as an interim solution to improve the safety of the conveyor belt for the purpose of personnel transportation is to change the idlers at platforms going down, from troughing idlers to flat idlers. The flat idlers would replace troughing idlers for a distance equal to the length of the platform plus one idler at either end of the platform. Two transition idlers either side of the platform would be added to assist the belt in changing from troughing idlers to flat idlers and back again. The idlers have been chosen based on the belt detail as contained in AAP Drawing ADB361 04 002118 01 TW 05.

Replacing the troughed idlers with flat idlers will immediately create a flatter transition surface between the conveyor belt and the platform and remove the height differential between the two.

This is illustrated conceptually in Figure 3.7.2b. Reducing the width of the platform from 1,200 mm to no more than 900 mm will also allow personnel to utilise the grab rail to steady themselves if in need. As there is no broken rock on the bottom conveyor belt there is no reason why this cannot be implemented. It is also recommend that the current grating used for the floor of the platform be replaced by the non-slip variety to prevent personnel slipping whilst attempting to brake rapidly.

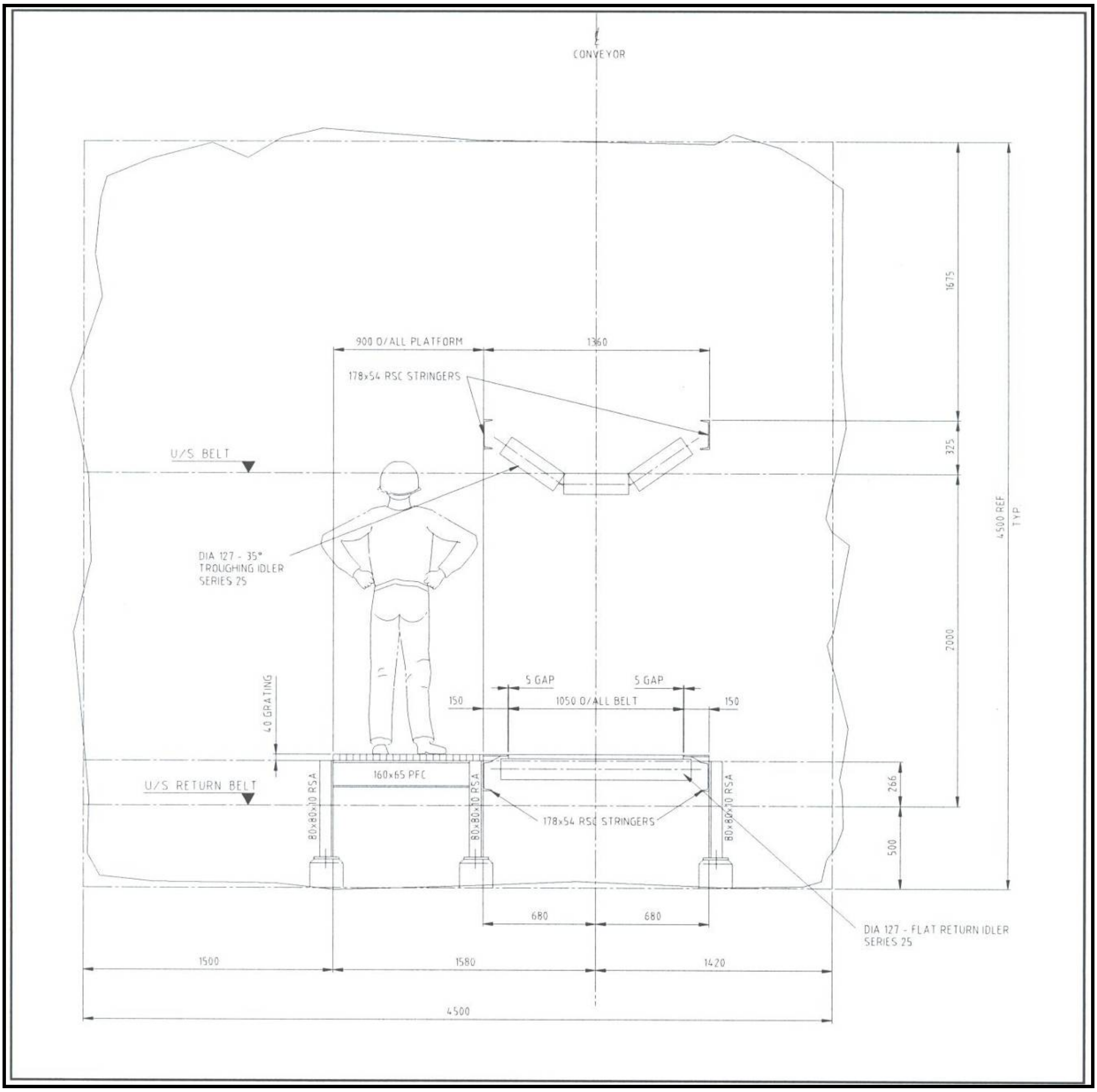

Figure 3.7.2b: Getting off the Belt (going down the mine) – Section through Platform (Bottom Belt – Modifications)

(BRPM, 2008)

Getting off the belt going out the mine

While this action does not carry the same risk as getting off the belt going down the mine, it would still be of assistance to improve the ergonomics of the platform, particularly when getting off broken rock. This could be achieved by lowering the platform by approximately 50 mm to reduce the height differential. Adjustable troughing idlers are proposed for the platform areas when going up. Flat idlers cannot be used for the up-going conveyor belt as this section of belt carries broken rock and there is a real possibility of the rock rolling off should flat idlers be incorporated here. Instead, adjustable idlers can be installed giving the potential to try various angles of trough to optimise the requirement of keeping broken rock on the conveyor belt and providing flatter belt at platform areas when going up. Adjustable idlers would replace the existing troughing idlers for the length of the platforms. The first option is to install adjustable idlers which could be tuned to reduce the trough as much as possible without causing spillage from the conveyor belt. The other option is through narrowing the platform to 900 mm so as to allow personnel to utilise the grab rail. The existing infrastructure and proposed modifications are illustrated in Figure 3.7.2c and 3.7.2d respectively.

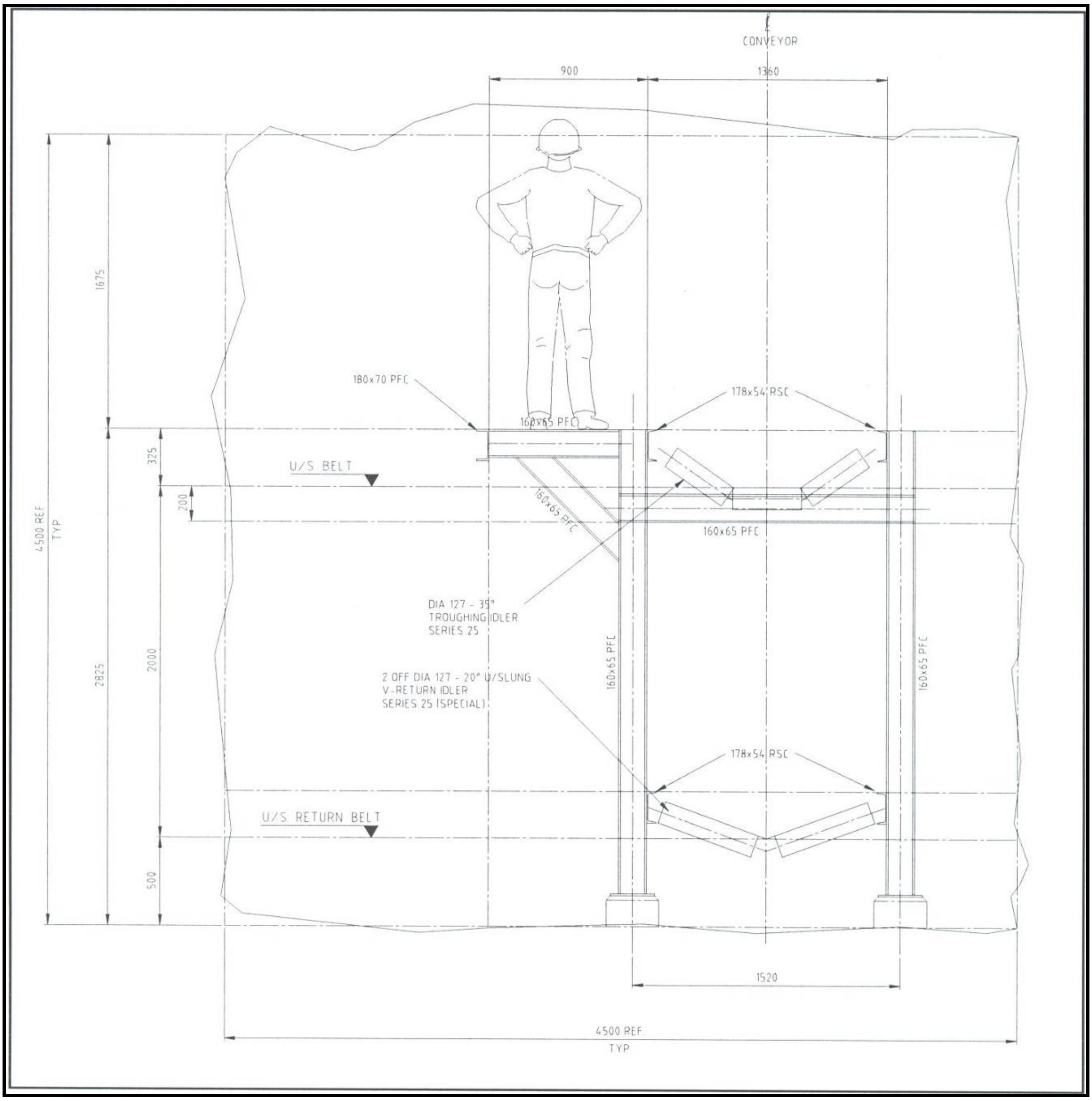

Figure 3.7.2c: Getting off the Belt (going out the mine) – Section through Platform (Top Belt – Existing)
(BRPM, 2008)

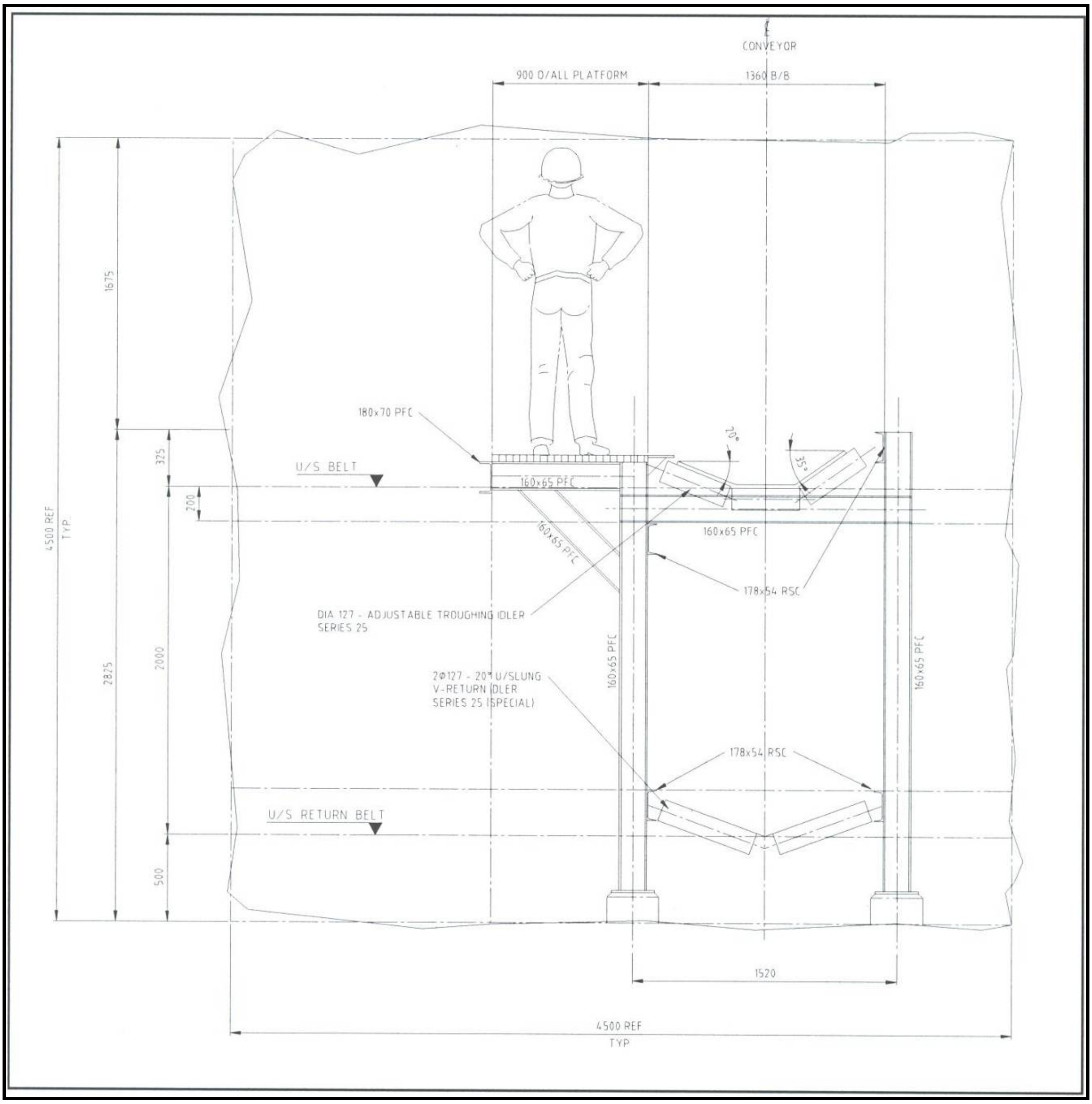

Figure 3.7.2d: Getting off the Belt (going out the mine) – Section through Platform (Top Belt – Modifications)
(BRPM, 2008)

Estimated CAPEX of Modifications

Estimated CAPEX (2014 money terms) for the modifications discussed in the above sections is tabulated in Table 3.7.2 for both North and South Shafts:

Table 3.7.2: Estimated CAPEX of Modifications to Platform Areas

Item	Quantity	Price per Unit (ZAR)	Total (ZAR)
Modifications to Platform Areas Going Down the Mine			
Flat return idler frame	8	268	2,144
Flat idler	8	1,417	11,342
10° return frame	2	478	957
10° return idler	4	957	3,828
Vastrap sheeting (m^2)	15	3,507	52,608
Total			**70,881**
Modifications to Platform Areas Going Out the Mine			
Adjustable idler cw frame	16	3,126	50 030
Vastrap sheeting (m^2)	24	3,507	84 173
Total			**134 203.56**
Grand Total			205,084
North Shaft Total	**5**	205,084	1,025,423
South Shaft Total	**6**	205,084	1,230,507
Grand Total			**2,255,931**

3.7.3. Addition of an Intermediate Conveyor Belt for Getting off the Belt

Installation of an intermediate conveyor belt for assisting personnel getting off the belt going down the mine is recommended. The belt speed will be 1.5 m/s and can be installed in place of the existing platforms. A 4 kW VSD and 4 kW motor driving through a bevel helical gearbox will power the conveyor belt. A multiply medium duty conveyor belt has been selected running on 127 mm flat idlers and skid plate with 324 mm diameter drive and return pulleys, unlagged. The VSD will allow an optimum speed to be selected should it be found that the initial estimate of 1.5 m/s is not ideal. A trial and error procedure will be run to determine the best speed on the intermediate belt. Table 3.7.3 shows an estimated CAPEX for this installation.

Table 3.7.3: Estimated CAPEX of Intermediate Conveyor Belt

Item	Quantity	Price per Unit (ZAR)	Total (ZAR)
4kW Bonfiglioli drive	1	19,346	19,346
324 mm dia. drive pulley	1	16,657	16,657
324 mm dia. return pulley	1	15,941	15,941
900 XL 400/2 belt	10	830	8,296
4kW Weg VSD	1	8,423	8,423
Conveyor frame	1	114,865	114,865
Carry idlers c/w frame	2	618	1,235
Return Idlers	1	605	605
Total			**185,368**
North Shaft Total	**5**	185,368	926,842
South Shaft Total	**6**	185,368	1,112,210
Grand Total			**2,039,053**

3.7.4. Addition of Overhead Endless Ropeway for Assisting Getting off the Belt

A third proposal for assisting personnel to get off from the conveyor belt when going down the mine is the installation of an overhead endless rope running across the conveyor belt to the platform. The system is driven by a 3 kW VSD drive with 400 mm diameter pulleys and a 16 mm plastic coated steel rope running at 1.5 m/s. The idea is for personnel to grab hold of the rope to steady them when getting off from the belt to the platform. Since the belt is running at 2.5 m/s and the rope at 1.5 m/s, the effect is that the rope is travelling towards the person. It would be mandatory that all personnel wear gloves when going down to help prevent possible rope burn. Again a process of trial and error is required to determine the best speed for the rope and the VSD will allow a suitable speed to be selected. Refer to Appendix H in this document for the patent pending on personnel-riding conveyor belt assistance. Table 3.7.4 shows an estimated CAPEX for this installation. Figure 3.7.4 illustrates rope assistance at a typical elevation.

Table 3.7.4: Estimated CAPEX of Endless Rope Arrangement

Item	Quantity	Price per Unit (ZAR)	Total (ZAR)
3 kW Bonfiglioli drive	1	13,654	13,654
300 mm dia. drive pulley	1	3,829	3,829
300 mm dia. return pulley	1	15,941	15,941
16 mm rope	8	45	361
3 kW Weg VSD	1	8,423	8,423
Frame cw concrete footings	1	63,814	63,814
Total			**106,022**
North Shaft Total	**5**	106,022	530,109
South Shaft Total	**6**	106,022	636,131
Grand Total			**1,166,240**

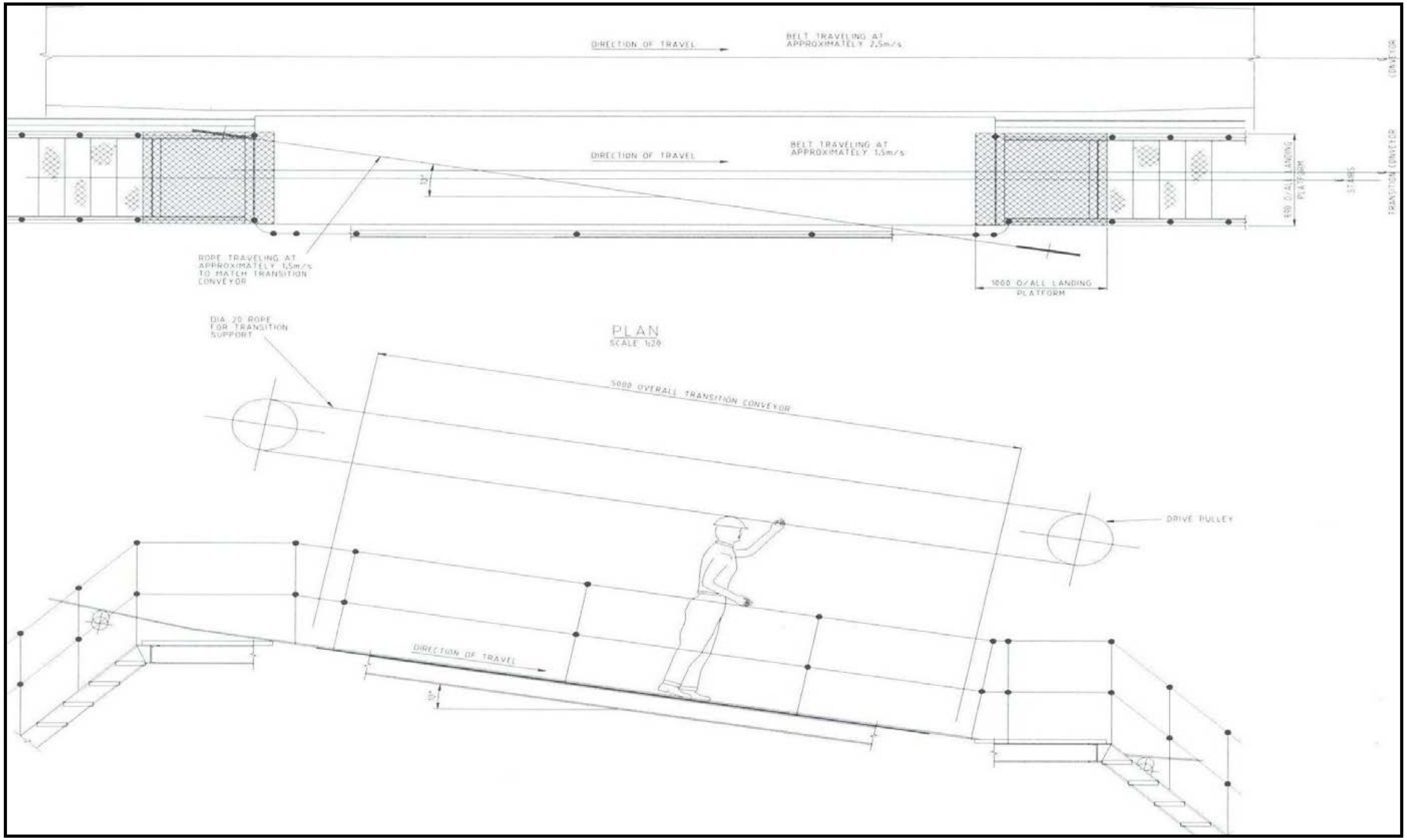

Figure 3.7.4: Rope Assistance – Typical Elevation
(BRPM, 2008)

3.7.5. Completely Modified Platform

Figure 3.7.5 illustrates a platform complete with all safety enhancements, namely flat idlers, ropeway assistance and an intermediate conveyor belt.

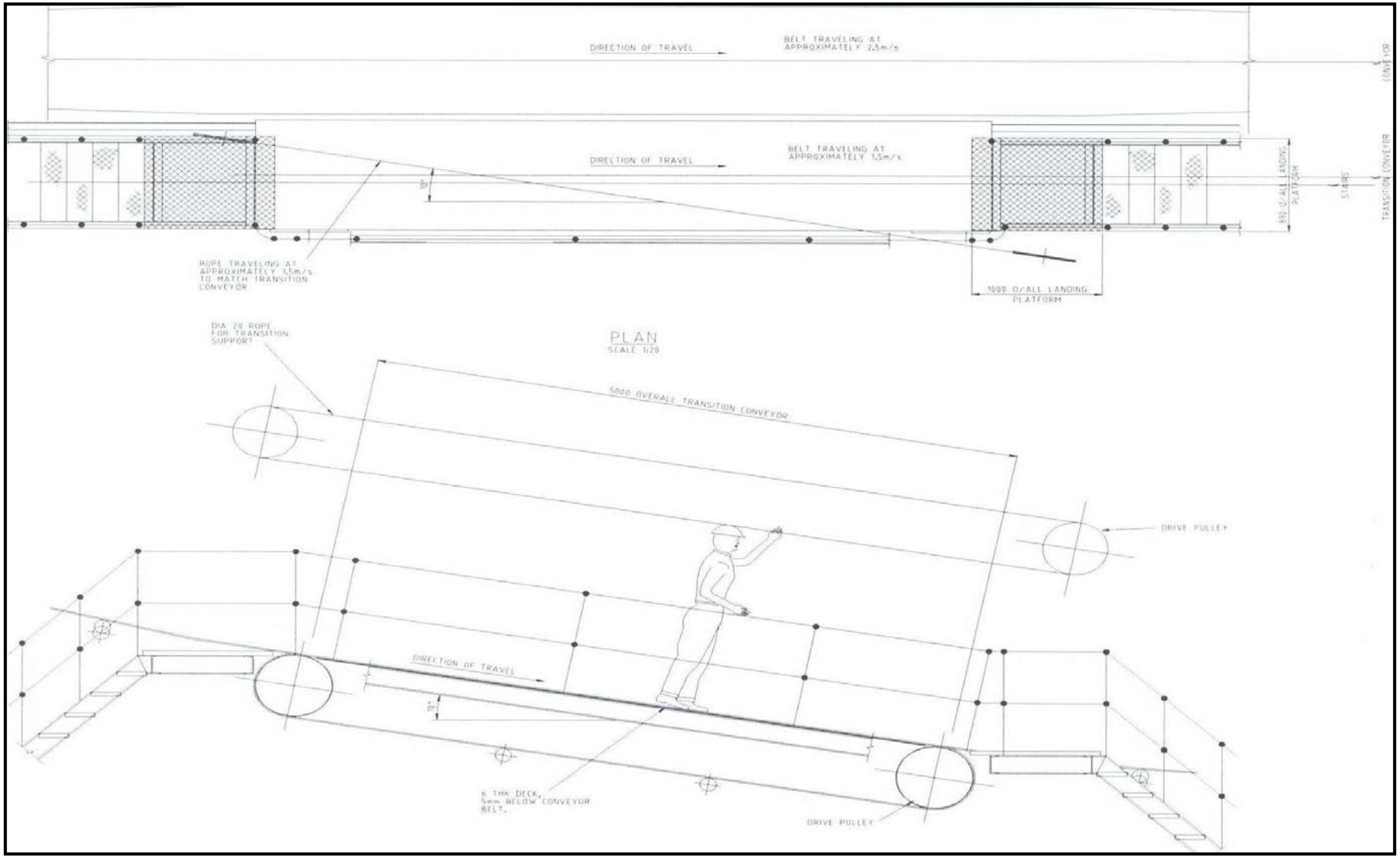

Figure 3.7.5: Completely Modified Platform, including Intermediate Belt and Rope Assistance
(BRPM, 2008)

3.7.6. General Comments on Enhancements to Current Conveyor and Belt Infrastructure

It is recommended that the above proposals be tested on the existing training conveyor belt at North Shaft to determine which proposals are best suited to improving safety when getting on and off the current conveyor belt. These modifications are seen only as a short term solution to the current problem experienced with personnel transportation at BRPM. These modifications could be done in quick time resulting in an immediate improvement on safety. These modifications will also come at a limited CAPEX (refer to Table 3.7.6 should all modifications prove viable (2014 money terms)). The reason why emphasis is placed on these modifications is due to the fact developing a new decline system at North and South Shafts would take approximately 12 and 15 months respectively. Two months could be added additionally for installation of the infrastructure. It is also assumed that approval of the feasibility study of capital funding would take an additional 18 months. Thus in total, before the new chairlift declines on both North and South Shafts could be utilised would take approximately 32 and 35 months respectively. Thus, for the time been, there would be always the risk of having injuries / incidents on the conveyor belt as a result of personnel transportation would could lead to possible safety stoppages.

Table 3.7.6: Total Estimated CAPEX of Modifications

Item	Quantity	Price per Unit (ZAR)	Total (ZAR)
Modifications to Platform Areas			
North Shaft Total	**5**	205,085	1,025,423
South Shaft Total	**6**	205,085	1,230,508
Sub Total			**2,255,931**
Intermediate Conveyor			
North Shaft Total	**5**	185,368	926,842
South Shaft Total	**6**	185,368	1,112,210
Sub Total			**2,039,053**
Endless Rope Arrangement			
North Shaft Total	**5**	106,022	530,109
South Shaft Total	**6**	106,022	636,131
Sub Total			**1,166,240**
North Shaft Total	**5**	496,475	2,482,375
South Shaft Total	**6**	496,475	2,978,849
Grand Total			**5,461,224**

3.8. Summary of Personnel Transportation Simulation Report

Simulation Engineering Technologies (SET) was requested to prepare a computer model by making use of the Arena ® Simulation Software, Version 12.0, to simulate the current personnel transportation system (belt riding) versus the proposed installation of a totally new chairlift decline system. The complete simulation report is available in Appendix I of this document.

It was a known factor from the start of the project that a sacrifice would have to be made in order to ensure the safety of personnel. The reason therefore is that the conveyor belt was running at a speed of 2.5 m/s compared to the 1.5 m/s of the chairlift. The other factor is also that the spacing increases from 5 m using the current conveyor belt compared to 6 m when utilising the chairlift system. The simulation however where conducted at a conveyor belt speed of 2.0 m/s to compare the current situation after the installation of the VSD's on both shafts. From this simulation conducted by SET, the following conclusion could be drawn (Nichol, 2009):

- The travel time when making use of the chairlift would be 33 % longer compared to that of the conveyor belt. Mainly as a result of reduced velocity and increased chair spacing. The chairlift velocity and spacing conform to regulations.
- The average queuing time would increase by approximately 20 minutes when utilising the chairlift compared to the conveyor belt transportation.
- The result of this is that there would be a tremendous increase in the total amount of travel time for personnel. The effect of this is that personnel could spend less time in the working areas.
- The only option to encounter this phenomenon is to have a pre-determine shaft schedule (per level – beginning of shift and end of shift) to reduce queuing times.

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CHAPTER 4

ANALYSIS AND EVALUATION OF RESULTS

4. ANALYSIS AND EVALUATION OF RESULTS

This chapter contains the analysis and evaluation of results from the study that were conducted on personnel transportation at BRPM.

4.1. Introduction

BRPM currently use conveyor belts for transporting personnel in and out of the Phase 1 areas of both North and South Shafts with the same conveyor belt being used for personnel and broken rock (reef and waste). The decision was taken by mine management to review this method used for transporting personnel due to increasing numbers of injuries / incidents occurring as a result of conveyor belt riding. Safety stoppages could be invoked when there are another belt accident / incident. The risk involved with this could have catastrophic repercussions which could result in the mine coming to a standstill. There are no other means for personnel to travel underground except for the current conveyor belts. Personnel walking up and down the declines would lead to reduced efficiencies. This means of transportation could also only be utilised by the upper levels of the Phase 1 areas as there is a restriction by the MHSA when exceeding the allowable vertical distance for unaided travelling.

The purpose of the investigation was to identify the appropriate option and / or combination of options through a process of evaluation that would be safe in terms of personnel transportation and cost effective. If alternative measures could be found to transport personnel (in other words not using belt riding as a means of transport) down and out the mine, it would have a significant positive spin-off increasing the belt availability, to increase production.

4.2. Option Identification and Elimination Processes

An entire process of option identification and elimination of the unfeasible options were followed. Initially seventeen different options were identified during P1 ***(Process 1)***. After following a process of elimination, the decision was taken by the Risk Assessment team to further investigate six options at North Shaft and nine options at South Shaft during P2 ***(Process 2)***. Finally only 3 options were selected at North Shaft during P3 ***(Process 3)*** of which one being a total new chairlift decline with infrastructure ***(primary option)*** and two being modifications to the current conveyor belt and belt infrastructure ***(secondary options)***. There were five options selected at South Shaft during P3 of which three being total new declines with infrastructure ***(primary options)*** and two being modifications to the current conveyor belt and belt infrastructure ***(secondary options)***. At the end of P3, there was only one primary (Option 3) and one secondary option (Option 10 - with alterations) feasible for each of the shafts. Table 4.2 is a summary of the process followed. The following legend is applicable:

- N # - North Shaft
- S # - South Shaft
- ✘ - Not applicable for further investigation
- √ - Applicable for further investigation

Table 4.2: Option Identification and Elimination Processes Summary

Option	Description	Process 1			Process 2			Process 3		
		N#	S#	Comment	N#	S#	Comment	N#	S#	Comment
1	Chairlift in current belt decline	✗	✗	Sliping required – damage to belt	✗	✗		✗	✗	
2a	Chairlift in zero raise – decline from surface	✗	√	N# zero raise line not straight and continuous. S# applicable for further investigation	✗	✗		✗	✗	
2b	Chairlift in zero raise – vertical shaft to surface	✗	✗	Surface infrastructure / communities	✗	✗		✗	✗	
3	New chairlift decline – new infrastructure	√	√	High CAPEX	√	√	High CAPEX	√	√	High CAPEX
4	Vertical shaft from surface to level 3	✗	✗	Still need transport / travelling through workings to upper levels	✗	✗		✗	✗	
5	Multiple chairlifts in ventilation bypass areas	✗	✗	Extensive infrastructure required with additional development	✗	✗		✗	✗	
6	Slower personnel – riding speed	√	√	Applicable for further investigation	√	√	Investigated impact	✗	✗	
7	Single chairlift at South 40 position for both shafts	✗	✗	Logistical and infrastructure constraints (single access between shafts)	✗	✗		✗	✗	
8	One way chairlift down belt decline, up zero raise (continuous loop)	√	√	Need connection to surface, engineering challenges when considering infrastructure installation in loop configuration	✗	✗		✗	✗	
9	Licence material winder for personnel transportation	✗	✗	Impact on already tight material supply schedule	✗	✗		✗	✗	
10	Safer platforms for getting off the belt	√	√	Applicable for further investigation	√	√		√	√	
11	1st Leg chairlift in belt decline then in zero raise	✗	✗	Sliping required – damage to conveyor belt and belt infrastructure	✗	✗		✗	✗	
12a	Chairlift in zero raise – incline under opencast	✗	√	N# zero raise line not straight and continuous. S# applicable for further investigation	✗	√	S# applicable for further investigation	✗	✗	
12b	Chairlift in zero raise – portal in opencast highwall	✗	√	N# zero raise line not straight and continuous. S# applicable for further investigation	✗	√	S# applicable for further investigation	✗	✗	
13	Vertical shaft from surface to level 5 at N# and level 6 at S#	✗	✗	Still need transport / travelling through workings to upper levels	✗	✗		✗	✗	
14	Monorail system	√	√	Applicable for further investigation	✗	✗		✗	✗	
15	New decline on UG2 horizon	✗	✗	Much higher CAPEX compared to MR horizon options	✗	✗		✗	✗	
16	Additional belt riding conveyor in belt decline	√	√	Applicable for further investigation	✗	✗		✗	✗	
17	Hector pipe	✗	✗	No personnel transport to surface, only down the mine	✗	✗		✗	✗	

4.3. Analysis and Evaluation of North Shaft Results

At the end of P3 there was only one primary (Option 3) and one secondary option (Option 10 - with alterations) feasible for North Shaft. Each of these options will be summarized in the paragraphs to follow.

4.3.1. Primary Option

Surface Access and Positioning

- A portal to be created within the shaft area. This would be the most logical approach as the entire infrastructure to support this is in place and there are no additional issues (internal, i.e. surface infrastructure or external, i.e. surrounding communities, either formal or informal settlements) involved.
- The best position would be between the UG2 and MR horizons, as this would be in competent ground and provide easy access to both the existing MR haulages and future UG2 workings. The middling between the two horizons at North Shaft is approximately 70 m which gives adequate space to develop the decline without impacting on the workings.
- The chairlift installation will begin at the exit from the existing lamp room with the first leg running to level 1. From there the decline will turn approximately 30° to the north and proceed directly to level 5. Landings will be provided at each level through which access to the workings (current MR and future UG2) will be achieved.
- From the SWOT analysis that was conducted, it is evident that there are a lot of strengths and opportunities associated with this option. The new chairlift decline could be secured for the next required 50 years due to the more stable ground conditions. There are also six attack points available that will ensure much faster development. The weaknesses and threats are commonly associated with general chairlift installations. A summary of the critical strengths and opportunities are as follows:

  Strengths
  - Access to underground workings from surface
  - Gives access to both MR and UG2 reef horizons
  - New development can be secured for LOM (50 years) – more stable ground conditions
  - Straight line – less wear and tear on moving parts
  - 6 attack points for quicker development

  Opportunities
  - Existing haulages to UG2 already in place
  - Install 2 / 3 legs to prevent total stop for maintenance / breakdown
  - Additional ventilation to UG2

  A summary of the critical weakness and threats are as follows:

  Weaknesses
  - Cost – CAPEX and maintenance
  - Maintenance time – if only 1 leg (between levels 2 and 5)
  - Breakdown time – No alternative to get to surface / workplace but to walk – shift down late and blast late
  - Cannot take material down on chairlift

  Threats
  - Long travelling distance in event of failure / stoppage (including safety stoppages)
  - Maintenance time
  - Workforce become negative if not running for a couple of shifts / days

Geology and Rock Engineering

- There are some geological features / structures that could be expected during the sinking of the chairlift decline. The major structures that could be a concern is the weathered zone (up to a vertical depth of 30 m), the water bearing shear within the first 10 m of sinking, a fault intersection with a 4.7 m throw at a dip of 80°, the Randal and Strike dykes and also the North Shaft UG2 fault. The decline system and some footwall development mined successfully through the features mentioned above. Specific rock engineering support recommendations need to be adhered too to ensure the success of mining through these features. Reduced mining rates are planned when features are encountered benchmarked from historical information.
- Jointing could also be expected. North Shaft has four major joint sets and two minor joint sets. These joint sets provide a clear understanding of the expected ground conditions in the vicinity of the proposed chairlift decline excavation. Mitigating the risk is similar to mining through the geological features mentioned above
- Some additional concerns include the proximity of the two portal high walls (proposed new portal and existing portal), the large excavations in a faulted block of ground between change over from leg one to leg two where drive units will be installed and the possible sterilization of some UG2 ore reserves due to the placement of the chairlift decline. Specific rock engineering guidance and recommendations need to be adhered too to ensure the mitigation of risk (BRPM Geology Department, 2008; BRPM Rock Engineering Department, 2008).

Ventilation

- There should be no holing to the reef-planes or UG2 excavations. If not adhered to, this could results in short-circuiting of fresh air. The ventilation controls in haulages should also be correctly placed to eliminate short-circuiting of fresh air into worked-out areas.
- There are some advantages for developing the chairlift decline in terms of ventilation. The additional airway as a result of the chairlift decline will be a major advantage from a ventilation perspective.
- There will be a reduction in the total shafts air resistance leading to reduced power consumption of the main surface fans due to the additional intake chairlift decline available to increase the overall shaft’s air intake. The additional intake could result in the velocities of the belt decline being reduced. The reduced velocities in the belt decline will result in less dust generation and hence reducing the risks of getting foreign bodies into people’s eyes (BRPM Ventilation Engineering Department, 2008).

Development and Construction Schedule

- Owing to the configuration of the chairlift decline and the fact that it will be developed through an existing mining infrastructure, it is possible to begin development from six attacking points and the schedule has been compiled as such.
- CADSMine Design and Scheduling software were used during the process. Development of the chairlift decline and associated landings and cross cuts has been scheduled at a rate of **32 m/month** (instantaneous). This rate has also been applied during the 2009 BP Process for ends with similar dimensions and inclination.
- From the scheduling it was concluded that the total duration to complete the development was 12 months. The total metres that needed to develop were **1,934 m**.
- The construction will be concurrent with the development. Once a leg between two levels is completed, it will be constructed. The only bottleneck would be the first leg from surface to 1 level. It would take two additional months to complete. Thus the total development and construction duration would be **14 months**.

Estimated CAPEX

- The estimated CAPEX on the mining costs was based on the fact that the development would take 12 months and the total metres that needed to be developed were 1,934 m.
- It was assumed that the development would be conducted by making use of AAP's CDS which are currently developing the Phase 2 declines on both shafts. The development cost used is as per agreed rate per cubic metre with CDS. The rate used was **ZAR 3,099/m^3**.
- The chairlift costs (infrastructure and installation) were obtained from Sareco, who was installing the Phase 2 chairlifts on both shafts.
- The total estimated CAPEX for chairlift decline at North Shaft would be **ZAR 94 million**.

4.3.2. Secondary Option (with alteration)

Platform Modifications

- Some relatively minor modifications could be made which will greatly assist with the process. The lower conveyor belt is deeply troughed, which, together with the fact that the platform itself is elevated above the level of the conveyor belt. This means that the rider has to take a step up of approximately 400 mm to get off the conveyor belt. The platform is also broad, being 1,200 mm from the side of the conveyor belt to the grab rail.
- Getting off the belt whilst going down the mine is the most challenging action to perform when considering the past safety performance at BRPM. This platform requires the most attention.
- One of the options is to change the idlers at platforms going down the mine, from troughing idlers to flat idlers. The flat idlers would replace troughing idlers for a distance equal to the length of the platform plus one idler at either end of the platform. Two transition idlers either side of the platform would be added to assist the belt in changing from troughing idlers to flat idlers and back again
- Replacing the troughed idlers with flat idlers will immediately create a flatter transition surface between the belt and the platform and remove the height differential between the two. Reducing the width of the platform from 1,200 mm to no more than 900 mm will also allow personnel to utilise the grab rail to steady themselves if in need.
- Getting off the belt going out the mine does not carry the same risk as getting off the belt going down the mine; it would still be of assistance to improve the ergonomics of the platform, particularly when alighting off broken rock. This could be done through lowering the platform by approximately 50 mm to reduce the height differential.
- Adjustable troughing idlers are proposed for the platform areas when going out the mine. Flat idlers cannot be used for the up-going conveyor belt as this section of belt carries broken rock and there is a real possibility of the rock rolling off should flat idlers be incorporated here. The first option is to install adjustable idlers which could be tuned to reduce the trough as much as possible without causing spillage from the conveyor belt. The other option is through narrowing the platform to 900 mm so as to allow personnel to utilise the grab rail.
- The estimated CAPEX to do the modifications is approximately **ZAR 1.0 million**.

Addition of an Intermediate Conveyor Belt for Alighting

- Installation of an intermediate conveyor belt for assisting personnel getting off the belt going down the mine is recommended. The belt speed will be 1.5 m/s and can be installed in place of the existing platforms. A 4 kW VSD and 4 kW motor driving through a bevel helical gearbox will power the conveyor. A multiply medium duty conveyor belt has been selected running on 127 mm flat idlers and skid plate with 324 mm diameter drive and return pulleys, unlagged.
- The estimated CAPEX to do the modifications is approximately **ZAR 0.9 million**.

Addition of Overhead Endless Ropeway for Alighting Assistance

- The proposal for assisting personnel to get off from the conveyor belt when going down the mine is the installation of an overhead endless rope running across the conveyor belt to the platform. The system is driven by a 3 kW VSD with 400 mm diameter pulleys and a 16 mm plastic coated steel rope running at 1.5 m/s. The idea is for personnel to grab hold of the rope to steady them when getting off from the belt to the platform. Since the belt is running at 2.5 m/s and the rope at 1.5 m/s, the effect is that the rope is travelling towards the person.
- The estimated CAPEX to do the modifications is approximately **ZAR 0.5 million**.

4.3.3. Summary of North Shaft Estimated CAPEX (Primary and Secondary Options)

The total estimated CAPEX for the total North Shaft could be viewed in Table 4.3.3. This is based on the assumption that the secondary options would be implemented while the development of the chairlift decline is in progress. This would have an immediate impact on safety. The implementation of the secondary options could be quick compared to the 32 month project duration of the chairlift decline.

Table 4.3.3: Total Estimated CAPEX – North Shaft

Item	Quantity	Price per Unit (ZAR)	Total (ZAR)
Primary Option			
New Chairlift Decline			
North Shaft Total	1,934 m	48,374	93,555,572
Secondary Options			
Modifications to Platform Areas			
North Shaft Total	5 levels	205,085	1,025,423
Intermediate Conveyor			
North Shaft Total	5 levels	185,368	926,842
Endless Rope Arrangement			
North Shaft Total	5 levels	106,022	530,109
Grand Total			**96,037,947**

4.4. Analysis and Evaluation of South Shaft Results

At the end of P3 there was only one primary (Option 3) and one secondary option (Option 10 - with alterations) feasible for South Shaft. Each of these options will be summarized in the paragraphs to follow.

4.4.1. Primary Option

Surface Access and Positioning

- A portal could be created within the shaft area. This would be the most logical approach as the entire infrastructure to support this is in place and there are no additional issues (internal or external) involved.
- The portal will be situated some 350 m from the current infrastructure.
- The best position would be between the UG2 and MR horizons, as this would be in competent ground and provide easy access to both the existing MR haulages and future UG2 workings. The middling between the two horizons at South Shaft is approximately 70 m which gives adequate space to develop the decline without impacting on the workings.
- The chairlift installation will begin at the exit from the existing lamp room with the overland walkway to the entrance of the chairlift decline. This walkway will be constructed over the existing road to South D mine as well as over the rehabilitated opencast. The entire walkway will be 353 m in length. From there the chairlift decline will be developed in a straight line

directly to level 6. Landings will be provided at each level through which access to the workings (current MR and future UG2) will be achieved.

- Mining from level 2 to the tail of the chairlift at level 6 could start from five different attacking points. Mining from surface to level 2 could only be done from underground due to surface infrastructure limitations. No access is required to level 1. From the scheduling done it was found that the installation from level 2 to the tail will be completed before the development from level 2 to surface is completed. Thus, this is definitely the bottleneck of the South Shaft chairlift installation. This installation will take another two months once the development is completed.
- The SWOT analysis is very similar to North Shaft with the difference in life of mine of 40 years and only having five attack points available. The only additional weakness is the very long overland walkway. There is however the opportunity to install an overland chairlift as an alternative to the overland walkway.

Geology and Rock Engineering

- The chosen path of the proposed chairlift decline is largely overstoped on the MR horizon and the geology is therefore well known.
- Stratigraphically the chairlift decline will lie almost entirely in FW7 - characteristically a very competent horizon of Norites and Anorthositic Norites. There is no way of traversing the mine from surface to level 6 without crossing all four features / geological structures that contribute to the major known geological losses. These features / geological structures have traditionally been used to divide the mine into Structural Zones. These features are: Randall's and Nyala Dykes, the UG2 Fault and the Shear Zone. In addition to these there are several minor faults, dykes and sills. The sills will require some secondary support as per recommendations from rock engineering department.
- The unavoidable structural knot between levels 4 and 5a will require special attention. Secondary support will also be required. Attention must also be given to the middling at the crossover positions of the chairlift decline and all the haulages (BRPM Geology Department, 2008; BRPM Rock Engineering Department, 2008).

Ventilation

- The ventilation planning and design is similar to that of North Shaft.

Development and Construction Schedule

- Similar planning parameters and scheduling rates were used as at North Shaft.
- From the scheduling it was concluded that the total duration to complete the development was 15 months. The total metres that needed to develop were **1,727 m**.
- The construction will be concurrent with the development. Once a leg between two levels is completed, it will be constructed. The only bottleneck would be the first leg from surface to level 2. It would take two additional months to complete. Thus the total development and construction duration would be **17 months**.

Estimated CAPEX

- The estimated CAPEX on the mining costs was based on the fact that the development would take 15 months and the total metres that needed to be developed were 1,727 m.
- It was assumed that the development would be conducted by making use of AAP's CDS which are currently developing the Phase 2 declines on both shafts. The development cost used is as per agreed rate per cubic metre with CDS. The rate used was **ZAR 3,452/m^3**.

- The chairlift costs (infrastructure and installation) were obtained from Sareco, who was installing the Phase 2 chairlifts on both shafts.
- The overland walkway was also included in the estimate at a cost of approximately **ZAR 5.6 million**.
- The total estimated CAPEX for chairlift decline at South Shaft would be approximately **ZAR 101 million**.

4.4.2. Secondary Option (with alteration)
Platform Modifications

- These modifications are exactly the same as at North Shaft with the only difference the amount of levels that are six compared to the five at North Shaft.
- The estimated CAPEX to do the modifications to the platform areas is approximately **ZAR 1.2 million**.

Addition of an Intermediate Conveyor Belt for Alighting

- These modifications are exactly the same as at North Shaft with the only difference the amount of levels that are six compared to the five at North Shaft.
- The estimated CAPEX to do the modifications is approximately **ZAR 1.1 million**.

Addition of Overhead Endless Ropeway for Alighting Assistance

- These modifications are exactly the same as at North Shaft with the only difference the amount of levels that are six compared to the five at North Shaft.
- The estimated CAPEX to do the modifications is approximately **ZAR 0.6 million**.

4.4.3. Summary of South Shaft Estimated CAPEX (Primary and Secondary Options)

The total estimated CAPEX for the total South Shaft could be viewed in Table 4.4.3. This is based on the assumption that the secondary options would be implemented while the development of the chairlift decline is in progress. This would have an immediate impact on safety. The implementation of the secondary options could be quick compared to the 35 month project duration of the chairlift decline.

Table 4.4.3: Total Estimated CAPEX – South Shaft

Item	Quantity	Price per Unit (ZAR)	Total (ZAR)
Primary Option			
New Chairlift Decline			
South Shaft Total	1,727 m (incl. walkway)	52,160	100,877,608
Secondary Options			
Modifications to Platform Areas			
South Shaft Total	6 levels	205,085	1,230,508
Intermediate Conveyor			
South Shaft Total	6 levels	185,368	1,112,210
Endless Rope Arrangement			
South Shaft Total	6 levels	106,022	636,131
Grand Total			**103,856,457**

4.5. Analysis and Evaluation of BRPM Results

In an attempt to reduce injuries on the conveyor belt, VSD was installed at both shafts at the end of 2008. The cost of implementation was ZAR 7.8 million. The intention was to reduce the belt speed to 1.5 m/s when personnel are riding the conveyor belt. A reduced impact of 47% was simulated by Anglo Technical Division (Jele, 2008). The calculated financial impact at that stage would have been ZAR 52.4 million per month if a belt speed of 1.5 m/s was maintained. The decision was taken by mine management to increase the belt speed to 2.0 m/s when personnel are travelling on the belt. However the impact was still persisting with possible losses of ZAR 26.2 million per month as a result of not achieving Business Plan targets. A very tight shaft schedule will have to be implemented to ensure that personnel only travel on the belt when the speed was reduced. Thus, the VSD's as a stand-alone are not the solution for BRPM. However, in conjunction with the reduction in belt speed, belt training was also reviewed. Sirens were implemented as early warning devices to notify personnel to get off at each level. Cushions were also installed against the rails at each of the landing areas. A soft start and stop mechanism was also installed. All these initiatives had a definite impact on the safety performance since the introduction towards the end of 2008 (refer to Figure 1.4.2), but the accidents / incidents have not been eliminated as a whole. Other options will have to be implemented to ensure the belt is running at design capacity delivering the planned tonnages with no harm to the safety and health of the employees.

The primary and secondary options considered, would not only reduce the risks of accidents / incidents, but it would also allow the mine to utilise the design capacity of the belt 24 hours a day. The total estimated CAPEX for both primary and secondary options at BRPM is approximately **ZAR 200 million**. This amount is relatively small compared to possible safety stoppages. It should also be emphasised that these options would play a vital role in the remaining 40 to 50 years of the estimated LOM.

When considering chairlifts as an option compared to conveyor belt riding, it was a known factor that some sacrifices were to be made to ensure the safety of personnel. The simulation conducted by Simulation Engineering Technologies (Nichol, 2009) proved this statement. Travel time is expected increased by 33 % as a result of severe queuing. The impact of this increase is that personnel would spend less time in the working areas. The only option to encounter this phenomenon is to have a pre-determined shaft schedule (per level – beginning of shift and end of shift) to reduce queuing times.

After the completion of the study, an application for CAPEX was submitted to continue with the primary options (new chairlift decline with new infrastructure) at both North and South Shafts. The decision by the RBH Executive Committee, based on the current economic climate and the financial position of BRPM, was to only approve the North Shaft CAPEX application. The sinking of the chairlift decline at North Shaft is currently in progress.

With the delay in continuing with the South Shaft new chairlift decline, BRPM will continue facing the risk of safety stoppages as a result of accidents / incidents due to conveyor belt riding. The opportunity of utilising the design capacity of the belt through increased productivity will remain lost.

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CHAPTER 5

CONCLUSIONS

5. CONCLUSIONS

This chapter contains the conclusions made after conducting the study on personnel transportation at BRPM.

a. Motivation for the study:

- The existing conveyor belt utilized for personnel transportation, installed in the Phase 1 areas of both shafts, was equipped with platforms for getting on and off the belt as well as an array of safety devices which were designed to ensure the safety of personnel travelling on the conveyor belt.
- Despite all the initiatives incorporated to mitigate the risk, BRPM has experienced a very bad track record with regards to conveyor belt safety as a result of personnel transportation. 106 injuries were recorded / reported between 2006 and May 2013.
- Since the introduction of chairlifts in the Phase 2 areas of both shafts in 2004, BRPM has not recorded a single accidents / incidents. According to the safety statistics it is clear that the chairlift installation is the safer method for the transportation of people down and out the mine.
- There is a specific belt training facility on the mine. Even with this intensive training program, accidents / incidents continued to occur.
- The risk of safety stoppages could be imposed should there be another belt accident / incident that would have a major impact on the mine, both in terms of production and financial performance.
- This resulted in the need for the study, to identify the appropriate option / combination of options that would be safe in terms of personnel transportation and cost effective.

b. Literature Study:

- From the literature study conducted prior to commencing with the study, several options / combination of options were identified that were applicable for further investigation during the next phase of the investigation / study.
- These options included chairlift installation (in a normal decline or with the variation of utilizing a raise bore shaft for access between levels / connections), monorail transportation system, modifications to the current belt infrastructure and utilizing an endless rope haulage system whereby the material winder will be used for material / equipment and personnel transportation.
- There were also options identified that was not applicable for further investigation. These options included walking, the current personnel transportation system utilized at BRPM (underground conveyor belt utilized for both broken rock and personnel transportation), LDV's and personnel carriers / carriages. These options were discarded based on the configuration of the decline shafts, specific requirements from the BRPM, historical safety performance and mining methods dictating the number of personnel and compliance with the MHSA.

c. Results:

- The options / combination of options applicable for further investigation followed a process of Option Selection and Decision Analysis. No option was discarded until proven to be ineffective, unsafe, impractical and uneconomical.
- Initially seventeen different options were identified during P1. After following a process of elimination, the decision was taken to further investigate six options at North Shaft and nine options at South Shaft during P2. Finally only three options were selected at North Shaft during P3 of which one being a total new chairlift decline with infrastructure and two being modifications to the current conveyor belt infrastructure. There were five options selected at South Shaft during P3 of which three being total new declines with infrastructure and two being

modifications to the current conveyor belt and belt infrastructure. At the end of P3, there was only one primary and one secondary option proven feasible for each of the shafts.

- Throughout the different stages of the investigation / study, all relevant specific responsible departments were involved during the selection and analysis of the various options.
- The final primary options on both shafts were designed and scheduled through making use of the CADSMine Design and Scheduling software packages. The proposed design criterion was benchmark against actual achievements, in terms of production, construction and costs.

d. Analysis and evaluation of results:

- The development and construction of the chairlift decline would take 14 and 17 months for North Shaft and South Shaft respectively. 1,934 m and 1,727 m of development will have to be done at a rate of 32 m/month and cost at ZAR 3,099/m^3 and ZAR 3,452/m^3 for North Shaft and South Shaft respectively. The total estimated CAPEX would be approximately ZAR 93.6 million and ZAR 100.9 million for North Shaft and South Shaft respectively.
- The secondary options included modifications to the current conveyor belt infrastructure. The total estimated CAPEX for these modifications at North Shaft and South Shaft were calculated as approximately ZAR 2.5 million and ZAR 3 million respectively.
- The total estimated CAPEX to implement both the primary and secondary options at North Shaft and South Shaft were calculated as approximately ZAR 96 million and ZAR 104 million respectively. The total for BRPM being calculated as approximately ZAR 200 million. This CAPEX spend will have a direct impact towards an improved safety record through eliminating accidents / incidents related to personnel transportation. This statement is proved by the fact that since the introduction of chairlifts in the Phase 2 areas of both shafts in 2004, BRPM has not recorded a single accidents / incidents. It is clear that the chairlift installation is the safer method for personnel transportation at BRPM.
- The installed VSD's on the current personnel transportation belts at BRPM will on its own not be the solution. The reduction in conveyor belt speed to 2.0 m/s definitely had an impact with regards to reducing accidents / incidents since the installation towards end of 2008. The risk of safety stoppages was still evident with associated losses. However the reduction of accidents / incidents was not sufficient. The impact of reducing the belt speed to 1.5 m/s (refer to Target mine in Literature study) were considered not economical viable for BRPM. This could have resulted in further reduction of accidents / incidents. Other options will have to be implemented to ensure the belt is running at design capacity and safety of personnel is improved and eliminated.
- The implementation of chairlifts will result in an increase in travelling time (33 %) as a result of the speed of the chairlift and the spacing of the seats. This increase in travelling time is mainly as a result of severe queuing. A proper shaft schedule will resolve this problem.

CHAPTER 6

RECOMMENDATIONS

6. RECOMMENDATIONS

This chapter contains the recommendations made after conducting the study on personnel transportation at BRPM.

- The mine should start immediately with the secondary options which will result in reduced risks in terms of accidents / incidents while still utilising the belt for personnel transportation. This will also reduce the risk of safety stoppages which will minimise unnecessary losses. The total estimated CAPEX for these secondary options was calculated as approximately ZAR 5.5 million. The implementation of these options could be very quick compared to the 32 and 35 months that would be required for fund approval, development and construction of the primary options at North Shaft and South Shaft respectively. This will buy the mine some time to complete the formal approval processes. Once the funds are available, the shafts could start immediately with the development of the chairlift declines.

- Development of the chairlift declines should start on available MR levels concurrently. The construction of infrastructure and the development of the chairlift declines should happen concurrently. As soon as a leg between two levels is completed, it should be constructed. This will ensure that the project schedule is achieved.

- Once the chairlift decline has been commissioned, it is very important to have a pre-determined shaft schedule in place. A schedule that focuses on each level (beginning of shift and end of shift). A proper shaft schedule will prevent excessive queuing that would increase the total travelling time and ultimately reduces the time personnel actually spend in the workplace.

- Once the chairlift decline has been commissioned, the ultimate design speed of the conveyor needs to be determined through adjustment of the installed VSDs. This could have a significant positive spin-off increasing the tonnage output form the shafts.

- The belt maintenance schedule needs to be reviewed as unnecessary personnel detecting safety devices could be removed. This will reduce the maintenance duration and intervals required.

- To fulfil the objectives / scope of this investigation / study, it is recommended that both primary and secondary options be considered for implementation on both North Shaft and South Shaft to reduce / eliminate accidents / incidents as a result of belt transportation. The associated CAPEX would be approximately ZAR 200 million. Considering the future impact on the business as a whole, this would definitely be CAPEX well spend!

CHAPTER 7

SUGGESTIONS FOR FURTHER WORK

7. SUGGESTIONS FOR FURTHER WORK

This chapter contains the suggestions for further work made after conducting the study on personnel transportation at BRPM.

During the final design and scheduling of the chairlift declines, the following should be considered and incorporated:

- A proper portal design will be required in the weathered zone.
- The size of excavations should be minimized and important excavations should not be sited in areas where known features exist.
- Placement of the excavations should be planned properly to avoid sterilization of the UG2 ore reserves.
- Slower development rates should be applied / planned through known features such as the weathered zone, Shear Zone and UG2 Fault. A robust support design will also be required when mining through these features and while intersecting sills as per rock engineering recommendations.

Considering the above, would require re-evaluation of the project duration and the CAPEX required.

The future planning for North Shaft indicates that the shaft will be developed to level 13 with production from the UG2 stopes in the upper levels of the mine taking place concurrently with MR stoping in the lower levels. Although total output from the shaft will remain constant the geographic diversity of the operations is likely to put additional strain on the materials handling system. For this reason it is suggested to investigate developing a decline of sufficient width (6 m) to accommodate both a chairlift and a winder system for materials transport. This would have the effect of almost doubling the CAPEX of the decline and raise several safety issues with regard to transporting men and material in the same excavation. A detailed simulation of the logistics should be carried out in order to ascertain the risk to production before making a decision in this regard.

It should be investigated if the installation of the secondary options / modifications to the current belt infrastructure would require additional OPEX with regards to increased electricity consumption, additional engineering requirements (maintenance and break downs) and labour.

The additional OPEX requirements as a result of the chairlift installations on both shafts will have to be considered. This will include the following:

- Normal running of the chairlift and costs associated with increase in electricity consumption and maintenance (preventative maintenance and break downs).
- Labour requirements in terms of chairlift attendants and engineering personnel responsible for maintenance. Training requirements should also be considered.

The trade-off between the above mentioned and the possible savings once the chairlifts are commissioned should be determined. Once the conveyor belt is only utilized for broken rock transportation, huge savings could be encounter due to less maintenance with specific reference to safety devices as well as possible reduction in labour numbers (both belt attendants and engineering personnel).

The increase in the availability of belt time as well as the increase in conveyor belt speed will have to be determined. This will lead to an increase in belt capacity and overall potential increase in tonnage output from the shafts. The business planning process will have to be revisited to utilize this potential. This could have a definite financial benefit to BRPM and its stakeholders.

APPENDICES

APPENDIX A

THE MINE HEALTH AND SAFETY ACT (ACT 29 OF 1996)

Chairlifts

- **Application for use**

16.105 No chairlift installation shall be used for the conveyance of persons unless it is permitted by a prescribed permit for such installation. [inserted by G.N.R2449, 1993]
16.106 No chairlift shall be installed in any portion of a mine or works where winding plants or moving machinery operates unless the persons using and operating the chairlift are adequately protected from the conveyances, other winding equipment or moving machinery or unless it is so arranged that simultaneous operation of the chairlift and the winding plant or other machinery is impossible.
16.107 The manager of a mine or works who intends to install and use or modify a chairlift after inurement of this sub regulation shall timeously apply in writing to the *Principal Inspector of Mines* for permission to do so before such installation or modification is commenced. [amended by G.N.R.94, 15.1.97]
16.108 Each application for permission to install, modify and use a chairlift shall be accompanied by -
(a) dimensioned drawings in plan, elevation and section to the scale of at least 1 in 100;
(b) the manufacturer's or supplier's specifications of the proposed installation; and
(c) full particulars of all ropes and chains intended for use in the installation.
16.110 In addition to the requirements of these regulations the *Principal Inspector of Mines* may grant permission to use a chairlift subject to such conditions as he may specify. [amended by G.N.R.814, 13.3.1992] [amended by G.N.R.94, 15.1 .97]

- **Use of chairlifts**

16.111 No chairlifts shall be used unless -
16.111.1 it is of good construction, sound material, adequate calculated strength and free from any patent defect;
16.111.2 it is so used that the safety of persons is not endangered;
16.111.3 the axis of its line of operation, in plan, between stations, is a straight line;
16.111.4 the slope of the loaded hauling rope or traction chain is less than 45 degrees;
16.111.5 the distance between the centre lines of two passing chairs or carriers is 900 mm or more and the distance from the centre line of a chair or carrier to a handrail or handrail support or to the sidewall is 500 mm or more along the entire operating length of the chairlift:
Provided that at all landing and boarding sites the clearance from the centre line of the chair to the outside is at least 1.5 metres;
16.111.6 the vertical clearance between the underside of a chair loaded with a passenger and the terrain below it, in underground installations, is not more than 1.5 metres or not less than 0.3 metres;
16.111.7 the minimum spacing in metres between any two consecutive carriers or chairs is equal to or greater than four times the velocity in metres per second for single-seat carriers or five times the velocity in metres per second for two-seat carriers where passengers board and leave simultaneously, or seven times the velocity in metres per second for two-seat carriers where passengers board and leave one after the other.
16.111.8 the gradient at boarding and landing sites is not more than six degrees and the length of both boarding and landing sites is 6 metres if the installation is designed to convey less than 500 persons per hour and 8 metres if the installation is designed to convey 500 or more persons per hour

or equal to the minimum spacing of carriers called for in regulation 16.111.7, whichever is the greater;
16.111.9 the speed of operation does not exceed 1.5 metres per second for a fixed grip system and does not exceed 3 metres per second for a detachable grip system;
16.111.10 all components which, whilst in motion, may be a source of danger are out of reach of a passenger when seated normally on the chair;
16.111.11 the type of carriers used are of a design and construction approved by the *Principal Inspector of Mines* and are either – [amended by G.N.R.94, 15.1.97]
(a) chairs with no seat equipped with a footrest;
(b) chairs with two seats, providing a seating width of not less than 0,5 metre per person, and equipped with suitable footrests;
(c) special, easily detachable receptacles attached to the chair or containers to permit the transport of material; or
(d) special stretcher carriers used for the transportation of stretcher cases.

- **Suitability of rope or chain**

16.112 Any rope used on a chairlift shall be made of steel wire and the bending stiffness of the rope shall be suited to the diameter of the sheaves.
16.112.1 Any chain used as a traction chain on a chairlift shall be manufactured from a class of steel approved by tile *Chief Inspector.* [amended by G.N.R.94, 15.1.97)
16.112.2 No rope or chain shall be used on a chairlift if the calculated breaking force at any point is less than nine-tenths of the breaking force of tile rope or chain when it was new.
16.112.3 Where a traction chain or rope is used on a chairlift with the carriers running in or on a rope or rail circuit, a safety rope or ropes clamped to each carrier shall be provided to prevent runback in the event of the traction chain or rope breaking.
16.112.4 Any rope or chain forming part of a chairlift installation shall have factor of safety of at least six, calculated on its static load.
16.112.5 In ca1rulating the total mass of persons for the purpose of regulation 16.112.4, 70 kilograms shall be allowed for each person.
16.112.6 Splices in ropes forming part of a chairlift installation shall be made by experienced persons and the length of such splice shall not be less than 1 200 times the rope diameter.
Whenever clamps are used on ropes the clamps used shall be sufficient in number to ensure an efficient joint.
16.112.7 Except with the written permission of the *Principal Inspector of Mines*, not more than two splices shall be allowed along a closed loop formed by a carrying-hauling rope. Where more than one splice is made the clear distance between successive splices shall be at least 3 000 times the diameter of the rope. [amended by G.N.R.94,15.1.97]

- **Carrying-hauling rope**

16.113 The force exerted by a carrying-hauling rope on each supporting roller shall be positive when the system is operating unloaded.

- **Carrier**

16.114 The carrier of a chairlift installation shall be free to incline itself in the direction of travel with respect to the vertical by an amount equal to the inclination of the installation. Swinging shall be restricted to within practical limits.

- **Passage of the carriers**

16.115 The passage of the carriers around the sheaves shall not be a source of danger to passengers who have been unable to alight.

- **Driving motor**

16.116 The driving motor of a chairlift installation shall be -
16.116.1 of adequate power to ensure starting the chairlift under the most unfavourable conditions;
16.116.2 stopped automatically when any brake is applied or if any safety device is operated;
16.116.3 provided with a reverse phase relay or other equivalent protection to prevent the reversal of the driving motor through and inadvertent reversal of the phases if the motor is supplied with polyphase alternating current.

- **Brakes**

16.117.1 Every chairlift installation shall be equipped with two independent brakes, a main brake and a back-up brake, so designed that either brake, is capable of holding, without slipping, the chairlift installation when loaded in such a way that the maximum static torque is produced on the brake. The provisions of this sub regulation are applicable even if the installation is filled with a special device which will automatically prevent reverse movement of the carriers.
16.117.2 Both brakes shall be so designed that they are automatically applied when the power supply to the driving motor is interrupted or if any safety device is operated.
16.117.3 The main brake of the chairlift shall operate on the driving sheave or on the shaft of the driving sheave and not on any intermediate shaft.

- **Emergency stopping device**

16.118 An emergency stopping device, which interrupts the power supply to the driving motor, shall be provided along the full length of the chairlift installation and shall be so arranged that it can easily be brought into operation by any passenger travelling on the chairlift.

- **Boarding and landing site for passengers**

16.119 Every passenger boarding and landing site as well as the entire length of the chairlift installation shall be adequately illuminated at all times underground and at night on the surface, whenever the chairlift is in use.

- **Warning system**

16.120.1 Except where some other warning system, approved by the *Principal Inspector of Mines*, is installed, every chairlift installation shall be equipped with an alarm or warning system, audible along the entire length of the installation, and such alarm or warning system shall be actuated automatically before the chairlift is set in motion. [amended by G.N.R.94, 15.1.97]

- **Emergency ladderway**

16.120.2 Every place where a chairlift is installed such that the inclination exceeds 20 degrees from the horizontal and where passengers are able to alight anywhere along its length when it is stationary, shall be provided with an emergency ladderway so arranged that it is either separate from the installation or situated between the carriers.

- **Chairlift attendants**

16.120.3 Where the ladderway is between the carriers chairlift attendants responsible for starting and stopping the installation shall be stationed at each boarding and landing site and their duty shall also be to ensure that the chairlifts is not set in motion whilst persons are on the ladderway.

- **Handrail**

16.120.4 Where the ladderway is separate from, but adjacent to, the chairlift installation, it shall be provided with a smooth handrail separating it from the chairlift.

- **Transport of goods and persons**

16.121.1 No person shall travel on a chairlift with material other than articles which are unlikely to endanger him or any other person and for which permission has been granted by the manager, mine overseer or an engineer or competent person appointed in terms of regulation 2.13.2, as the case may be. [amended by G.N.R.160, 1.2.1991]
16.121.2 At all boarding and landing sites the manager shall cause a list to be kept of all articles for which permission has been granted in terms of regulation 16.121.1 and he shall ensure that all persons concerned are made aware of the articles included in the list.
16.122 No person travelling on a chairlift and no person in the vicinity of a chairlift installation shall in any way interfere or attempt to interfere with the equipment of the chairlift or any other person travelling on the chairlift or any other person who is in the vicinity of the chairlift.

- **Inspection**

16.123.1 The complete chairlift installation or any part thereof shall be examined regularly by such persons and at such intervals as may be determined by the [an engineer or competent person appointed in terms of, regulation 2.13.2, as the case may be] having due regard to the duty and frequency of operation of the installation: Provided that the *Principal Inspector of Mines* may insist on more frequent inspections or inspections by such other persons as he may deem necessary. [amended by G.N.R.160, 1.2.1991] [amended by G.N .R.94, 15.1.97]
16.123.2 A written record of each such inspection shall be kept by the person or persons responsible for the inspection in a book specially provided for the purpose by the manager.

APPENDIX B

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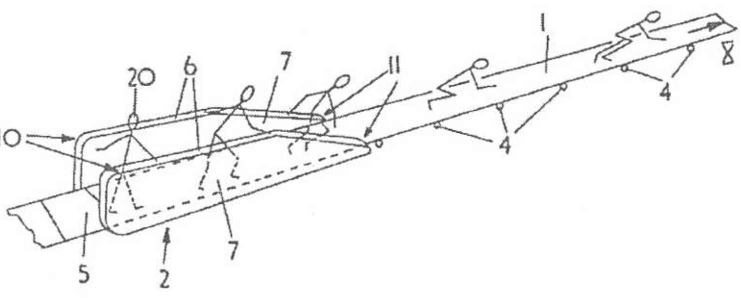
(54) **Manriding conveyor equipment assisting transfer to or from conveyor**

(57) A mounting and/or dis-mounting station (2) is provided for assisting passengers mounting on or dis-mounting from a manriding conveyor (1) or transferring from one conveyor to another conveyor, the station comprising a mounting or dis-mounting section, for example, a stationary platform (5) and a moving handrail (6) adapted to move in the same direction as the associated conveyor and extending between a relatively high location (10) adjacent to the mounting or dis-mounting section and a relatively low location (11) at a position relatively remote from the mounting or dis-mounting section.

FIG. 2



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

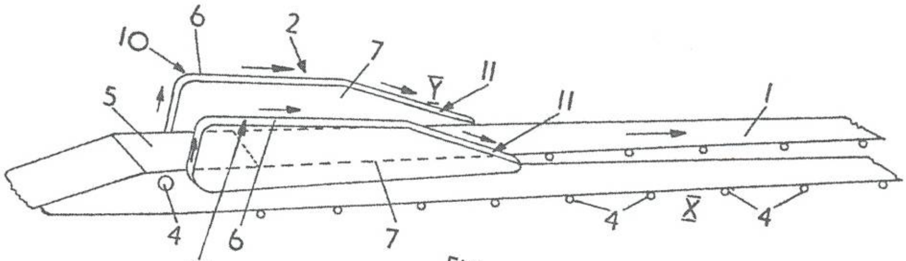


FIG. 1

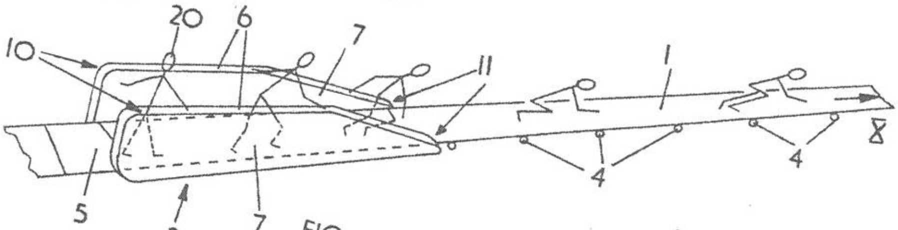


FIG. 2

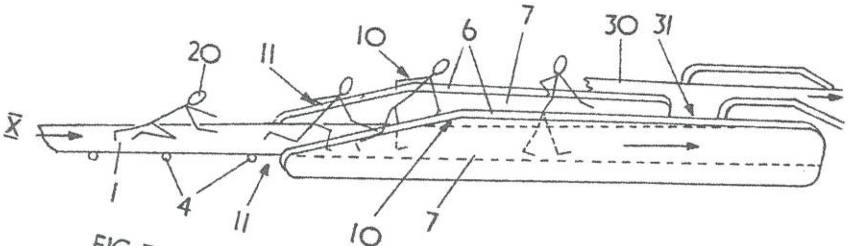


FIG. 3

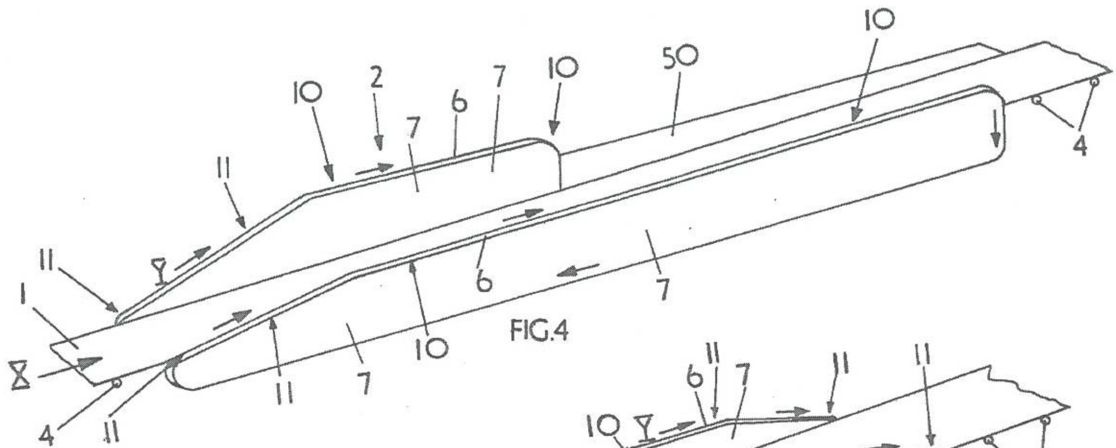


FIG. 4

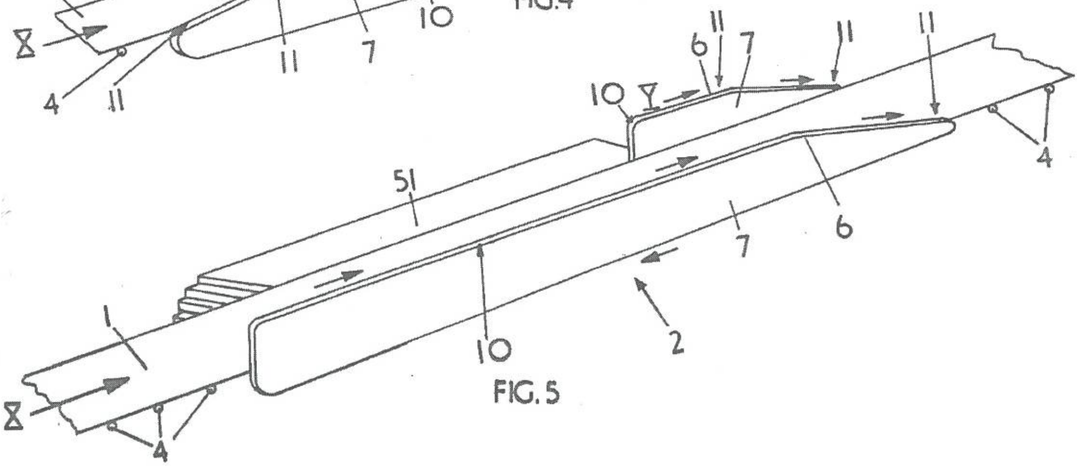


FIG. 5

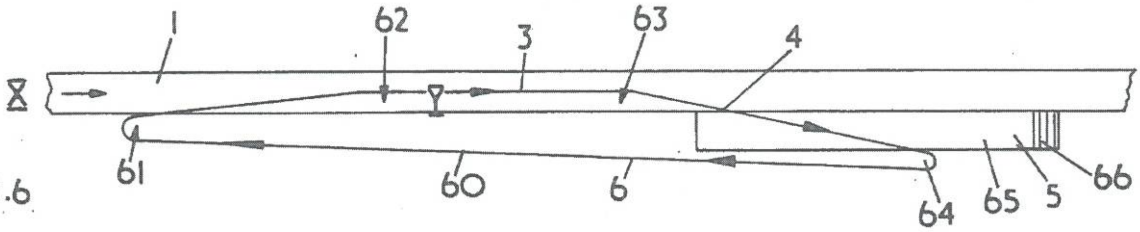


FIG.6

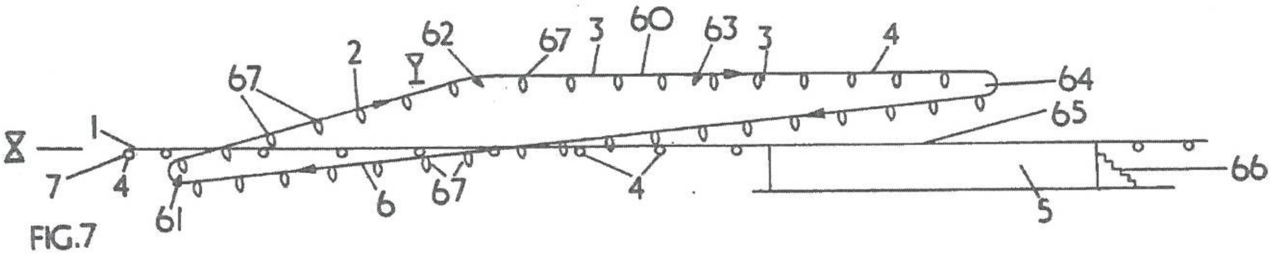


FIG.7

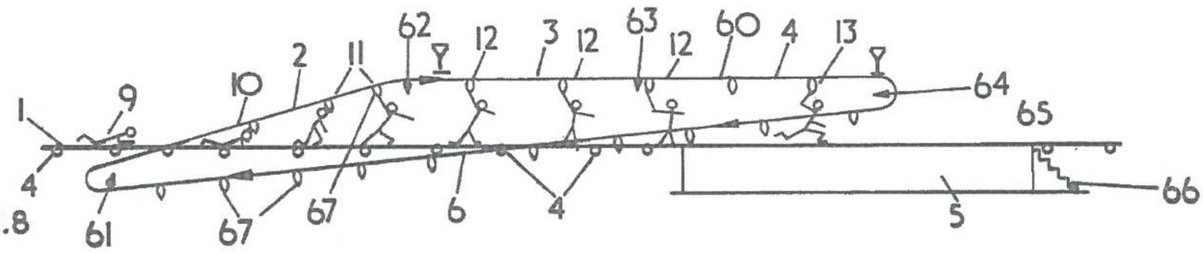


FIG.8

SPECIFICATION

Manriding conveyor equipment

This invention relates to manriding conveyor equipment.

In particular, although not exclusively, the present invention related to manriding conveyor equipment for use with relatively fast speed conveyors.

It is known, for example, in underground mines to have endless belt manriding conveyor equipment installations with mounting and dis-mounting transfer stations provided at appropriate locations along the length of the conveyor, the installations being used to transport miners along the underground roadways towards and/or away from their place of work on the working rock or mineral faces. The known mounting and dis-mounting transfer stations typically comprise a stationary platform which the miners use in getting on or off the moving conveyor belt.

As time passes and the working progressively becomes more remote from the mine shafts it is desirable to reduce the miners' travelling time by employing relatively fast speed conveyor equipment. Unfortunately, at conveyor speeds above about two to four meters per second it becomes difficult and potentially dangerous for passengers to transfer from the mounting transfer station to the relatively fast moving conveyor or vice versa.

An object of the present invention is to provide manriding conveyor equipment which tends to overcome or reduce the above mentioned problems.

According to the present invention manriding conveyor equipment for assisting passengers to mount on or to dis-mount from a moving conveyor comprises a mounting or dismounting transfer station and a passenger stabiliser, the stabiliser being adapted to extend along the general direction of the conveyor and to extend between a relatively high location adjacent to the transfer station and a relatively low location at a position relatively remote from the transfer station.

Preferably, the stabiliser is movable in the conveying direction.

Conveniently, the stabiliser comprises at least one movable component for engagement by passenger.

Advantageously, the movable component comprises an effectively endless handrail.

Alternatively, the movable component comprises a plurality of elements movable in series around an effectively endless track.

Preferably, the elements are hauled around the track by an effectively endless elongated member.

Preferably, the mounting or dis-mounting transfer station comprises a stationary platform.

Preferably, the platform is adapted to extend over the conveyor.

Conveniently, where it is desired to transfer passengers from one conveyor to another conveyor, the conveyors running alongside one another, the conveyor equipment comprises a central transfer station with two passenger stabilisers arranged on opposite sides of the transfer station.

Preferably, at least portions of the two stabilisers are aligned.

By way of example only, four embodiments of the present invention will be described with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic perspective view of manriding conveyor equipment constructed in accordance with one embodiment of the present invention;

Figure 2 is a diagrammatic perspective view of equipment of Figure 1 being used by a passenger to mount a conveyor;

Figure 3 is a diagrammatic perspective view of manriding equipment constructed in accordance with a second embodiment of the present invention, the equipment being used by a passenger to transfer from one conveyor to another conveyor;

Figure 4 is a diagrammatic perspective view of manriding equipment constructed in accordance with a third embodiment of the present invention, the equipment assisting passengers dismounting from the conveyor;

Figure 5 is a diagrammatic perspective view of manriding equipment similar to that of Figure 4, the equipment assisting passengers mounting on the conveyor;

Figure 6 is a diagrammatic plan of manriding equipment constructed in accordance with a fourth embodiment of the present invention;

Figure 7 is a diagrammatic side view of the equipment of Figure 6; and

Figure 8 is a similar diagrammatic side view to Figure 7 and showing a passenger dismounting from the conveyor.

Figure 1 of the drawings shows a portion of a manriding belt conveyor 1 adjacent to manriding conveyor equipment 2 constituting mounting equipment for assisting passengers to mount the belt conveyor which is running at a relatively high speed in a direction indicated by arrow X and which is carried on a plurality of conveyor idler rollers 4 arranged along the length of the conveyor.

The mounting equipment includes a mounting transfer station comprising a stationary platform 5 extending along and over the conveyor 1 and two parallel passenger stabilisers constituted by moving handrails 6 each supported on a guide framework 7 and moving substantially at the same relatively high speed of the conveyor 1 and in the same direction as the belt conveyor 1, the direction of movement of the handrails being indicated by arrows Y. Each handrail 6 extends between a relatively high location 10 adjacent to the platform 5 and a relatively low location 11 at a position relatively remote from the platform, the handrail in the vicinity of location 10 extending substantially parallel to the conveyor 1 and in the vicinity of location 11 being inclined downwardly towards the belt conveyor height. The handrail then returns along the bottom of the framework 7 before climbing vertically back to the relatively high location 10.

Figure 2 illustrates the mounting equipment 2 being used by a passenger 20 who first climbs steps (not shown) to reach the elevated platform 5. The passenger then steps onto the moving belt conveyor 1 with his hands grasping both handrails 6 at the relatively high location 10. Thus, upon stepping onto the conveyor the passenger remains in a stable standing position. Next the passenger prepares to step forward so that by the time he reaches the downwardly inclined portion of the handrail he is able to maintain hand contact on the handrail by first crouching and subsequently laying down in a prone position as indicated in Figure 2. Thus the mounting equipment assists the passenger mounting onto the moving conveyor.

Upon the passenger arriving at his desired dis-mounting equipment he grasps the handrail while in the laid down prone position, the dis-mounting equipment being arranged the opposite way round to the mounting equipment so that the oncoming passenger first encounters the handrail at the relatively low location. (A similar situation is shown in Figure 3.) As the handrail moves up the inclined portion towards the relatively high location the passenger performs the reverse procedure to that described on mounting the conveyor. He first moves to a kneeling position, then a crouch position and subsequently a standing position, all the time being assisted by the handrails. Upon reaching the dis-mounting equipment comprising a transfer station constituted by a stationary platform he steps off the conveyor onto the platform and then climbs onto the mine floor.

Figure 3 illustrates an installation of a transfer equipment where the passenger is transported from a relatively low speed conveyor 1 to a relatively high speed conveyor 30, the two conveyors running alongside one another in the vicinity of the central transfer station.

The transfer equipment comprises two pairs of handrails 6 (similar reference numbers being used for similar features described previously with reference to Figures 1 and 2). One handrail in each pair being aligned with one handrail of the other pair, both these aligned handrails being arranged between the two conveyors with a gap 31 between them. The gap constituting a central transfer station for dis-mounting from the conveyor 1 and mounting on the conveyor 30. Thus, upon the passenger reaching the gap 31 he is able to stride from conveyor 1 onto conveyor 30 which as previously stated is travelling at a relatively high speed compared to the speed of conveyor 1. Again the passenger is assisted by the handrails into a laid down position on the conveyor 30.

A similar transfer arrangement is provided at the remote end of conveyor 30 so that the passenger can dis-mount from the relatively high speed conveyor onto a relatively slow moving conveyor which may be provided with a dismounting station as described previously with reference to Figures 1 and 2.

Figures 4 and 5 show a third embodiment of manriding conveyor equipment constructed in accordance with the present invention. Figure 4 shows the equipment being used to assist passengers dismounting from the conveyor belt 1 at a location along the length of the conveyor, i.e. the dis-mounting equipment is not located at the ends of the conveyor and therefore it must not hinder passengers wishing to travel beyond the intermediate transfer equipment.

Figure 5 shows equipment similar to that shown in Figure 4, the equipment being used to assist passengers mounting on the conveyor belt 1 at an intermediate location remote from the ends of the conveyor.

The equipment shown in Figures 4 and 5 is somewhat similar to the equipment previously described with reference to Figures 1 and 2 and the same reference numbers have been used for similar items.

The main differences between the transfer stations of Figures 4 and 5 compared to Figures 1 and 2 are that the two moving handrails 6 provided by each set of equipment are of differing length. One of the handrails extending at the relatively high location along the opposide side of the conveyor to the transfer station constituted by a stationary platform 50 and 51. As shown in the drawings the stationary platforms extend along one side of the conveyor and not over the conveyor as the platform disclosed in the first described embodiment. The side located platform 50 and 51 permit passengers who do not wish to dis-mount the conveyor at the intermediate transfer equipment to continue their journey unhindered.

Figures 6, 7 and 8 show a fourth embodiment of manriding conveyor equipment constructed in accordance with the present invention.

The fourth embodiment comprises a passenger stabiliser constituted by an effectively endless elongated member 60 which is hauled around an endless track (not shown) comprising guide pulleys for the elongated member and drive means to haul the member around the track in the direction indicated by arrows Y. As seen in plan in Figure 6 the endless track moving from left to right first crosses from a location 61 adjacent to the side of the conveyor belt to a location 62 directly over the conveyor belt and then crosses from a location 63 directly over the conveyor belt to a location 64 adjacent to the side of the conveyor belt, the location 64 being situated adjacent to a transfer station constituted by an elevated stationary platform 65 provided with steps 66.

From Figures 7 and 8 it can be seen that the track adjacent to location 61, i.e. relatively remote from the transfer station 65, is at a relatively low location and that the track is inclined upwards towards the relatively high location 62, the track maintaining its relatively high position through location 63 to location 64.

A plurality of stabilising elements 67

comprising suspended hand grips are hauled in series around the endless track by the driven elongated member 60.

Figure 8 illustrates the fourth embodiment of dis-mounting equipment in use. A passenger wishing to dis-mount the conveyor and approaching the transfer equipment in a lying down prone position first clasps a conveniently positioned hand grip 67 adjacent to the relatively low location 61. As the passenger travels towards the transfer station 65 he progressively climbs to a standing position, all the time tightly gripping the hand grip which thereby tends to steady and stabilise the passenger. By the time the passenger reaches the relatively high location 62 he is fully standing with the clasped hand grip 67 now situated directly overhead. While travelling between locations 62 and 63 the passenger prepares to dis-mount the conveyor which he accomplishes while travelling between locations 63 and 64. Once on the stationary platform 65 the passenger releases the hand grip 67 and descends the stairs 66.

A similar procedure, but in reverse, is adopted when mounting on the conveyor, the mounting equipment being the same as the dis-mounting equipment except that the endless elongated member 60 is hauled in a direction away from the transfer station. As with the previously described embodiment, a passenger clasps a convenient stabilising element at a relatively high location while stood on the stationary platform and thereby is stable while mounting on the conveyor in a standing position. By the time clasped stabilising element reaches the relative low location the passenger is lying down in a prone stable position on the conveyor belt.

From the above description it will be appreciated that the present invention provides manriding conveyor equipment for assisting passengers in mounting or dis-mounting conveyors, the equipment being relatively simple and robust.

CLAIMS

1. Manriding conveyor equipment for assisting passengers to mount on or to dis-mount from a moving conveyor, comprising a mounting or dismounting transfer station and a passenger stabiliser, the stabiliser being adapted to extend along the general direction of the conveyor and to extend between a relatively high location adjacent to the transfer station and a relatively low location at a position relatively remote from the transfer station.

2. Equipment as claimed in claim 1, in which the stabiliser is movable in the conveying direction.

3. Equipment as claimed in claim 2, in which the stabiliser comprises at least one movable component for engagement by passenger.

4. Equipment as claimed in claim 3, in which the movable component comprises an effectively endless handrail.

5. Equipment as claimed in claim 4, in which the movable component comprises a plurality of elements movable in series around an effectively endless track.

6. Equipment as claimed in claim 5, in which the elements are hauled around the track by an effectively endless elongated member.

7. Equipment as claimed in any one of the preceding claims, in which the mounting or dis-mounting transfer station comprises a stationary platform.

8. Equipment as claimed in claim 7, in which the platform is adapted to extend over the conveyor.

9. Equipment as claimed in any one of the preceding claims, in which it is desired to transfer passengers from one conveyor to another conveyor, the conveyors running alongside one another, the conveyor equipment comprises a central transfer station with two passenger stabilisers arranged on opposite sides of the transfer station.

10. Equipment as claimed in claim 9, in which at least portions of the two stabilisers are aligned.

11. Manriding conveyor equipment for assisting passengers to mount on or to dis-mount from a moving conveyor, substantially as described herein and as shown in Figures 1 and 2, or Figure 3, or Figures 4 and 5, or Figures 6, 7 and 8 of the accompanying drawings.

12. A conveyor installation comprising manriding conveyor equipment as claimed in any one of the preceding claims.

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APPENDIX C

DU PLESSIS, G.L. Material and personnel transport by endless rope haulage — the 21st century approach. *6th International Symposium on Mine Mechanization and Automation*, South African Institute of Mining and Metallurgy, 2001.

Material and personnel transport by endless rope haulage — the 21st century approach

G.L. DU PLESSIS
Dowding Reynard and Associates, South Africa

This paper describes the design, installation and operation of an endless rope haulage system recently built for and commissioned at Evander Gold Mines in Mpumalanga, South Africa. The factors which lead to the choice of such a system and the advantages gained over more commonly used winding systems are outlined.

Introduction

For many years, materials used in hard rock mines have been transported to the working areas underground down small-angle declines known as Material Declines.

Usually, the winding equipment consists of a comparatively small winch or winder with a power rating of 250kW or less. The material is transported in cars, running on rails in the decline. The cars are usually attached directly to the winding rope and often, a string of three or four cars, all attached to one another, are transported at once. Winding speeds are low, typically 2.5m/sec or less and because the installation is not used for the transport of personnel, the winder is not 'licensed' under the SA Mines Regulations.

It is also an inescapable fact that the standard of maintenance on these installations is generally poor and the tendency is that the only time such an installation receives any technical attention is when something breaks or does not function correctly.

The winder or winch itself is normally of very basic design, fitted with only the minimum of safety devices. The operators are usually semi-skilled people.

The frequency of accidents in these material declines has been high over the years, with runaways and derailments having been the chief causes of such accidents.

The kinds of accidents which occur are typically due to:

- Failure of the rope due to corrosion
- Failure of the rope due to mechanical damage such as abrasive wear or damage resulting from the material cars having run over the rope
- Failure of the rope attachment to the material car and failure of the attachments between the cars when more than one car is transported at once
- Derailments due to bad trackwork
- Derailments due to worn or damaged wheels and axles

Yet another common cause of accidental runaway is when the material decline starts on the horizontal before dipping to its angle of inclination. Such an installation requires that the material car is pushed towards the brow of the decline whilst the winder driver pays out slack rope. As the car traverses the brow, the slack in the rope is taken up and the speed of descent is then controlled by the winder driver. Frequently, too much slack is paid out and the speed of the car is too great by the time the slack is taken up, culminating in rope breakage. A rope weakened by corrosion or mechanical damage only serves to aggravate the situation, such that it often takes a comparatively small tensile force to break the rope.

There have been cases of rope breakage when the winder has tripped out during an ascending wind. Because of the rudimentary brakes usually fitted to these winders, no discrimination between the braking requirements of a descending and an ascending load is allowed for. Thus, the winder would stop too rapidly during an ascending wind, resulting in slack rope and then rope breakage when the attached load ran back.

Evander Gold Mines (EGM) no.3 Material decline

The current expansion of the underground operations at EGM involves the sinking of decline shafts at an inclination of 14 degrees from 15 level down to 19 level. These decline shafts are used for the transport of the ore by conveyor belts and of the personnel by means of chairlifts.

At the time that the endless rope haulage project was first considered, materials such as timber, explosives, machinery, building and construction materials, piping, rails, locomotives, hoppers and everything normally used in hard rock mining operations was being transported down one of these decline shafts, in which a conveyor belt had been installed, with front end loaders.

Not only was this a costly exercise because of the expense in running and maintaining the vehicles, but it was also slow and cumbersome, involving triple handling of the materials from the cars on 15 level, into the front end loader and back into cars on the lower levels, for transport to the working areas.

No 3 decline starts horizontally on 15 level for the first thirty or so metres and then dips to 14 degrees. This, coupled with the other problems associated with material declines described above, caused EGM management to reject the idea of replacing the front end loaders with a conventional winch/winder arrangement, yet an alternative to the front end loaders had to be found.

In addition, EGM management had considered the purchase of a monorail system to do the duty but had rejected it because of the cost.

It was then that the Engineering Manager of EGM approached the author and having recently visited the funicular railway at Cape Point, suggested a similar solution to the underground problem. The author proposed an endless rope haulage system and development of the concept into what culminated as the current installation. Dowding Reynard and Associates were thereupon appointed as Consultants and principle contractor for the project.

Operational and production requirements

The requirements were for a transport system that would handle up to 20 material cars to and from each of three levels below 15 level within a 24 hour period. The haulage system was to be installed in two stages, the first stage down to 18 level at a winding distance of approximately 800 metres from 15 level. The final length of the decline will be approximately 1100 metres, at 19 level.

The system was to be automated in terms of operation of the driving machinery, i.e. automatic acceleration to full speed, deceleration and stopping at the desired level.

Operation was to be performed by one man, with possibly an assistant for loading and unloading.

The system was to be installed into the same decline shaft as that which contained the man-riding chairlift so all regulations regarding minimum allowable clearances had to be complied with.

The endless rope haulage concept

Endless rope haulages have been in use in various forms for nearly 200 years. The principle employs a rope which has its two ends spliced together. The rope is driven by passing over a friction wheel which in turn is driven by a motor. The conveyances are fixed to the rope which pulls them along rails. Tension is maintained in the rope by a weight loaded tensioning car at the return end of the rope.

In South Africa before World War 2, endless rope haulages were popular forms of transport for material cars and coco pans carrying ore. They were used underground and on surface. On many installations the haulage rope ran continuously at about 1 metre per second and cars were attached and detached 'on the run'. In other cases, the haulage was started and stopped by the haulage driver and the loads attached or detached as required. With most of these systems, the rope ran over the top of the vehicle which it pulled. The vehicle ran on rails and when it reached its destination, it would be detached from the rope and pushed by hand through a rail switch and on to another track. Communication between the station attendants and the driver was by bell signals. Most of these haulages were uni-directional, with two adjacent tracks, an 'out-bye' and an 'in-bye', with the traction rope over one track and the return rope over the other. Loaded cars were attached to the traction rope and empties were pulled by the return rope. Occasionally, bi-directional haulages were used but the drive for both types was always with the rope wrapped around a Chimes wheel.

Haulages operated in inclined shafts and on horizontal haulage-ways but because these installations required attendants at every station to manhandle the cars, they were labour intensive. Accidents were frequent and these haulages rapidly became obsolete.

The Evander Gold Mines system

This system comprises of a friction wheel or drive sheave with two adjacent rope grooves. The drive sheave is powered by a 200kW, 1000rpm thyristor-fed DC motor through a speed reduction gearbox.

Closed loop speed control is employed. The speed/distance profile and current control for the motor are generated digitally and processed by a PLC. Signals and commands received from the operator are processed by the same PLC.

Mechanical braking is effected by means of three disc brake calipers, acting on two brake paths which form an integral part of the main drive sheave. The brakes are hydraulically released and the brake control system incorporates a raise/lower discriminator to alter the brake application rates for descending and ascending loads.

In front of the drive sheave and inclined to the vertical, is the idler sheave. This deflects the rope from one groove on the drive sheave into the other so that a full 360 degrees angle of wrap around the drive sheave can be obtained.

A conveyance or gondola which runs on a pair of rails on the footwall of the decline shaft is permanently attached to the live or T1 side of the rope which passes underneath the gondola. The rest of the rope is supported on rollers midway between the rails and at a height about level with the rails.

Material cars are loaded on to this gondola. Up to four material cars of gross mass 4500kg each, are loaded at once. Two 8 ton locos may be transported together. Loaders, pipe and rail bogies, explosive cars and ore hoppers are typical of the types of vehicles transported on the gondola.

Tension is maintained in the rope by a weight car situated at the bottom of the decline. This weight car also runs on the same rails as the gondola and can move up or down the decline to accommodate rope stretch and maintain the required rope tension.

The return rope on the T2 side is supported on rollers about midway between the T1 rope and the inner rail. Whilst the T1 rope enters and leaves the drive sheave and weight car sheaves at rail level, the T2 rope is deflected down to rail level by a deflector sheave at the drive unit and another deflector sheave on the weight car.

A complication which was introduced into the EGM system was the discovery, during the sinking of the decline shaft, that between 17 level and 18 level the angle of inclination changed twice from 14 degrees to 6 degrees and back to 14 degrees. The vertically upward curves so created required the installation of special top-hat shaped rope trapping pulleys. These were required to maintain the T1 rope at rail level and stop it from rising and striking the hanging wall of the decline when the gondola was at another position in the shaft.

At the same time, a specially designed torpedo, fitted to the underside of the gondola, forces the rope trapping pulleys apart, allowing removal of the rope and passage of the gondola. As the gondola passes, the other end of the torpedo places the rope back into the trapping pulleys.

The T2 rope is constrained to rail level at these positions merely by running it underneath the rollers.

Overspeed protection is afforded by a mechanically driven Tecno model T overspeed controller, backed up by electronic speed supervision.

Overwind protection at the top and the bottom of the decline shaft consists of conveyance operated magnetic switches, electronic position supervision and 'ultimate' Tarzan wires.

The author worked in close collaboration with the designers at Blane and Company, who were contracted by

Dowding Reynard and Associates to build the equipment.

Design of the drive sheave arrangement

In any winding system employing the friction drive principle, it is of utmost importance not to exceed the maximum permissible T1/T2 ratio in order to avoid rope slippage on the drive sheave. In fact, it is better to adopt a somewhat conservative approach and to allow a safety margin of some 15% or so, since the calculation of this ratio is based on an assumed figure for the coefficient of friction between the rope and rope tread of the drive sheave.

From the formula

$$T1/T2 = e^{\mu}$$

where μ is the coefficient of friction between the rope and the drive sheave and _ is the angle of wrap of the rope around the sheave in radians, it can be seen that, for a given T1/T2 ratio, the required number of turns of rope around the drive sheave increases proportionately as the coefficient of friction between the rope and drive sheave surface reduces.

In the case of designs employing a Chimes wheel (named after the inventor, also known as a Surge wheel or Fleeting wheel), which was the traditional form of drive for endless rope haulages used before world war 2, several wraps of rope were employed because the tread of the wheel was hardened cast iron (often meehanite) and the coefficient of friction between the rope and wheel was a little less than 0.2. In any case, the ratio between T1 and T2 when the haulage was in operation, seldom exceeded 3 to 1.

A distinct drawback of such installations was that, since the profile of a Chimes wheel was usually parabolic, sometimes double-parabolic, the latter being used in the case of reversing drives and this, by nature of its design, always resulted in axial and circumferential slipping of the individual rope coils to compensate for the change of rope tension as it wound around the wheel. This slippage between the rope and the wheel, as well as relative movement between adjacent coils of rope added to the abrasive wear to which the rope was subjected in the overall.

The following table gives a comparison of T1/T2 ratios for a half wrap, a full wrap and various coefficients of friction:

For 180° angle of wrap, e for various values of:

	0.2	0.3	0.35	0.4	0.45
e	1.87	2.57	3.0	3.51	4.11

For 360° angle of wrap, e for various values of:

	0.3	0.35	0.4	0.45	0.5
e	6.58	9.01	12.34	16.9	23.14

In the case of the Evander installation, a decision was taken at the very outset that a Koepe type sheave, fitted with friction inserts in the rope groove would be used rather than a Chimes wheel so that rope wear would be minimised.

The highest unbalance between T1 and T2 would occur when a descending load on the T1 side was stopped under emergency braking conditions. The calculations in APPENDIX 1 show that the T1/T2 ratio would rise, under such conditions, to 6.2

The friction inserts chosen were imported from Germany. The manufacturers guarantee a minimum coefficient of friction of 0.4, even with a lubricated rope, so the material was therefore quite adequate for the required application.

This meant that one complete revolution, or a full wrap, was required around the drive sheave, necessitating two adjacent, but separate rope grooves. In order to achieve a full revolution, the rope had to be taken halfway around the sheave, then onto the idler sheave, which, inclined to the vertical, deflected the rope onto the second rope groove and halfway around the drive sheave again, thus achieving 360 degrees or a full wrap. In fact, the deflector sheave shown in figure 2, required to bring the T2 rope back down to rail level, results in the total angle of wrap slightly exceeding 360 degrees, but this was ignored in the actual calculations.

Loading and unloading the material cars

Access to the decline from 15 level is at right angles to the decline whilst 17 level and 18 level stations are situated at an angle of approximately 30 degrees to the decline shaft.

This meant that a roll-on, roll-off arrangement for the material cars on to the gondola would not be possible and it was decided to install crawl beams on each level so that the material cars could be loaded and unloaded with an electric hoist.

The material cars used have all been fitted with lifting eyes. A spreader beam with hooks is attached to the electric hoist.

To facilitate easy railing of the material cars at the levels after unloading from the gondola, a device copied from the author's model railways hobby was used. The ends of the rails are flared to about 1.5 times the rail gauge and the space between the rails is filled with a flat plate. The material car is set down anywhere on this plate and when pushed towards the throat of the flare, it automatically rails itself, every time!

Modes of operation

The control system is capable of being operated in three different modes:

Full Automatic Mode

In this mode, the operator has full and exclusive control over the winder. After loading the cars on to the gondola he selects his destination by ringing the desired station signal on an 'intelligent' electronic locked bell signaling system. He then climbs aboard the operator's cab on the gondola. (There are two cabs, one at each end of the gondola and the operator climbs into the one facing the direction of travel).

The operator then inserts his pass key, which he has just removed from the control box at the shaft side, into a control box in the cab and pushes the dispatch button.

After a 10 second delay, during which about to run alarms are sounded and warning lights are flashed, the winder accelerates to full speed. The gondola, together with load and operator, travels through the shaft, retards and stops at the desired level. The bell system rings a 'three' signal, indicating that the winder's brakes are on, that the system is 'locked' and that the operator may alight from the cab.

The operator then inserts his pass key into the control box at the shaft side and re-assumes control over the winder. He is then able to "jog" the gondola up or down within pre-set limits of distance, in order to position each material car under the hoist for unloading.

Semi-automatic, shaft-side control

In this mode, two operators are required, one on each of the levels between which winding operations are being conducted. The procedure is similar to fully automatic operation, except that the operator does not travel on the gondola – he merely dispatches it to the selected destination level from the shaft side control box. After a 10 second delay, during which about to run alarms are sounded and warning lights are flashed, the winder accelerates to full speed. The gondola, without an operator this time, travels through the shaft, retards and stops at the desired level. The bell system rings a 'three' signal, indicating that the winder's brakes are on and that the system is 'locked'.

At the destination level, a second operator assumes control over the gondola and he can then jog it up or down for loading/unloading.

Fully manual control

In this mode of control, the winder may be driven from a driver's desk which is equipped with power lever, brake lever, digital depth indicator, speed indicator and armature current meter. Other alarms and indications normally fitted to a winder are also provided.

In this mode of operation, the driver will respond to locked bell signals and will have to retard and stop manually at all levels other than the extremity levels of the decline, where slowdown is automatic.

Communication system

Signals from the shaft-side control boxes are relayed to the winder's control system by cables. These signals are generated by an 'intelligent' electronic bell system which verifies that the signal code rung is valid before the signals are transmitted to the winder. This prevents the ringing of 'short-cut' signals or signals which are not in accordance with the official code, a feature which is particularly important in enhancing safety during manual operation.

However, signals, such as dispatch, and emergency stop are transmitted from within the cab of the gondola via a radio and leaky feeder aerial to the winder.

Monitoring, such as gondola derailed also makes use of this radio link to trip the winder. This monitoring is effected by means of proximity switches mounted at each axle of the gondola, just above the rail.

The radio signal transmitted from the gondola is continuously monitored at the winder, such that loss of signal will trip the safety circuit.

The leaky feeder also provides voice communication between the gondola and the winder, a useful feature when track or shaft maintenance is required.

Leaky feeder radio communication

The control PLC is an Allen Bradley SLC 5/03. The processor runs the automation control logic as well as the software safety circuit, intelligent bell signalling system, and winder position and torque controller.

The control PLC communicates with an Allen Bradley Micrologix 1000 PLC which is mounted in the conveyance. Stop, Reset and Go signals as well as status information are relayed to and from the conveyance via a leaky feeder radio communication system.

The radios are custom built full duplex units operating at 172.450MHz and 156.225Mhz.

Current consumption is approximately 150 milliamps and the 42 amp-hour batteries fitted to the gondola and changed every day, are therefore more than ample for a 24 hour shift.

Rails

The rails on which the gondola runs were designed, supplied and installed by Tubular Track®. This is a high quality proprietary product which utilizes a reinforced concrete beam, cast in situ longitudinally below each rail to support the rail and the weight of the rolling stock. The rail gauge is maintained by fabricated steel gauge bars, which also carry the rope support rollers. The rails are fixed to the gauge bars with bolted clamps.

The rails are continuously welded for the full length of the decline shaft and in order to ensure a smooth ride for the gondola and increased vertical stability, a rail gauge of 1220 mm was chosen. (The track gauge for the material cars is 910 mm).

Advantages

The advantages of the Evander system over a single drum winder installation can be summarized as follows:

- Since the rope tension is not maintained by the gravitational component of force on the conveyance, slack rope conditions will never occur in normal operation.
- The system can be used on any angle of inclination including zero angle (horizontal), negative angles (downward) and positive angles (upward)
- The system can negotiate vertical and horizontal curves and a combination thereof.
- By transporting the material cars on a dedicated conveyance (the gondola) the risks attributed to derailments, disconnections and runaways of cars are eradicated.
- The system is labour efficient – it can be operated by one person.
- The system is inherently safer than the conventional single drum winder installation.

Cost

The final, all inclusive cost of the system at EGM was approximately 10% greater than a single drum winder installation to do the same duty and approximately 40% less than the monorail which had been proposed.

Since commissioning, the cost to the mine of transporting materials to the working areas has reduced by approximately R350 000.00 per month.

Personnel transport

Because the operator is required to travel in the gondola, it was necessary to license the winder in terms of Chapter 16 of the Minerals Act and Regulations and the installation therefore complies with all the requirements of a man riding winding installation.

Whilst EGM's requirements do not extend to using the system for personnel transport it can be easily adapted for that purpose. By loading two man carrying conveyances on to the gondola, 50 men could be transported at once.

Conclusions

Merely by applying modern technology, a two-century old idea has been transformed and projected into the 21st century.

It is foreseen that the manually operated material decline will soon become a thing of the past and that the accidents and poor safety record associated with such installations will disappear.

Transporting of materials and personnel by modern endless rope haulages is likely to become popular, once more.

Technical specifications

LENGTH OF WIND (CURRENT):	800m
LENGTH OF WIND (FUTURE):	1 120m
ANGLE OF INCLINE:	0°, 14°, 6°
PAYLOAD MASS:	18 000kg
MASS OF GONDOLA:	7 400kg
MASS OF TENSIONING CAR AND WEIGHTS:	16 120kg
WINDING SPEED:	3m/sec
RAIL GAUGE:	1 220mm
ROPE DIAMETER:	32mm
MOTOR:	200kW DC
DRIVE SHEAVE DIAMETER:	1 800mm
DRIVE TYPE:	THYRISTOR CONVERTER
INCOMING SUPPLY:	550v AC
COMMUNICATION SYSTEM:	RADIO AND LEAKY FEEDER
BELL SIGNALLING SYSTEM:	'INTELLIGENT' ELECTRONIC

Acknowledgement

The author wishes to thank Dowding Reynard and Associates (Pty) Ltd and Evander Gold Mines Ltd for permission to present this paper.

Appendix 1

Specifications:

Payload: M_L 4 x 4500kg	= 18000kg	
Conveyance: M_C 3770 + 3440 + 160	= 7370kg	
Weight car:	= 3130kg	
Weights: (2 x 2500) + (2 x 2700)	= 10400kg	
Tail sheaves:	= 2590kg	
Length of Incline: **L**	= 1200m	
Rope:	32mm diam., 4.42kg/m	
Rope Mass per side: M_R 1200 x 4.42kg	= 5304kg	
Emergency braking rate	= 1.5m/sec²	
Inertias: I = mk² Assuming k = 0.75r		
Drive sheave: m = 800kg, d = 1.8m, k = 0.675		I_1 = 364.5kgm²
Deflector sheave: m = 440kg, d = 1.5m, k = 0.563		I_2 = 139.5kgm²
Idler sheave: m = 600kg, d = 1.8m, k = 0.675		I_3 = 273.4 kgm²
Return sheaves (3 off): m = 440kg, d = 1.5m, k = 0.563		I_4 = 418.4 kgm² total

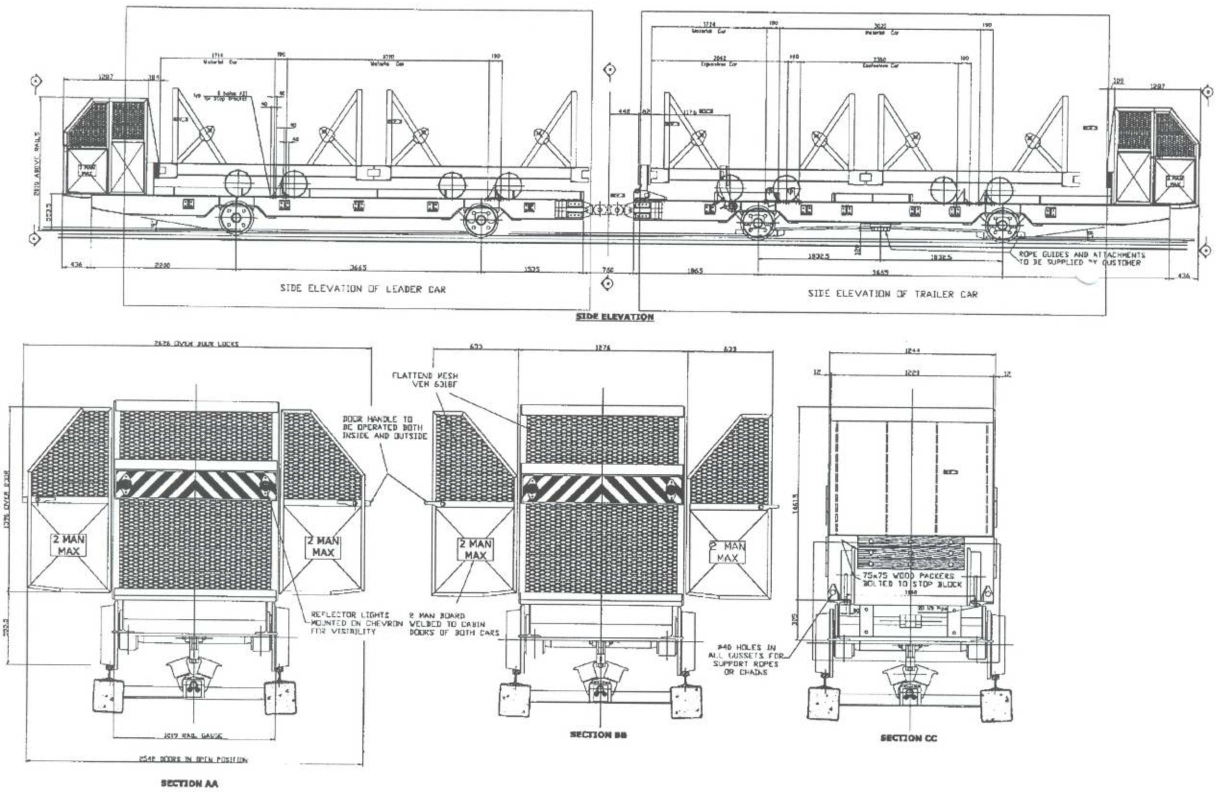

Figure 1 . Conveyance (Gondola) Assembly

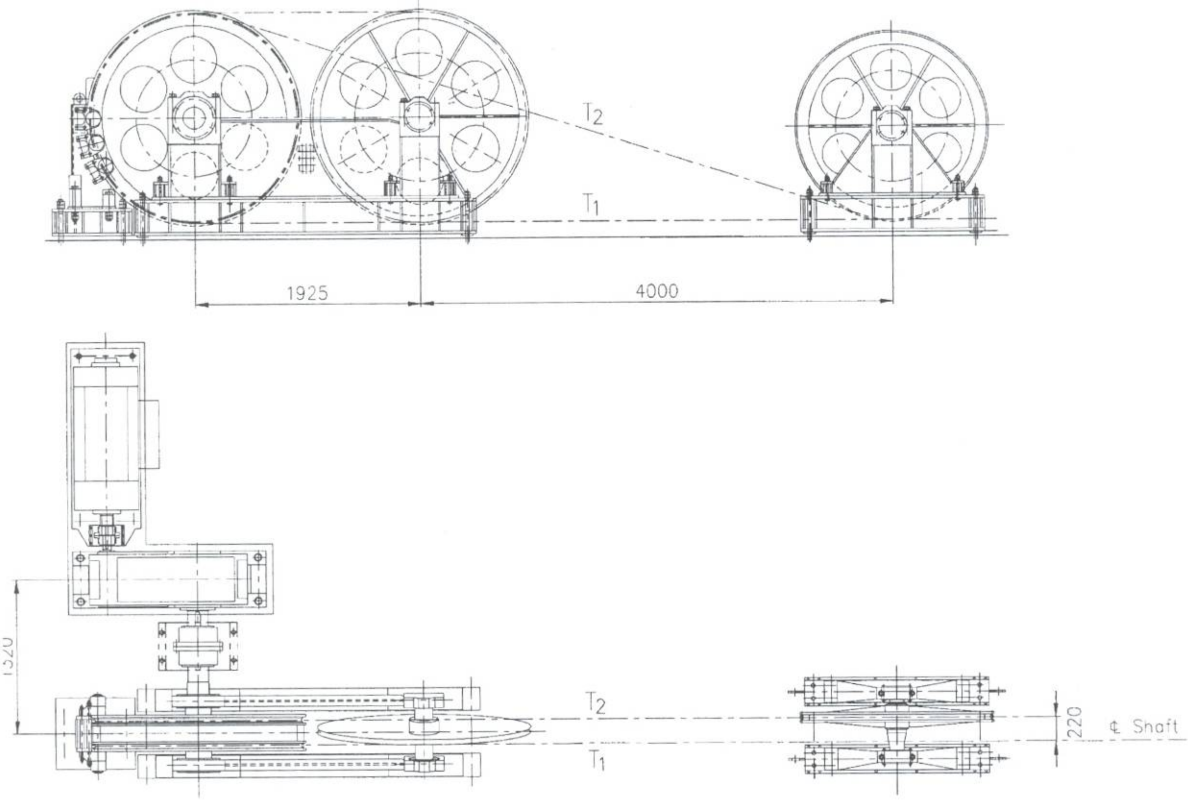

Figure 2 . Friction Winder Assembly. Drive Station

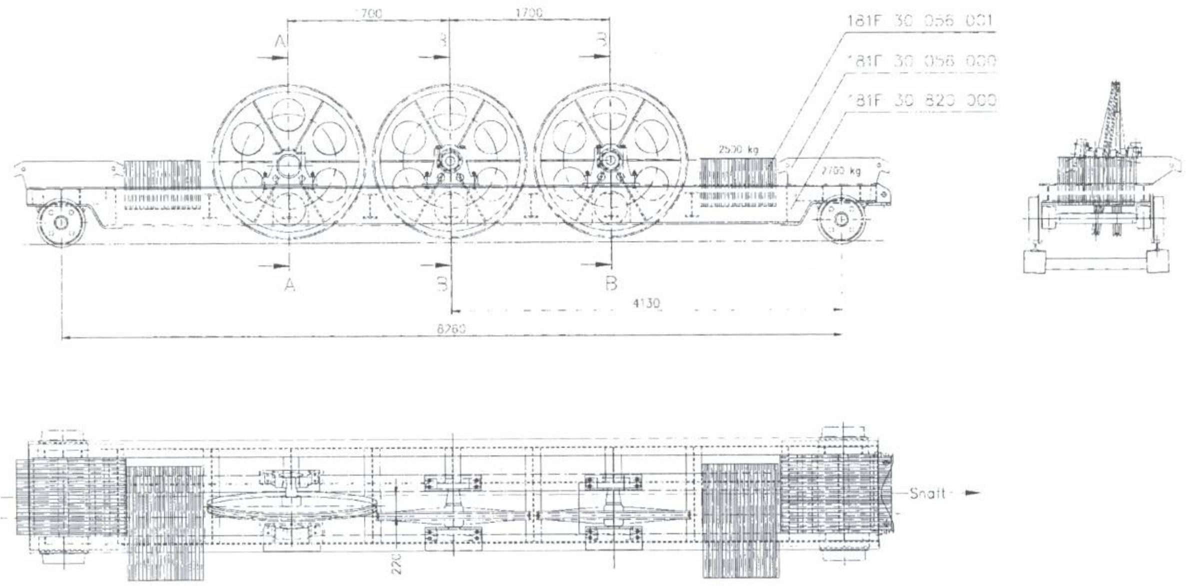

Figure 3 . Tensioning Car Assembly

Motor armature ref. to sheave: 3.6kgm2 x 31.4122, $I_5 = 3552.2kgm^2$

TOTAL ROTATING INERTIA $I_T = 4748kgm^2$

Static condition:

Tensioning car mass = 3130 + 10400 + 2590 = 16120kg

Tensioning force in each rope (doubled-down) T_T = 16120 sin 14° x 9.81 / 2 = 19.13kN

T_2 = TT + (M_R /1000 X 9.81 x sin 14°)
= 19.13 + (5304/1000 x 9.81 x 0.2419)
= 19.13 + 12.59
= 31,72kN

T_1 = TT + (M_R + M_L + M_C)/1000 X 9.81 X sin14°
= 19.13 + (5304 + 18000 + 7370)/1000 x 9.81 x 0.2419
= 19.13 + 72.8
= 91.93kN

Tension in ropes due to emergency braking of a descending load @ 1.5m/s²

Notes: T_1 will increase due to deceleration of the rope self mass, the linear moving masses as well as due to retardation of three return sheaves.
T_2 will decrease due to deceleration of the rope self-mass as well as due to deceleration of the deflector sheave, and 3 return sheaves.

Calculate tangential force, or tension in the rope, due to deceleration of the sheaves @ 1.5m/s²:

F = T/r = I_/r where _ = a/r

F = Ia/r²

Deflector sheave (2):

F_2 = I_2/1000 x 1.5/0.75²
= 139.5/1000 x 1.5/0.75²
= 0.37kN

Idler sheave (3)

F_3 = I_3 /1000 x 1.5/0.9²
= 273.4/1000 x 1.5/0.9²
= 0.5kN

3 Return sheaves (4)

F_4 = I_4/1000 x 1.5/0.75²
= 418.4/1000 x 1.5/0.75²
= 1.12kN

Total increase in T_1 due to braking of the sheaves will be $F_4/2$
= 1.12/2
= 0.56kN (i)

Total decrease in T_2 due to braking of the sheaves will be $F_2 + F_3 + F_4/2$
= 0.37 + 0.5 + 1.12/2
= 1.43kN (ii)

Force to brake linear moving masses on T_1 side
= (M_R + M_L + M_C)/1000 x 1.5
= (5304 + 18000 + 7370)/1000 x 1.5
= 46.0kN (iii)

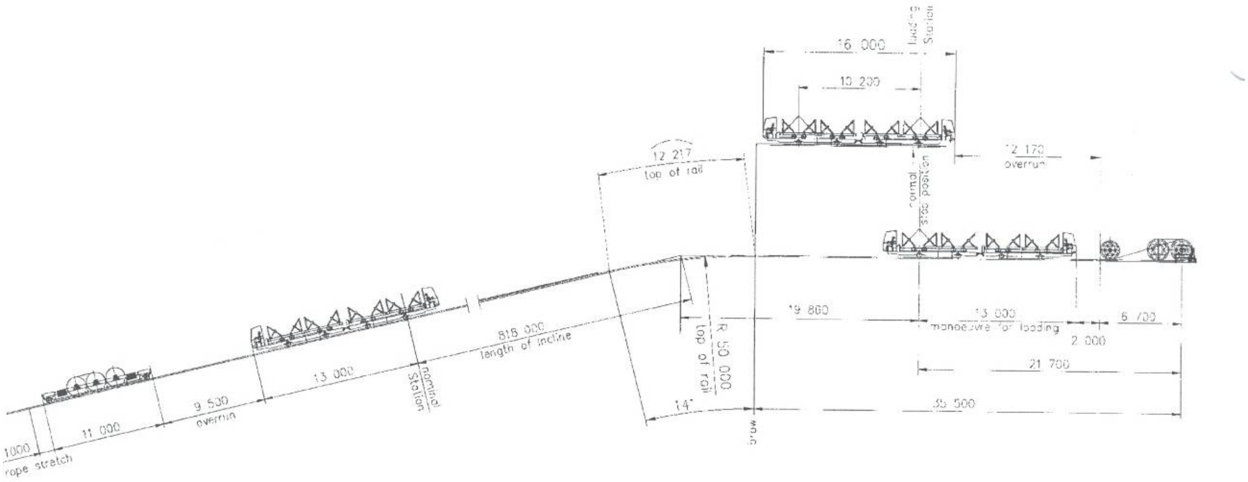

Figure 4. Haulage System Assembly

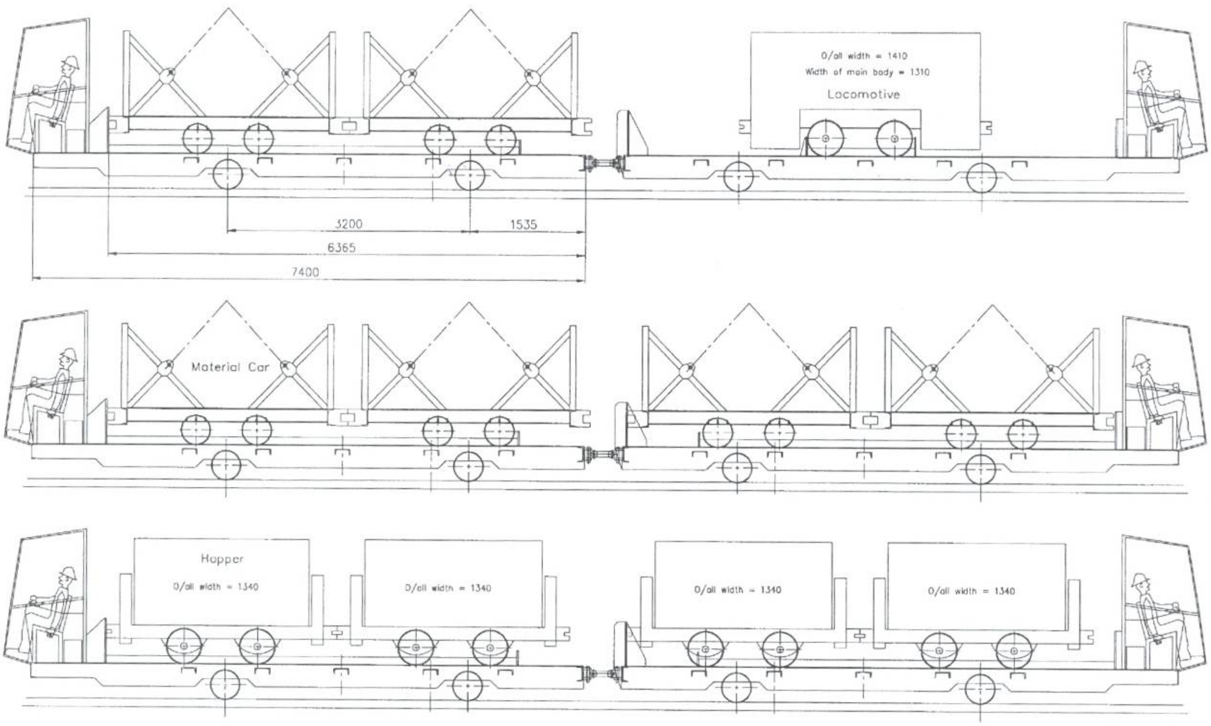

Figure 5. Cars loaded on conveyance

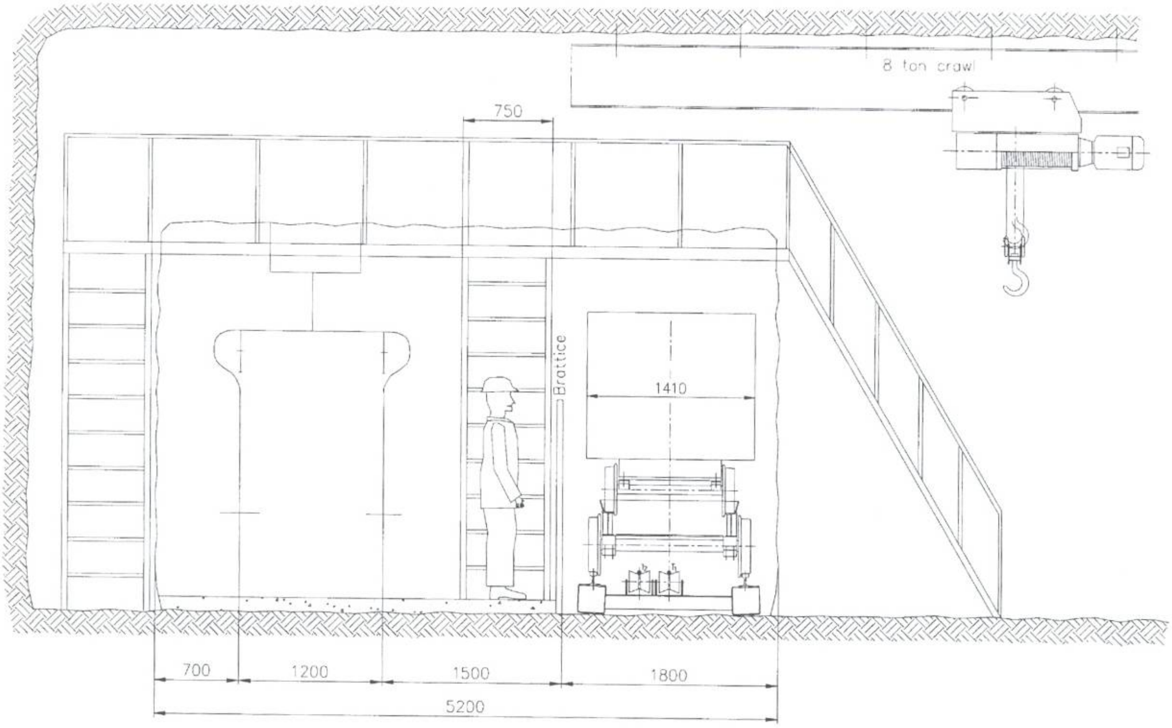

Figure 6. Section at 17 level

APPENDIX D

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ANGLO PLATINUM
Bafokeng – Rasimone Platinum Mine

NORTH SHAFT CONVEYOR

Conveyor Simulation Report

March 2008

SABS tt100 2004 FINALIST

ANGLO AMERICAN

Report Nº
SEENG-513530-01

Report Date
26 March 2008

Title

ANGLO PLATINUM
Bafokeng Rasimone Platinum Mine

Conveyor Simulation Report

Client
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Rasimone North Shaft

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Executive Summary

A simulation model of the Rasimone North Shaft conveyor belt was done to determine the daily tonnages that can be achieved when conveying men and material separately versus the current system.

Four scenarios were investigated :

- SCENARIO 1 :2.5 m/s with men riding on ore
- SCENARIO 2 :2.5 hr delay at shift start to allow for transport of men separate to ore
- SCENARIO 3 :2.5 m/s with men riding separately to ore
- SCENARIO 4 :2.5 m/s with men riding separately to ore at 1.5 m/s

The separation of men and material results in 15 to 16 % drop in production. The major drop (47 %) in production occurs in scenario 4 where men travel separately to ore at a reduced speed of 1.5 m/s. Therefore the model quantifies how much production will be lost due to safety requirements

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1. INTRODUCTION

ATD has been contracted to do ARENA Simulation on material hoisting conveyor of Bafokeng Rasimone Platinum Mine. The mine is currently transporting men and material on the same conveyor belt and ATD is to simulate the following operating scenarios:

- As Is – Men and materials together at conveyor speed 2.5 m/s
- Men and materials together at conveyor speed 1.5 m/s
- Separate men and material at conveyor speed 2.5 m/s

The target daily tonnage to meet is

Reef: 5000 Tons

Waste: 2000 Tons

2. SCOPE OF WORK

The following is included in the model:

- Main conveyor transporting material and men from 6th level to material tip and bank level respectively
- Material loading from Levels 1 to 6
- Production/pulling schedule

The project objective is to:

- Test the conveyance of reef/waste and men separately at a belt speed of 2.5m/s
- Test belt schedules to see if daily targets are met.

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3. MODEL ASSUMPTIONS/INPUTS

The model assumptions are as follows:

1. There is a daily maintenance delay of one (1) hour on main conveyor, as defined by the production schedule
2. Arrival tonnage for reef is Tria (350, 400, 450) tons per hour.
3. Arrival tonnage for waste is Tria (350, 400, 450) tons per hour.
4. Blasting will take place daily delaying pulling for an hour.
5. Ad hoc reef and waste production stoppage is included, spread over the duration of the day; down unif (5,8) min every expo(60) min

4. INPUT SHEET AND USER INTERFACE

A spreadsheet input is supplied with the model for relevant model inputs (See figure 4.1). The user is able to alter the values of variables from the spreadsheet in order to test various scenarios. The shaded cells are inputs, which can be changed.

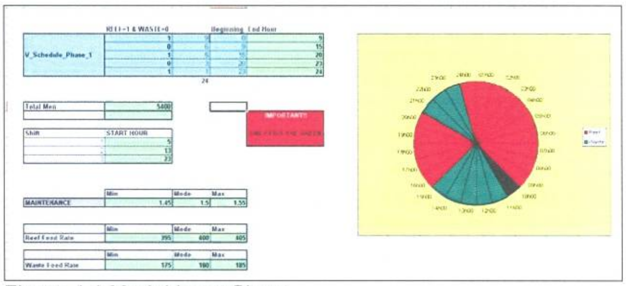

Figure 4.1 Model Input Sheet

5. MODEL ANIMATION

A snapshot of the model animation is illustrated in figure 5.1

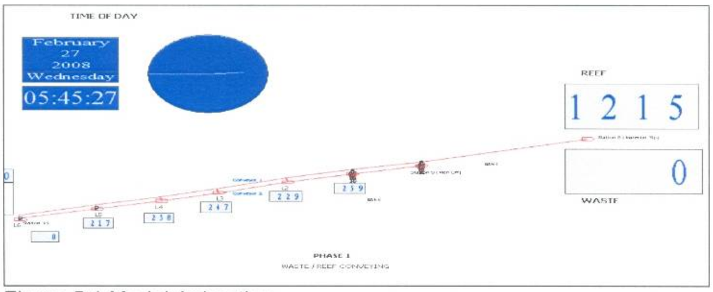

Figure 5.1 Model Animation

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6. MODEL VALIDATION

The model was validated using data from actual production on selected days, the conditions were replicated and results are compared to actual (See Table 6.1).

Table 6.1 Model vs. Actual

	ACTUAL DAILY TONS		MODEL DAILY TONS	
Day	Reef	Waste	Reef	Waste
05-Feb	4129	942	3782	438
12-Feb	3025	518	3864	318
19-Feb	4398	370	4198	153
AVG	**3850.67**	610.00	**3948.00**	303.00
STD DEV	727.59	296.89	220.35	143.09

7. MODEL RUNS

Scenarios were investigated using the simulation model. The scenarios are run using the 1 PHASE PULLING TIME SCHEDULE (Table 7.1) below, In each scenario, there are three runs, the first being "As is" the original schedule , on the second run, an hour is added to reef.

Table 7.1 PHASE PULLING TIME SCHEDULE

REEF=1 & WASTE=0	Duration	Beginning	End Hour
1	9	0	**9**
0	6	9	**15**
1	5	15	**20**
0	3	20	**23**
1	1	23	**24**

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The results of the runs are tabulated in Table 7.2.

Table 7.2 Model Results

SCENARIO 1 :2.5 m/s with men riding on ore					
	Material	**Tonnage**	**Run Duration**	**Daily Tons**	**Total**
As is schedule	**Reef**	46574	10	4657.4	
	Waste	27519	10	2751.9	7409.3
Plus 1 hr reef	**Reef**	49765	10	4976.5	
	Waste	24328	10	2432.8	7409.3
Plus 2 hr reef	**Reef**	52561	10	5256.1	
	Waste	21532	10	2153.2	7409.3
SCENARIO 2 :2.5 hr delay at shift start to allow for transport of men separate					
	Material	**Tonnage**	**Run Duration**	**Daily Tons**	**Total**
As is schedule	**Reef**	39906	10	3990.6	
	Waste	23941	10	2394.1	6384.7
Plus 1 hr reef	**Reef**	42693	10	4269.3	
	Waste	21154	10	2115.4	6384.7
Plus 2 hr reef	**Reef**	45091	10	4509.1	
	Waste	18756	10	1875.6	6384.7
SCENARIO 3 :2.5 m/s with men riding seperately to ore					
	Material	**Tonnage**	**Run Duration**	**Daily Tons**	**Total**
As is schedule	**Reef**	42095	10	4209.5	
	Waste	22169	10	2216.9	6426.4
Plus 1 hr reef	**Reef**	42280	10	4228	
	Waste	21984	10	2198.4	6426.4
Plus 2 hr reef	**Reef**	44400	10	4440	
	Waste	18771	10	1877.1	6317.1
SCENARIO 4 :2.5 m/s with men riding seperately to ore at 1.5 m/s					
	Material	**Tonnage**	**Run Duration**	**Daily Tons**	**Total**
As is schedule	**Reef**	33614	10	3361.4	
	Waste	16944	10	1694.4	5055.8
Plus 1 hr reef	**Reef**	33614	10	3361.4	
	Waste	16944	10	1694.4	5055.8
Plus 2 hr reef	**Reef**	33975	10	3397.5	
	Waste	14818	10	1481.8	4879.3

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8. CONCLUSIONS /RECOMMENDATIONS

Four Scenarios were simulated namely:

- SCENARIO 1 :2.5 m/s with men riding on ore
- SCENARIO 2 :2.5 hr delay at shift start to allow for transport of men separate to ore
- SCENARIO 3 :2.5 m/s with men riding separately to ore
- SCENARIO 4 :2.5 m/s with men riding separately to ore at 1.5 m/s

The change in total daily tonnage is illustrated in Table 8.1.

Table 8.1 Model Results

SCENARIO	Total daily Tonnage	% Change to base
SCENARIO 1	7409.3	0
SCENARIO 2	6384.7	-16%
SCENARIO 3	6426.4	-15%
SCENARIO 4	5055.8	-47%

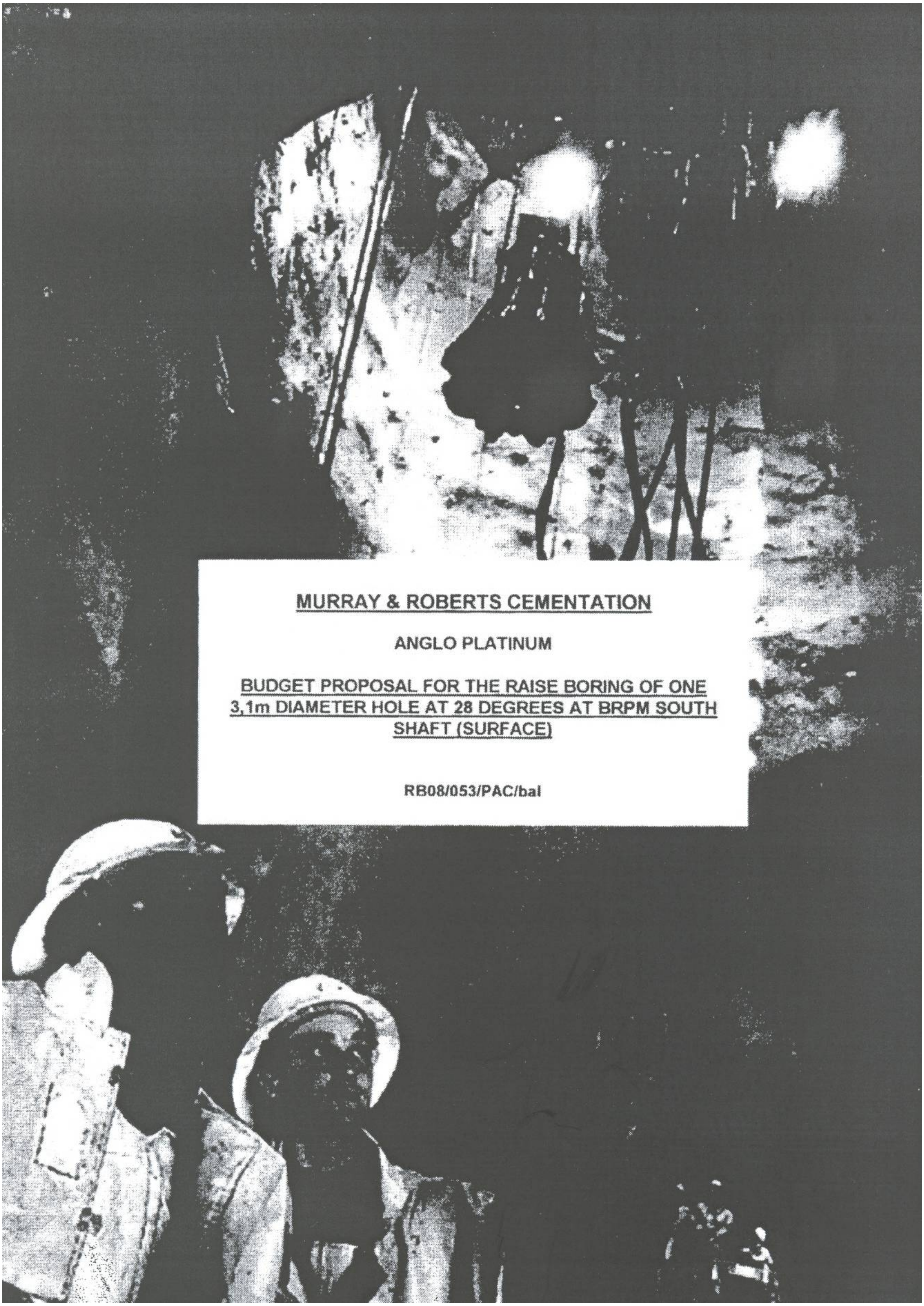
Allowing for 2.5 hours at beginning of each shift results in a 16 % drop in daily tonnage and holding back the ore until all men are transported results in 15 % drop. The separation of men and material results in 15 to 16 % drop in production. The major drop (47 %) in production occurs in scenario 4 where men travel separately to ore at a reduced speed of 1.5 m/s.

Therefore the model quantifies how much production will be lost due to safety requirements

APPENDIX E

ITEM NO'	CODE	DESCRIPTION	QUANTITY	UNIT	RATES SUPPLY	RATES ERECTION	H.O. ED ORDERS EXTERNAL SUPPLY	H.O. ED ORDERS EXTERNAL ERECTION	BUSINESS UNIT INTERNAL SUPPLY	BUSINESS UNIT INTERNAL ERECTION	TOTAL
1	T	**MV and LV Supply**									
3	MLS	11 kV XLPE LH, 3c 70mm2 feeders cables	200	m	285.00	110.00	57,000	22,000			79,000
5	MLS	11 kV 3c x 70 mm2 xlpe LH Cable Termination	4	no	860	550.00	3,440	2,200			5,640
7	MLS	630kVA 11kV/550V Minisub skid mounted	2	no	378,595.00	65,000.00	757,190	130,000			887,190
8	MLS	100kVA 550/400Lighting Transformer	2	no	55,000.00	6,000.00	110,000	12,000			122,000
10	T	**600/1000V PVCSWA Cables**									
12	MLS	2.5mm2 7 core	2,000.00	m	25.47	21.00	50,940	42,000			92,940
15	MLS	70mm2 4 core	200.00	m	187.87	85.00	37,574	17,000			54,574
17	T	**600/1000V PVCSWA Cable Terminations**									
19	MLS	2.5mm2 7c	100.00	no	80.00	209.00	8,000	20,900			28,900
22	MLS	70mm2 3c	4.00	no	184.00	328.00	736	1,312			2,048
30	T	**EARTHING**									
32	MLS	70mm2 BCEW Earthwire	2,000.00	m	21.09	11.82	42,180	23,640			65,820
33	MLS	70mm2 BCEW Earthwire Termination bolted	20.00	no	21.00	66.00	420	1,320			1,740
35	T	**CABLE TRENCHING WBS 254**									
36	MLS	Trenching-soft rock digging	200.00	m3		500.00		100,000			100,000
37	MLS	Cable protection tiles	400.00	no	32.50	5.00	13,000	2,000			15,000
38	MLS	Cable warning tape	2,900.00	m3	1.00	1.00	2,900	2,900			5,800
39	MLS	Cable route markers	10.00	no	80.00	20.00	800	200			1,000
43	T	**Walkway lighting**									
25	MLS	4-way Junction box	100.00	no	320.00	100.00	32,000	10,000			42,000
26	MLS	DB Board	2.00	no	15,000.00		30,000				30,000
46	MLS	Open chassis Fluorescent Light Fittings	100.00	no	320.00	300.00	32,000	30,000			62,000
49	T	**Underground Lighting**									
50	T	Gulley Boxes									
51	MLS	Incomer box 225A	16.00	no	12,272.00	200.00	196,352	3,200			199,552
57	MLS	Lighting Transformer 5kVA mounted in gulley box	16.00	no	8,959.00	1,000.00	143,344	16,000			159,344
58	MLS	Gulley rig	16.00	no	760.00	2,500.00	12,160	40,000			52,160
70	MLS	100 M U/G 4mm2 4c lighting cable 6m spacings	12.00	3496	3,496.00	135.00	41,952	1,620			43,572
71	MLS	12 mm straining steel wire	3,500.00	m	35.00	25.00	122,500	87,500			210,000
72	MLS	Fluorescent lamps	55.00	no	14.00		770	100			870
		Total									2,261,150
		35% P&G									791,403
		Contingencies									915,766
						SUB TOTALS	1,695,258	565,892			
										TOTAL UNESCALATED	3,968,318

APPENDIX F



MURRAY & ROBERTS CEMENTATION

ANGLO PLATINUM

BUDGET PROPOSAL FOR THE RAISE BORING OF ONE 3,1m DIAMETER HOLE AT 28 DEGREES AT BRPM SOUTH SHAFT (SURFACE)

RB08/053/PAC/bal

Murray & Roberts

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17 June 2008

The Commercial Manager
Anglo Platinum
South shaft
RUSTENBURG

RB08.053/PAC/bal

Attention: Mr. Stephan Roestorff

Dear Sir

BUDGET PROPOSAL FOR THE RAISE BORING OF ONE 3,1m DIAMETER HOLE AT 28 DEGREES AT BRPM SOUTH SHAFT (SURFACE)

1. **INTRODUCTION**

   We thank you for the invitation to tender for the above mentioned work and take pleasure in submitting our budget proposal comprising:

   a. This Covering Letter;

   b. Annexures as Itemised in the Index.

2. **BASIS OF PROPOSAL**

   Our budget proposal is based on and subject to this Tender letter and all of the conditions, qualifications and provisions set out herein and the Annexures forming part hereof.

We trust that our budget proposal meets with your approval, is sufficient for your adjudication requirements and hold ourselves available to any further discussions you may require.

Yours faithfully

A C WIDLAKE
BUSINESS DEVELOPMENT DIRECTOR

M OOSTHUIZEN
GENERAL MANAGER
MINING SERVICES

Murray & Roberts

Index	
1.	Schedule of Rates
2.	Schedule of Responsibilities
3.	Technical Data
4.	Method Statement
5.	Schedule of Qualifications and Clarifications

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ANNEXURE 1

SCHEDULE OF RATES

MURRAY & ROBERTS CEMENTATION
BRPM SOUTH SHAFT
TENDER ENQUIRY No: E.MAIL

PILOT AND REAM 1 x 206m x 3.1m @ 28 DEGREES UNDERGROUND

BUDGET SCHEDULE OF RATES (EXCLUDING V.A.T.)

Ref: RB 08 / 0 53 / PAC.bal — **Date: 5/30/2008**

ITEM NO	DESCRIPTION	UNIT	QUANTITY	DURATION CONCURRENT	DURATION CRITICAL	RATE RANDS	AMOUNT RANDS
1	**Site Establishment**						
1.1	P&G	Sum					253,234.59
1.2	Mobilise Men and Equipment to Mine	Sum			2.0		138,013.42
1.3	Medical Examinations	Day			1.0	25,202.74	25,202.74
1.4	Induction	Day			5.0	18,260.87	91,304.35
2	**Miscellaneous**						
2.1	Transport Reamer to Underground Site						By Client
2.2	Cranage (50T) - Offloading ,Assembling And Reloading						By Client
2.3	Design Drawings For Pad	Sum				30,625.00	30,625.00
3	**Pilot And Ream 1 x 206m x 3.1m (28 Deg)**						
3.1	Machine Foundation						By Client
3.2	Erect Machine And Connect All Services	Per Day			3.0	40,008.11	120,024.34
3.3	Commission Machine	Per Day			1.0	62,508.11	62,508.11
3.4	Collar and Pilot 381mm Diameter	Metre	150.0		10.0	4,526.15	678,922.34
3.5	Retract Drill String ,Replace Bit And Lower	Day			1.9	40,008.11	76,015.41
3.6	Collar and Pilot 381mm Diameter	Metre	56.0		3.7	4,526.15	253,464.34
3.7	Retract Drill String ,Remove Stab. And Lower	Day			2.5	40,008.11	100,020.28
3.8	Client Prepare Hook Up Chamber (If Required)	Day		1.0		40,008.11	Rate Only
3.9	Assemble Reamer And Attach To Drill String And Collar	Day			3.0	40,008.11	120,024.34
3.10	Ream 3.1m Diameter	Metre	68.6		22.9	25,714.20	1,763,994.07
3.11	Lower Reamer,Replace Cutters And Pull Rods	Day			1.2	40,008.11	48,009.73
3.12	Ream 3.1m Diameter	Metre	68.6		22.9	25,714.20	1,763,994.07
3.13	Lower Reamer,Replace Cutters And Pull Rods	Day			1.8	40,008.11	72,014.60
3.14	Ream 3.1m Diameter	Metre	68.8		22.9	25,714.20	1,769,136.91
3.15	Remove Reamer On Surface	Day			2.5	40,008.11	100,020.28
3.16	Dismantle Machine	Per Day			3.0	47,508.11	142,524.34
4	**Site Clearance**						
4.1	Exit Medical	Per Day			1.0	25,202.74	25,202.74
4.2	Demobilise Men & Equipment	Sum			2.0		138,013.42
5	**Operational Delay Time**	Hour				1,667.00	Rate Only
	ESTIMATED CONTRACT VALUE (EXCLUDING RATE ONLY ITEMS)			1.0	111.3		7,772,269.43

NB: Should any of the days in items 1.3; 1.4; 2.1; 2.2; 3.1; 3.8; 3.13 and 4.1 in the above schedule be exceeded due to no fault of the Contractor then the additional days will be charged at the Operational Delay Time.However should the days be less, then the actual days will be charged.

ANNEXURE 2

SCHEDULE OF RESPONSIBILITIES

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ANNEXURE 2

SCHEDULE OF RESPONSIBILITIES

1. **RESPONSIBILITIES OF THE CONTRACTOR**

The Contractor will:-

1.1 Provide 'on site' supervision and technical advice by competent personnel.

1.2 Provide a competent skilled foreman, skilled operators as well as semi-skilled labour for rod handling.

1.3 Ensure that all personnel employed by him are in possession of valid Pneumoconiosis certificates of fitness as well as valid first aid certificates where applicable.

1.4 Employ only operators who are qualified for the work.

1.5 Provide the required equipment for the efficient execution of the raise boring works.

1.6 Pay all wages, bonuses, Provident Fund contributions, unemployment insurance, medical benefit contributions, leave pay and allowances to his employees.

1.7 Ensure that the works are carried out in compliance with the relevant laws and regulations, and the Employer's standards, as far as they affect him or his staff. [NB. The operators are not normally Blasting Certificate holders thus all statutory examinations required for safety, including those concerning holing points, must be done by the Employer's personnel.]

1.8 Ensure the effective and efficient use of all equipment supplied by the Employer and ensure its safekeeping whilst in use by the Contractor.

1.9 Supply all relevant information and progress reports as required by the Employer.

1.10 Supply the necessary maintenance and back up for his equipment.

1.11 Daily and monthly reports on performance will be provided and signed for by the Employer's representative.

1.12 Provide generic risk assessment and procedures. Should the Employer require detailed documentation the Contractor shall be notified timeously and the cost for preparation will be charged at the applicable daily rate. [This will only be provided on award of the contract.]

1.13 Supply accommodation and feeding for his employees.

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2. **SERVICES FOR THE ACCOUNT OF THE EMPLOYER**

The Employer is to provide, free of charge:-

2.1 Change house facilities, caplamps, gas detection equipment and self rescuers for the Contractor's personnel.

2.2 Adequate services as specified here below:-

2.2.1 Water in a pipe of a minimum diameter of 100mm or two settling dams and at a minimum pressure of 600kPa with one 50mm and two 25mm connections within 10m of the machine. The Contractor has made provision for one pump but should the water supply be such that a second pump is required then such pump will be supplied by the Employer.

2.2.2 3 Phase, 50Hz electrical power at a supply voltage of 525V A.C. ± 5%.

2.2.3 The normal power demand for the 83R raise borer is 450kVA.

2.2.4 A 500A circuit breaker fitted with a 500 milli Amp earth leakage unit will be required within 9m of the machine. All cables to be provided for the machine.

2.3 The services of a surveyor will be required to set and align the machine in terms of position and verticality, from two points at right angles to each other. This must be carried out prior to the commencement of drilling, and again for final verification, following collaring of the pilot hole. Such survey will be checked by raise boring personnel and results signed off by both parties.

2.4 All electrical connections and disconnections [Mine supply only].

2.5 The drilling of a sufficient number of lifting and rigging holes in the reamer cubbies and the supply of 1,5m x 20mm sling eyebolts.

2.6 The services of a rigger and provision of all rigging equipment to transport and erect raise bore equipment and all ancillary equipment including the reamer.

2.7 Telephonic communication between the reamer head bay and the raise bore machine.

2.8 All rolling stock required for the movement of the Contractor's equipment from surface to the underground works.

2.9 The supply and installation of a dust suppression system at the reamer hook up site should this be required.

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Annexure 2
Schedule of Responsibilities — Page 3

2.10 Construct foundation pad in consultation with the Contractor.

2.11 Cleaning of all raise bore chips at a rate which will not impede the reaming rate of the Contractor. (± 4-6m/day) The Client to make provision for a Swivel, Scraper Winch plus Operator, plus a Scraper to clean the raise bored chips.

2.12 A suitable mobile crane for the offloading of equipment and reloading thereof after completion of contract.

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ANNEXURE 3

TECHNICAL DATA

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ANNEXURE 3

TECHNICAL DATA

1. **MACHINE AND REAMER BAY**

   It is suggested that we be contacted prior to our arrival on site with a view to the Employer and our representative conducting an actual examination to check the dimensions of such bay, and to ensure adequate time for any changes which may be required. The minimum size for the reamer cubby to be 6m x 6m by 4,5m high – on dip (excluding rod storage space).

2. **REQUIREMENTS, MASSES AND SIZES OF EQUIPMENT: 83R**

   2.1 The machine has a mass of 24 000kg and is 7,0m high in the extended position.

   2.2 This unit can be dismantled with the heaviest component weighing 8 000kg.

   2.3 The concrete foundation required will be as per the Contractor's recommendation and in consultation with the Employer.

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ANNEXURE 4

METHOD STATEMENT

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ANNEXURE 4

METHOD STATEMENT

The Contractor will send the crew to site before the actual site establishment to attend induction and medical on the mine.

Once the crew has completed such activities the raise bore equipment will be transported and offloaded on the surface bank. The Employer will transport the reamer to the underground site.

Once the machine is erected and commissioned on the pre-constructed machine pad on surface, the Employer's surveyor will line up the machine before the drilling of the pilot hole commences.

The Contractor will now pilot the hole to a depth of 206m at 381mm diameter. The rods will be pulled back, the stabilizers will be removed and the rods lowered to where the 3,1m diameter reamer will be attached and collaring will commence until a full face is obtained. The hole will be back reamed to 3,1m diameter and stop at the bottom of the support beams. The reamer will be tied off onto the support beams where after the machine will be removed from the pad. Thereafter the reamer and the support beams will be removed simultaneously using a suitable crane.

The Employer to provide a proper swivel and scraper to be attached to the back of the reamer and a winch to clean the raise bore chips from inside the hole.

In the unlikely event that the Contractor needs to lower the reamer due to the 28 degree angle, the Contractor will request the Employer to blast a cubby in the hanging at the bottom of the hole to inspect / dress the reamer. The standing time during this period will be charged at our operational delay time.

NOTE: The duration for medical examination and induction; and mobilizing of crews and equipment are estimated. Should these delays be exceeded due to no fault of the Contractor the additional days will be charged at the day rate as shown in the Schedule of Rates.

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ANNEXURE 5

SCHEDULE OF QUALIFICATIONS AND CLARIFICATIONS

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ANNEXURE 5

SCHEDULE OF QUALIFICATIONS AND CLARIFICATIONS

Our proposal is based on and subject to this letter and all of the Conditions, Qualifications and Provisions set out herein and in the Annexures forming part hereof.

1 **GROUND CONDITIONS**

Our rates and time schedule are based on the assumption that the ground to be traversed will be clear of cavities and fissures and will be sufficiently stable, homogeneous and free of water to allow efficient mechanical boring. Any requirement for the use of casings, compressed air or drilling muds shall be for the Employer's account.

The Employer or his representative will be notified within 24 hours in the event of any change in conditions which, in the opinion of the Contractor might adversely affect the cost or rate of progress of the programme. The Contractor will then be entitled to apply for a variation in which case a mutually agreed compensation and/or extension of time is granted. The ground to be traversed will not exceed 230MPa. Unplanned lowering due to blocky ground to clear the reamer head will be charged at operational daywork rates [as per Bill of Quantities].

The Contractor suggests that a Stacey/McCracken Geotechnical Risk Assessment is carried out to determine the competency of the ground.

In the unlikely event that the reamer or drill string be lost in the hole due to reasons beyond our control including ground compression, etc., all replacement costs will be for the account of the Employer.

2. **PRICING**

2.1 We intend working three x eight hour shifts (minimum of 24 hours on the machine), working an eleven day fortnight.

2.2 All quantities shown on our Schedule of Rates are re-measurable especially the items beyond our control including transporting of equipment underground.

2.3 Please note that day rates are applicable on various items in our price schedule and these rates are not added to the estimated contract value (see bottom of priced schedule sheet).

3. **PROGRESS REPORTS**

The Contractor will furnish the Employer with daily reports indicating the progressive amount of drilling done, actual drilling done during this period, actual drilling time, stoppages and reasons therefore and the Contractor shall be held responsible for the correctness and accuracy of all data so presented.

Murray & Roberts Cementation RB08.053.PAC.Sel - Anglo Platinum - BRPM South Shaft.Doc

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Annexure 5
Schedule of Qualifications and Clarifications Page 2

4. **ACCURACY**

The Contractor shall use its best endeavours to achieve the most accurate holing during conventional drilling, however no specific accuracy can be guaranteed.

5. **LEGAL RESPONSIBILITY**

The Contractor has allowed for suitably qualified site personnel but the Manager, Resident Engineer, Mine Overseer, Shift Boss and Surveyor required in terms of the Minerals Act shall be the responsibility of the Employer for the duration of the contract.

6. **MACHINE AVAILABILITY**

The prices submitted are dependant on the availability of a machine and crew. Therefore should our prices be of interest a firm Order/Letter of Acceptance should be forwarded to us to have a machine scheduled for this contract.

7. **PLANNING**

7.1 Should we be awarded this work, we would request a meeting with the Employer, approximately two to three weeks prior to the commencement date, to conduct final discussions on the planning and scheduling of the works.

7.2 We would request monthly meetings to discuss progress and problem solving, following commencement of the works. Such meetings would be in the order of 20 to 30 minutes long.

8. **CUBBY AVAILABILITY**

The Employer to ensure that the reamer cubby is available in time, day rates will apply if the Contractor is delayed.

9. **LOWERING OF REAMER**

Should the Contractor be required to lower the reamer for any reason and delayed due to build up of chips in the raise bore hole then such delay time will be for the Employer's account.

10. **MOVING EQUIPMENT UNDERGROUND AND TO SURFACE**

The Contractor has made allowance for a rate per day for the movement of the equipment underground and to surface. Therefore regardless of the duration time, it will be invoiced for the days taken, at the day rate.

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ADDITIONAL QUALIFICATIONS AND CLARIFICATIONS

11. In the unlikely event (as result of 28 degree angle) that the reamer or drill string be;

   a) damaged during drilling,
   b) damaged while lowering or retracting drill pipe for cutter change or inspection (drill string or reamer),
   c) delays caused due to inability to pull reamer back to the face due to poor ground conditions,
   d) delays or damage due to broken or blocky ground.

   Then all costs for repairs and/or replacement will be for the account of the Employer.

   The reamer will not be lowered out of the hole for cutter inspection or replacement and an access to the reamer will have to be excavated (blasted) at the mouth of the hole. The reamer will however be lowered to the mouth of the hole for inspection or cutter replacement.

APPENDIX G

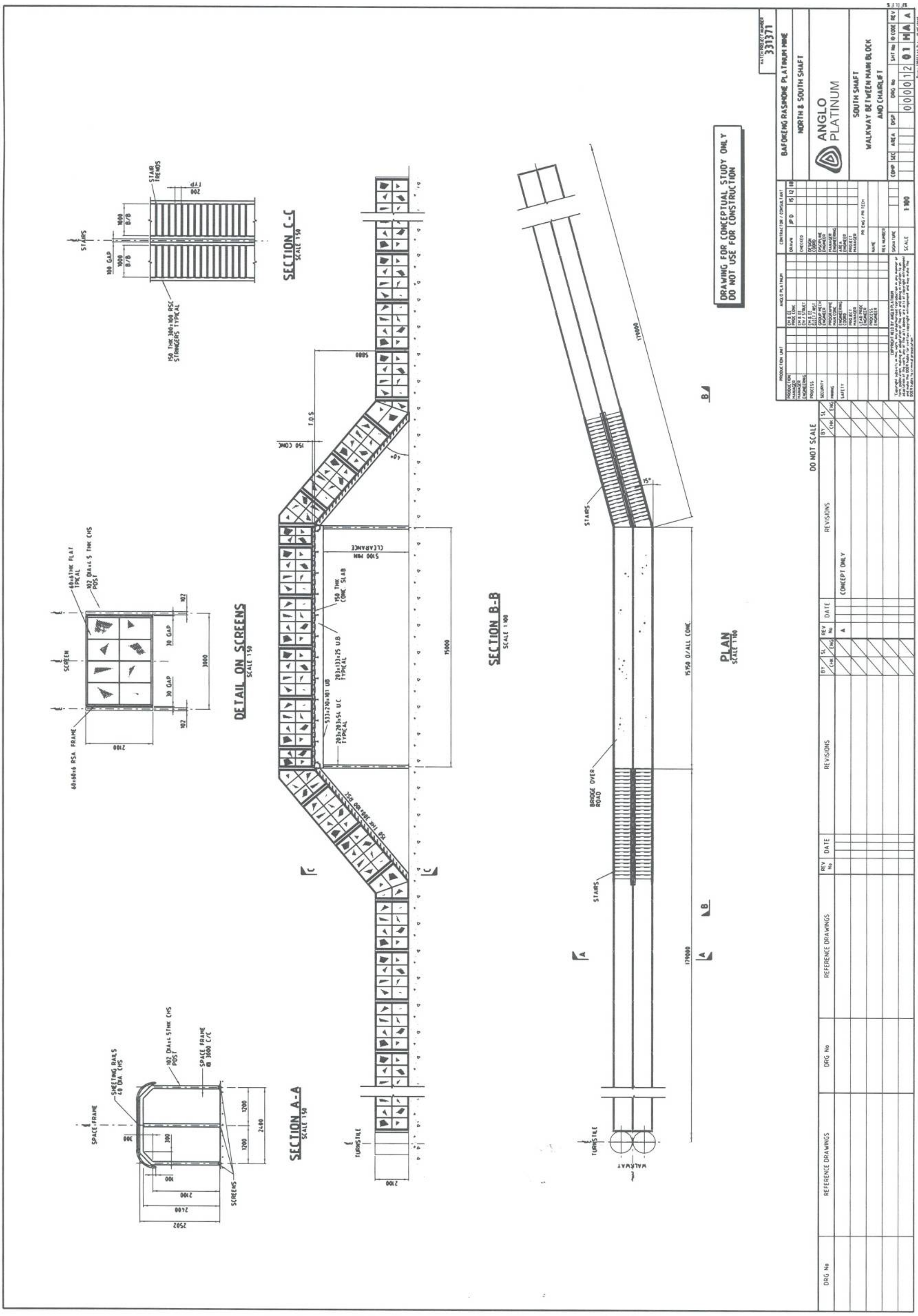
Bafokeng Rasimone Platinum Mine
Walkway steelwork
Based on walkway for Impala 11c

By: S Lo Drago
Rev: 0
Date: 2008/12/10

Area	Quantity Calculation Number	Item	Member Size	Mass per m (kg/m)	Length (m)	Quantity	Medium (T)
		Totals:					76.45
	Horizontal walkway	Column	102 x 5.0 CHS	12.0	2.1	244	6.1
		Rafter	102 x 5.0 CHS	12.0	2.6	122	3.8
		Purlins	43 x 4.0 CHS	3.9	3	360	4.2
		Bracing side	70 x 70 x 6 L	6.4	3.34	8	0.2
		Bracing roof	70 x 70 x 6 L	6.4	4	8	0.2
		Eaves tie	43 x 4.0 CHS	3.9	3	240	2.8
		10% Connections					1.73
	Stair section	Stringers	300 x 100 x 46 C	46.1	8.7	8	3.2
		Column	102 x 5.0 CHS	12.0	5.1	8	0.5
		Rafter	102 x 5.0 CHS	12.0	2.6	4	0.1
		Purlins	43 x 4.0 CHS	3.9	3	18	0.2
		Bracing roof	70 x 70 x 6 L	6.4	3.34	2	0
		Eaves tie	43 x 4.0 CHS	3.9	3	2	0
		Side Bracing	70 x 70 x 6 L	6.4	4	2	0.1
		10% connections					0.41
	Bridge section	Main girder beam	533 x 210 x 101 UB	101.0	16	2	3.2
		Columns	102 x 5.0 CHS	12.0	2.1	10	0.3
		Rafter	102 x 5.0 CHS	12.0	2.6	5	0.2
		Purlins	43 x 4.0 CHS	3.9	3	15	0.2
		Bracing side	70 x 70 x 6 L	6.4	4	4	0.1
		Bracing roof	70 x 70 x 6 L	6.4	3.34	2	0
		Eaves tie	43 x 4.0 CHS	3.9	3	10	0.1
		Main columns	203 x 203 x 52 UC	52.1	5.1	4	1.1
		Vertical Bracing Horizontal	152 x 152 x 23 UC	23.3	2.6	2	0.1
		Vertical Bracing Diagonal	80 x 80 x 8 L	9.6	3.676	8	0.3
		Floor beams	152 x 152 x 23 UC	23.3	2.6	5	0.3
		10% Connections					0.59
	Screens	Posts	102 x 5.0 CHS	12.0	2.1	132	3.3
		Frame	60 x 60 x 8 L	7.1	2	960	13.6
		Frame	60 x 60 x 8 L	7.1	1.5	960	10.2
		Flats	60x8thk plate	3.77	2	480	3.6
		Flats	60x8thk plate	3.77	1.5	480	2.7
		Valmatex	type 310	3.7	1	2365	8.8
		10% Connections					4.22
		Stair treads	132 off standard treads			132	
		Handrailing				70	
		Sheeting	550m2			550	
	Concrete						
		Foundations for column plinths	115				
		Re-bar	9.2 tonne				
		Foundations for walkways	200				
		Re-bar	16 tonne				

Total cost of walkway	Steelwork	76.6 tonne at R40 000.00	3058000
	Concrete	$315m^3$ at R4000.00	1260000
	Turnstile unit		80000
			4398000

APPENDIX H



DRAWING FOR CONCEPTUAL STUDY ONLY
DO NOT USE FOR CONSTRUCTION
SECTION C-C
DETAIL ON SCREENS
SECTION B-B
PLAN
SECTION A-A
DO NOT SCALE
REVISIONS
REFERENCE DRAWINGS
CONCEPT ONLY
BAFOKENG RASIMONE PLATINUM MINE
NORTH & SOUTH SHAFT
ANGLO PLATINUM
SOUTH SHAFT
WALKWAY BETWEEN MAIN BLOCK AND CHAIRLIFT

APPENDIX I

ANGLO PLATINUM

BAFOKENG RASIMONE PLATINUM MINE

PERSONNEL TRANSPORTATION SIMULATION REPORT

05 OCTOBER 2009
THIRD DRAFT

SIMULATION ENGINEERING
TECHNOLOGIES

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Revision Notes

Revision	Date	Description	Originator
A	29 July 2009	Draft for Comment	Stephen Nichol
B	17 August 2009	Second Draft	Stephen Nichol
C	05 October 2009	Third Draft	Stephen Nichol

Revision Approval

Revision	Designation	Reviewer	Date	Signature

TABLE OF CONTENTS

1. Executive Summary

Simulation Engineering Technologies (SET) prepared a computer model to simulate the personnel handling options at the Bafokeng-Rasimone Platinum Mine (BRPM). BRPM considers replacing the current man-conveyor with a chairlift system. The simulation will be able to quantify the relative performance of each option for both declines.

The main objectives of the simulation models are to determine:

Maximum personnel transportation capacity of both options,

- Expected queuing time and quantity that can be expected on surface and at each level station (Average, Maximum),
- Total personnel transportation time (Average, Minimum, Maximum).

The Weighted average for the conveyor and the chairlift on the original arrival schedule is summarized in Table 1-1. It is calculated that that the chairlift requires 966 hours and 827 hours more for the North and South Shaft respectively, to transport the personnel daily.

Table 1-1-Weighted average summary

	Unit	North Shaft	South Shaft	Description
Conveyor	min	36.9	36.2	Average travel time per personnel
Chairlift	min	65.3	61.7	Average travel time per personnel
Difference	min	28.33	25.55	Average increase using the chairlift
Total Personnel	ea	1983	1942	Average daily personnel
Man Hours p/d	h	936	827	Increase in daily man hour travel time

The chairlift and conveyor velocity and spacing has to conform to regulations, thus the only way to decrease travel time on the chairlift and conveyor is to streamline the schedule to decrease the queue times.

Table 1-3 shows the amount of man hours that could be used more constructively when defining the arrival schedule for the North shaft

Table 1-2-North shaft schedule comparison

		North Shaft			
Description	**Unit**	**Conveyor**		**Chairlift**	
Schedule		Original	Alternative	Original	Alternative
Weighted Average	h	36.9	28.0	65.3	35.0
Total Man hours to travel p/d	h/shift	1220.4	925.0	2156.6	1157.0
Man hours gained	h	295.4		999.7	

Table 1-3 shows the amount of man hours that could be used more constructively when defining the arrival schedule for the South shaft.

Table 1-3-South shaft schedule comparison

		South Shaft			
Description	**Unit**	**Conveyor**		**Chairlift**	
Schedule		Original	Alternative	Original	Alternative
Weighted Average	h	36.2	28.8	61.7	34.8
Total Man hours to travel p/d	h/shift	1170.9	931.3	1997.9	1124.9
Man hours gained	h	239.6		872.9	

2. Introduction

Simulation Engineering Technologies (SET) prepared a computer model to simulate the personnel handling options at the Bafokeng-Rasimone Platinum Mine (BRPM). BRPM considers replacing the current man-conveyor with a chairlift system. The simulation will be able to quantify the relative performance of each option for both declines.

This document describes the modeling logic and associated assumptions, model inputs, and simulation results. The model was developed using the Arena® simulation software, Version 12.0. Model development followed a modular approach to ensure that future enhancements and system add-ons may be accommodated.

A user-friendly Microsoft Excel® interface was provided to enable future entry of alternative simulation inputs, including conveyor and chairlift speed and spacing, shift times and personnel per level. Model results are presented and updated by Arena in Excel worksheets.

3. Objectives

Simulation models were constructed for both the South and North declines. The model's battery limit is at the shaft stations and no additional personnel movement was modeled. Instead, it is assumed that men will return to the shaft stations after a typical shift length delay according to a statistical distribution.

The main objectives of the simulation models are to determine:

Maximum personnel transportation capacity of both options,

- Expected queuing time and quantity that can be expected on surface and at each level station (Average, Maximum),
- Total personnel transportation time (Average, Minimum, Maximum).

The following deliverables are provided:

- Discrete-event simulation model of two personnel transportation systems between surface and 1 Level to 5 Level ,including
  - Personnel arrival schedule on surface,
  - Personnel loading time and capacity,
  - Current conveyor personnel transportation system
  - Alternative chairlift model,
  - Loading and Offloading of personnel at level stations,

- Excel input spreadsheet that provides the means to insert alternative input parameters to the model and conduct sensitivity analysis.
- Excel output spreadsheet and graphics that summarize simulation results.
- Computer animation of the transportation systems in two-dimensional colour that aids in understanding and validating that the model works as intended.
- Report on the model findings of both personnel transportation scenarios,
- A compact disk containing the following.
  - Excel spreadsheets, including input and output interfaces.
  - Arena Simulation model files.
  - A copy of the report provided in Adobe Acrobat PDF format.

4. Model Inputs and Assumptions

The following section describes model logic, inputs and assumptions incorporated in the simulation model.

4.1 Process Overview

Fig 4.1 describes the schematic flow for both transportation options. All the models are simulated for a period of 365 days. The personnel assigned to 6 Level to 10 Level are dropped off at 5 Level in the model from where they use a secondary chairlift from 5 level to reach their destination levels.

The chairlift / conveyor segment length between levels for the North shaft is described in Table 4-1

Table 4-1-North Shaft segment length

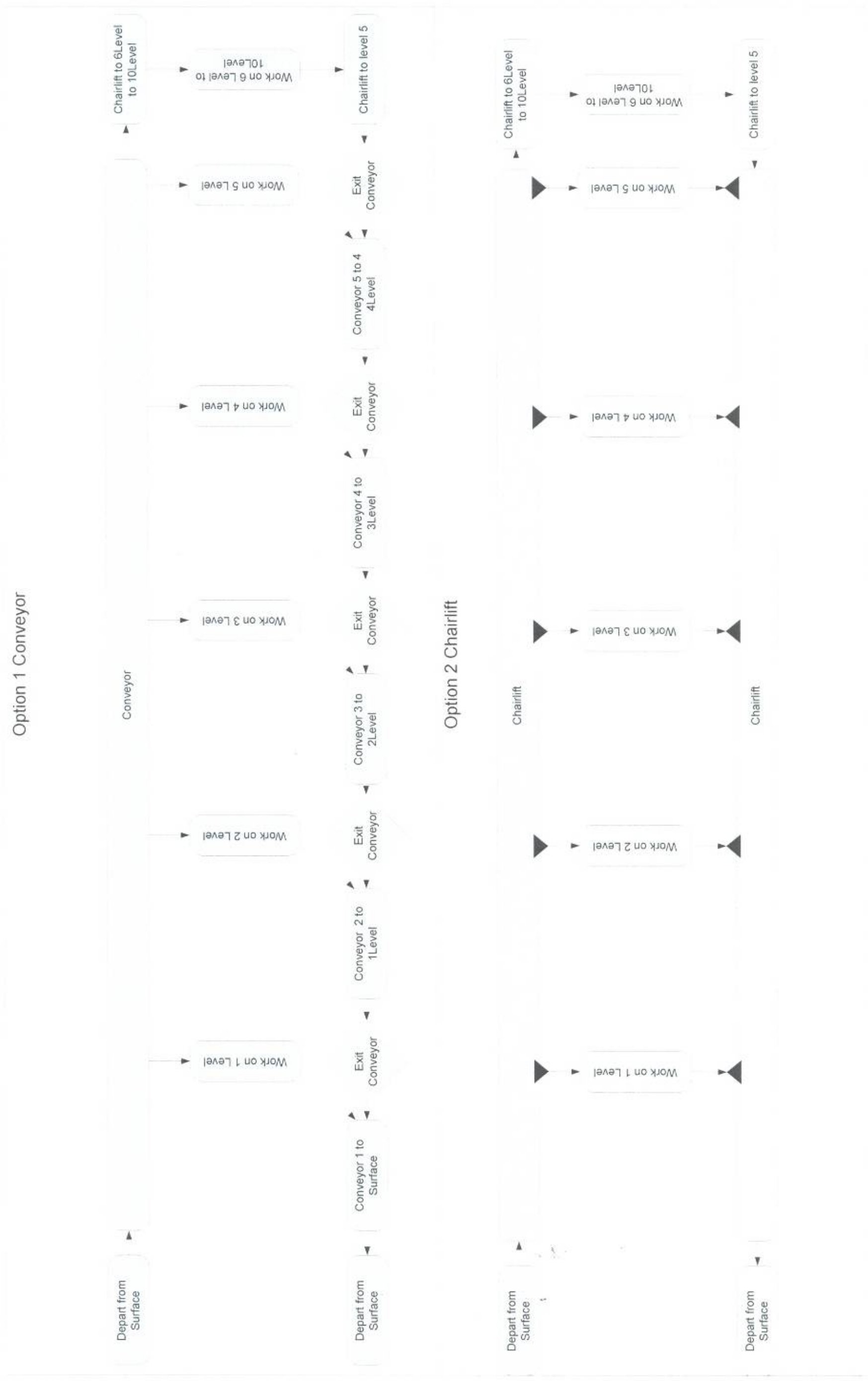
Segment	Description	Chairlift Length (in m)	Conveyor Length (in m)
1	Surface to 1 Level	665	745
2	1 Level to 2 Level	175	170
3	2 Level to 3 Level	285	260
4	3 Level to 4 Level	115	180
5	4 Level to 5 Level	335	315

The segment length between levels for the South shaft is described in Table 4-2

Table 4-2-South shaft segment length

Segment	Description	Chairlift Length (in m)	Conveyor Length (in m)
1	Surface to 1 Level	775	770
2	1 Level to 2 Level	300	235
3	2 Level to 3 Level	140	155
4	3 Level to 4 Level	260	275
5	4 Level to 5 Level	228	305

Fig 4-1-Schematic Flow of Transportation systems



4.2 Conveyor Transportation Option

The conveyor parameters for the simulation are

- Conveyor speed = 2m/s,
- Conveyor spacing = 5m,
- Conveyor length per segment as described in Table 4-1 and Table 4-2 for the North and South shaft, respectively.

It is assumed that personnel queue at the surface to enter the conveyor and exit the conveyor on their assigned level. The personnel allocated to 6level to 10level are conveyed to 5 level.

It is also assumed that on the return to the surface, personnel enter the conveyor from the level that they are assigned to and exit the conveyor on each level. They will queue for the conveyor on each level and re-enter the conveyor until they reach the surface.

4.3 Chairlift Transportation Option

The chairlift parameters for the simulation are

- Chairlift speed = 1.5m/s,
- Chairlift spacing = 6m,
- Chairlift length per segment as described in Table4-1 and Table 4-2 for the North and South shaft, respectively.

It is assumed that the personnel queue at the surface to enter the chairlift to go down to their assigned level. The personnel only exit the chairlift when they have reached their assigned level.

On completion of their work the personnel queue to enter the chairlift, and when entered, they only exit the chairlift when they have reached the surface. The personnel assigned to 6level to 10 level reenter the chairlift at 5level to return to the surface.

4.4 Personnel shift schedule

North shaft shift schedule

Table 4-3 describes the day shift schedule and personnel quantities per level for the North shaft

Table 4-3-North Shaft Day Shift Schedule

Description	Personnel Quantity	Shift Start Time	Shift Start Midpoint	Shift Start Closing Time
1 Level	41	5:30 AM	5:52 AM	6:15 AM
2 Level	56	5:30 AM	5:52 AM	6:15 AM
3 Level	223	5:30 AM	5:52 AM	6:15 AM
4 Level	305	5:30 AM	6:00 AM	6:30 AM
5 Level	369	5:30 AM	6:07 AM	6:45 AM
6 Level	309	5:30 AM	6:15 AM	7:00 AM
7 Level	371	5:30 AM	6:15 AM	7:00 AM
8 Level	181	5:30 AM	6:15 AM	7:00 AM
9 Level	128	5:30 AM	6:15 AM	7:00 AM
10 Level	0	5:30 AM	6:15 AM	7:00 AM
Total	**1 983**			

South shaft shift schedule

Table 4-4-describes the day shift schedule and personnel quantities per level for the South shaft

Table 4-4-South Shaft Day Shift Schedule

Description	Personnel Quantity	Shift Start Time	Shift Start Midpoint	Shift Start Closing Time
1 Level	302	5:00 AM	5:40 AM	6:20 AM
2 Level	170	5:00 AM	5:45 AM	6:30 AM
3 Level	105	5:00 AM	5:50 AM	6:40 AM
4 Level	96	5:00 AM	5:55 AM	6:50 AM
5 Level	411	5:00 AM	6:00 AM	7:00 AM
6 Level	302	5:00 AM	5:40 AM	6:20 AM
7 Level	186	5:00 AM	5:30 AM	6:00 AM
8 Level	185	5:00 AM	5:30 AM	6:00 AM
9 Level	185	5:00 AM	5:30 AM	6:00 AM
10 Level	0	5:00 AM	5:30 AM	6:00 AM
Total	**1 942**			

5. Results

The results for the North and South Shaft are captured individually and are described in the following section.

5.1 North Shaft Results

Table 5-1 shows the comparative total travel time for the conveyor model and the chairlift model for the North shaft. The Table also describes the difference used to transport personnel in man hours between the conveyor and chairlift. Appendix A Table A-1 shows the detail comparative simulation outputs for the conveyor model and the chairlift model for the North shaft

Table 5-1-North Shaft Average total travel time comparison table

	Conveyor	**Chairlift**	**Description**
Nr of personnel	1983	1983	Total nr of personnel to enter shaft
	Weighted Average (in m)	**Weighted Average (in m)**	**Description**
Queue time at surface Travel time to level	10.75 12.71	33.05 15.94	The time in queue to enter the mine Time spend on conveyor/chairlift downwards
Total Time inbound	23.79	49.04	Queue time + travel time to level
Level queue times outbound Travel time to surface	0.01 13.14	0.23 15.94	Time in queues on levels to surface Time spend on conveyor/chairlift to surface
Total time outbound	17.55	16.22	Level queue time + travel time to surface
Total travel time	36.93	65.25	Total time inbound + total time outbound
Total man hours to travel p/d	1220.43	2156.63	Total travel time x total no of personnel /60min

5.2 South Shaft Results

Table 5-2- Compares the total travel time of the Conveyor model and the Chairlift model on the South Shaft. The Table also describes the difference used to transport personnel in man hours between the conveyor and chairlift. Appendix A Table A-2 shows the detail comparative simulation outputs for the conveyor model and the chairlift model for the South shaft.

Table 5-2-South shaft average total travel time comparison table

	Conveyor	**Chairlift**	**Description**
Nr of personnel	1942	1942	Total nr of personnel to enter shaft
	Weighted Average (in m)	**Weighted Average (in m)**	**Description**
Queue time at surface Travel time to level	7.27 12.91	27.89 16.07	The time in queue to enter the mine Time spend on conveyor/chairlift downwards
Total Time inbound	20.46	44.00	Queue time + travel time to level
Level queue times outbound Travel time to surface	0.41 15.72	1.62 16.07	Time in queues on levels to surface Time spend on conveyor/chairlift to surface
Total time outbound	18.75	17.73	Level queue time + travel time to surface
Total travel time	36.18	61.73	Total time inbound + total time outbound
Total man hours to travel p/d	1170.88	1997.88	Total travel time x total no of personnel /60min

6. Alternative Personnel Schedule Scenario

An alternative arrival schedule was used where personnel arrive within a pre-defined interval, where the interval length is the time required to access all the personnel allocated to a level at full capacity.

6.1 North Shaft Alternative Schedule s

The conveyor parameters are:
The conveyor velocity = 2m/s
The conveyor spacing = 5m
The Entry interval =2.5 s (Time between entries to the conveyor)

Table 6-1 shows the original schedule compared to the new alternative schedule for the North Shaft conveyor. 24 personnel can enter the conveyor in a minute

For example, 41 personnel are allocated to 1 Level on the North shaft. The conveyor has a velocity of 2m/s with a spacing requirement of 5m. This means that personnel can enter the conveyor after each 2.5 s (5m/s / 2s). The time required for all the personnel allocated to 1 level to access the conveyor is: 41 personnel x 2.5s = 102.5 s. The alternative schedule for 1 level personnel is from 05:30:00 to 05:31:43. The alternative schedule for 2Level will start when the schedule for 1level ends.

Table 6-1-Revised North shaft schedule-Conveyor

Description	Personnel Quantity	Original Shift Start Time	Alternative Shift Start Time	Original Shift Start Closing Time	Alternative Shift Start Closing Time
1 Level	41	5:30 AM	5:30 AM	6:15 AM	5:31 AM
2 Level	56	5:30 AM	5:31 AM	6:15 AM	5:34 AM
3 Level	223	5:30 AM	5:34 AM	6:15 AM	5:43 AM
4 Level	305	5:30 AM	5:43 AM	6:30 AM	5:56 AM
5 Level	369	5:30 AM	5:56 AM	6:45 AM	6:11 AM
6 Level	309	5:30 AM	6:11 AM	7:00 AM	6:24 AM
7 Level	371	5:30 AM	6:24 AM	7:00 AM	6:39 AM
8 Level	181	5:30 AM	6:39 AM	7:00 AM	6:47 AM
9 Level	128	5:30 AM	6:47 AM	7:00 AM	6:52 AM
10 Level	0	5:30 AM	6:52 AM	7:00 AM	6:52 AM

Table 6-2 compares the outputs of the original schedule against the alternative schedule total travel time. Appendix B Table B-1 describes the difference in outputs for the conveyor in the North shaft with the original schedule against the alternative schedule.

Table 6-2-North shaft conveyor total travel time comparison

	Original Schedule	**New Schedule**	**Description**
Nr of personnel	1983	1983	Total nr of personnel to enter shaft
	Weighted Average (in m)	**Weighted Average (in m)**	**Description**
Queue time at surface	10.75	1.90	The time in queue to enter the mine
Travel time to level	12.71	12.71	Time spend on conveyor/chairlift downwards
Total Time inbound	23.79	14.95	Queue time + travel time to level
Level queue times outbound	0.01	0.00	Time in queues on levels to surface
Travel time to surface	12.71	12.71	Time spend on conveyor/chairlift to surface
Total time outbound	13.14	13.04	Level queue time + travel time to surface
Total travel time	36.93	27.99	Total time inbound + total time outbound
Total man hours to travel p/d	1220.43	924.99	Total travel time x total no of personnel /60min

The chairlift parameters are:

- The chairlift velocity = 1.5m/s
- The chairlift spacing = 6m
- The Entry interval =4s (Time between entries to the chairlift)

Table 6-3 shows the original schedule compared to the new alternative schedule for the North shaft chairlift. 15 personnel can enter the chairlift in a minute.

Table 6-3-Revised North shaft schedule-Chairlift

Description	Personnel Quantity	Original Shift Start Time	Alternative Shift Start Time	Original Shift Start Closing Time	Alternative Shift Start Closing Time
1 Level	41	5:30 AM	5:30 AM	6:15 AM	5:32 AM
2 Level	56	5:30 AM	5:32 AM	6:15 AM	5:36 AM
3 Level	223	5:30 AM	5:36 AM	6:15 AM	5:51 AM
4 Level	305	5:30 AM	5:51 AM	6:30 AM	6:11 AM
5 Level	369	5:30 AM	6:11 AM	6:45 AM	6:36 AM
6 Level	309	5:30 AM	6:36 AM	7:00 AM	6:56 AM
7 Level	371	5:30 AM	6:56 AM	7:00 AM	7:21 AM
8 Level	181	5:30 AM	7:21 AM	7:00 AM	7:33 AM
9 Level	128	5:30 AM	7:33 AM	7:00 AM	7:42 AM
10 Level	0	5:30 AM	7:42 AM	7:00 AM	7:42 AM

Table 6-4 compares the outputs of the original schedule against the alternative schedule total travel time. Appendix B Table B-2 describes the difference in outputs for the conveyor in the North shaft with the original schedule against the alternative schedule.

Table 6-4-North shaft chairlift total travel time Comparison

	Original Schedule	New Schedule	Description
Nr of personnel	1983	1983	Total nr of personnel to enter shaft
	Weighted Average (in m)	**Weighted Average (in m)**	**Description**
Queue time at surface	33.05	3.03	The time in queue to enter the mine
Travel time to level	15.94	15.94	Time spend on conveyor/chairlift downwards
Total Time inbound	49.04	19.02	Queue time + travel time to level
Level queue times outbound	0.23	0.01	Time in queues on levels to surface
Travel time to surface	15.94	15.94	Time spend on conveyor/chairlift to surface
Total time outbound	16.22	15.99	Level queue time + travel time to surface
Total travel time	65.25	35.01	Total time inbound + total time outbound
Total man hours to travel p/d	2156.63	1156.97	Total travel time x total no of personnel /60min

6.2 South Shaft Alternative Schedule

The conveyor and chairlift parameters for the South shaft are the same as the North shaft. Table 6-5 shows the original schedule against the alternative schedule for the South shaft conveyor.

Table 6-5-Revised South shaft schedule-Conveyor

Description	Personnel Quantity	Original Shift Start Time	Alternative Shift Start Time	Original Shift Start Closing Time	Alternative Shift Start Closing Time
1 Level	302	5:00 AM	5:00 AM	6:20 AM	5:12 AM
2 Level	170	5:00 AM	5:12 AM	6:30 AM	5:19 AM
3 Level	105	5:00 AM	5:19 AM	6:40 AM	5:24 AM
4 Level	96	5:00 AM	5:24 AM	6:50 AM	5:28 AM
5 Level	411	5:00 AM	5:28 AM	7:00 AM	5:45 AM
6 Level	302	5:00 AM	5:45 AM	6:20 AM	5:57 AM
7 Level	186	5:00 AM	5:57 AM	6:00 AM	6:05 AM
8 Level	185	5:00 AM	6:05 AM	6:00 AM	6:13 AM
9 Level	185	5:00 AM	6:13 AM	6:00 AM	6:20 AM
10 Level	0	5:00 AM	6:20 AM	6:00 AM	6:20 AM

Table 6-6 compares the total travel time of the original schedule against the alternative schedule. Appendix B Table B-3 describes the difference in outputs for the conveyor in the South shaft with the original schedule against the alternative schedule

Table 6-6-South shaft conveyor total travel time comparison

	Original Schedule	New Schedule	Description
Nr of personnel	1942	1942	Total nr of personnel to enter shaft
	Weighted Average (in m)	**Weighted Average (in m)**	**Description**
Queue time at surface	7.27	2.08	The time in queue to enter the mine
Travel time to level	12.91	12.91	Time spend on conveyor/chairlift downwards
Total Time inbound	20.46	15.28	Queue time + travel time to level
Level queue times outbound	0.41	0.28	Time in queues on levels to surface
Travel time to surface	12.91	12.91	Time spend on conveyor/chairlift to surface
Total time outbound	15.72	13.49	Level queue time + travel time to surface
Total travel time	36.18	28.77	Total time inbound + total time outbound
Total man hours to travel p/d	1170.88	931.25	Total travel time x total no of personnel /60min

Table 6-7 shows the original schedule against the alternative arrival schedule for the chairlift in the South shaft

Table 6-7-Revised South shaft schedule-Chairlift

Description	Personnel Quantity	Original Shift Start Time	Alternative Shift Start Time	Original Shift Start Closing Time	Alternative Shift Start Closing Time
1 Level	302	5:00 AM	5:00 AM	6:20 AM	5:20 AM
2 Level	170	5:00 AM	5:20 AM	6:30 AM	5:31 AM
3 Level	105	5:00 AM	5:31 AM	6:40 AM	5:38 AM
4 Level	96	5:00 AM	5:38 AM	6:50 AM	5:44 AM
5 Level	411	5:00 AM	5:44 AM	7:00 AM	6:12 AM
6 Level	302	5:00 AM	6:12 AM	6:20 AM	6:32 AM
7 Level	186	5:00 AM	6:32 AM	6:00 AM	6:44 AM
8 Level	185	5:00 AM	6:44 AM	6:00 AM	6:57 AM
9 Level	185	5:00 AM	6:57 AM	6:00 AM	7:09 AM
10 Level	0	5:00 AM	7:09 AM	6:00 AM	7:09 AM

Table 6-8 compares the total travel time of the original schedule against the alternative schedule. Appendix B Table B-4 describes the difference in outputs for the conveyor in the South shaft with the original schedule against the alternative schedule.

Table 6-8-South Shaft Chairlift Total Travel Time Comparison

	Original Schedule	New Schedule	Description
Nr of personnel	1942	1942	Total nr of personnel to enter shaft
	Weighted Average (in m)	**Weighted Average (in m)**	**Description**
Queue time at surface Travel time to level	27.89 16.07	3.35 16.07	The time in queue to enter the mine Time spend on conveyor/chairlift downwards
Total Time inbound	44.00	18.16	Queue time + travel time to level
Level queue times outbound Travel time to surface	1.62 16.07	0.01 16.07	Time in queues on levels to surface Time spend on conveyor/chairlift to surface
Total time outbound	17.73	16.59	Level queue time + travel time to surface
Total travel time	61.73	34.76	Total time inbound + total time outbound
Total man hours to travel p/d	1997.88	1124.93	Total travel time x total no of personnel /60min

7. Conclusion

The North and the South shaft travel time increases immensely when using the chairlift as transportation method. The velocity decreases from 2m/s to 1.5 m/s and the spacing increases from 5m to 6m. The travel time on the chairlift is 33% longer than the travel time on the conveyor.

The arrival time schedules at the surface stay constant, but with personnel being transported at a slower pace, the average queue time increases by 307% from 10.75min to 33.05min and by 383% from 7.27min to 27.89min to access the chairlift for the North and South Shaft respectively.

The average queue times to exit the levels increase on the North shaft levels by 2300% from 0.01min to 0.23min. The average queue time on the South shaft increase from 395% from 0.41min to 1.62min. It is observed that the capacity of the chairlift is obtained in the lower levels and there are personnel on 1 level and 2 level who queue to enter access the chairlift for extensive periods.

The Weighted average for the conveyor and the chairlift on the original arrival schedule is summarized in Table 7-1. It is calculated that that the chairlift requires 936 hours and 827 hours more for the North and South Shaft respectively, to transport the personnel daily.

Table 7-1-Weighted average summary

	Unit	North Shaft	South Shaft	Description
Conveyor	min	36.9	36.2	Average travel time per personnel
Chairlift	min	65.3	61.7	Average travel time per personnel
Difference	min	28.33	25.55	Average increase using the chairlift
Total Personnel	ea	1983	1942	Average daily personnel
Man Hours p/d	h	936	827	Increase in daily man hour travel time

The alternative arrival schedule was used were personnel arrive within a pre-defined interval, were the interval length is the time required to access all the personnel allocated to a level at full capacity. Table 7-2 shows the amount of man hours that could be used more constructively when defining the arrival schedule for the North shaft.

Table 7-2-North shaft schedule comparison

		North Shaft			
Description	**Unit**	**Conveyor**		**Chairlift**	
Schedule		Original	Alternative	Original	Alternative
Weighted Average	h	36.9	28.0	65.3	35.0
Total Man hours to travel p/d	h/shift	1220.4	925.0	2156.6	1157.0
Man hours gained	h	295.4		999.7	

Table 7-3 shows the amount of man hours that could be used more constructively when defining the arrival schedule for the South shaft.

Table 7-3-South shaft schedule comparison

		South Shaft			
Description	**Unit**	**Conveyor**		**Chairlift**	
Schedule		Original	Alternative	Original	Alternative
Weighted Average	h	36.2	28.8	61.7	34.8
Total Man hours to travel p/d	h/shift	1170.9	931.3	1997.9	1124.9
Man hours gained	h	239.6		872.9	

It is observed that the schedule can influence the queue times. The chairlift and conveyor velocity and spacing has to conform to regulations, thus the only way to decrease travel time on the chairlift and conveyor is to streamline the schedule to decrease the queue times.

Appendix A

Table A-1-North Shaft Results Comparison Table

			Conveyor		Chairlift	
1. Surface	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
Queue time at surface	min	1983	10.75	22.25	33.05	63.83
No of personnel in queue	ea	1983	14.80	534.00	45.52	958.00
2.Travel time on conveyor/chairlift to:	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	6.21	6.21	7.39	7.39
2 Level	min	56	7.63	7.63	9.39	9.39
3 Level	min	223	9.79	9.79	12.56	12.56
4 Level	min	305	11.29	11.29	13.83	13.83
5 Level	min	1358	13.92	13.92	17.50	17.50
Weighted Average	min	1983	12.71		15.94	
3.Total Time inbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	10.71	25.58	21.40	57.13
2 Level	min	56	12.19	26.71	23.50	59.06
3 Level	min	223	14.39	29.21	26.59	63.30
4 Level	min	305	20.14	33.75	38.87	75.88
5 Level	min	1358	27.02	36.54	56.89	81.37
Weighted Average	min	1983	23.79		49.04	
4. Level queue times Outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	0.02	0.71	3.87	32.36
2 Level	min	56	0.02	0.67	1.65	17.76
3 Level	min	223	0.03	0.87	0.48	13.63
4 Level	min	305	0.03	0.67	0.31	7.34
5 Level	min	1358	-	-	0.01	0.01
Weighted Average		1983	0.01		0.23	
5. No of personnel in level queues	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	ea	41	0.03	17.00	0.11	20.00
2 Level	ea	56	0.03	17.00	0.06	18.00
3 Level	ea	223	0.04	21.00	0.07	17.00
4 Level	ea	305	0.04	16.00	0.07	15.00
5 Level	ea	1358	-	1.00	0.01	1.00
Weighted Average	ea	1983	0.01		0.03	

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6.Travel time on conveyor/ chairlift to surface from:	Unit	No of Personnel	AVG	Max	AVG	Max
1 Level	min	41	6.21	6.21	7.39	7.39
2 Level	min	56	7.63	7.63	9.39	9.39
3 Level	min	223	9.79	9.79	12.56	12.56
4 Level	min	305	11.29	11.29	13.83	13.83
5 Level	min	1358	13.92	13.92	17.50	17.50
Weighted Average	min	1983	12.71		15.94	
7. Total time outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	6.30	6.92	11.30	39.79
2 Level	min	56	7.84	8.75	11.08	27.19
3 Level	min	223	10.14	11.50	13.08	26.23
4 Level	min	305	11.72	13.12	14.19	21.21
5 Level	min	1358	14.37	15.79	17.55	17.55
Weighted Average	min	1983	13.14		16.22	
8.Utilization	**Unit**					
Inbound	%		7.16%		10.65%	
Outbound	%		7.55%		11.17%	

Table A-2-South Shaft Results Comparison Table

			Conveyor		Chairlift	
1. Surface	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
Queue time at surface	min	1942	7.27	18.10	27.89	54.34
No of personnel in queue	ea	1942	9.80	435.00	37.61	816.00
2.Travel time on conveyor/chairlift to:	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	6.42	6.42	8.39	8.39
2 Level	min	170	8.38	8.38	11.72	11.72
3 Level	min	105	9.67	9.67	13.28	13.28
4 Level	min	96	12.79	12.79	16.17	16.17
5 Level	min	1269	15.33	15.33	18.70	18.70
Weighted Average	min	1942	12.91		16.07	
3.Total Time inbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	14.57	24.52	36.27	62.59
2 Level	min	170	17.24	26.60	43.66	66.05
3 Level	min	105	18.68	27.86	48.05	67.66
4 Level	min	96	21.52	31.11	52.61	70.43
5 Level	min	1269	22.36	33.81	44.90	73.06
Weighted Average	min	1942	20.46		44.00	
4. Level queue times Outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	2.39	7.53	10.02	33.43
2 Level	min	170	0.09	1.47	0.41	5.23
3 Level	min	105	0.03	0.54	0.23	3.38
4 Level	min	96	0.02	0.38	0.14	2.01
5 Level	min	1269	0.04	0.76	0.01	0.01
Weighted Average		1942	0.41		1.62	
5. No of personnel in level queues	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	ea	302	3.22	162.00	2.10	77.00
2 Level	ea	170	0.11	33.00	0.05	12.00
3 Level	ea	105	0.03	13.00	0.02	8.00
4 Level	ea	96	0.02	9.00	0.01	7.00
5 Level	ea	1269	0.03	19.00	0.00	1.00
Weighted Average	ea	1942	0.53		0.34	

6.Travel time on conveyor/ chairlift to surface from:	Unit	No of Personnel	AVG	Max	AVG	Max
1 Level	min	302	6.42	6.42	8.39	8.39
2 Level	min	170	8.38	8.38	11.72	11.72
3 Level	min	105	9.67	9.67	13.28	13.28
4 Level	min	96	12.79	12.79	16.17	16.17
5 Level	min	1269	15.33	15.33	18.70	18.70
Weighted Average	min	1942	12.91		16.07	
7. Total time outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	8.30	13.95	18.45	41.86
2 Level	min	170	11.22	16.10	12.18	16.99
3 Level	min	105	13.08	17.49	13.55	16.70
4 Level	min	96	16.25	20.85	16.35	18.21
5 Level	min	1269	18.26	23.57	18.75	18.75
Weighted Average	min	1942	15.72		17.73	
8.Utilization	**Unit**					
Inbound	%		9.09%		10.65%	
Outbound	%		10.05%		11.25%	

Appendix B

Table B-1-North shaft conveyor schedule comparison

			Original Schedule		New Schedule	
1. Surface	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
Queue time at surface to enter mine	min	1983	10.75	22.25	1.90	5.59
No of personnel in queue to enter mine	ea	1983	14.80	534	2.62	135
2.Total Time inbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	10.71	25.58	6.52	7.02
2 Level	min	56	12.19	26.71	8.12	8.80
3 Level	min	223	14.39	29.21	11.26	13.31
4 Level	min	305	20.14	33.75	13.30	15.96
5 Level	min	1358	27.02	36.54	16.45	19.88
Weighted Average		1983	23.79		14.95	
3. Level queue times Outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	0.02	0.71	0.00	0.07
2 Level	min	56	0.02	0.67	0.00	0.07
3 Level	min	223	0.03	0.87	0.00	0.07
4 Level	min	305	0.03	0.67	0.00	0.07
5 Level	min	1358	-	-	-	-
Weighted Average	min	1983	0.01		0.00	
4. Total time outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	6.30	6.92	6.25	6.25
2 Level	min	56	7.84	8.75	7.75	7.80
3 Level	min	223	10.14	11.50	10.00	10.09
4 Level	min	305	11.72	13.12	11.58	11.70
5 Level	min	1358	14.37	15.79	14.29	14.42
Weighted Average	min	1983	13.14		13.04	

Table B-2-North shaft chairlift schedule comparison

			Original Schedule		New Schedule	
1. Surface	**Unit**	**No of Personnel**	**Avgas**	**Max**	**Avgas**	**Max**
Queue time at surface to enter mine	min	1983	33.05	63.83	3.03	8.73
No of personnel in queue to enter mine	ea	1983	45.52	958	4.18	131
2.Total Time inbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	21.40	57.13	7.86	8.76
2 Level	min	56	23.50	59.06	10.03	11.15
3 Level	min	223	26.59	63.30	14.61	18.08
4 Level	min	305	38.87	75.88	16.60	20.49
5 Level	min	1358	56.89	81.37	20.99	26.27
Weighted Average		1983	49.04		19.02	
3. Level queue times Outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	3.87	32.36	0.01	0.01
2 Level	min	56	1.65	17.76	0.01	0.01
3 Level	min	223	0.48	13.63	0.01	0.01
4 Level	min	305	0.31	7.34	0.01	0.01
5 Level	min	1358	0.01	0.01	0.01	0.01
Weighted Average	min	1983	0.23		0.01	
4. Total time outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	41	11.30	39.79	7.44	7.44
2 Level	min	56	11.08	27.19	9.44	9.44
3 Level	min	223	13.08	26.23	12.60	12.60
4 Level	min	305	14.19	21.21	13.88	13.88
5 Level	min	1358	17.55	17.55	17.55	17.55
Weighted Average	min	1983	16.22		15.99	

Table B-3-South shaft conveyor schedule comparison

			Original Schedule		New Schedule	
1. Surface	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
Queue time at surface to enter mine	min	1942	7.27	18.10	2.08	5.55
No of personnel in queue to enter mine	ea	1942	9.80	435	2.81	134
2.Total Time inbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	14.57	24.52	8.15	10.91
2 Level	min	170	17.24	26.60	10.22	12.12
3 Level	min	105	18.68	27.86	11.60	12.97
4 Level	min	96	21.52	31.11	14.81	16.17
5 Level	min	1269	22.36	33.81	17.99	21.26
Weighted Average		1942	20.46		15.28	
3. Level queue times Outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	2.39	7.53	0.01	0.92
2 Level	min	170	0.09	1.47	0.01	0.52
3 Level	min	105	0.03	0.54	0.00	0.26
4 Level	min	96	0.02	0.38	0.00	0.31
5 Level	min	1269	0.04	0.76	0.42	1.98
Weighted Average	min	1942	0.41		0.28	
4. Total time outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	8.30	13.95	6.53	7.37
2 Level	min	170	11.22	16.10	8.57	9.43
3 Level	min	105	13.08	17.49	9.93	10.35
4 Level	min	96	16.25	20.85	13.12	13.44
5 Level	min	1269	18.26	23.57	16.14	17.69
Weighted Average	min	1942	15.72		13.49	

Table B-4-South Shaft Chairlift Schedule comparison

			Original Schedule		New Schedule	
1. Surface	**Unit**	**No of Personnel**	**AVG**	**Max**	**Avgas**	**Max**
Queue time at surface to enter mine	min	1942	27.89	54.34	3.35	9.54
No of personnel in queue to enter mine	ea	1942	37.61	816	4.52	144
2.Total Time inbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	36.27	62.59	10.11	14.25
2 Level	min	170	43.66	66.05	12.17	15.19
3 Level	min	105	48.05	67.66	15.35	17.87
4 Level	min	96	52.61	70.43	16.62	19.16
5 Level	min	1269	44.90	73.06	21.23	27.08
Weighted Average		1942	44.00		18.16	
3. Level queue times Outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	10.02	33.43	0.01	0.01
2 Level	min	170	0.41	5.23	0.01	0.01
3 Level	min	105	0.23	3.38	0.01	0.01
4 Level	min	96	0.14	2.01	0.01	0.01
5 Level	min	1269	0.01	0.01	0.01	0.01
Weighted Average	min	1942	1.62		0.01	
4. Total time outbound	**Unit**	**No of Personnel**	**AVG**	**Max**	**AVG**	**Max**
1 Level	min	302	18.45	41.86	7.44	7.44
2 Level	min	170	12.18	16.99	9.44	9.44
3 Level	min	105	13.55	16.70	12.60	12.60
4 Level	min	96	16.35	18.21	13.88	13.88
5 Level	min	1269	18.75	18.75	17.55	17.55
Weighted Average	min	1942	17.73		16.59	