

https://dspace.org/

# An investigation of factors contributing to low face time at Impala 14 Shaft trackless mechanised section: case study

**Simango, Kgomotso Betty**

**2018**

https://hdl.handle.net/10539/26911

Simango, Kgomotso Betty, (2018) An investigation of factors contributing to low face time at Impala 14 Shaft trackless mechanised section: case study, University of the Witwatersrand, Johannesburg, https://hdl.handle.net/10539/26911.

Downloaded from a DSpace repository. https://dspace.org/




# An investigation of factors contributing to low face time at Impala 14 Shaft Trackless Mechanised Section:

## Case study

**Kgomotso Betty Simango**

(Student number: 1015546)

School of Mining Engineering

University of Witwatersrand

Johannesburg, South Africa

**Supervisor: Dr D Vogt**

A research report submitted to the Faculty of Engineering and Built Environment, University of Witwatersrand, in fulfilment of the requirements for the degree of Masters of Science in Engineering by advanced course work and research.

**Declaration**

I declare that this research report is my own independent work. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. This project report has not been submitted before for any degree or examination in any other university.

**……..**

Kgomotso Betty Simango

……..day of ……... (Year)……

## Abstract

Face time refers to the total time spent by employees performing production mining activities at their working places to achieve the monthly set production targets. Various factors negatively influence face time. Therefore, the focus of this study was to investigate the factors contributing to low face time, which would assist in planning for current and future operations.

An in-depth literature review was conducted to gain insight from others who did similar research in the past. The literature reveals that mining is progressing deeper and further from the shaft. This results in distant working places, which leads to employees travelling long distances. The literature also revealed the issue of long queues and overcrowding of employees at the shaft bank before entering the cage. To address the low face time, the use of lean principles was used to identify different categories of non-value adding activities.

The descriptive quantitative observation study was conducted using convenience sampling on 66 employees of section 147 trackless mechanised mining working at 24$^{th}$ level. Data were collected by conducting a time and motion study to quantify the time spent by section 147 participants in each activity between clocking-in at the bank, getting to the face and returning to surface. Collected data were analysed by the Statistical Package for Social Sciences (SPSS), version 23, software.

The findings indicated that the activities contributing the most to low face time are queuing for the cage, time spent on walking to and from the working places, long safety meetings and resting before entering the working place. All the identified areas of concern can be addressed by changing the shaft schedule, sorting out the transportation systems, ensuring that the transport is operated on time and studying alternative transport systems, including trackless, to allow the smooth running of the shaft.

It is also recommended that capacity analysis of number of employees and the capacity of the different elements using theory of constraints model could be a useful step.

**Key words**

face time, hoisting, queuing, cage, chairlifts, man carriage

**Acknowledgement**

I would like to thank my Heavenly Father for the unlimited strength and wisdom to complete this study. I give Him all the honour and glory.

I would also like to express my sincere gratitude to the following persons and institutions:

- Dr D. Vogt for steadfast supervision, guidance and support,
- Impala Platinum Limited, 14 Shaft, for granting me the opportunity to embark on this research project,
- M. Fox for organising access to the mechanisation section at Impala 14 Shaft,
- Section 147 trackless mechanised employees for allowing me to conduct this study in their section,
- My husband, J. Simango, for supporting and allowing me the time to complete my studies,
- My children for their patience and support during the course of my studies,
- My family and friends for understanding and for the encouragement,
- My colleagues for the support and assistance,
- Wits University for allowing me to complete this study.

## Glossary of terms

Face: refers to the underground production working place where employees perform their different daily mining activities in order to complete the mining cycle so as to achieve a safe and quality blast every day.

Miner: a holder of a blasting ticket responsible for declaring the working places, marking off the face and the hanging wall for the RDOs' to drill holes and for connecting the blasting cable to the blasting box.

Rock drill operator (RDO): drills holes in the hanging wall and in the face.

Long Haul Dump (LHD) driver: It is a driver who drives the LHD machine

Equipment helpers: are responsible for ordering and distributing the materials, tools and supplies.

# TABLE OF CONTENTS

**DECLARATION** ..... **I**

**ABSTRACT**… ..... **II**

**KEY WORDS**.. ..... **III**

**ACKNOWLEDGEMENT** ..... **IV**

**GLOSSARY OF TERMS** ..... **V**

**TABLE OF CONTENTS** ..... **VI**

**LIST OF FIGURES** ..... **XI**

**LIST OF TABLES** ..... **XII**

**CHAPTER 1: INTRODUCTION** ..... **1**

1.1 Introduction ..... 1

1.2 Mining background ..... 2

1.3 Research motivation ..... 7

1.4 Problem statement ..... 7

1.5 Research questions ..... 8

1.6 Research objectives ..... 8

1.7 Methodology ..... 8

1.8 Content of the project report ..... 9

1.9 Conclusion ..... 9

**CHAPTER 2: LITERATURE REVIEW ..... 10**

2.1 Introduction ..... 10

2.2 Transportation of employees ..... 11

2.2.1 Mine cage ..... 12

2.2.2 Chairlifts ..... 13

2.2.3 Man carriages ..... 13

2.3 Management of transportation ..... 14

2.4 Travelling sequences from the bank area to the working places ..... 16

2.5 Factors contributing to low face time ..... 18

2.5.1 Queuing for a cage and for the chairlifts ..... 20

2.5.2 Loading and offloading the cage ..... 21

2.5.3 Walking to and from the working places ..... 21

2.5.4 Fixed times for transport system ..... 22

2.6 5 Lean thinking principles ..... 23

2.6.1 Lean principle 1: Identify customer and specific value ..... 24

2.6.2 Lean principle 2: Identify the value stream ..... 25

2.6.3 Lean principle 3: Create flow by eliminating waste ..... 26

2.6.4 Lean principle 4: Let the customer pull the process ..... 26

2.6.5 Lean principle 5: Pursue perfection ..... 27

2.7 Executive summary ..... 28

**CHAPTER 3: RESEARCH METHODOLOGY ..... 29**

3.1 Introduction ..... 29

3.2 Research design ..... 29

3.2.1 Quantitative research ..... 29

3.2.2 Descriptive research ..... 30

3.2.3 Observational research ..... 31

3.3 Sampling method ..... 31

3.3.1 Convenient Sampling ..... 32

3.4 Units of analysis ..... 33

3.5 Data collection and Recording ..... 34

3.5.1 Primary data collection methods ..... 34

3.5.1.1 Time and motion study ..... 34

3.5.2 Observation method as a means of collecting data ..... 35

3.5.2.1 Secondary data collection method ..... 37

3.6 Data analysis ..... 38

3.7 Criteria for validity ..... 38

3.8 Executive summary ..... 39

**CHAPTER 4: RESULTS AND DATA ANALYSIS ..... 40**

4.1 Introduction ..... 40

4.2 Time and motion study feedback ..... 41

4.3 Descriptive statistics ..... 42

4.3.1 Summary statistics of different variables (in minutes) ..... 42

4.3.2 Average times and standard deviations of the activities ..... 44

4.3.3 Average times and standard deviation times of the total non- value adding activities ....47

4.4 Total number of safety meetings.... 48

4.5 Total time percentages of each category over 22 days .... 51

4.6 Observational table of non-value adding activities .... 52

4.7 Categories of non-value adding activities.... 56

4.8 Executive summary .... 57

4.9 Conclusion.... 57

**CHAPTER 5: DISCUSSION.... 59**

5.1 Introduction.... 59

5.2 Discussion on literature review .... 59

5.3 Discussion of the findings .... 60

5.3 Shortcomings and limitations .... 61

5.4 Implications for the mining industry.... 62

5.5 Conclusion.... 62

**CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS .... 63**

6.1 Introduction.... 63

6.2 Conclusions.... 63

6.3 Recommendations for future work .... 64

**BIBLIOGRAPHY.... 65**

**APPENDIX A: TIME AND MOTION STUDY TEMPLATE .... 67**

**APPENDIX B: 14 SHAFT SCHEDULE ..... 68**

## LIST OF FIGURES

Figure 1: Mining cycle ..... 1

Figure 2: An example of a bord and pillar stoping ..... 3

Figure 3: Triple deck cage (Matsui, 2009) ..... 4

Figure 4: 14 Shaft chairlift 1 information ..... 5

Figure 5: Impala Platinum Rustenburg shafts in Bushveld Complex ..... 6

Figure 6: Traditional management structure (Maslen as cited in Rupprecht, 2003) ..... 15

Figure 7: Process management structure (Maslen as cited in Rupprecht, 2003) ..... 16

Figure 8: Travelling sequence from the bank area to the levels below (Rampedi and Genc, 2012) ..... 17

Figure 9: Diagram of travelling sequences from bank area to chairlift (Rampedi and Genc, 2012) ..... 17

Figure 10: Time distribution for employees walking (Rampedi and Genc, 2012) ..... 19

Figure 11: Time distribution for employees using carriages (Rampedi and Genc, 2012) ..... 19

Figure 12: Employees queuing (a) bank area and (b) underground station (Bhulose, 2004) .... 21

Figure 13: Average time distribution for employees walking (Rampedi and Genc, 2012) ..... 45

Figure 14: Average time distribution for employees using man carriage (Rampedi and Genc, 2012) ..... 45

Figure 15: Average times and standard deviations of the activities ..... 46

## LIST OF TABLES

Table 1: Descriptive statistics of different variables (in minutes) ..... 43

Table 2: Analysis of non-value adding safety meetings ..... 50

Table 3: Observational table of non-value adding activities ..... 53

Table 4: Categories of non-value adding activities..... 56

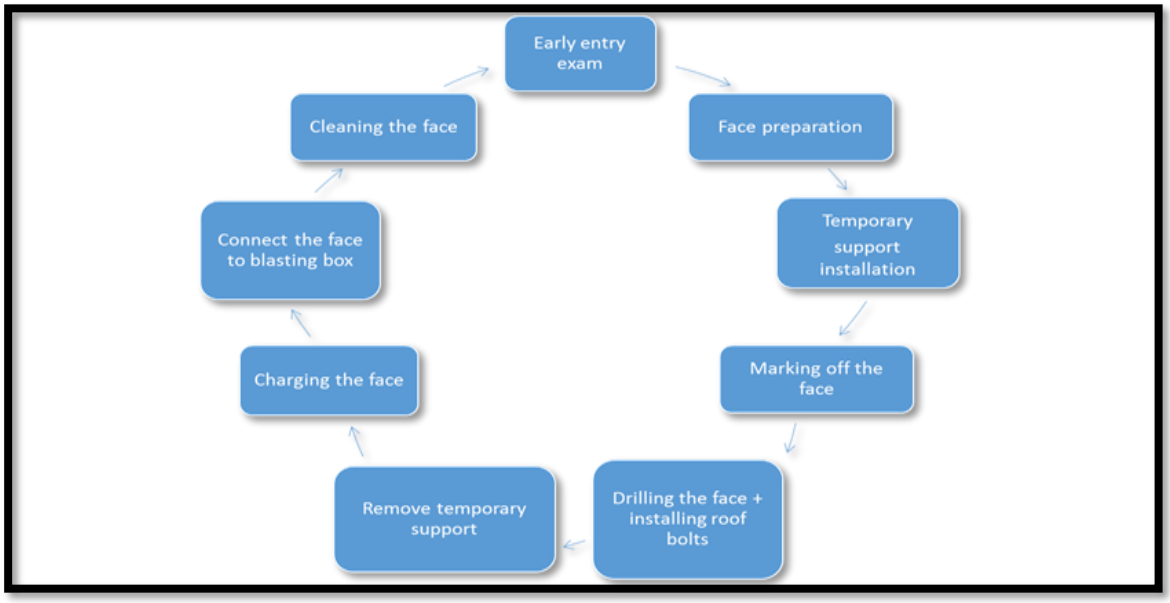
# Chapter 1: Introduction

## 1.1 Introduction

The purpose of this study is to research the factors that contribute to low face time at Impala 14 Shaft trackless mechanised, and assist by putting forward recommendations appropriate for the mining industry environment. In mining, a face refers to the underground production working place where employees perform their different daily mining activities (see figure 1) in order to complete the mining cycle so as to achieve a safe and quality blast every day.

The mining activities are sequential and are called the mining cycle. In order to complete the entire mining cycle and to achieve a safe and quality blast a sufficient face time is needed (Rupprecht, 2016). Face time refers to the total time spent by employees performing production mining activities at the working place. Face time has a significant impact on the overall mining production targets.

Figure 1: Mining cycle



The mining cycle has to be completed daily in order to achieve the monthly set production targets and for the shaft to remain productive, profitable and sustainable. The monthly production targets are divided into daily blasting targets and for the daily production targets to be achieved it is critical for the teams to report to their working places at the scheduled starting time every single day.

Mining operations are currently taking place at greater depths than ever before (Berglund and Gunther, 2014). They further states that with the depth new challenges to mining has risen and existing challenges has become even greater. The working places are far from the shaft (Vogt, 2015), which results in excessive travel distances. Employees spend, for example, three hours out of their eight-hour shift travelling instead of performing productive work at the face (Vogt, 2015).

It is clear that transport-related issues affect the production face time as well as the shift time. This report investigates the factors contributing to low face time at Impala 14 Shaft trackless mechanised Section 147 at 24$^{th}$ level (hereinafter referred to as 14 Shaft) by identifying all the activities that the employees are involved in before reaching their working places and when returning to surface. It is important in order to recognise and realise the root causes of the factors that contribute to low face time and to recommend sustainable solutions to the management of the shaft.

## 1.2 Mining background

The Impala Platinum mining operation is located just to the north of Rustenburg on the western limb of the Bushveld Complex. The mine holds contiguous mining and prospecting rights over a total area of 33 562 ha across 20 farms. Both mineralised Merensky Reef and UG2 Reef are mined concurrently. The mining method is predominantly conventional breast mining.

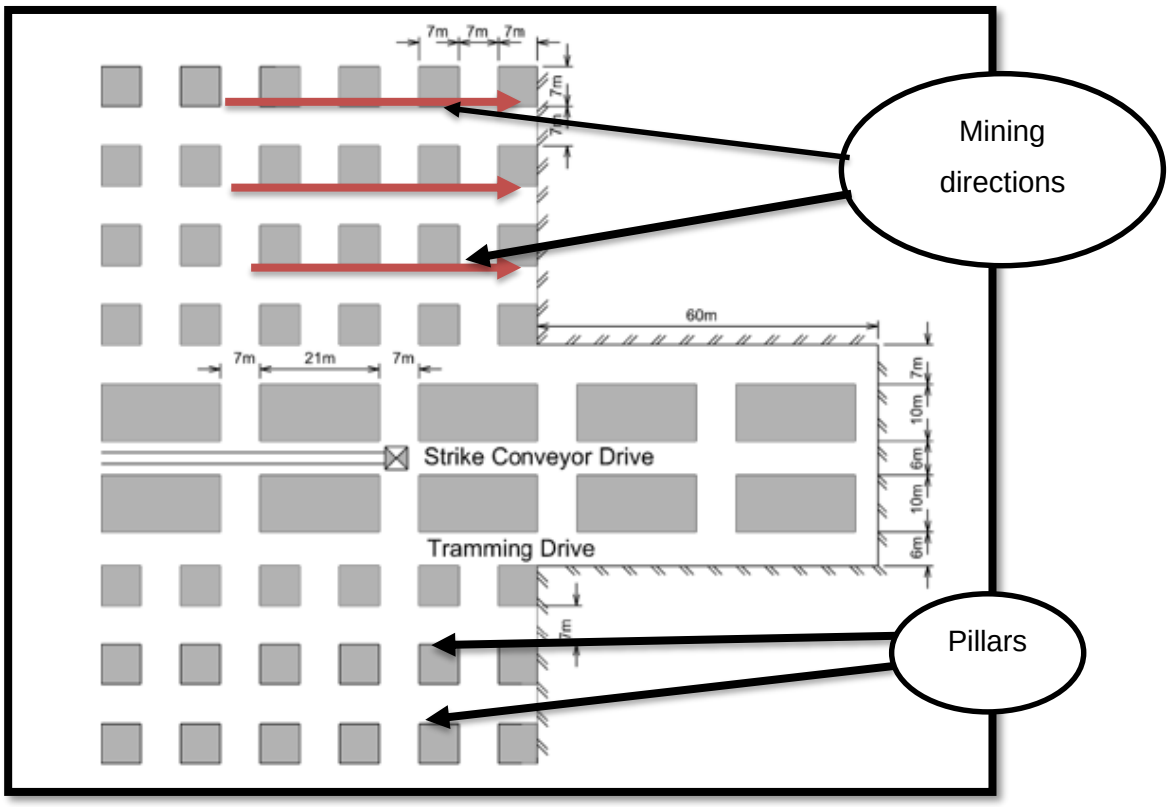
Conventional mining method refers to mining using handheld drilling machines for drilling blasting holes and support holes. Cleaning is completed by means of scraper winches with scoops. Mechanised (trackless) bord and pillar mining occurs in selected Merensky

Reef areas at 14 Shaft. The average stoping width of the mechanised panels is about 1.9m and the bord length is 7m.

14 Shaft is situated in Phokeng, the northern part of the mining lease area (see figure 5). The shaft is divided into a top section and a bottom section. The top section is from 15th level to 23rd level and employs conventional mining method. The bottom section (decline) is from 24th level to 28th level and uses a mixture of conventional mining methods as well as bord and pillar stoping with a degree of mechanisation.

Bord and pillar stoping is an underground mining method where ore is extracted from rectangular shaped rooms, leaving parts of the ore as pillars to support the roof (Implats, 2016). They further state that pillars are usually rectangular and arranged in a regular pattern. Figure 2 depicts a typical bord and pillar stoping as well as the mechanised breast mining method.

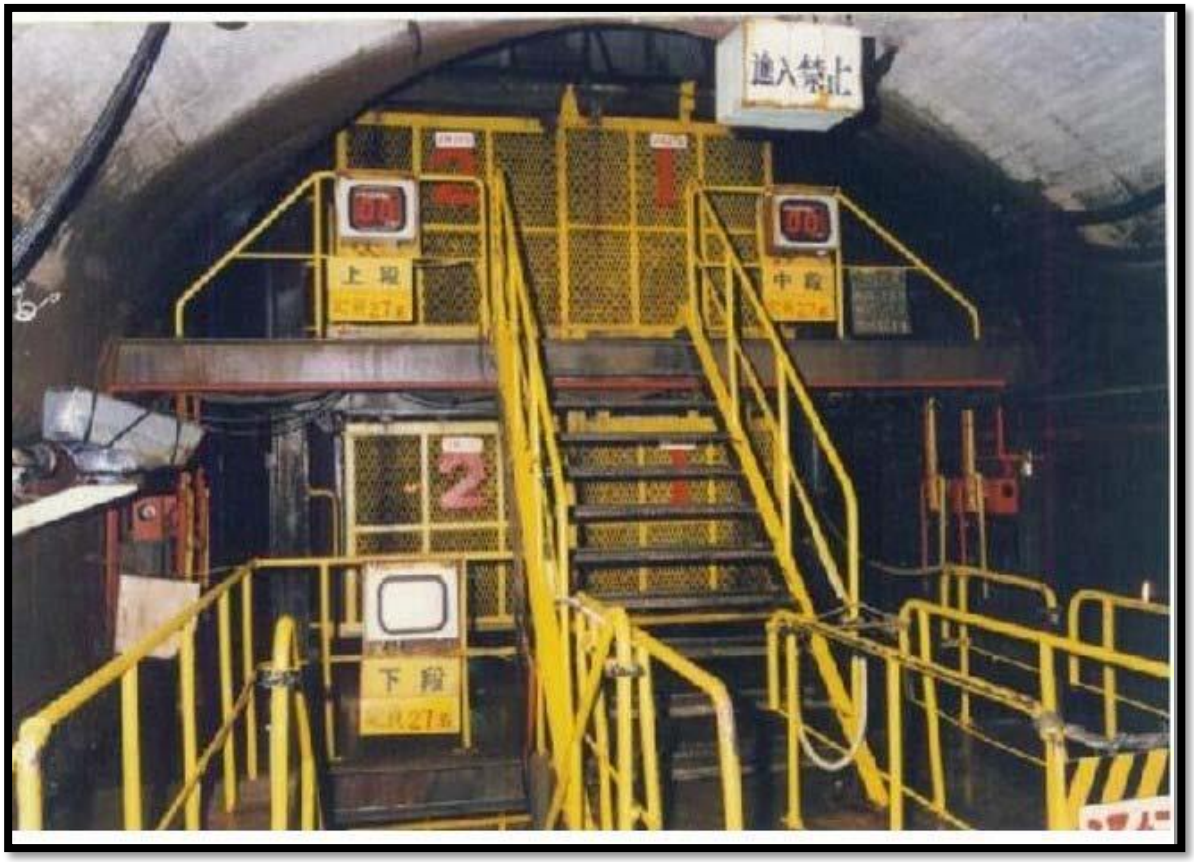
**Figure 2: An example of a bord and pillar stoping**



7m Bord and pillar design used, falls within rock engineering recommendations. The bottom section, therefore, is not fully mechanised and, hence, the mining method is considered a hybrid. Hybrid refers to a compromise between the conventional mining method and mechanised method; whereby, hand-held drilling machines are used for drilling blasting holes and support holes while cleaning the bord is completed by load haul dump (LHD). Production is largely dependent upon rock drill operator crew efficiency.

Employees are transported to and from underground by a triple-deck cage capable of carrying a maximum of 40 people per deck (see figure 3 below). The average speed of a cage is 15 m/s. Each shaft has its own schedule designed and employed for transporting teams to and from various levels. Therefore, employees are transported to and from their respective production levels as per time scheduled.

**Figure 3: Triple deck cage (Matsui, 2009)**



At 14 Shaft, the cage transports employees from surface to 15th level and ends at 22nd level (top section); therefore, teams working at the bottom sections are transported further by chairlifts from 22nd level to 28th level. Their average speed is 1.5 m/s. The two chairlift systems are in series from 22nd level to 28th level and are interlinked at level 26. The first set of the chairlift is from level 22 to level 26 (see figure 4 below) while the second chairlift is from level 26 to level 28.

**Figure 4: 14 Shaft chairlift 1 information**

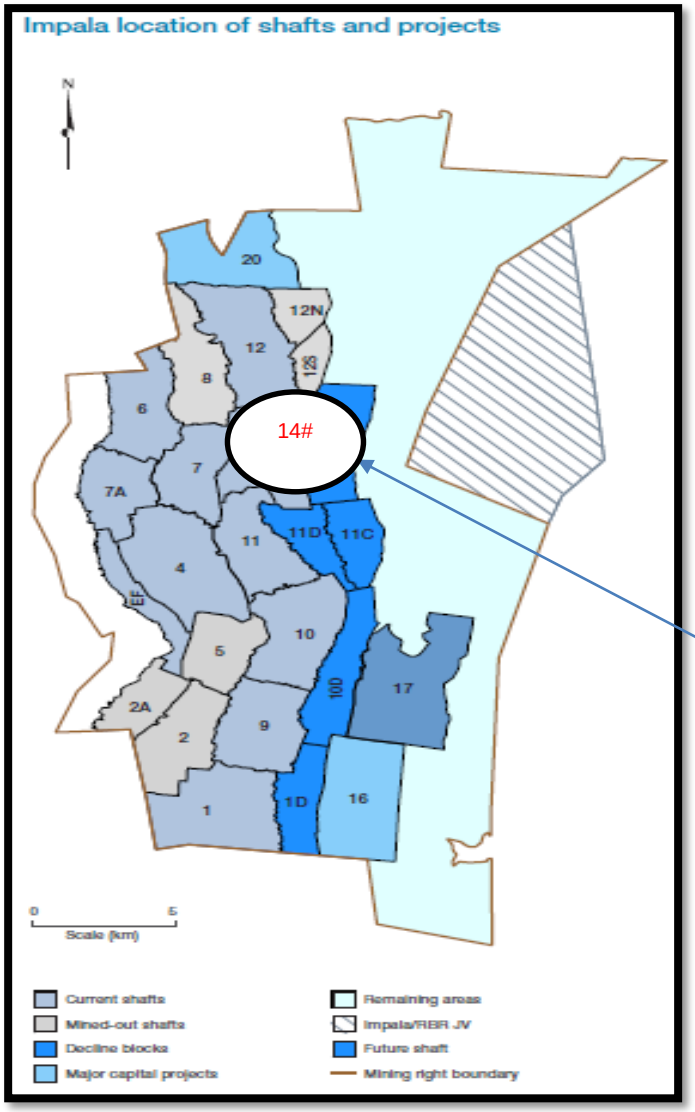



Transportation of employees to and from their working places underground is the responsibility of the engineering department. Therefore, the engineering department

plays an essential role and they need to ensure that cages and chairlifts are always on time.

Figure 5 represents the Impala shafts in the Rustenburg operations. The shafts are locally divided into three groupings, the so-called Old Men shafts (4, 6, 7, 7A, 9 and E/F), the Big 5 shafts (1, 10, 11, 12 and 14) and the Build-up shafts (16 and 20) (Implats, 2016).

**Figure 5: Impala Platinum Rustenburg shafts in Bushveld Complex**




**Impala 14 Shaft**

## 1.3 Research motivation

Almost everyone at 14 Shaft attributed the low face time to the long distance the employees travel by walking from the chairlift station to their working places. However, they did not have quantitative data to support their claim. There was no clear idea of what factors were significantly impacting the low face time.

It, therefore, is paramount to identify those factors with the greatest impact in order to plan for the current and future operations. This, in turn, will contribute to the performance levels of the shaft to achieve and meet its monthly production targets to remain productive, profitable and sustainable.

## 1.4 Problem statement

Effective and appropriate shaft schedules and transportation systems are key factors towards determining the smooth running of any shaft. Failure of appropriate shaft schedules and transport systems normally leads to overcrowding of employees at the shaft bank on surface, queuing and waiting for transport from surface to underground as well as to and from their working faces. Employees also ended up walking long distances from the stations to their working faces, which results in fatigue.

The abovementioned issues are seen as the obstacles towards the entire mining workflow, which have a negative impact on the total shift time. They also indicate that management do not really pay attention to the operation of the entire system within the shaft. These lead to employees at 14 Shaft mechanised section 147 at 24$^{th}$ level spending between 45 percent and 50 percent of their total eight hour shift at their working places, leading to working places not blasted as planned, which can impact mining productivity. This study thus investigated the factors contributing to low face time.

## 1.5 Research questions

- What are the contributing factors to low available face time at the trackless mechanised section 147 at 24$^{th}$ level?
- Which lean principles can be used as a theoretical lens in order to identify and reduce the waste streams?
- How can the available face time be optimised?

## 1.6 Research objectives

In order to address the problem stated in this study, the research objectives are to:

- Review the current transportation systems of personnel from surface to their working places and back to surface.
- Determine the activities employees are involved in between clocking in and getting to the face and when departing from the waiting place and returning to surface,
- Determine the average time spent on each activity,
- To explore the manner in which the use of the 5 Lean principles as a theoretical lens could guide the improvement of the overall travelling process by identifying the waste and reducing or eliminating it.

## 1.7 Methodology

A time and motion study was undertaken and a convenience sample observed to provide an evidence based understanding on how personnel spend their time before reaching their work places and returning to surface. The observation was conducted over a period of a month inclusive of Mondays to Fridays during morning shift. The researcher recorded the start time and end time of each activity performed by the employees.

## 1.8 Content of the project report

This chapter consists of the general introduction of the research. 14 Shaft mining information is also discussed. Different mining methods are identified and explained and the problem and objectives of this study are highlighted.

Chapter 2 consists of a comprehensive literature review of work conducted by other researchers that influence and impact on this research.

Chapter 3 deals with the research methodology applicable to the collection of information and data for this research study.

Chapter 4 presents the results of the data by statistical methods, where possible, and the analyses and interpretation of findings gathered from the research.

Chapter 5 presents discussion of the findings and compare with other studies that were discussed in Chapter 2. The limitations of the research and implication for the mining industry are also discussed.

Chapter 6 draws conclusions from all findings and research results reported in Chapter 4 and 5 and presents recommendations concerning the research study.

## 1.9 Conclusion

An overview of the research and its processes was discussed in this chapter. The definitions of face time and the mining cycle were highlighted. The chapter and the content analysis were also explained.

In Chapter 2, more of the literature is reviewed in trying to find relevance from previous studies done on similar topics or any other related topics. The aim of the literature review in the following chapter is to compare the extent of the problem from the viewpoint of other researchers. The outcome of the literature review assisted in directing the nature of the scientific study reported on in Chapter 3.

# Chapter 2: Literature review

## 2.1 Introduction

In this chapter, a literature review was conducted in an attempt to highlight some of the key factors contributing to low face time. A preliminary investigation revealed that the key factors are actually some of the activities that employees are involved in before reaching and coming back from their working places. Those activities are part of the entire transportation process from surface to underground and back to surface. Therefore, in order to identify the key factors, all the activities are elaborated upon and reviewed.

The previous work directly related with this research was done by Rampedi and Genc (2012). In their work, they presented an analysis of travelling time distribution for mine personnel using the man carriage and those walking in the conveyor belt haulage, comparing models that the mine can adopt to reduce the increasing travelling time and analysis of a new transport system showing the advantages and disadvantages thereof.

Webber-Youngman and Van Heerden (2016) present analysis of the engineering principles for the design of a personnel transportation system incorporating conveyor belt as a mode of transport for conveying employees from surface to underground, the operation of the chairlift and including the changes to the existing conveyor belt infrastructure. Their aim was to identify an appropriate, safe and cost effective transportation option for personnel.

Rupprecht (2003) represents an analysis on the best practice of the design of the ultra-deep level underground transportation system for personnel, material and rock. Rupprecht (2003) is of the opinion that the transport design could contribute significantly in reducing accidents related to transport in the South African mining industry as well as improving productivity and the durations of faces, reducing fatigue, supplying material on time and removing blasted rocks efficiently.

Bhulose (2004) reports on the physical constraints of the sub-decline shaft covering the transportation of men from the vertical shaft to the decline shaft system, transportation of

materials down the vertical shaft, transportation of broken rock through the decline shaft and identification of critical areas if an increase in production takes place.

The abovementioned studies show that investigations have been conducted on underground transportation systems, even though there is a dearth of scientific evidence. An extensive literature search was conducted on both the underground transportation systems and on factors contributing to low face time, but yielded no results other than the abovementioned studies.

In attempts to reduces or eliminates any waste within the transportation process, the use of the Lean principles as the theoretical lens was considered. This is because the principles are able to assist in changing the culture to a true culture of continuous improvement within the organisation emphasising on a small but constant improvements.

Therefore, the findings of the research study by Rampedi and Genc (2012) were covered in much detail in this study's literature review, since the methodology and findings of their research were significant to this study. The section below presents a discussion on the transportation of employees, the key factors as the activities that employees are involved in between clocking in and getting to the face and when returning to surface as well as the use of the Lean principles in more details.

## 2.2 Transportation of employees

Transportation and movement of employees, materials and run-of-mine are the most important processes in the mining operations(Pieczora and Tokarczyk, 2017) and are critical to the success of the shaft. There are cases where the transport system run as planned but it still takes a long time for employees to reach their respective working places at the beginning of every shift (Pareja, 2000).

It is therefore essential to have transportation system that is more efficient and uses the appropriate technologies to ensure that employees and materials arrive at the workforce at the appropriate time and that ore is removed timeously to support the planned production rates (Ruppert, 2003).

Transportation of employees is about how employees are conveyed from the bank area on surface to their underground working places and back to surface. Transportation requires the employees to be conveyed safely, quickly and efficiently thus as to maximise the face time at the working places (Rupprecht, 2003).

According to Rupprecht (2003) an efficient transportation system is the one that conveys the employees to their working places in less than one hour. Therefore, it is important to plan and design the transportation system that meet those requirements (Webber-Youngman and van Heerden, 2016).

There are quite a number of modes of transport used for transporting employees into and outside the mines. All mine transportation systems are regulated on the maximum speeds (Rampedi and Genc, 2012) to ensure the safety of employees.  Examples include:

### 2.2.1 Mine cage

The mine cage is an equipment that works like an elevator in tall buildings (Daviau, n.d). It is used extensively in deep mining to transport employees and materials from surface to underground and back to surface in a lined inclined or vertical mine shaft. The cages are available in different shapes and sizes and contain necessary safety features.

Mine cages are designed to strict industry standards as well as to the client's specific requirements, using well-treated aluminium and steel, to provide required capacities and ensure the safety of passengers and the continuity of the operation (Daviau, n.d). The size and number of decks on the cage depends on the size of the operation and the equipment being handled and vary from a single deck up to a triple deck (Matsui, 2009).

This type of a transport mode is able to handle up to 300 employees or more or internal loads of trucks, equipment, and material of 50 tons or more per trip (Flsmidth, 2015).

### 2.2.2 Chairlifts

Chairlifts have been introduced as a mode of underground transport to the South African mining industry since the 1970s' (Van Heerden, 2014). This mode of transport is used in inclined shafts for short fixed distances and is an efficient and cost effective transportation of employees (Rupprecht, 2005). The chairlifts provide capacity of up to 900 employees per hour (Becker, n.d).

Technical data from the chairlift manufacturer indicate that the permissible speed is between 1.5 m/s – 3 m/s (Becker, n.d). The allowable chairlift speed at Khuseleka No. 1 Shaft of Anglo American Platinum was 1.5 m/s, which is the minimum speed. The speed is still 1.5 m/s but can be increased as long as it is under the safe permissible range, which will reduce the time spent on chairlifts.

However, it remains the responsibility of the employer, the shaft, "to ensure, as far as reasonably practicable, that the mine is designed, constructed and equipped to provide conditions for safe operation and a healthy working environment and that the equipment is safe and without risk to health and safety when used properly" (MHSA, 2015:9).

As mentioned above, the safe chairlift speed is 1.5 m/s and mining houses prefer the speed of 1.5m/s including Impala Platinum.

### 2.2.3 Man carriages

Man carriages are track or rail systems, which provide transport for employees to and from their working places. The carriages are designed according to the mine specifications so as to meet the customer's requirements and are available with a capacity from 12 to 120 workers (Rupprecht, 2003). It is recommended that the man carriage schedule should be linked to the shaft schedule and that the capacity of the carriages match the capacity of the cage (Rupprecht, (2003).

Rupprecht (2003) is of the opinion that the use of man carriages is necessary if the travelling distance from the shaft to the working places exceeds 1400 m to 1800 m. Thus,

travelling by man carriage lowers the amount of time spent walking but does not lower the total travel time. This is because loading the carriages wastes time as it takes longer than the actual time to walk to the working places (Rupprecht, 2003) though, it decreases the level of fatigue.

Travelling by using man carriage will improve the face time as employees will arrive at their working places in a fit state and start to work immediately (Rampedi and Genc, 2012).

Lastly, transportation systems must be drawn up based on the specific requirements of each mine and it requires good transportation management with dedicated manager for transport (Rupprecht, 2003). The following section below discuss the management of transportation.

## 2.3 Management of transportation

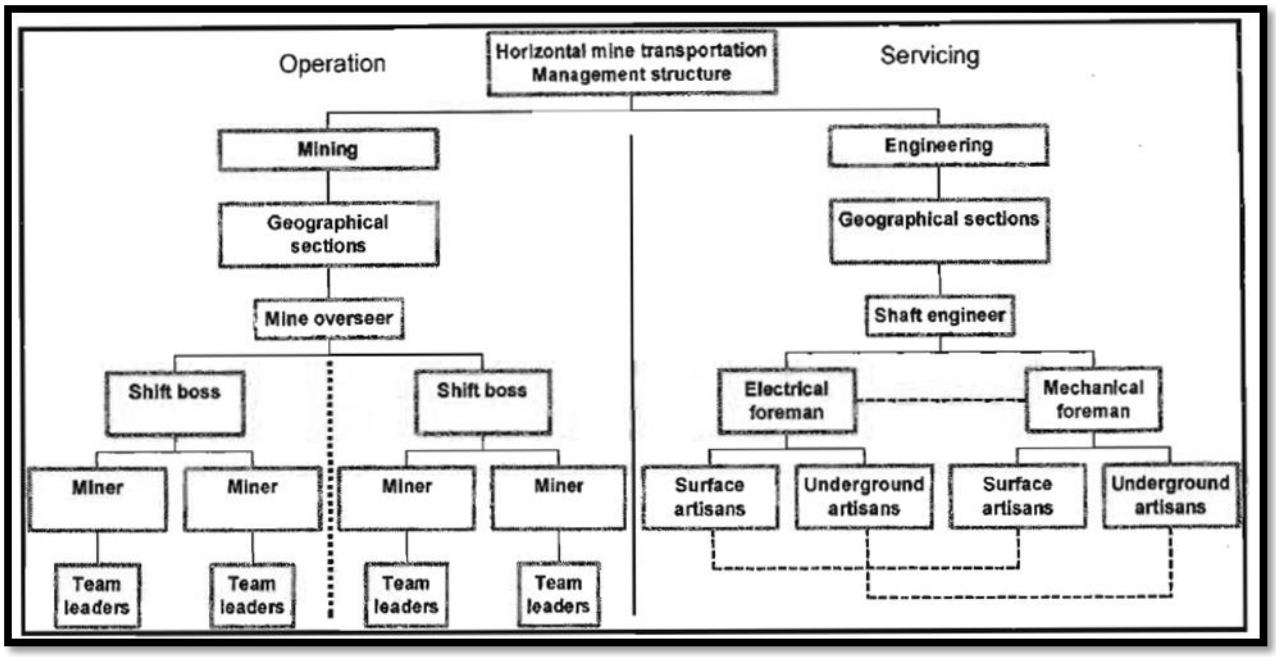
Rupprecht (2003) is of the opinion that the mine management gives low attention to the transportation of employees while giving more consideration to the transportation of rocks. That results to poor safety, low productivity rates and high transportation costs. Rupprecht (2003) suggested that when considering to design a mine certain factors such as the available face time, delivery of material and rock removal must be regarded as essential elements as they directly affect the overall productivity of the mining method.

That can be achieved as a result of ensuring that some proper transportation systems are designed in the main and secondary haulages (Rupprecht, 2003). The first priority is to have a process orientated management structure required to co-ordinate all factors associated with the transportation system, such as planning, management and maintenance (Rupprecht, 2003).

Figure 6 shows a usual traditional management structure for a horizontal mine transportation in a typical mining industry. It is divided into two parts, namely operation and servicing, even though it may differ from one mining house to another. As indicated in figure 6, the transportation management is shared between the mining and engineering

disciplines and that often result in poor control (Rupprecht, 2003). Therefore, the disciplines need to be separated so that they can focus and manage their areas of responsibilities. In order to have a transport system that will contribute to the achievement of higher performance and efficiency by maximising the capacity of production and minimising delays to production, operational and maintenance manpower, and costs (Rupprecht, 2003).

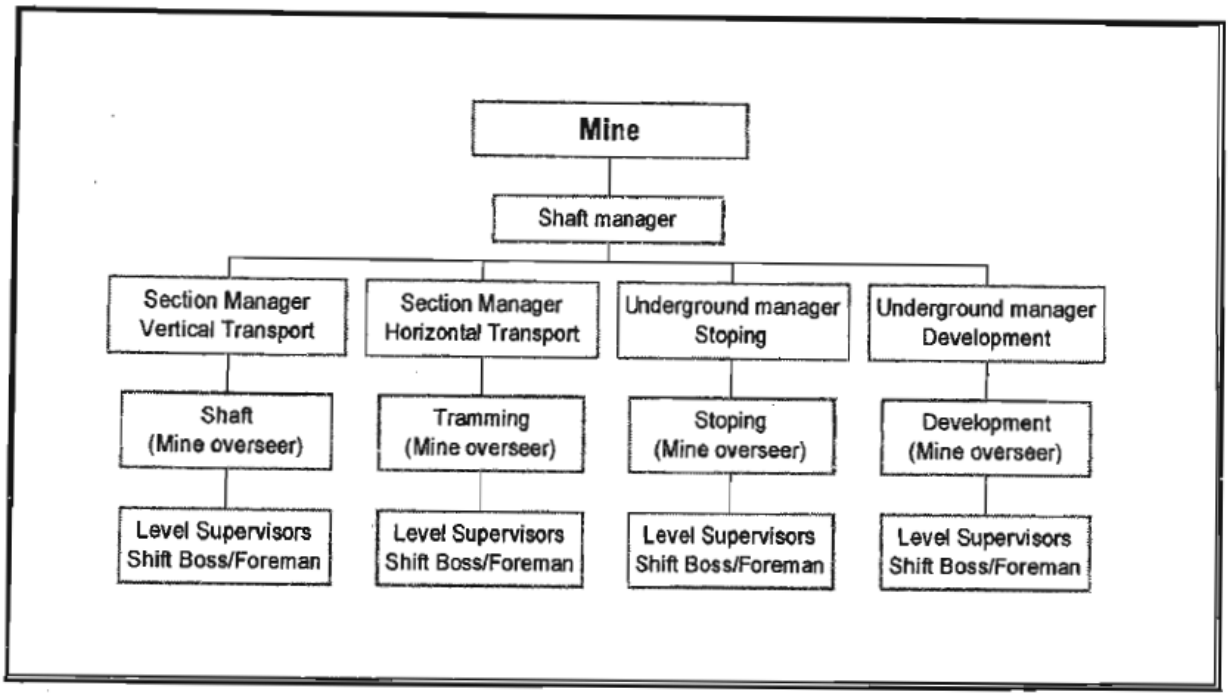
**Figure 6: Traditional management structure (Maslen as cited in Rupprecht, 2003)**




Rupprecht (2003) recommended a need to have a processed orientated system (see figure 7 below) whereby a transportation system is controlled by one person rather than several, thus is streamlined with duplicate equipment removed. Consequently, the areas of responsibilities of shaft hoisting and mining will be clearly defined and curb conflicts and poor communication (Rupprecht, 2003).

The process management structure below clearly indicates that transportation system needs to be divided into horizontal and vertical transport having its own section manager. Both section managers' and underground mining managers' report to the shaft manager.

Figure 7: Process management structure (Maslen as cited in Rupprecht, 2003)

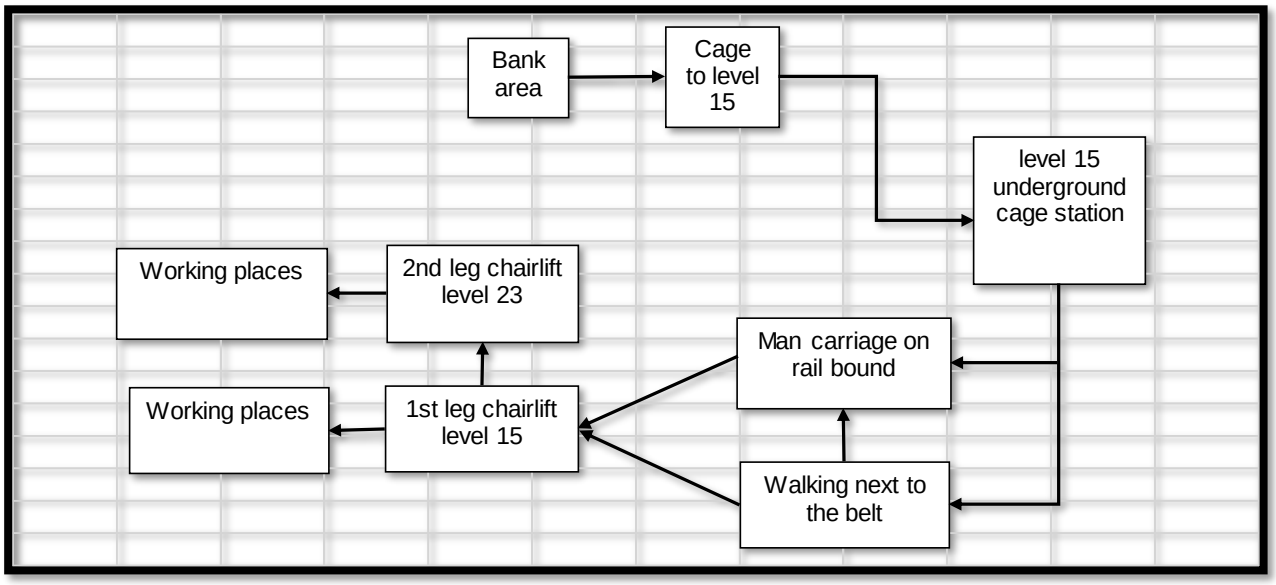



In order to fulfil an efficient transportation system one needs to know and understand the travelling sequences of the employees from surface to their working places and back to surface. Therefore, the travelling sequences are addressed in the next section.

## 2.4 Travelling sequences from the bank area to the working places

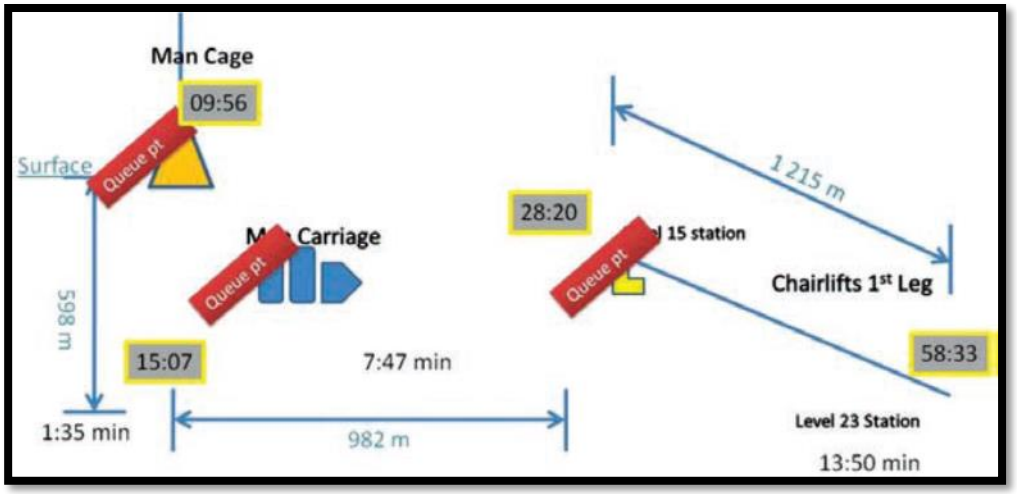
There are numerous transportation sequences that employees are involved in when travelling to and back from their working places. Figure 8 reflects a typical travelling sequences. This figure shows that the Khuseleka No. 1 Shaft of Anglo American Platinum has two haulages with two different travelling options running between the shaft station and the first leg chairlift station (Rampedi and Genc, 2012).

Figure 8: Travelling sequence from the bank area to the levels below (Rampedi and Genc, 2012)




Employees have a choice of either walking next to the belt or using the man carriage to the first leg chairlift station. This is not the case for all mining houses as each company design its own transportation system in order to meet specific shaft requirements. Figure 9 depicts the motion path of employees from the bank area to the end of the first leg of the chairlift and shows the points where queuing normally occurs.

Figure 9: Diagram of travelling sequences from bank area to chairlift (Rampedi and Genc, 2012)



As can be seen in figure 9, queuing occurs at the beginning of every transportation point such as at the surface shaft bank, man carriage station and at the chairlift stations; this consumes time within the transportation systems. Queuing can be defined as a time during which employees arrive at designated areas and have to wait for the cage, man carriage or chairlifts in order to arrive at their working places.

The researcher attests that this is also the case at 14 Shaft, long queues happen at the shaft bank and at the chairlift stations. If this is not addressed, it will become worse as the mine opens up more working places and gets more employees in the trackless mechanised sections. It will result in employees spending more time on queuing and less time at the working places, which will impact the productivity negatively.

Travelling sequences have been viewed above and some areas identified where constraints happen. Therefore, in order to better plan for the management and scheduling of the travelling sequences of the employees it is important to take a step back and identify the activities that they are involved in between clocking in and getting to the face and when returning to surface.

## 2.5 Factors contributing to low face time

There are various factors that directly contribute to low face time. In order to identify those key factors, all the activities that employees are involved in before reaching the working places and returning to surface ought to be reviewed and explained. Figures 10 and 11 reflect typical activities for employees walking or using carriages from surface after clocking-in at the bank to the first leg of chairlift station during different times such as peak, average and low times.

Such activities include queuing for cage and for chairlifts, loading and off-loading cage, hoisting of cage, walking to the carriage station and to the working places and riding on chairlifts. The difference between figures 10 and 11 is that figure 10 displays the time distribution of different activities, where employees walk on the walkway next to the conveyor belt, from the cage underground station to the first leg chairlift station. However,

figure 11 shows the time distribution of different activities for employees using the man carriage to travel from the underground shaft station to the first leg chairlift station.

**Figure 10: Time distribution for employees walking (Rampedi and Genc, 2012)**

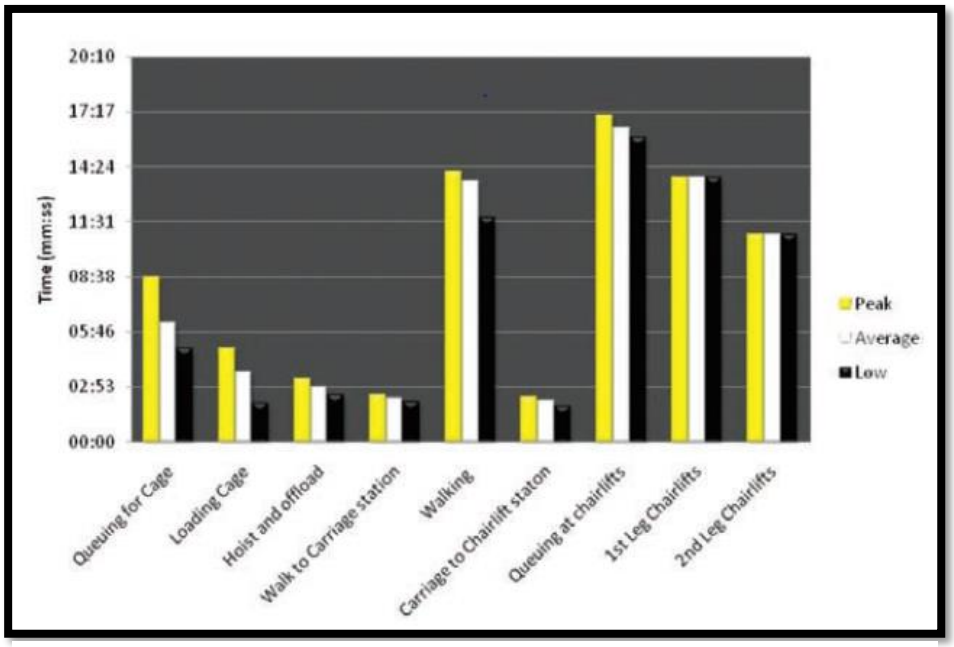
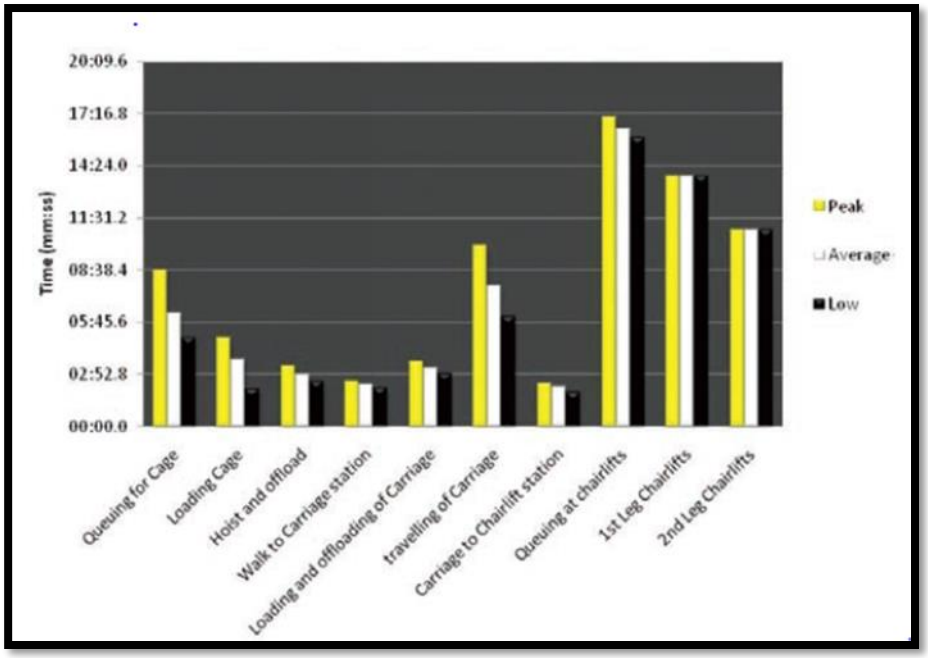



**Figure 11: Time distribution for employees using carriages (Rampedi and Genc, 2012)**



The activities identified in figures 10 and 11 are the results of a time and motion study conducted at Khuseleka No. 1 Shaft of Anglo American Platinum during peak, average and low times (Rampedi and Genc, 2012). However, the peak time was chosen as the guideline during this study.

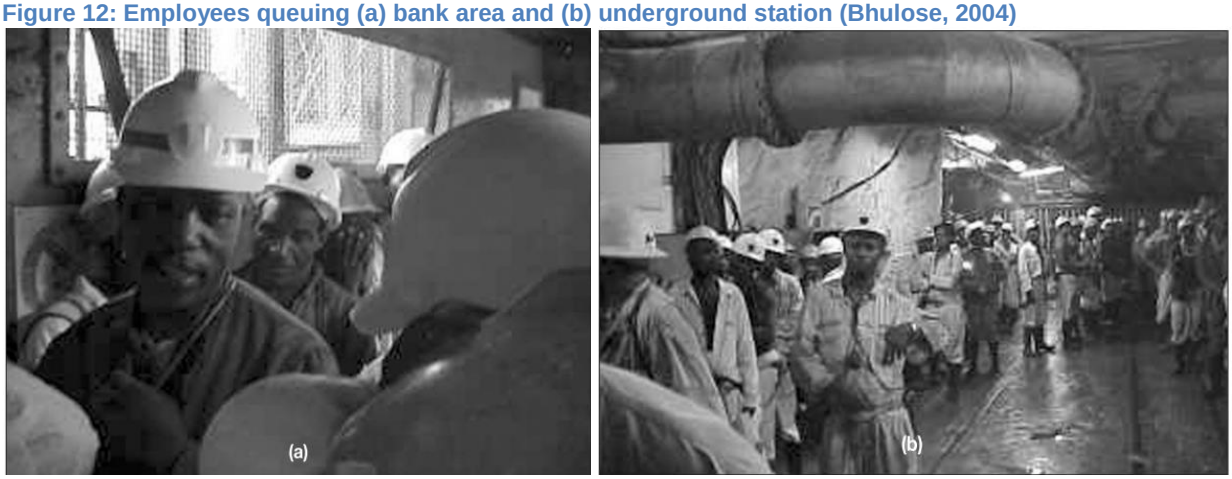
### 2.5.1 Queuing for a cage and for the chairlifts

Queuing can be defined as a long waiting time where employees arrive at their designated areas and have to wait before entering into the cage or to ride on the chairlifts. Hence, this is considered to be an amount of 'idling time' (Rampedi and Genc, 2012). It is normally observed during peak, average and low times. However, it is worse during peak time, where employees clock-in to the bank area and queue before entering into the cage and at the chairlift stations before riding on the chairlifts (Rampedi and Genc, 2012).

Queuing is also realised when the transport mode changes from a 'batch' transport mode (i.e. cage) to a continuous transport mode (i.e. chairlifts) (Rampedi and Genc, 2012). This can result in delays in getting the employees on time (Bhulose, 2004) and spending less time at their working places (Webber-Youngman and van Heerden, 2016) such as face time of less than four hours and in some cases approaching only three hours (Rupprecht, 2016). Figure 12 below reflects typical situations that occur at many of South African mining industry every morning where employees clock-in and in the afternoon where they clock-out.

Bhulose (2004) pointed out that modifying the shaft schedule by lowering employees working in the lowest level far from the shaft first could assist in reducing overcrowding at boarding points. Rampedi and Genc (2012) recommended that each shaft level have its specified clocking-in time to contribute towards getting employees to their working places in time.

Figure 12: Employees queuing (a) bank area and (b) underground station (Bhulose, 2004)




### 2.5.2 Loading and offloading the cage

Loading is when the onsetters allow the employees to enter into the cage and offloading is when the employees get out of the cage either on surface at the shaft bank or underground at the shaft station. According to figures 10 and 11, loading of the cage takes slightly more time during peak hours due to the high number of employees going underground. This is because the onsetters have to count and make sure that the numbers of the employees do not exceed the required cage capacity.

### 2.5.3 Walking to and from the working places

In some mines, employees would walk for about 55 minutes to their working places (Rupprecht, 2003). This was evident at the Khuseleka No. 1 Shaft of Anglo American Platinum where a long distance travelled by employees from the chairlift station to their working places was identified as a contributing factor to lower productivity (Rampedi and Genc, 2012) and the actual time spent in the working place.

A long distance travelled by employees to their working places will have a negative impact to the actual face time. Therefore, decreasing the travelling time will result in increased overall face time (Rampedi and Genc, 2012). It was found that employees walking long distances to their working places also experienced fatigue and have to rest first when

they arrive at their working places before starting to work, losing further face time (Rampedi and Genc, 2012). The researcher confirms that the same occurs at 14 Shaft section 147, where employees rest at the central waiting place before getting to their working places.

Similarly, Rampedi and Genc (2012) agree that installing transportation systems at each level will resolve the travelling time and fatigue problems. Therefore, efficient and safe transport systems would contribute to ensuring that employees arrive at their working places in a fit state to begin work immediately.

### 2.5.4 Fixed times for transport system

Fixed times means the total times, which remain unchanged due to the mine regulations on maximum speeds for transportation modes such as the winding cycle time or hosting time of the cage, which means time taken to transport employees from surface to underground shaft station and back to surface, travelling time of the man carriage and riding on the chairlifts.

**Hoisting or winding**

Hoisting or winding cycle time is when the cage is travelling up and down transporting employees or materials from the surface at the shaft bank to different levels underground. The average speed of the cage was 6.30 m/s, which included the full cycle of travel starting from acceleration, constant speed motion and deceleration until it stops (Rampedi and Genc, 2012).

Rampedi and Genc (2012) observe the maximum allowable speeds for each mode as:

**Cage:**

- Cage 6.30 m/s (hoisting)

**Chairlifts:**

- Chairlifts (1st and 2nd leg) 1.50 m/s

**Man carriages:**

- Man carriage 2.10 m/s

This section has examined the activities that employees are involved in between clocking in and getting to the face and when returning to surface. The entire process of getting employees to the face is non-value adding but it is a necessary one because without it employees will not be able to reach their working places. It is therefore useful to explore the manner in which the use of 5 Lean principles as a theoretical lens could guide the improvement of the overall travelling process by identifying the waste and reducing or eliminating it.

## 2.6 5 Lean thinking principles

Lean thinking principles were developed from the Toyota Production System (Womack and Jones, 2000). Lean thinking principles is a systematic approach to improving flow by identifying problems as they occur and centres on eliminating wastes and non-value adding activities while providing customers with exactly what they want. Waste is defined as anything that does not add value to the final product or impedes the flow of the process.

Examples of non-value adding activities are waiting, queuing, motion, transportation and under-utilisation of employees in terms of working hours (Ofori-Okyere et al., 2016). Although transportation is considered a non-value adding activity, without it in the mining industry the value added activities will not be achieved as transport is required to connect value added activities (Al-Araidah et al., 2010). Therefore, transport is a type 1 necessary waste.

In mining, the value added activities are reflected as drilling, blasting and cleaning of the face daily, safely and within the specified shift time as well as supporting the hanging and side walls. To do this, employees need to arrive at their working faces in a fit state and on time to commence work immediately.

Lean principles were adopted successfully by the healthcare fields, which enabled hospitals and clinics to streamline their operations and improve their efficiency (Al-Araidah et al., 2010). This resulted in a reduction of delays and waiting for care, speeding up of drugs delivery to the patient and a reduction of cycle time of the process that led to physicians and nurses spending more time caring for patients. Other accomplishments reported included reducing waiting time and delays and reducing redundant walking (Al-Araidah et al., 2010).

The attempt of this research is to explore whether the same lean thinking principles may be applied to effect similar results as in healthcare

Womack and Jones (2000) describe the five fundamentals of lean principles as follows:

### 2.6.1 Lean principle 1: Identify customer and specific value

According to Womack and Jones (2000) value is the most critical starting point of the lean thinking principle. Value is defined by the customer and should meet the customer's needs at a specific price or cost and time. Failure in defining the value might result in highly inefficient operations undertaking non-value adding activities (Andi et al., 2009). Therefore, the first point is to identify the customer and understand the internal customer-supplier relationships (Haque and James-Moore, 2004).

The requirements of the customers need to be clear and communicated effectively throughout the planning and implementation stages. Therefore, the key success factor in developing any product specification is to involve the customer (Haque and James-Moore, 2004).

In the study conducted by Dickson et al. (2009) at a hospital, the researcher asked the patients to define value in their perspective. Patients indicated that waiting for laboratory test results or consultants to arrive adds no value to them (Dickson et al., 2009). Value is added only when they receive test results from the laboratory or are being attended to by the consultant. Therefore, the hospital adopted lean and a significant improvement was

experienced in patient flow and satisfaction without direct expenses towards the patients and the hospital (Dickson et al., 2009).

In another study, it was found that transportation of prescription sheets between floors was time-consuming. The process was eliminated by using information technology after utilising lean tools applied at the pharmacy (Al-Araidah et al., 2010), resulting in time saving for the satellite pharmacist.

### 2.6.2 Lean principle 2: Identify the value stream

The value stream is identified in order to minimise or remove any waste in the process or system. It is defined as the entire set of activities required to create and produce a specific product (a good or a service) from concept to a finished product in the hand of the customer, while minimising or removing any non-value adding activities (Womack and Jones, 2000).

Value stream brings valuable information by providing means of disclosing how a current process actually works and performs (Tortorella et al., 2017), as well as providing knowledge for the development of more economically efficient future value streams (Tortorella et al., 2016). Therefore, all the activities or individual actions involved in the process should be mapped and the flow analysed (Kollberg et al., 2006).

Activities that cannot be measured cannot be properly managed and the ones necessary to create, order and produce a specific product that cannot be accurately identified, analysed and linked together, cannot be improved and perfected (Womack and Jones, 2000). It, therefore, is important to know and understand the whole value stream from start to end so that it can be properly improved and moved towards perfection.

Thus, during process mapping, value adding and non-value adding activities are identified, which provides an important foundation for minimising or eliminating waste (Kollberg et al., 2006). In health care, value adding can be defined from the point the patient arrives and reports at the hospital until the treatment is completed (Kollberg et al., 2006). Delays between the expected times and actual time for a visit or operation,

preparation time for an operation or visit, medical device downtime and procedures to manage referrals as well as transportation of patients are some of the examples of wastes in healthcare (Kollberg et al., 2006).

### 2.6.3 Lean principle 3: Create flow by eliminating waste

The third lean principle is to design and implement a value stream that runs smoothly to make the remaining value added steps flow (Haque and James-Moore, 2004). For example, in the health care sector this can be achieved by focusing on following the patient from the beginning to the end (Kollberg et al., 2006). The aim should be to reduce or eliminate any non-value adding activities such as failures and long waiting times (Kollberg et al., 2006).

Therefore, the results will mean to redesign the whole value map stream in order to reduce or eliminate non-value activities. Kollberg et al. (2006) suggests that work practices may need to be redesigned in order to eliminate backflows, failures and long waiting time such as adjusting the schedule by moving staff from periods with low demand to high demand. It simply means having more staff members to assist during busy working times and few during low or normal times.

### 2.6.4 Lean principle 4: Let the customer pull the process

Pull is introduced between steps where continuous flow of a process seems to be impossible (Burgess and Radnor, 2013). The authors recognise that even if it might be impossible to eliminate all non-value adding steps immediately, this principle aims at eliminating waste as far as possible by ‘pulling’ the customer to the next process step.

According to Kollberg et al. (2006), pull thinking is when the supplier moves backwards and observe the whole production line step-by-step until the final product is delivered to the customer. For instance, in the healthcare sector the degree of the pull strategy merge when “a patient visits a care centre for an appointment, the interaction with the doctor

leads to a diagnosis and/ or treatment measure" (Grönroos quoted by Kollberg et al., 2006).

### 2.6.5 Lean principle 5: Pursue perfection

The first four principles interact with each other (Womack and Jones, 2000) and expose problems that require solutions. Therefore, the fifth and final principle, pursue perfection, is to integrate and move the system towards perfection so that the first four principles can be implemented effectively and more efficiently (Ofori-Okyere et al., 2016).

The one thing about pursuing perfection is it never ends. If there were an objective perfect state, a task would end when it was achieved. However, lean recognises that there is always a better way. Therefore, it tries to put in systems that allow the better way to be pursued under all circumstances. Organisations need to set practical and realistic targets to pursue perfection and for continuous improvements (Kollberg et al., 2006).

Continuous improvement is important and is achieved by identifying the problems continuously within the systems and finding ways of solving them. Organisations also need both radical and incremental improvement to pursue perfection (Womack and Jones, 2000). For example, by applying the first four lean principles and deciding on which form of waste to focus on first.

Hence, it is important for the suppliers and the customers to have direct discussions in creating value as well as enforcing flow and pull (Womack and Jones, 2000) in order to ensure that the system works properly. Transparency amongst the suppliers and the customers encourages perfection and makes it easy and better to create value (Womack and Jones, 2000). Therefore, the whole process of creating value should be clear and visible to all the members.

## 2.7 Executive summary

In this chapter, literature relating to the research topic was reviewed. The idea was to indicate different views expressed by other researchers relating to the problem stated in Chapter 1 of this study.

# Chapter 3: Research methodology

## 3.1 Introduction

Data were statistically analysed to find solutions to a specific problem described in the research question. In view of the nature of this study, the researcher decided to use mainly the quantitative approach and convenience sampling. Throughout this study, observations were conducted to assist the researcher to get a better understanding of factors contributing to low face time.

## 3.2 Research design

A research design is the plan according to which the researcher obtains research participants and collects information from them (Welman et al., 2005). Research designs differ depending on the type of research, such as exploratory, descriptive and hypothesis testing (Sahu, 2016). A descriptive, quantitative, observation research design using time and motion study was used for this study.

### 3.2.1 Quantitative research

Quantitative research is when phenomena is explained by collecting numerical data and that are analysed using mathematically based methods (in particular statistics) (Muijs, 2010). “Quantitative study designs are specific, well structured, have been tested for their validity and reliability, and can be explicitly defined and recognised” (Kumar, 2011).

A time and motion study is defined as a quantitative data collection method, which involves an external observer capturing and recording the time and movements required to perform a specific task (Lopetegui et al., 2014). This study planned to investigate the factors contributing to low face time.

After identifying possible factors, it was decided to determine all the activities that the employees are involved in and how much time is spent on each activity. This was done to understand where time was wasted. In search of a solution, the researcher conducted a time and motion study to collect data.

### 3.2.2 Descriptive research

Descriptive research is a type of research where the description of the characteristics of the group or a particular situation is dealt with (Sahu, 2016). In this type of the research design, a researcher indicates what needs to be measured and how it should be measured for a particular population (Sahu, 2016). Sahu (2016) further states that the research design must be well equipped to protect the bias and to maximise the reliability and at the same time, it must be rigid and should not be flexible in placing attention on the following points:

- What the study is about and why it is being undertaken,
- Designing the methods for data collection in the most efficient manner,
- Selection of the samples and processing and analysis of data after examinations, and
- Interpreting the results and drawing conclusions.

The purpose of a descriptive research is to identify the characteristics of a situation under investigation as it is without changing or modifying it (Leedy and Ormrod, 2010). A descriptive research was appropriate to use because the purpose of the study was to identify factors contributing to low available face time at 14 Shaft. The researcher had to deploy the time and motion study to confirm the first two research objectives.

The first objective being: What activities employees are involved in and how much time is spent on each activity between clocking in and getting to the face and when departing from the waiting place and returning to surface and the second objective being: Why do things take time that they take? Therefore, a time and motion observational study was conducted to understand each activity.

### 3.2.3 Observational research

Observation is a planned and well thought out method of data collection, which can result in accurate findings and conclusions (Sahu, 2016). In this method, the researcher is able to observe the elements or employees under study without asking them questions (Sahu, 2016). Sahu (2016) further states that the researcher should keep the following points in mind when applying the observation method, namely what to observe, how observations are required to be noted and how to ensure the accuracy of the information.

Three employees were observed at a time while collecting quantitative data discussed above. The researcher was focused on observing how many minutes were used on every activity, paying special attention to aspects such as:

- How long do the employees take on each activity?
- What are the things the employees do that might be wasting time?

At the end of the research, these observations helped the researcher analyse the root problems of the time wasted, as well as ways in which transportation of employees from surface to the working places and back can result in better effectiveness. Thus observing the employees was effective in analysing data and explaining the results from the quantitative data collected.

## 3.3 Sampling method

Sampling is a process of selecting a number of participants from the population so that the findings and the characteristics of the drawn sample can be generalised to the population elements (Sahu, 2016). There are two types of sampling techniques, namely probability sampling and non-probability sampling (Sahu, 2016).

Probability sampling is defined as a technique that ensures that each unit has a chance of being selected from the population through a random selection procedure (Etikan et al., 2016). Non-probability sampling is a technique that does not give all participants or units in the population equal chances of being included (Etikan et al., 2016). Sampling

technique is chosen depending on the nature and scope of the investigation and the situations under which the study is being carried out (Sahu, 2016).

### 3.3.1 Convenient Sampling

This research study used non-probability sampling method where people or units of the target population are chosen because of the close proximity to the researcher, or are easier for the researcher to access and are easiest and readily available for the study sample (Etikan et al., 2016 & Leedy and Ormrod, 2010). Convenience sampling was used to develop the sample of the research under discussion.

The participants of this research study were conveniently chosen because their working places were being the furthest in the trackless section and that they were available and accessible. Other trackless sections were excluded since their working places are closer to the chairlift stations. Prior to commencing the study all the 78 employees working at trackless section 147 consented to participate in this study and that would make the research outcomes reliable and inclusive.

The sample of 78 participants were chosen because they are the total number of employees working at trackless section 147 but only 66 employees participated because the other 12 were absent from work as the study progressed. The participants were approach at safety meeting where the study was explained.

The study was conducted over a period of four weeks between July and August 2017 at $24^{th}$ level trackless section 147. The researcher was able to follow three different employees per day as they walked in pairs or groups during the morning shift, leading to a total sample size of 66. All the activities they were involved in were timed and recorded in detail. 14 Shaft management granted permission to conduct this study.

## 3.4 Units of analysis

Units of analysis are members or elements of a population such as humans, groups of people or things in a particular year or area, organisations or institutions and human products or output (Welman et al., 2005). In this study, the unit of analysis was the employees who worked at the trackless mechanised section 147 at 24$^{th}$ level. The unit of analysis consisted of a group of 9 miners, 45 rock drill operators (RDO), 9 LHD drivers and 15 equipment helpers. The total number of employees working at the trackless mechanised section 147 was 78.

A convenience sample of three employees, of which two were RDOs in each group and the other one being an LHD driver or equipment helper or a miner were grouped by the researcher. A list of names of employees was generated by the researcher a day before the start of the observations for all the days of the observations. The reason was that RDOs were more than the other groups. A group was also formed by employees belonging to the same team. All groups then agreed that they would meet with the researcher at shaft bank at the beginning of each morning shift. One time was recorded for each group as they were working at the same place.

The miners are responsible for declaring the working place safe, marking off the face and the hanging wall for RDOs to drill holes and connecting the blasting cable to the blasting box. LHD drivers clean the working places after blasting. Equipment helpers are responsible for cleaning the driveway and extending water and compressed air pipes from the driveways closer to the working places.

The employees were to be observed and timed as they travel from the bank at surface to their underground working places and back to surface. The distance from 24$^{th}$ level chairlift station is roughly 2.5 km to the central waiting place. Their allocated scheduled clocking time was from 04:10 am to 04:50 am.

## 3.5 Data collection and Recording

Data are required to be collected or collated in the most scientific manner to address and fulfil the research aims and objectives (Sahu, 2016). There are different types of data collection methods that can be used to obtain data such as primary data and secondary data. Primary data are that data collected by the researcher afresh and for the first time from the field of investigations with specific goals and objectives in mind (Sahu, 2016).

Primary data collection methods, according to Sahu (2016) include:

- Observation method
- Interview method
- Questionnaire method
- Experimental method.

Secondary data can be described as data that already exists, which were collected by someone, an agency or an organisation, but are being used by some other researchers (Sahu, 2016) for their research purpose or problem at hand. Secondary data are found in different sources such as government, private, industrial, business, research or voluntary organisations (Sahu, 2016). Both primary and secondary data were used in completing this study.

### 3.5.1 Primary data collection methods

The primary data were collected using the time and motion study as well as observation method. The method was chosen because the researcher was able to observe, time and record all the activities undertaken during a normal working shift. This was to quantify the time spent by section 147 participants in each activity between clocking-in at the bank, getting to the face and returning to surface.

#### 3.5.1.1 Time and motion study

A time and motion study is described as the work measurement technique used for timing a specific job and for analysing the data so as to obtain the time necessary for a person

to carry it out at the defined rate of performance (Kanawaty, 1992). It has been successfully applied in different sectors such as hospitals, banks, libraries, factories, housework, department stores and in many other human activities (Naik et al., n.d).

The time and motion study equipment are a stop watch, a study board and time study forms. Time and motion studies are essential sets of tools used by the managers in the industrial sector to improve the performance or the operational efficiency (Naik et al., n.d). This is done by breaking down the work into simpler units, making it easier to observe and record exactly how much time is being spent on each activity (Naik et al., n.d)

The method was chosen because it can also be applied in the mining industry. The researcher was able to observe, measure how long each activity takes and record all the activities undertaken during a normal working shift. This was to quantify the time spent by section 147 participants in each activity between clocking-in at the bank, getting to the face and returning to surface. The plan was also to assist in understanding why activities took the time that they did. Time was measured using a stopwatch. The time and motion study was conducted from Monday to Friday during morning shift only.

The morning shift was selected because it was regarded as the demanding shift. There are many variety of mining activities (see figure 1) taking place than in night shift. During the night shift, employees only do two activities such as making the work places safe and cleaning them.

### 3.5.2 Observation method as a means of collecting data

All participants were fully informed about the purpose of the study and that the purpose for observing was to document the activities they are involved in from the bank area to their waiting places and when returning to surface. The activities and the notes were recorded in front of the employees to confirm that data collected were for research purposes. No personal information was held. Employee confidentiality was maintained to ensure that there was no revealing of the names of the participants. To prepare for the study, the researcher developed a data collection form (see Appendix A).

The data collection form included columns for dates, recording the start and stop (end) time of each activity, activity name and total time spent for each activity. Time was measured using a stopwatch. The researcher observed and timed all the activities participants were involved in before reaching their workplaces and after departing from the waiting place and returning to surface.

The measurements of times were taken for the following activities:

- Waiting time for the cage: the total time that employees have to wait at the bank before entering the cage;
- Loading the cage: the total time employees take to get into the cage and the time onsetters take to close the cage doors;
- From the bank to 22$^{nd}$ level (winding cycling time): the time the cage takes from the surface bank to 22$^{nd}$ level (underground);
- Offloading the cage: total time taken by onsetters opening the cage doors plus time taken by the employees when getting out of the cage at 22$^{nd}$ level (underground);
- Walk from 22$^{nd}$ station to 1$^{st}$ leg of chairlift: time taken by employees walking out of the cage from the station to the 1$^{st}$ leg of chairlifts;
- Queuing to climb chairlift: time the employees have to wait before climbing on a chairlift;
- Waiting time for climbing a chairlift: total time the employees have to wait to ride on a chairlift;
- 1$^{st}$ leg chairlift riding from 22$^{nd}$ level to 24$^{th}$ level: time taken by the employees when riding on a chairlift;
- From 24$^{th}$ level chairlift station to central waiting place: total time taken by the employees after climbing off a chairlift, walking to their waiting places where they all have to meet before entering the working place;
- Safety meeting (Wednesdays only): time taken by employees when having a safety meeting where they discuss all the safety and production issues;
- Resting before entering working places: time taken by employees to rest before going to their working places, as they will be tired of walking long distances;

- Walk from central waiting place to the closest working places: time taken by employees to their respective working places;
- Walk from working place to waiting places: time taken by employees from their respective working places to the central place;
- Walk from section waiting place to 24$^{th}$ level chairlift station: time taken by the employees after departing from the waiting place, walking to climb chairlift at 24$^{th}$ level to 22$^{nd}$ level;
- From 24$^{th}$ to 22$^{nd}$ level chairlift station (chairlift riding): time taken by an employee when riding on a chairlift;
- Walk from 22$^{nd}$ level 1$^{st}$ leg to 22$^{nd}$ cage station: time taken by employees climbing off the chairlift, walking to catch the cage from the station to surface;
- Waiting time for the cage (after work): the total time that employees have to wait at 22$^{nd}$ level shaft station before entering into the cage.

In addition to primary data methods above, the following secondary methods collected.

#### 3.5.2.1 Secondary data collection method

Literature review was conducted in Chapter two of this research study to formulate a theoretical framework of the ideas of the research topic. The secondary data assisted in conceptualising what was important and in collecting data that was relevant to validate the observed study.

The secondary data also provided a baseline to compare the collected primary data results with those previously published to provide supporting evidence that the time and motion method provides valid results when quantifying amount of time spent on different activities. The results and findings from the secondary data assisted with the overall goal in this study. The secondary data were collected from technical publications such as books and journals.

## 3.6 Data analysis

Descriptive statistics were used to calculate all the activities identified and measured before reaching the participants' working places. Descriptive statistics refers to graphical and tabular methods used to summarise and order data (Swanepoel et al., 2015). Means, standard deviations, minimum and maximum values were calculated for all variables of the activities. Statistical inference was then used to make conclusions of the decisions from the information obtained from the data collected.

Statistical inference refers to the methods used to make conclusions about a population from a sample data (Swanepoel et al., 2015). Statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS), version 23. This statistical software is used extensively in social science but can also be employed in other fields of research for analysing data statistically. It can be used to create graphs and tables that could be utilised to predict what will happen next and to make smarter decisions, solve problems and improve the outcomes of the findings.

## 3.7 Criteria for validity

"Validity is defined as the extent to which a concept is accurately measured in a quantitative study" (Heale and Twycross, 2015). Subsequently it is concerned with the accuracy and truthfulness of scientific findings and should demonstrate what actually exists and a valid instrument or measure should actually measure what it is supposed to measure (Brink, 1993).

The researcher used the stopwatch and data collection form to record all the activities of the employees. The empirical data was validated by comparing their outcomes to those discussed in literature review.

## 3.8 Executive summary

This chapter described the methodology used by discussing the steps followed in the research process in this study. Justification for selecting convenience sampling was included. This chapter has outlined the process of collecting data. The data collected from the activities through the time and motion study in this study are further analysed, interpreted and presented in the next chapter.

# Chapter 4: Results and data analysis

## 4.1 Introduction

Chapter 3 dealt with the research methodology and the process of data collection used. Chapter 4 reports on the results, analysis of the data and findings from the data collected from observations and timed activities that participants were involved in before reaching their workplaces and after departing from the waiting place and returning to surface. There is limited discussion regarding the underground mining activities related to low face time. Studies have referred to underground transportation constraints but have not expanded further on the subject.

The data for this study were collected using the time and motion study where a form was developed in accordance to the information needed for analysis. The researcher deployed the time and motion study to confirm the first two research objectives:

- Determine the activities employees are involved in between clocking in and getting to the face and when departing from the waiting place and returning to surface,
- Determine the average time spent on each activity.

The aim of the study was to identify the contributing factors to low available face time at 14 Shaft. There are a variety of factors that can impact the face time such as walking long distances from the shaft area to the working places as well as queuing up at the bank before entering the cage and before riding on the chairlifts (Rampedi and Genc, 2012).

A decision, therefore, was taken to document all the activities that employees are involved in during travel and how much time is spent on each activity between clocking in and getting to the face and when departing from the waiting place and returning to surface. Data were collected by means of the researcher using averages while travelling with three

employees each day from the surface to their working places. The data excluded the mining cycle activities where employees are productively working at the face.

The descriptive quantitative observation study was conducted on 66 employees of section 147 trackless mechanised mining working at 24$^{th}$ level through convenience sampling. This was an appropriate method since the sample was easy to access and available at a given time. The sample was selected based on the working places being the furthest in the trackless section and that the clock-in time is the same. Other trackless sections were excluded since their working places are closer to the chairlift stations.

The findings from the observational data are presented in Table 1. This chapter begins with some time and motion study feedback as well as the descriptive statistics, which is followed by an analysis of the findings and an interpretation of results in relation to the literature reviewed in Chapter 2. The research findings outlined are related to the literature.

## 4.2 Time and motion study feedback

The researcher conducted the time and motion study over a period of 22 working days. The study and observations took place from Mondays to Fridays during morning shift. The researcher accompanied three different employees per day while observing them as they travelled to their working places in pairs or groups. The researcher then averaged the results over the number of employees on each day.

The reason for that is that they were aware that once they were at the shaft bank they were safe since there is no other clocking needed.

17 different activities were captured during the day, which employees were involved in before reaching their workplaces and after departing from the waiting place and returning to surface. The intention of documenting all the activities the employees were involved in was to identify the dominant factors contributing to low face time. During the study, the researcher noted that the most time is spent on travelling to and from the working places as well as during section safety meetings that take place every Wednesday.

## 4.3 Descriptive statistics

The researcher was required to define and name each variable before analysing data. The variable names in this research are all the activities that employees are involved in before getting to their working places and after departing from the waiting place and returning to surface.

Descriptive statistics are used to describe the characteristics of each variable to check the variable for any violation of the assumptions underlying the statistical technique to be used to address the research question and to address a specific research question(s) (Pallant, 2013). Descriptive statistics also refers to graphical and tabular methods, which can be used to draw conclusions from the data (Swanepoel et al., 2015).

### 4.3.1 Summary statistics of different variables (in minutes)

An analysis of the data generated summary statistics of different variables (activities) is presented in Table 1. The data are listed from immediately after the employees' clock-in before reaching their working faces and when departing from the waiting place and returning to surface. The employees were not tracked when performing their actual productive activities at their working places.

The results reflect the time spent by the employees undertaking each activity in minutes over a period of 22 different days. Safety meetings take place once a week every Wednesday morning at the central waiting place before commencing work. As indicated in Table 1, the meetings happened five times during this study.

Resting before entering the workplace is recorded 17 times. This is due to the safety meetings taking place on Wednesday. After the safety meeting, employees do not need to rest because they have rested enough during the meeting. Therefore, they enter their working places without wasting any time.

The rest of the activities took place over a period of 22 days. The activities listed below occur in the linear manner whereby each activity follows the previous. The minimum,

maximum and mean time spent doing each activity as well as the standard deviation and number of days are displayed in Table 1.

**Table 1: Descriptive statistics of different variables (in minutes)**

| Variables (Activities) | Number of days | Independent samples | Min. | Mean | Max | Std. Dev |
|---|---|---|---|---|---|---|
| Waiting time for cage | **22** | **66** | 28,90 | 32,49 | 37,00 | 2,29 |
| Loading the cage (morning) | **22** | **66** | 4,40 | 4,81 | 5,20 | 0,22 |
| Bank to 22 level (winding cycle time) | **22** | **66** | 2,00 | 2,00 | 2,00 | 0,00 |
| Off-loading the cage | **22** | **66** | 3,10 | 3,68 | 4,10 | 0,30 |
| Walk from 22nd station to 1st leg of chairlift | **22** | **66** | 4,20 | 4,92 | 6,00 | 0,36 |
| Queuing to climb chairlift | **22** | **66** | 15,30 | 16,54 | 18,30 | 0,96 |
| Waiting time for climbing a chairlift | **22** | **66** | 0,06 | 0,06 | 0,06 | 0,00 |
| 1st leg chairlift riding: 22nd- 24th level (chairlift riding) | **22** | **66** | 4,00 | 4,00 | 4,00 | 0,00 |
| 24th level chairlift station to central waiting place | **22** | **66** | 38,00 | 40,59 | 43,00 | 1,30 |
| Safety meeting (Wednesdays only) | **5** | **79** | 52,00 | 57,6 | 70,00 | 7,40 |
| Resting before entering working places | **17** | **66** | 31,00 | 36,94 | 43,00 | 3,13 |
| Walk from central waiting place to the closest working places | **22** | **66** | 4,00 | 4,45 | 5,00 | 0,51 |
| Walk from working place to waiting place | **22** | **66** | 5,00 | 5,5 | 7,00 | 0,74 |
| Section waiting place to 24th level chairlift station | **22** | **66** | 46,00 | 46,41 | 49,00 | 1,05 |
| 24th- 22nd level chairlift station (chairlift riding) | **22** | **66** | 4,00 | 4,00 | 4,00 | 0,00 |
| Walk from 22nd level 1st leg to 22nd cage station | **22** | **66** | 6,00 | 5,68 | 8,00 | 1,25 |
| Waiting time for cage | **22** | **66** | 20,00 | 23,59 | 26,00 | 1,68 |
| Loading the cage (afternoon) | **22** | **66** | 3,00 | 3,37 | 4,00 | 0,20 |
| 22 level to bank (winding cycle time) | **22** | **66** | 2,00 | 2,00 | 2,00 | 0,00 |
| Off-loading the cage | **22** | **66** | 2,03 | 2,31 | 2,53 | 0,13 |

As shown in Table 1, some speeds of the activities were constant. This is because the constant speeds are regulated by safety considerations (MHSA, 2015) as well as set on the computers and the cage is driven by a machine. The minimum, maximum and mean times as well as the standard deviations of the activities such as travelling time of a cage from the surface bank to 22$^{nd}$ level cage station, the waiting time each employee takes for climbing on a chairlift as well as riding on the chairlift from 22$^{nd}$ level to 24$^{th}$ level are constant and presented no variations.

Compared to Rampedi and Genc (2012), the findings in this study are reported differently even though the sequence of activities are the same. For example, there are no minimum, maximum, mean or standard deviations reported in Rampedi and Genc. The values reported in their research are being reported as they are. For this study, the focus of the results was on the means and standard deviations of all activities identified and timed.

### 4.3.2 Average times and standard deviations of the activities

Figures 13 represents the bar graphs of the average times results for employees walking in the conveyor belt haulage at Khuseleka No. 1 Shaft of Anglo American Platinum during peak, average and low times (Rampedi and Genc, 2012). However, the peak time was chosen as the guideline during this study. Figure 14 displays the bar graphs and standard deviation times results of this study of different activities.

As can be seen from the below figures 13 and 14, safety meetings, walking, queuing and waiting for a cage and chairlifts as well as resting before entering the working places yielded as the most activities where most of the time is spent.

Figure 13: Average time distribution for employees walking (Rampedi and Genc, 2012)

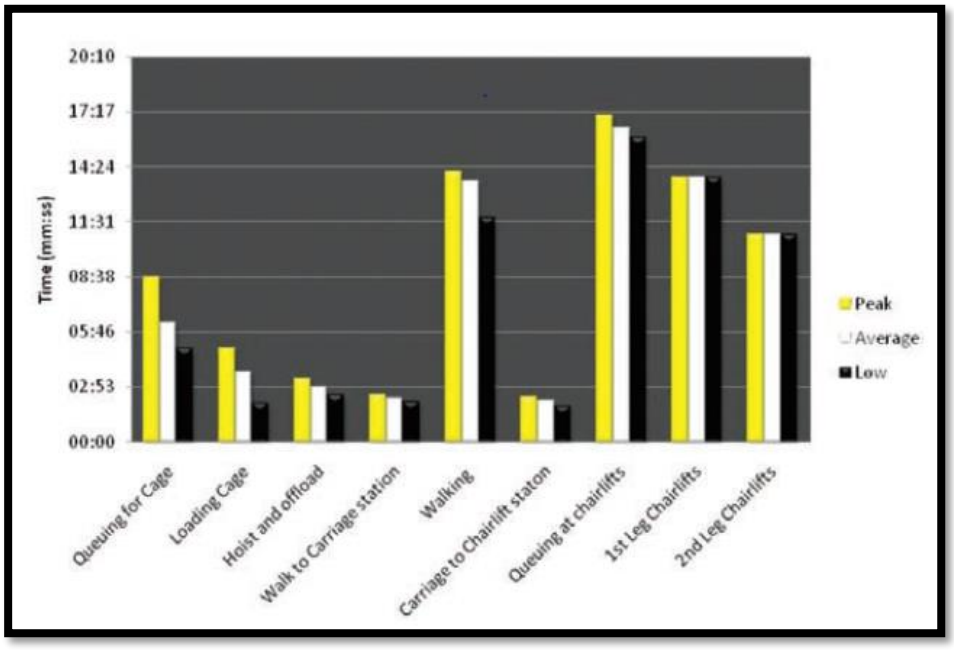



Figure 14: Average time distribution for employees using man carriage (Rampedi and Genc, 2012)

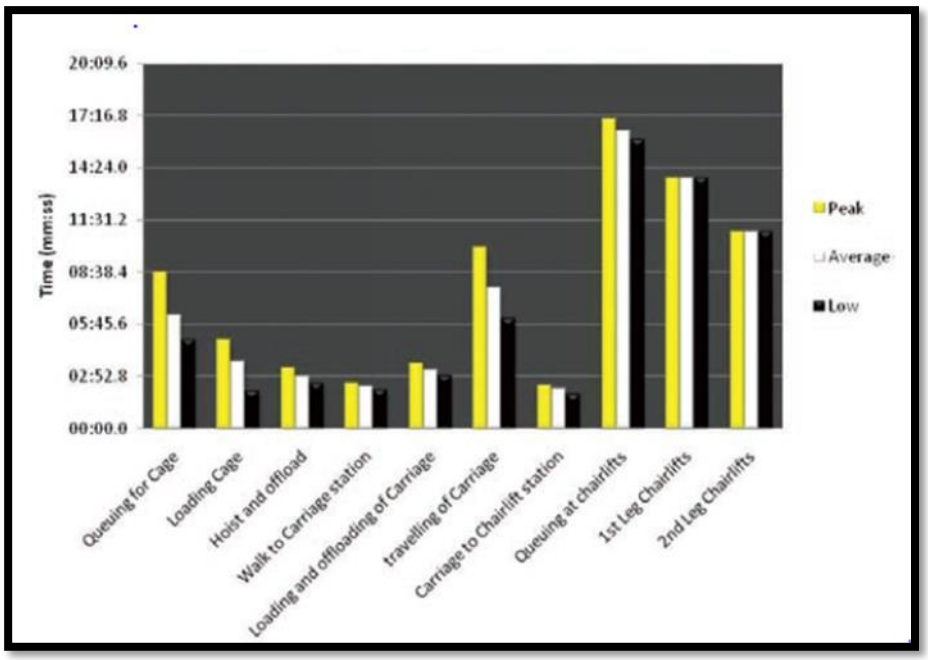
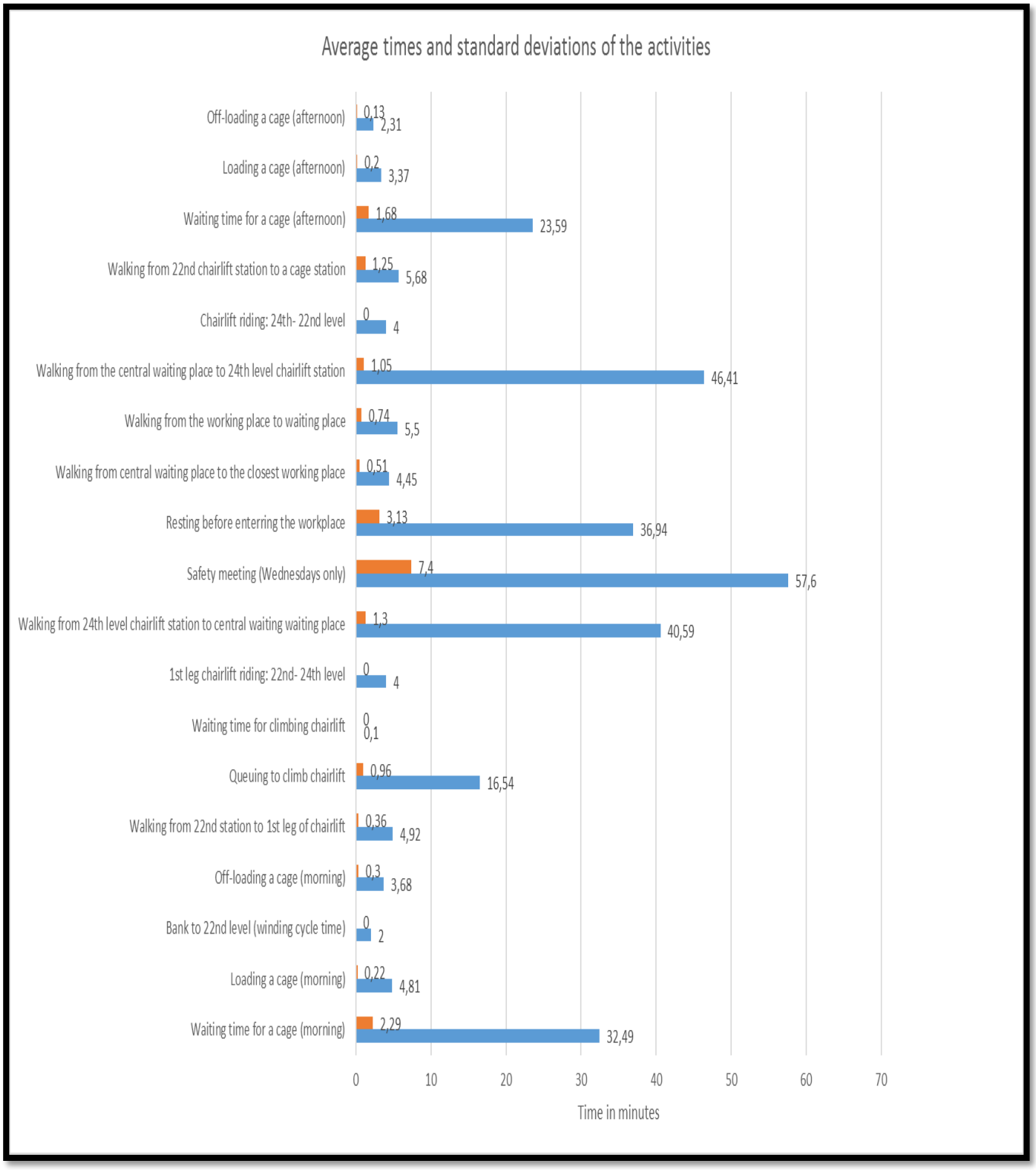


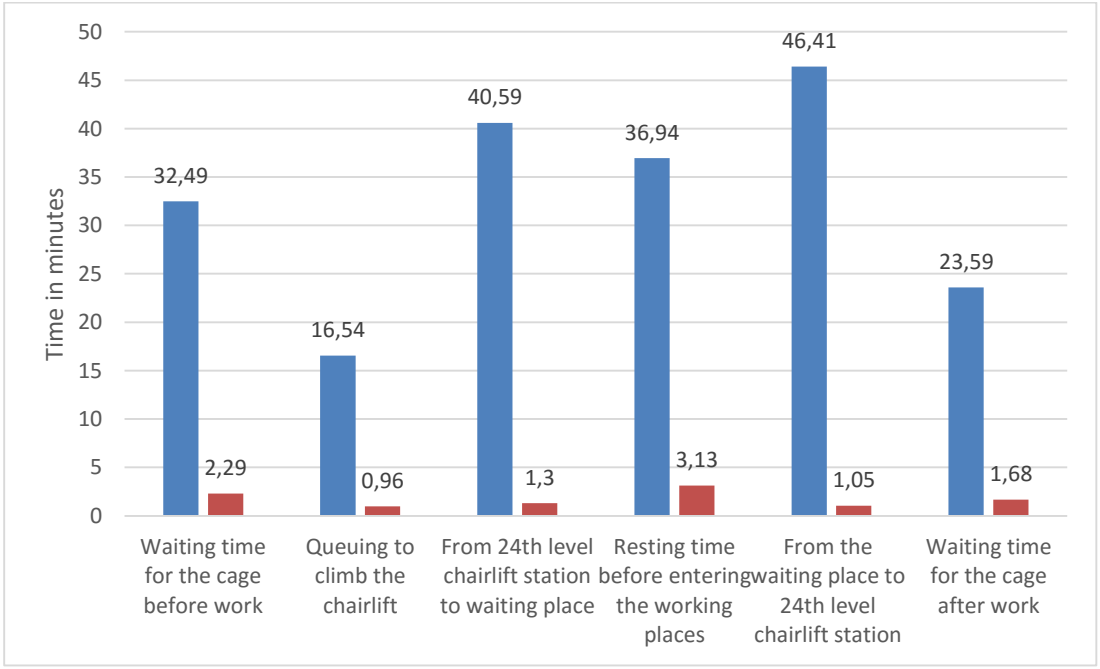
**Figure 15: Average times and standard deviations of the activities**



### 4.3.3 Average times and standard deviation times of the total non-value adding activities

Figure 15 illustrates the average times and the standard deviations of the activities that take the longest time during the shift when travelling underground from surface to the waiting place. According to the results depicted in figure 15, the activity of walking to and from a waiting place is the highest time waster.

**Figure 15: Deviation bars on the means of total avoidable non-value adding activities**




The distance is the same but the travelling time is different due to the fact that employees are tired after departing from the waiting place, which is why walking from the waiting place to the chairlift station takes longer.

Queuing and waiting for the cage on surface is reflected as the fourth non-value adding activity. This is due to the overcrowding that took place at the shaft bank every morning. The overcrowding was the result of the way the shaft schedule is designed. All employees working at the mechanised section have to wait for 30 minutes or more for the cage.

Resting at the waiting place before entering their working places is the third non-value adding activity. It is important for employees to be fit when entering their working place in order for them to work safely.

Therefore, after walking long distance, employees rested before entering their working places. This was because of fatigue. Some employees arrive at the waiting place early whereas others arrive late. Therefore, they must wait for them at the waiting place so that they enter the working place as a team.

Queuing and waiting for the cage at the underground station is recorded as the fifth non-value adding activity. The cage came and raised employees several times, while other employees queued, waiting for their turn. The cage started raising employees as per the shaft schedule and on time, unlike in the morning where it was always 30 minutes late.

Unfortunately, the employees knocked off two to three hours late, just to make sure that they blast their working places. Queuing and waiting is not as bad as in the morning because most of the employees would have knocked off earlier as their working places are not as far as the one of section 147.

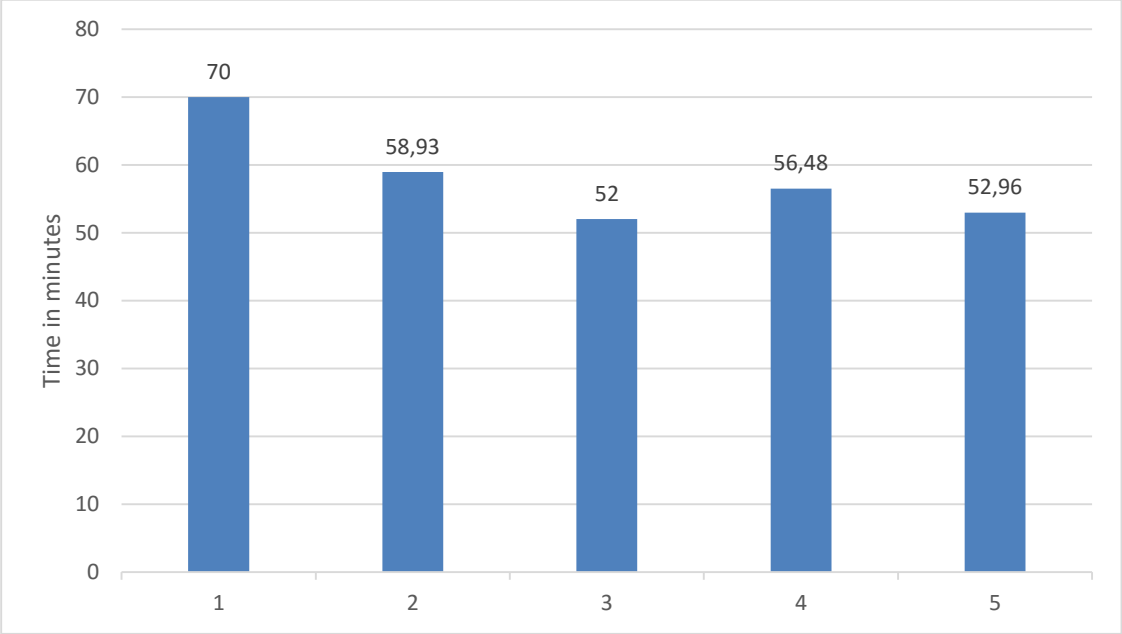
The last significant non-value adding activity is queuing at the chairlift station. This is because a cage transports employees as a batch of 120 per trip. The queue moved fast due to the fact that the chairlift is continuously running and it took each employees 0.1 minutes to climb on a chairlift. Again, the speed of the chairlift is constant and cannot be changed due to safety precautions.

### 4.4 Total number of safety meetings

The total number of safety meetings is provided in figure 16. Safety meetings take place weekly, every Wednesday morning at the central waiting place before commencing work. All team members together with their miners meet with their shift supervisors and sometimes with their mine overseer or their mine manager to discuss the production and safety challenges as well as affording compliments where they are due.

Five safety meetings times were recorded. Safety meetings are important but appeared to be a waste, because the meetings took time which might lead to employees not completing the mining cycle on Wednesdays. Different teams reporting to one shift supervisor attend the safety meetings.

**Figure 16: Total number of safety meetings**




Daily both the morning and the night shifts teams have a 10 to 15 minutes meeting before entering their working places in order for the miners to give a night and morning shifts reports to the team and to plan for their day. It is not easy to say that the safety meetings should be split to daily meetings in order to save time because those meetings are sectional meetings where shift supervisors are able to see all their teams at once.

Table 2: Analysis of non-value adding safety meetings

| Activities discussed | Necessary Non-Value adding | Non-value adding |
|---|---|---|
| Review production performance. The miners discuss the production targets with the employees. Reporting how many meters they have blasted thus far and how many left for them to achieve their monthly target. The miners also inform the employees about the scheduled measuring dates of each working place. Employees are then given opportunities to ask questions where they do not understand. | X | |
| Reporting of injuries and accidents. This is where all the injuries and accidents happened at any of the Impala shaft are discussed so as to make sure that the same injury or accident does not happen again at any shaft. | X | |
| Reminder about safety procedures. The miners remind the employees about 5 platinum rules, 5 rules of barring and daily safety rules. | X | |
| Updates about COP. Should there be an amendment in the code of practice, the changes are then discussed. | | |
| Discuss the safety challenges in the section. Employees are given to report any challenge that they come across in their working place. | X | |

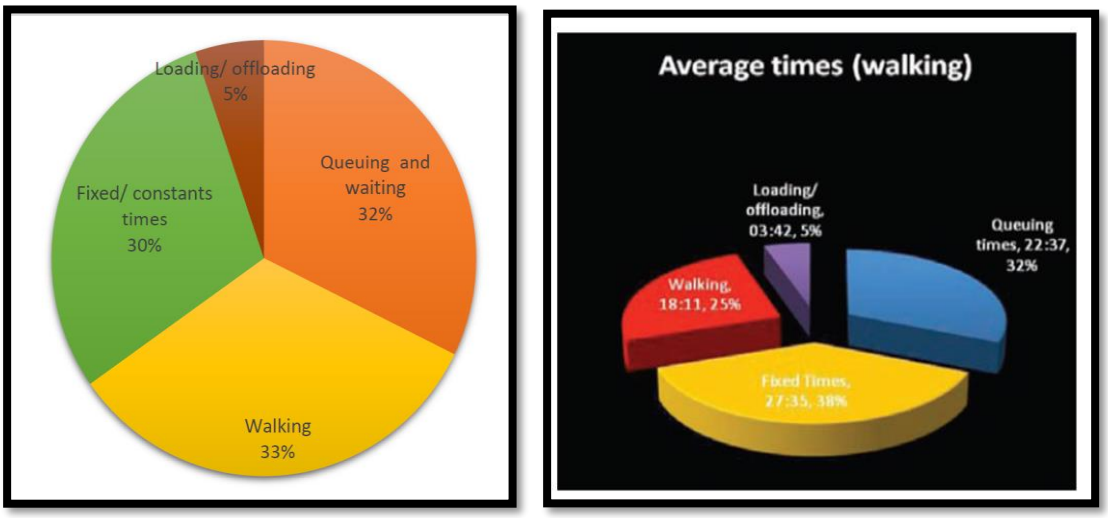
## 4.5 Total time percentages of each category over 22 days

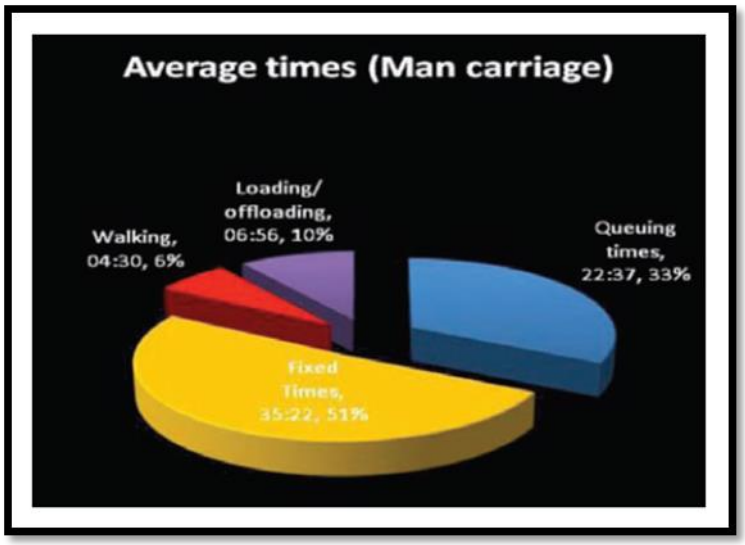
Figures 17 represents the total time and percentages of certain categories over 22 days of the non-effective face time.

According to the results, queuing and waiting is the second time waster since employees are idling whilst waiting to be transported and not performing any of their productive mining activities.

Walking is the first time waster with 45.6 percent of non-working time. This is because the working places are far from the shaft and there is no means of transport to convey them quicker. Resting is the third time waster and takes 15.7 percent of the total non-effective face time. The employees rest at their waiting place before entering due to fatigue as they have walked for 40.59 minutes before arriving at their waiting place.

**Figure 17: Analysed total time percentages spent of each category**






The fixed constant activities are times that cannot be changed as they are regulated for safety purposes. These are the cage travelling times from surface to underground and back, as well as the chairlifts' riding times from one station to another. These activities take 5.1 percent of non-working time.

Loading and offloading employees takes 3.6 percent of the total non-effective face time. There is no other way of lowering and raising employees except by the cage, because the shaft is deep.

## 4.6 Observational table of non-value adding activities

Table 3: Observational table of non-value adding activities

| Activity | Average time (minutes) | Comments/Observations |
|---|---|---|
| Queuing for a cage | 32,49 | After clocking-in at the shaft gates, some employees immediately went to the shaft bank to queue and wait for a cage while others waited to talk with friends. As a result, they arrive late at their waiting places. Waiting and queuing for a cage is long because when section 147 employees clock-in at the bank gates there are already queues at the bank area of employees working at lower levels also waiting for a cage. Therefore creates overcrowding of the employees on the bank and at underground stations. |
| Loading a cage | 4,81 | There was no waste of time in this activity. Each deck of the cage at both surface and underground was allocated an onsetter to open and close the cage doors before lowering or raising of employees. |
| Bank to 22nd level (winding cycle time) | 2 | The travelling time is constant because the speed of the cage is regulated and driven by the machine. This includes the full cycle of travel starting from when the cage accelerates its constant speed and deceleration until it stops. |
| Off-loading a cage (morning) | 3,68 | When employees entered into the cage they turned and faced the direction they came from to save time when coming out of the cage. |
| Walking from 22nd station to 1st leg of chairlift | 4,92 | The employees walked from the cage station straight to the chairlift station without stopping or talking with friends. They appeared to want to retain their position, as there was a queue for the chairlifts. |
| Queuing to climb chairlift | 16,54 | The queue is created and leads to a real bottleneck due to the fact that the cage carries a maximum of 120 employees per trip. Therefore, the employees arrived at the chairlift station as a batch of 120 and have to |

| | | |
|---|---|---|
| | | wait in the queue for their turn to ride on the chairlift. |
| Waiting time for climbing chairlift | 0,06 | After queuing, each employee has to wait for 6 seconds before riding on the chairlift. This is due to the 6m spacing distance between chairs required to allow for safe boarding and disembarking of employees. |
| 1st leg chairlift riding: 22nd-24th level | 4 | The average riding time on a chairlift from the 22$^{nd}$ level chairlift station to the 24$^{th}$ level chairlift station is constant. This is because the speeds are constant and regulated for safety considerations (MHSA, 2015) as well as set on the computers. |
| Walking from 24th level chairlift station to central waiting waiting place | 40,59 | The employees took a long time walking because their working places are far from the shaft and there is no mode of transport to carry them closer to their waiting places. Some of the employees walks faster than the others. |
| Resting before entering the workplace | 36,94 | Employees rest before entering their working places due to fatigue. This is because they travel long distance walking in order to reach their working places. |
| Walking from central waiting place to the closest working place | 4,45 | The average walking time from the central waiting place to the closest working places was shorter and the employees were energetic, as they have rested at the waiting place. |
| Walking from the working place to waiting place | 5,5 | The average walking time from the working place to the central waiting place was always longer in the afternoon than in the morning because the employees it was after the shift and the employees were tired. |
| Walking from the central waiting place to 24th level chairlift station | 46,41 | The average walking time was longer in the afternoon than in the morning because it was after the shift and the employees walked slowly as they were tired. |

| | | |
|---|---|---|
| Chairlift riding: 24th- 22nd level | 4 | The average riding time on a chairlift from the 22nd level chairlift station to the 24th level chairlift station is constant. This is because the speeds are constant and regulated for safety considerations (MHSA, 2015) as well as set on the computers. |
| Walking from 22nd chairlift station to a cage station | 5,68 | The average walking time was longer in the afternoon than in the morning because it was after the shift and the employees walked slowly as they were tired. |
| Waiting time for a cage (afternoon) | 23,59 | The waiting time is less than the waiting time at the shaft bank in the morning because more employees have already left underground. Also because the employees were arriving at the chairlift from across the mine, more strung out in time than the single arrival that occurs in the morning when the cage load of employees arrives at once. This also suggests that this queuing time could be lowered by staggering shift time. The employees were also two to three hours behind their schedule clocking out time. |
| Loading a cage (afternoon) | 3,37 | The loading time was quicker than in the morning because most of the employees have already left underground. |
| 22nd level to bank (winding cycle time) | 2 | The travelling time is constant because the speed of the cage is regulated and driven by the machine. This includes the full cycle of travel starting from when the cage accelerates its constant speed and deceleration until it stops. |
| Off-loading a cage (afternoon) | 2,31 | The off- loading time was quicker than in the morning because most of the employees have already left underground. |
| Safety meetings (Wednesdays only) | 57,6 | The teams are affected negatively because they have to wait for other team members before starting with the meeting. This also leads to long safety meetings because the employees arrive late and at different times. |

## 4.7 Categories of non-value adding activities

Table 4 represent the categories of non-value adding activities. There are different kinds of non-value adding activities. There are those who are necessary, avoidable and non-avoidable.

**Table 4: Categories of non-value adding activities**

| Activity | Necessary Non-value adding | Avoidable non-value adding | Non-avoidable non-value adding |
|---|---|---|---|
| Waiting time for a cage (morning) | | X | |
| Loading a cage (morning) | | | X |
| Bank to 22nd level (winding cycle time) | X | | |
| Off-loading a cage (morning) | | | X |
| Walking from 22nd station to 1st leg of chairlift | | | X |
| Queuing to climb chairlift | | | X |
| Waiting time for climbing chairlift | | | X |
| 1st leg chairlift riding: 22nd-24th level | X | | |
| Walking from 24th level chairlift station to central waiting waiting place | | X | |
| Safety meeting (Wednesdays only) | X | | |
| Resting before entering the workplace | | X | |
| Walking from central waiting place to the closest working place | | | X |
| Walking from the working place to waiting place | | | X |
| Walking from the central waiting place to 24th level chairlift station | | X | |
| Chairlift riding: 24th- 22nd level | | | X |

| | | | |
|---|---|---|---|
| Walking from 22nd chairlift station to a cage station | | | **X** |
| Waiting time for a cage (afternoon) | | **X** | |
| Loading a cage (afternoon) | | | **X** |
| Off-loading a cage (afternoon) | | | **X** |

## 4.8 Executive summary

This chapter has presented the findings from the time and motion study of underground section 147 trackless mechanised at 24$^{th}$ level as they worked a morning shift. The research study aimed to describe and analyse the activities that employees were involved in and how much time was spent on each activity between clocking in and arriving at their working places and when departing from the waiting place and returning to surface. The time and motion study and the observation process were explored in order to determine the activities undertaken by employees.

It was found that the queuing for cages and chairlifts, walking to and from the working places, long safety meetings and resting before entering the working places are activities consuming the most time. Employees clock-in and queue at the bank before getting into the cage (Rampedi and Genc, 2012). They further state that queuing takes the longest time at the chairlift station.

It is important to note that an increase of time in any variable (activity) will definitely have an impact on the face time. Therefore, decreasing the time consumed by each variable (activity) will increase the face time.

## 4.9 Conclusion

In this chapter, data collected from Chapter 3 were analysed in detail and the results compared with the outcome from the literature review conducted in Chapter 2. The key findings, recommendations and conclusions of the results analysed in this chapter is

discussed in Chapter 6. The root cause analysis − critical analysis of identified root causes of low face time and how they can be reduced or eliminated so that the face time can be improved − is further analysed in the next chapter.

# Chapter 5: Discussion

## 5.1 Introduction

This chapter will evaluate the outcome of the results that were analysed in Chapter 4, using the data that was collected through the time and motion approach discussed in Chapter 3 of this study. The analysed data will be discussed and will be compared with other studies that were discussed in Chapter 2.

## 5.2 Discussion on literature review

In an effort to establish the cause of the problem, various literary sources were reviewed with the aim of finding more insight into the problem. The findings of the literature review revealed that although the transportation systems run as planned but it takes a long time to reach their respective working places at the beginning of every shift (Pareja, 2000).

This is particularly because the mine management gives low attention to the transportation of employees while giving more consideration to the transportation of rocks (Rupprecht, 2003). Rupprecht (2003) is also of the opinion that sharing the responsibility of transport management between the mining and engineering departments, often results in poor coordination. As a result, employees endure:

- Queuing and waiting for a cage and chairlifts. The time spent in a queue depends on different factors such as the number of people who are ahead in a queue (Carvalho and Belo, 2016). As a result, the queue become long and congested and excess waiting time is imposed on the employees (Ford, 1980).
- Walking long distances to and from the working places.

The outcomes of the literature review also indicated that each level has its own designated time of getting the employees to their working places (Rampedi and Genc, 2012) as per the shaft schedule (Bhulose, 2004). Furthermore, the shaft schedule should

be modified so that employees working in the lowest levels are lowered first in order to assist in reducing overcrowding at boarding points (Bhulose, 2004).

Rupprecht (2003) is of the opinion that the use of man carriages is necessary if the travelling distance from the shaft to the working places exceeds 1400 m to 1800 m.

## 5.3 Discussion of the findings

The observational results of this study reveal that there was inadequate long term planning of transportation systems as there was no provision made for transporting employees closer to their working places as mining is progressing deeper and further from the shaft resulting in working places that are far from the shaft.

The second highest ranking avoidable non-value adding activity prevalent was found to be queuing and waiting for a cage. This finding confirms previous findings by Rampedi and Genc (2012) where employees queue up at the bank area before entering the cage. Waiting and queuing for a cage is long because when employees working at 24$^{th}$ level clock-in at the bank gates there are already queues at the bank area of employees working at lower levels also waiting for a cage. Queue at 14 shaft is due to the current shaft schedule that requires that:

- Employees working at 27th level waste 30 minutes waiting for a cage. They clock-in at the gate from 04:00 am until 04:40 am and the cage starts lowering them down from 04:30 am as per the shaft schedule. This is because employees that work in the bottom levels are lowered first in the morning and the upper levels follow thereafter.
- Employees working at 24$^{th}$ level clock-in at the shaft gates from 04:10 am until 04:50 am. Employees clock-in any time within the specified time as per their level time schedule. When employees for the 24$^{th}$ level clock-in they find employees working at 25$^{th}$, 26$^{th}$ and 27$^{th}$ levels already queuing and waiting for the cage. Therefore, creates overcrowding of the employees on the bank and at underground stations.

The results also indicate that walking from the chairlift station to and from the working places was the highest ranking avoidable non-value adding activity that contributes to less face time resulting to lower productivity. The results confirm findings from literature that at the Khuseleka No. 1 Shaft of Anglo American Platinum where a long distance travelled by employees from the chairlift station to their working places was identified as a contributing factor to lower productivity (Rampedi and Genc, 2012) and the actual time spent in the working place.

Such substantial distance has the adverse effect of causing employees to be fatigued at the beginning and end of every shift. Hence, employees have to rest at their waiting places before entering their respective working places. The distance of section 147 working places are 2.5 km from the shaft. Therefore, according to Rupprecht (2003) 14 Shaft qualifies for using man carriages because the travelling distance exceeds 1800 m.

## 5.3 Shortcomings and limitations

There are a number of limitations to this study. Although literature is replete with issues affecting the mining industry, there is a dearth of scholarly materials on factors contributing to low face time. Available studies highlight the importance on underground transportation systems without necessarily linking to the face time.

Although the study was carefully prepared, the researcher was aware of its limitations and shortcomings. The study was conducted over a period of four weeks between July and August 2017. A month was not enough for the researcher to observe but a longer time was prevented due to the limited access at 14 Shaft.

Another limitation of this study is that the study was conducted at 14 Shaft only and the sample size was small therefore the results should be interpreted with cautions because they do represent the all mining houses.

In terms of the scope of this study, the study excluded the mining cycle activities where employees are productively working at the face. This is because the focus was only on

the activities employees are involved in between clocking in and getting to the face and when departing from the waiting place and returning to surface.

## 5.4 Implications for the mining industry

Findings from this study imply that the working places are far from the shaft area and employees end up spending a significant amount of time walking to their working places. The distance has a negative impact on the working time available at the working places as the employees spend less time working at the face and also causing employees to be fatigued at the beginning and ending of every shift.

Poor transport management will lead to employees walking long distances, queuing and waiting for a cage for a long time. If this is not addressed, it will become worse as the mine opens up more working places and gets more employees in the trackless mechanised sections. It will result in employees spending more time on queuing and less time at the working places, which will impact the productivity negatively.

## 5.5 Conclusion

In this chapter all the factors mentioned above have a direct link to low face time. The study found that the activities contributing most to low face time are queuing for a cage, time spent on walking to and from the working places, long safety meetings and resting before entering the working place. In the next chapter, the research is concluded from all findings and research results reported in chapters 4 and 5 and recommendations are present

# Chapter 6: Conclusions and recommendations

## 6.1 Introduction

This chapter presents a summary of the conclusions drawn from the study and provides recommendations according to the problem areas as identified in the study. It begins by recalling the objectives of the research and later links them to the actual conclusions. It finally summarises the chapter and the study overall.

## 6.2 Conclusions

The main objectives of the study were to:

- Review the current transportation systems of personnel from surface to their working places and back to surface.
- Determine the activities employees are involved in between clocking in and getting to the face and when departing from the waiting place and returning to surface,
- Determine the average time spent on each activity,
- To explore the manner in which the use of the 5 Lean principles as a theoretical lens could guide the improvement of the overall travelling process by identifying the waste and reducing or eliminating it.

The overall conclusion drawn from both the literature review and observed study is that effective management of transportation systems is the core issue that mining industry is faced with. While mining companies mainly focus on meeting monthly production targets, they overlook the importance of properly managing the transportation systems of employees. As a result, the employees are congested at the bank and underground station and have to queue and wait for a cage.

In order to eliminate or reduce the ongoing problems at the shaft, management have to ensure that a safe and reliable transport system operates properly and on time to maximise the time spent at the working places (Rupprecht, 2003). Employees are key and it, therefore, is essential for the shaft to ensure that a transport system is in place to carry them closer to their working places.

This will decrease the travelling time and ensure that employees arrive at their working place in a fit state to begin work immediately (Rampedi and Genc, 2012). That will cut off the resting time since the employees will not be walking long distances and thus decrease fatigue; therefore, increasing the time spent at the working places.

This means that the engineering department is responsible to ensure that it involves all other departments and communicates with them when planning and wanting to implement any transport system instead of only informing them of the new solutions. Long term planning is important in that the more the working places are drilled and blasted, the further they are from the shaft.

## 6.3 Recommendations for future work

Based on the results of this study, the following were recommended as a possible solution to the challenge queuing for a cage and walking long distances:

- Locate the constraints and conduct capacity analysis of the number of employees and capacity of the different elements using theory of constraints model
- Mine management to appoint personnel to be responsible for managing transportation at the shaft. Also investigate alternative transportation systems that can convey employees from the chairlift station closer to their working places. They have an option of bringing in the man carriages that were used at 12 Shaft since they are no longer in use and are still in good condition. The tracks at 14 Shaft are well maintained.

## Bibliography


AL-ARAIDAH, O., MOMANI, A., KHASAWNEH, M. & MOMANI, M. 2010. Lead-Time Reduction Utilizing Lean Tools Applied to Healthcare: The Inpatient Pharmacy at a Local Hospital. *Journal for Healthcare Quality,* 32**,** 59-66.

ANDI, R., WIJAYA, R., KUMAR, R. & KUMAR, R. Implementing lean principle into mining industry issues and challenges. International Symposium on Mine Planning and Equipment Selection nov, 2009.

BECKER n.d. Transporting you into the future (Chairlift system). *In:* AFRICA, B. M. S. (ed.).

BERGLUND, K. & GUNTHER, D. 2014. *Challenges with deep mining.* MSc, Lulea University of Technology.

BHULOSE, M. 2004. An investigation into the physical constraints of the current sub-decline at Turffontein Shaft. *Journal of the Southern African Institute of Mining and Metallurgy,* 104**,** 153-162.

BRINK, H. 1993. Validity and reliability in qualitative research. *Curationis,* 16**,** 35-38.

BURGESS, N. & RADNOR, Z. 2013. Evaluating Lean in healthcare. *International journal of health care quality assurance,* 26**,** 220-235.

CARVALHO, A. & BELO, O. Predicting waiting time in customer queuing systems. Knowledge Engineering and Applications (ICKEA), IEEE International Conference on, 2016. IEEE, 155-159.

DAVIAU, J. n.d. The components of a mine shaft: Mine skips and cages. *In:* WABICORP (ed.).

DICKSON, E. W., SINGH, S., CHEUNG, D. S., WYATT, C. C. & NUGENT, A. S. 2009. Application of lean manufacturing techniques in the emergency department. *The Journal of emergency medicine,* 37**,** 177-182.

ETIKAN, I., MUSA, S. A. & ALKASSIM, R. S. 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics,* 5**,** 1-4.

FLSMIDTH 2015. Mine shaft systems Dorr-Oliver & Vecor Equipment. *In:* FLSMIDTH (ed.).

FORD, J. L. Two applications of Queuing theory. Proceedings of the Annual Symposium on Computer Application in Medical Care, 1980. American Medical Informatics Association, 1690.

HAQUE, B. & JAMES-MOORE, M. 2004. Applying lean thinking to new product introduction. *Journal of Engineering design,* 15**,** 1-31.

HEALE, R. & TWYCROSS, A. 2015. Validity and reliability in quantitative studies. *Evidence-based nursing***,** ebnurs-2015-102129.

IMPLATS 2016. Implats mineral resource and mineral reserve statement. Johannesburg: Impala Platinum Holdings Limited (Implats).

KANAWATY, G. 1992. *Introduction to work study*, International Labour Organization.

KOLLBERG, B., DAHLGAARD, J. J. & BREHMER, P.-O. 2006. Measuring lean initiatives in health care services: issues and findings. *International Journal of Productivity and Performance Management,* 56**,** 7-24.

KUMAR, R. 2011. Research Methodology (ed.). Sage Publications, Place of publication.

LEEDY, P. D. & ORMROD, J. 2010. *Practical Research: Planning and Design*, Upper Saddle River, New Jersey: Pearson, Merril Prentice Hall.

LOPETEGUI, M., YEN, P.-Y., LAI, A., JEFFRIES, J., EMBI, P. & PAYNE, P. 2014. Time motion studies in healthcare: what are we talking about? *Journal of biomedical informatics,* 49**,** 292-299.

MATSUI, K. 2009. UNDERGROUND MINING TRANSPORTATION SYSTEMS. *Civil Engineering-Volume II,* 2**,** 285.

MHSA 2015. Mine Health and Safety Act 29 of 1996 & Regulations. Fifth ed. Cape Town: Juta Law.

MUIJS, D. 2010. *Doing quantitative research in education with SPSS*, Sage.

NAIK, M., AGOLA, J. & RATHOD, H. n.d. TIME AND MOTION STUDY: A CASE STUDY ON A COMMERCIAL BUILDING AT KADODARA.
OFORI-OKYERE, I., ATANGA, R. A. & OKINE, B. A. 2016. Managing Lean Principles applicability and implementation in the mining industry in Ghana. A Review Paper on Related Literature. *Archives of Business Research,* 4.
PALLANT, J. 2013. *SPSS survival manual*, McGraw-Hill Education (UK).
PAREJA, L. D. 2000. *Deep Underground Hard-rock Mining: Issues, Strategies, and Alternatives*, Queen's University.
PIECZORA, E. & TOKARCZYK, J. 2017. Development of mine underground transportation with use of suspended monorails. *Mining–Informatics, Automation and Electrical Engineering,* 55.
RAMPEDI, M. & GENC, B. 2012. An investigation into the optimization of personnel transportation to level 15 and below at Khuseleka No. 1 Shaft, Anglo Platinum. *Journal of the Southern African Institute of Mining and Metallurgy,* 112**,** 323-330.
RUPPRECHT, S. 2016. The need for material change in the South African mining industry.
RUPPRECHT, S. M. 2003. *Best Practice for Personnel, Material and Rock Transportation in Ultra Deep Level Gold Mines.* University of Natal, Durban.
SAHU, P. K. 2016. *Research methodology: A guide for researchers in agricultural science, social science and other related fields*, Springer.
SWANEPOEL, J., SWANEPOEL, C., VAN GRAAN, F., ALLISON, J. & SANTANA, L. 2015. *Elementary Statistical Methods*, AndCork Publishers

TORTORELLA, G. L., FOGLIATTO, F. S., ANZANELLO, M., MARODIN, G. A., GARCIA, M. & REIS ESTEVES, R. 2017. Making the value flow: application of value stream mapping in a Brazilian public healthcare organisation. *Total Quality Management & Business Excellence,* 28**,** 1544-1558.
VAN HEERDEN, G. 2014. *Engineering principles for the design of a new/existing mine's personnel transportation system (Case study Bafokeng Rasimone Platinum Mine).* University of Pretoria.
VOGT, D. 2015. Where we are, where we are going. *Mining Review Africa.*
WEBBER-YOUNGMAN, R. & VAN HEERDEN, G. 2016. Engineering principles for the design of a personnel transportation system. *Journal of the Southern African Institute of Mining and Metallurgy,* 116**,** 441-454.
WELMAN, C., KRUGER, F. & MITCHELL, B. 2005. *Research methodology*, Oxford University Press Cape Town.
WOMACK, J. P. & JONES, D. T. 2000. *Lean thinking,* .

## Appendix A: Time and motion study template

| Time and Motion study | | | |
|---|---|---|---|
| | | | |
| **Supervisor:** Patrick Magolela | | | |
| **Section:** 147 | | | |
| **Company:** Impala Platinum 14 Shaft | | | |
| **Level:** 24 Trackless Mechanised | | | |
| **Date:** | | | |
| | | | |
| **Start time** | **End time** | **Activity name** | **Av. time spent** |
| | | Waiting time for cage (at bank surface) | |
| | | Loading the cage | |
| | | From bank to 22 level | |
| | | Off-loading the cage (22 level u/g) | |
| | | Walk from 22nd station to 1st leg of chairlift | |
| | | Queuing to climb chairlift | |
| | | Waiting time for climbing a chairlift | |
| | | 1st leg chairlift riding: 22nd- 24th level | |
| | | 24th level chairlift station to central waiting place | |
| | | Safety meeting (Wednesdays only) | |
| | | Resting and eating before entering working places | |
| | | Walk from central waiting place to the closest working places | |
| | | Knocking off | |
| | | Walk from working place to waiting place | |
| | | Section waiting place to 24th level chairlift station | |
| | | 24th- 22nd level chairlift station (chairlift riding) | |
| | | Walk from 22nd level 1st leg to 22nd cage station | |
| | | Waiting time for cage (after work). | |

## Appendix B: 14 Shaft schedule

**Service winder M/S**

| Level | Number of Cage and time start 1 | 2 | 3 | 4 | 5 | Window Clocking Open | Close | Time per lev min |
|---|---|---|---|---|---|---|---|---|
| 15 | 04:30 | 04:40 | | | | 04:10 | 04:30 | 00:20 |
| 16 | 04:50 | 05:00 | 05:10 | | | 04:30 | 05:00 | 00:30 |
| 17 | 05:20 | 05:30 | 05:40 | 05:50 | | 05:00 | 05:40 | 00:40 |
| 18 | 06:00 | 06:10 | | | | 05:40 | 06:00 | 00:20 |
| 19 | 06:20 | 06:30 | 06:40 | | | 06:00 | 06:30 | 00:30 |

**Man winder M/S**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20 | 05:50 | 06:00 | | | 05:30 | 05:50 | 00:20 |
| 21 | 05:30 | 05:40 | | | 05:10 | 05:30 | 00:20 |
| 22 | 04:30 | 04:40 | 04:50 | 05:00 | 04:10 | 04:50 | 00:40 |
| 23 | 05:20 | | | | 05:00 | 05:10 | 00:10 |

**Service winder N/S**

| Level | Number of Cage and time start 1 | 2 | 3 | 4 | 5 | Window Clocking Open | Close | Time per lev min |
|---|---|---|---|---|---|---|---|---|
| 15 | 20:30 | | | | | 20:10 | 21:00 | 00:50 |
| 16 | 20:40 | | | | | 20:10 | 21:00 | 00:50 |
| 17 | 20:50 | | | | | 20:10 | 21:00 | 00:50 |
| 18 | 21:00 | | | | | 20:10 | 21:00 | 00:50 |
| 19 | 21:10 | | | | | 20:10 | 21:00 | 00:50 |
| 15-19 | All level up to 4:00 | | | | | | | |

**Man winder N/S**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20 | 21:20 | | | | 20:10 | 21:00 | 00:50 |
| 21 | 21:10 | | | | 20:10 | 21:00 | 00:50 |
| 22 | 20:30 | 20:40 | | | 20:10 | 21:00 | 00:50 |
| 23 | 21:00 | | | | 20:10 | 21:00 | 00:50 |
| 15-19 | All level up to 4:00 | | | | | | |

**Shift duration M/S**

| Level | Down | Up |
|---|---|---|
| 15 | 04:30 | 12:30 |
| 16 | 04:50 | 12:50 |
| 17 | 05:20 | 13:20 |
| 18 | 06:00 | 14:00 |
| 19 | 06:20 | 14:20 |
| 20 | 05:50 | 13:50 |
| 21 | 05:30 | 13:30 |
| 22 | 04:30 | 12:30 |
| 23 | 05:20 | 13:20 |

**Shift duration N/S**

| Level | Down | Up |
|---|---|---|
| 15 | 20:30 | 04:30 |
| 16 | 20:40 | 04:50 |
| 17 | 20:50 | 05:20 |
| 18 | 21:00 | 06:00 |
| 19 | 21:10 | 06:20 |
| 20 | 21:20 | 05:50 |
| 21 | 21:10 | 05:30 |
| 22 | 20:30 | 04:30 |
| 23 | 21:00 | 05:20 |

① 20:00 – 20:30
② 20:30 – 21:00